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Critical Silvics of Conifer Crop Species and Selected Competitive Vegetation in Northwestern Ontario

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Abstract

The purpose of this project was to draw together practical information on the silvics of selected coniferous species in northwestern Ontario in a field guide that will aid forest managers in developing vegetation-management strategies. The project involved no original research; the information was compiled primarily from a review of relevant literature, incorporating selected soil/site data from the Northwestern Ontario Forest Ecosystem Classification (NWO FEC) database.

The guide contains silvicultural and ecological information on five coniferous species (balsam fir, black spruce, white spruce, jack pine and red pine) and 23 woody and herbaceous potential competitor species (including trembling aspen, balsam poplar, white birch, beaked hazel and mountain maple).

The field guide summarizes, for each species, information on identification and taxonomy, autecology in the context of the NWO FEC, phenology, and reproductive and growth habits. In addition, potential competitors are evaluated and discussed with respect to their competitive effects and mechanisms, their wildlife values, and their response to disturbance and silvicultural treatments, including their adaptation to the latter. The five conifers are also evaluated in terms of their response to competition and their ability to respond to release from different competing species.

The guide does not provide specific prescriptions for the control of competing vegetation, but allows forest managers to develop site-specific vegetation management strategies on the basis of ecological and phenological criteria. Knowledge of the autecological characteristics of key competitive species will help to change the focus of vegetation management from corrective to preventative measures.

Résumé

Ce projet avait pour but de réunir, dans un guide, des données pratiques sur l'écoloqie forestière d'essences résineuses choisies dans le nord-ouest de l'Ontario, et ce pour aider les forestiers à mettre au point des stratégies d'aménagement de la végétation. Il ne nécessitait aucune recherche initiale; l'information a été compilée principalement à partir d'une revue de la documentation existante, intégrant des données choisies sur les sols et les sites de la base de données de la Classification des écosystèmes forestiers du nord-ouest de l'Ontario (NWO FEC).

Le guide contient des données sylvicoles et écologiques sur 5 essences de résineux (sapin baumier, épinette noire, épinette blanche, pin gris et pin rouge) et 23 essences ligneuses et herbacées potentiellement compétitrices (y compris le peuplier faux-tremble, le peuplier baumier, le bouleau à papier, le coudrier à long bec et l'érable à épis).

Le guide résume, pour chaque essence, les données sur l'identification et la taxonomie, l'autécologie dans le cadre de la NWO FEC, la phénologie, la reproduction et le port. De plus, les compétiteurs potentiels sont évalués et examinés en fonction des effets et des mécanismes de la compétition, de leur importance pour la faune et de leur réaction aux perturbations et aux traitements sylvicoles, y compris leur adaptation à ces derniers. Les cinq résineux sont également évalués en termes de réaction à la compétition et de leur capacité de réagir à la dissémination des différences essences compétitrices.

Le guide ne contient aucune prescription quant au contrôle de la végétation compétitrice, mais il permet aux forestiers d'élaborer des stratégies d'aménagement de la végétation en fonction des sites particuliers, selon des critères écologiques et phénologiques. La connaissance des caractéristiques autécologiques des principales essences compétitrices permettra d'axer l'aménagement de la végétation non plus sur l'application de mesures correctrices mais sur la prévention.

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Introduction

Critical silvics may be defined as the vital information on the biological behaviour of a plant species that is needed to understand its growth, reproduction and response to silvicultural activities or response to competition.

"As we proceed into an era of wider choice in vegetation management strategies, it becomes increasingly important to be able to predict the effect each vegetation management technique will have on competing vegetation. Through increased knowledge of critical silvics of competing species we can begin to have this predictive capability" (DeLong 1989). Although much is known about the general critical silvics of plant species that compete with conifer reproduction in northern Ontario, most information is scattered and not readily available to forest managers who must develop and implement vegetation management strategies.

This publication contains information on 23 plant species which may compete with conifer crop species, and five commercially important conifer species. Information is summarized on each species' identification and taxonomy, autecology in the context of the Northwestern Ontario Forest Ecosystem Classification (NWO FEC), reproductive habits and growth habits. In addition, each of the 23 potential competitors were evaluated and discussed with respect to their competitive effects and mechanisms, possible wildlife values and their response to disturbance and silvicultural treatments, including their adaptation to the latter (e.g., forest canopy removal, fire, cutting, soil disturbance, herbicides and fertilization).

The five conifer species were similarly evaluated with respect to their response to competition and ability to respond to release from various competitive species. The quantity and scope of this type of information varies considerably among these species. To avoid repetition, references have been consolidated into a single literature cited section. A glossary is provided to help clarify and define some technical terms used in the text.

While this publication does not provide specific prescriptions for control of competing vegetation, it will assist forest managers to develop site-specific, vegetation management strategies.

Plant Recognition

Field recognition of the competitive species and conifers is the first step in developing a vegetation management plan. In this handbook, plants are organized into two main groups: 1. competitive herbs, grasses, shrubs, and trees, and 2. conifers. Within each group, plants are arranged alphabetically by scientific name, following Baldwin and Sims (1989) '*Field Guide to the Common Forest Plants in Northwestern Ontario*.' Key diagnostic information for identifying each species was obtained from Baldwin and Sims (1989).

Habitat Requirements and Relationships

The Forest Ecosystem Classification system recently developed for NW Ontario (Sims *et al.* 1989) provides quantitative information on the relationships between vegetation ('V'-Types) and site characteristics. These baseline data, combined with some knowledge of the moisture, nutrient and light requirements of potential competing species can lead to a better understanding of those sites where an individual species is most likely to become a problem.

Information from both the NWO FEC data and the literature was combined and summarized to describe the distribution of each species within Ontario; site and soil relations; and nutrient, moisture and light requirements.

The NWO FEC system provides a method for classifying, identifying and naming distinct forest vegetation and soil conditions in NW Ontario. The classification was derived from quantitative vegetation and soil data from over 2,100 plot locations. NWO FEC data was collected from within two administrative regions of the Ontario Ministry of Natural Resources: the North Central (NC) and NW Regions. The study area ranges from the Ontario-Manitoba border in the west to the general vicinity of Manitouwadge and White River in the east. The area extends northward from the Ontario-Minnesota international border and the northern shore of Lake Superior as far as the limit of commercial forest in NW Ontario, a line which roughly coincides with the southern edge of the Hudson Bay Lowland physiographic zone. The total area exceeds some 184,000 sq km.

NWO FEC Vegetation Types

The plotted diagram shown below is based on a computer-assisted "ordination" analysis of vegetation data collected during the NWO FEC program. Ordination is a mathematical procedure that synthesizes and graphically summarizes large, complex datasets into a simple, readable form. The ordination presented here represents an "executive summary" of all the abundance information for the vegetation species recorded in over 2100 NWO FEC field plots.

Each of the 38 plotted points (V1-V38) in the ordination diagram represents an average vegetational composition for a V-Type. Types which are close together on the ordination (e.g. V20 and V33) tend to be more alike in terms of their general vegetation conditions than those which are far apart (e.g. V27 and V2). The distance between any two points (V-Types) graphically illustrates the relative degree of similarity between those Types.

Although neither axis is calibrated to an absolute scale, there are two main gradients that can be inferred along the axes of this ordination. Along axis 1, from left to right, the gradient is from nutrient-poor to nutrient-rich. Axis 2, from bottom to top, represents a wet to dry gradient. Thus, the ordination effectively provides a pictorial representation within which the V-Types can be related to moisture/nutrient conditions as well as to patterns of average vegetational composition.

The habitat diagrams should only be considered as guides. Because of the natural variability that characterizes forests throughout NW Ontario, species may be found in V-Types not indicated in the habitat diagrams. In addition, since the NWO FEC data collection was directed at mature forest ecosystems, the habitat diagrams do not indicate species distributions in non-forested or disturbed habitats.

In the NWO FEC system, a forest stand is allocated to one of 38 Vegetation Types (V-Types) (Sims *et al.* 1989). There are three main groupings: Mainly Hardwood (11 V-Types), Conifer Mixedwood (9 V-Types) and Conifer (18 V-Types).

Mainly Hardwood

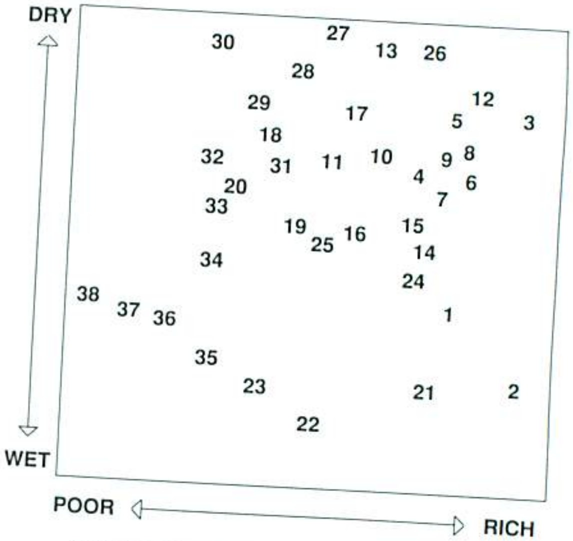
V1.....Balsam Poplar Hardwood and Mixedwood
V2.....Black Ash Hardwood and Mixedwood
V3.....Other Hardwoods and Mixedwoods
V4.....White Birch Hardwood and Mixedwood
V5.....Aspen Hardwood
V6.....Trembling Aspen (White Birch) - Balsam Fir / Mountain Maple
V7.....Trembling Aspen - Balsam Fir / Balsam Fir Shrub
V8.....Trembling Aspen (White Birch) / Mountain Maple
V9.....Trembling Aspen Mixedwood
V10....Trembling Aspen - Black Spruce - Jack Pine / Low Shrub
V11....Trembling Aspen - Conifer / Blueberry / Feathermoss

Conifer Mixedwood

V12....White Pine Mixedwood
V13....Red Pine Mixedwood
V14....Balsam Fir Mixedwood
V15....White Spruce Mixedwood
V16....Balsam Fir - White Spruce Mixedwood / Feathermoss
V17....Jack Pine Mixedwood / Shrub Rich
V18....Jack Pine Mixedwood / Feathermoss
V19....Black Spruce Mixedwood / Herb Rich
V20....Black Spruce Mixedwood / Feathermoss

Conifer

V21....Cedar (inc. Mixedwood) / Mountain Maple
V22....Cedar (inc. Mixedwood) / Speckled Alder / Sphagnum
V23....Tamarack (Black Spruce) / Speckled Alder / Labrador Tea
V24....White Spruce - Balsam Fir / Shrub Rich
V25....White Spruce - Balsam Fir / Feathermoss
V26....White Pine Conifer
V27....Red Pine Conifer
V28....Jack Pine / Low Shrub
V29....Jack Pine / Ericaceous Shrub / Feathermoss
V30....Jack Pine - Black Spruce / Blueberry / Lichen
V31....Black Spruce - Jack Pine / Tall Shrub / Feathermoss
V32....Jack Pine - Black Spruce / Ericaceous Shrub / Feathermoss
V33....Black Spruce / Feathermoss
V34....Black Spruce / Labrador Tea / Feathermoss (Sphagnum)
V35....Black Spruce / Speckled Alder / Sphagnum
V36....Black Spruce / Bunchberry / Sphagnum (Feathermoss)
V37....Black Spruce / Ericaceous Shrub / Sphagnum
V38....Black Spruce / Leatherleaf / Sphagnum



NWO FEC Vegetation Ordination

NWO FEC Soil Types

Soil relations are described in terms of soil texture and NWO FEC Soil Types. Based on NWO FEC data, the texture triangle (Ontario Institute of Pedology 1985) is used to illustrate the frequency of occurrence of a species on a texture class. Each texture class is positioned in the triangle according to percentage

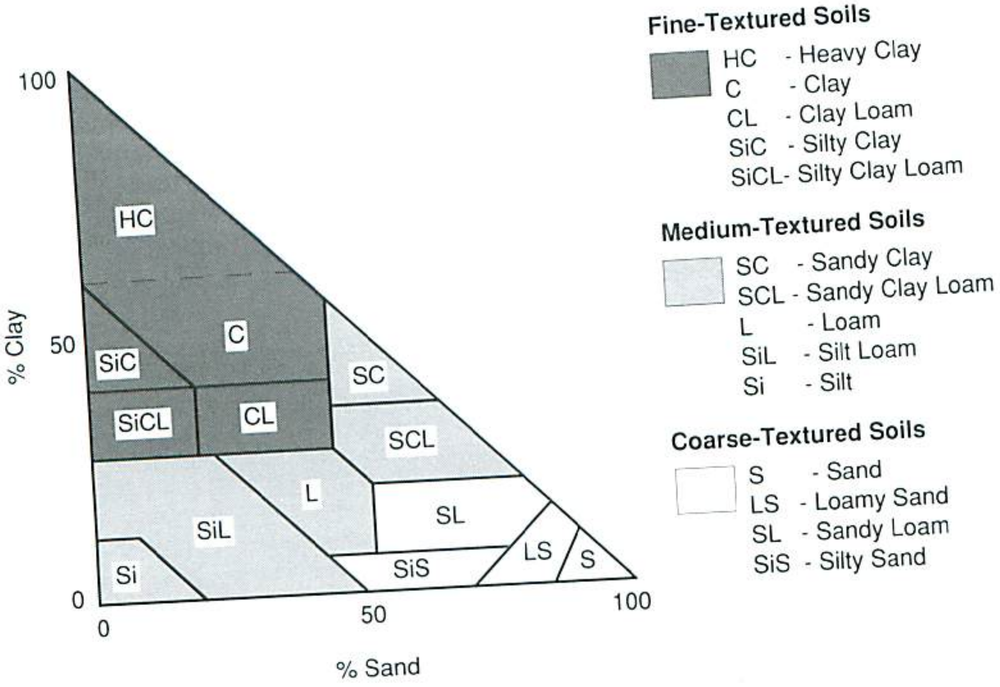


Figure 1. Soil texture diagram depicting fine-, medium- and coarse-textured soils.

amounts of the 3 primary particle fractions - sand, silt and clay. In the triangle, percentage composition of sand and clay are represented along the horizontal and vertical axes, respectively (Figure 1). Percentage composition of silt is not shown but may be inferred along an imaginary axis that runs from upper right (low % silt) to lower left (high % silt) in the triangle.

Soil Types are characterized by the NWO FEC system in terms of several parameters (e.g. moisture regime, depth of type of organic matter, parent material texture, depth to bedrock) (Sims *et al.* 1989). Two field keys were developed: a key to deep soils defining 13 S-Types (Soil Types with ≥ 100 cm of mineral or organic substrate), and a key to shallower soils defining 9 SS-Types (very shallow to moderately deep Soil Types with < 100 cm of mineral or organic substrate).

Deep Soils

S1.....Dry / Coarse Sandy
S2.....Fresh / Fine Sandy
S3.....Fresh / Coarse Loamy
S4.....Fresh / Silty - Silt Loamy
S5.....Fresh / Fine Loamy
S6.....Fresh / Clayey

S7.....Moist / Sandy
S8.....Moist / Coarse Loamy
S9.....Moist / Silty - Silt Loamy
S10....Moist / Fine Loamy - Clayey
S11....Moist / Peaty Phase

S12F...Wet / Organic (Feathermoss)
S12S...Wet / Organic (Sphagnum)

Shallow Soils

SS1....Discontinuous Organic Mat on Bedrock
SS2....Extremely Shallow Soil on Bedrock
SS3....Very Shallow Soil on Bedrock
SS4....Very Shallow Soil on Boulder Pavement
SS5....Shallow - Moderately Deep / Sandy
SS6....Shallow - Moderately Deep / Coarse Loamy
SS7....Shallow - Moderately Deep / Silty - Fine Loamy - Clayey
SS8....Shallow - Moderately Deep / Mottles - Gley
SS9....Shallow - Moderately Deep / Organic - Peaty Phase

For the Vegetation Type, soil texture, and Soil Type, each species is represented by percent (%) frequency of occurrence. The following classification was used for all diagrams and summary charts:

Percent Occurrence

☐ Absent
⬚ 1 - 25 %
▨ 26 - 50 %
▩ 51 - 75 %
■ 76 - 100 %

Reproductive Characteristics

The need to control a plant species and the methods used to control the species can be greatly influenced by reproductive characteristics, growth habit and competitive mechanisms of that species. Plant species with high reproductive capabilities and rapid juvenile growth rates are likely to be more aggressive competitors than species with low reproductive capabilities and slower growth rates.

Reproductive characteristics of a plant species include: age at which the plant is capable of producing viable seed; frequency and abundance of sexual reproduction; seed longevity and viability; seed germination requirements; and whether the plant can reproduce vegetatively.

Regeneration of sites by seed depends on the availability of seed either from adjacent areas or from the seedbank, and the ability of seed to germinate and seedlings to establish on disturbed microsites. Potential seed production for each species ranges from hundreds to millions of seed per individual each year. Annual potential is rarely realized for any given species, yet total failures seldom occur (Zasada 1988). Those species able to produce seed in significant quantities relatively early in their life cycle have a competitive advantage over species producing seed later (Zasada 1971). The size and quality of seed crops determines the amount of seed potentially available for regeneration. Seed quantity, quality and dispersal mechanisms determine each species' ability to occupy large disturbed areas such as clearcut or burned sites.

Seeds are dispersed by wind, water, gravity, animals and birds, each influencing the distance travelled from the parent plant. Successful colonization of a disturbed site by wind-borne seeds depends on the coincidence of several largely independent events, including a good seed year and migration of seeds from other sites. In addition, timing of seed arrival with the time of disturbance, so that the seed arrives neither so far in advance of the soil disturbance that its viability is lost before conditions become favourable for germination, nor so long after disturbance that other species have become established in large numbers, is also a major factor in successful seed germination (Marks 1974).

Another important method of plant reproduction is via seeds buried in the organic layer and upper mineral soil. Buried seeds, some of which remain dormant in the soil for many years, germinate in response to changes in light, soil temperatures, or other factors following site disturbance (Kramer and Johnson 1987). Plant species which are seemingly rare or absent in mature forest stands may become established from buried seeds and quickly dominate the pioneer vegetation community following timber harvest, fire or other major disturbance. Seed bank species composition and seed densities will vary greatly from site to site (Kramer and Johnson 1987).

Seed longevity in soil is also an important consideration when designing weed control systems. While it is possible to eradicate species with short-lived seed using weed control strategies that eliminate seed production, this is not a feasible strategy with species having long-lived seed. Knowledge of seed longevity in the soil is critical to the understanding and prediction of weed population dynamics (Conn and Farris 1987).

An important reference regarding the sexual reproduction of plant species is the textbook 'Seeds of Woody Plants of the United States' (Anon. 1974).

Vegetative reproduction is generally of greater importance than is sexual reproduction in the rapid recovery of vegetation immediately following a disturbance. Vegetative reproduction has a distinct advantage over seed regeneration because it is not dependent on seedbed conditions and the sprouts of suckers have the root system of the parent tree available as a source of food reserves and water supply (Zasada 1971). Obviously, the species must have been present on the site prior to disturbance. Methods of vegetative reproduction include sprouts, layers, underground stems (rhizomes) and root suckers.

Growth Habit

Growth habits of a plant species include descriptions of its lifecycle (e.g. annual, biennial or perennial) and form (e.g. herb, shrub or tree), longevity, maximum height, and rate and pattern of growth.

Annuals and biennials complete their life cycles after producing seeds in one and two years, respectively. These plants reproduce only by seeds, some of which may remain viable in the ground for many years. Perennials persist for more than two years. Some perennials reproduce only by seeds while others, including some of the most difficult to control in forest management, reproduce from both seeds and underground parts. Trees, shrubs, and vines are woody perennials that reproduce by seed, and by basal sprouts or root suckers following disturbance (Estabrooks 1988).

Because they start each year from seed and die in the fall, annuals rarely constitute a serious obstacle to conifer regeneration. Only some reduction of height growth and occasional smothering of small conifer seedlings may occur (Eis 1981). Biennials and perennials usually constitute greater competition than annuals because of their rapid spring growth from overwintered roots. Perennials such as grasses create thick mats that impede regeneration by shading out seedlings in summer or by smothering them with dead stems and foliage compressed by snow during winter months. Shrubs and trees may constitute a more significant source of long-term competition than annuals, other perennials or biennials.

Growth and development characteristics influencing the competitive status of a plant species include:

1. Maximum Height - the maximum height a species achieves will determine if it will be a competitor for only a few years or for many years;
2. Leaf Area and Leaf Morphology - the more leaf area a species has the more light is prevented from reaching the seedlings underneath;
3. Rate of Colonization - the more rapidly a species can colonize a site and increase cover, the more shade it will cause and the further it can be from a seedling and still shade it;
4. Rooting Location - if a species roots in the same profile as young seedlings it will outcompete seedlings for nutrients, light and space; and,
5. Water Use - the more soil water a competing species uses, the less that is available for seedlings (DeLong 1989).

Phenology

Phenological cycles of major competing species and conifer species are not well documented. A review of published information pertaining to yearly phenological cycles of several species is provided.

Shoot phenology includes timing of leaf flush, leaf elongation, radial expansion, leaf fall and dormancy. Most boreal vegetation is generally fully developed, or nearly so, by mid-July (DeLong 1988). Leaf growth rate is generally more rapid and occurs earlier in the season for deciduous than evergreen species (Eis 1981; Chapin and Tryon 1983). As its height and density increase, deciduous shade is progressively more detrimental to conifer regeneration (Eis 1981).

Reproductive phenology includes time of flowering, seed maturation and seed fall. Many trees and shrubs initiate flowering in the growing season preceding floral bud break (Anon. 1974). Seeds of most tree and shrub species are shed and dispersed after fruits are mature in fall or early winter months. Seed dispersal can continue into early spring (Anon. 1974).

Silvicultural Treatments

Silvicultural treatments can enhance or reduce competing vegetation. Response of a plant species to a silvicultural treatment depends primarily upon the reproductive mechanisms of that species. Species with buried viable seed, windborne seed, or which sprout or sucker readily, can quickly re-invade disturbed sites. However, even the most aggressive weed species have key growth and reproductive characteristics that can be exploited by the forest manager to help reduce competition problems.

Unfortunately, control methods that effectively reduce competition from one species may lead to severe competition from another. For this reason, growth habits, reproductive characteristics, and primary competitive mechanisms of all potentially competitive species found on a site should be evaluated before embarking upon a particular management strategy.

Silvicultural treatments presented in this handbook are: a) overstory removal, b) fire, c) mechanical site preparation, d) cutting, e) chemical treatments, and f) fertilization.

Overstory Removal

Literature pertaining to how a plant responds to partial or complete overstory removal through harvesting or thinning is summarized in this section.

Because of variations in logging disturbance, relationships between pre- and post-logging species composition are often obscure, especially for the first few years following tree removal. Typically, those sites where the forest floor remains virtually undisturbed following logging support vegetation which most resembles the understory species composition that existed before logging (Dyrness 1973). Often on undisturbed sites residual species greatly increase coverage following overstory removal and virtually exclude invading species.

Species composition in the original stand could be expected to have some impact on stand composition following logging (Yang and Fry 1981). Although the forest floor is often dramatically altered by harvesting and scarification equipment, seeds from competing vegetation are not removed from the site by these treatments (Moore and Wein 1977). Intense competition from competitive non-crop vegetation often occurs immediately after logging, and originates from the sprouting of basal buds, rhizomes, and/or root suckers (Zasada *et al.* 1988). Depending on the degree to which they damage young growth, disturb the forest floor, and affect the amount and distribution of slash, different logging equipment and systems could be expected to have differing effects on subsequent revegetation (Yang and Fry 1981). For example, winter harvest typically disturbs the ground surface less than summer harvest, and may result in less competition from species such as pin cherry (*Prunus pensylvanica* L.f.), raspberry (*Rubus* spp.) or Canada blue-joint (*Calamagrostis canadensis* (Michx.) Beauv.) (Campbell 1981).

Fire

This section summarizes the response of competing species to natural or prescribed fires.

Fire can be a useful site preparation treatment, but is not a panacea for competition control. It cannot be used for release operations until conifers have matured beyond the stage of sensitivity to low ground fire (Vanden Born and Malik 1984). In some cases, a dense cover of competitive species may develop shortly after burning (Campbell 1981). In addition, fire may actually improve microsite conditions for establishment of several non-crop species such as pin cherry and paper birch (*Betula* *papyrifera* Marsh.). Abundant vegetative reproduction by some species (e.g. trembling aspen (*Populus tremuloides* Michx.) is also common following fire.

Two main processes are operative in post-fire succession on any area, namely, regeneration either from underground reproductive structures or viable seeds present in the soil, and invasion by wind, animal, or bird-disseminated seed (McLean 1969). Post-fire increases in soil moisture, soil temperature, surface light, or the removal of surface litter and senescent plant parts have been cited as stimuli to both vegetative and seedling growth (Smith and James 1978b).

A plant's response to fire is dependent upon several factors including severity of the fire, season in which the fire takes place, and location and number of plant reproductive organs produced by the plant (McLean 1969, Noste *et al.* 1987). Intense burning can reduce, and in some cases eliminate, the ability of plants to reproduce vegetatively. In these instances, regeneration must be from seed on the site or from unburned forests adjacent to the burn. In contrast, species composition re-established after light surface fires will closely resemble that of the pre-burn condition, especially where the majority of species regenerate from underground plant parts (Smith and James 1978b). Post-fire vegetation may also be characterized by a small complement of species of wind-disseminated seed origin or from seed buried in the soil prior to fire (Smith and James 1978b). During light surface burns, subsurface soil temperatures rarely increase to levels lethal to plant tissue, even at shallow depths (1-2 cm) (Smith and Sparling 1966).

Plant response to fire is also dependent upon seasonal changes in plant carbohydrate reserves (Noste *et al.* 1987). This response may also be due to changes in soil moisture, which affects thermal conductivity and thus the transfer of heat to underground plant parts (Noste *et al.* 1987). High soil moisture content may be involved in the destruction of underground parts of some vegetatively reproduced species. Uggla (1958) showed that soil moisture tends to condense in the upper soil stratum and to function during fire as a thermo-insulator protecting lower levels from high temperatures. This moisture, in the uppermost layer of organic soil, forms steam during intense fires. Such heat is more damaging to living tissue than the dry heat to which vegetative parts would be subjected on drier sites.

Boreal plant species may be ranked according to relative fire resistance of the root system. "Susceptible" species are usually those having fibrous root systems or producing stolons or rhizomes growing above mineral soil. "Moderately resistant" species usually have fibrous roots with rhizomes growing less than 5 cm below the mineral soil surface. "Resistant" species are those with rhizomes growing between 5 and 13 cm below the mineral soil surface and species capable of regenerating via adventitious buds formed on their tap root (McLean 1969).

All species presented here are capable of regenerating by means of seed disseminated from stems (living or dead) on prescribed burn sites or in adjacent, unburned stands. Most of the species are also capable of prolific vegetative reproduction.

Mechanical Site Preparation

Literature pertaining to plant responses to mechanical site preparation is presented in this section. Mechanical methods of site preparation include bulldozing, shearing, crushing, chopping, plowing, disking, and bedding.

Mechanical site preparation can be used to reduce competing vegetation; however, it can also aggravate future weed problems (Campbell 1981). Exposure of large expanses of bare mineral soil under full sunlight may encourage regeneration of seral annual grasses and other non-crop species (Vanden Born and Malik 1984). This phenomenon is frequently overlooked in site prescriptions.

There are three primary types of mechanical site preparation treatments, differentiated by how the treatment alters the composition and structure of the existing vegetation:

1. Treatments in which trees and shrubs are pushed aside or sheared off, but low shrubs, herbs, and humus are left relatively undisturbed (e.g., piling or winter shearing). In this case there is little change to the floristic composition, but height and cover are reduced.
2. Treatments in which small areas of mineral soil are exposed but much vegetation is left relatively undisturbed (e.g., spot scarification or mounding). Composition and structure of vegetation outside of the mineral soil patch is unchanged, and there will be no vegetation on the mineral soil until plants seed in or sprout up. Vegetation developing on the mineral soil is often of a different composition than vegetation on the undisturbed area.
3. Treatments through which large areas of mineral soil are exposed (e.g., plowing or deep blading), drastically changing vegetation composition and structure. Areas of mineral soil are soon occupied by pioneer species, usually by seeding-in (DeLong 1989).

Seed longevity is generally reduced by soil cultivation. However, if even a small portion of the original number of seeds of competitive plant species are left in the soil, populations may rapidly re-establish (Conn and Farris 1987).

Cutting

Manual methods of vegetation management include hand slashing with axes, machetes or saws. Although more expensive than applications of herbicides, manual tending can be focussed on vegetation that is directly competing with crop trees. As a result, manual release treatments are usually selective (Vanden Born and Malik 1984, Towill *et al.* 1988).

In many instances, hand weeding operations must be repeated because of the suckering and sprouting properties of the competing vegetation. Cut stems tend to grow rapidly, and one or two years later, they are again competing for light, moisture, and nutrients (Bailey 1984).

When the above-ground portion of a sprouting woody plant is damaged by mechanical means (e.g., cut by chainsaw), the photosynthetic surface area is either reduced or eliminated. Consequently, when suppressed buds respond and shoot elongation begins, the plant is forced to utilize a portion of its carbohydrate reserves. Timing manual tending to coincide with periods when carbohydrate reserves are low may help reduce regrowth of sprouts (Hobbs and Crawford 1988). Carbohydrate reserves are generally low for a period of about two to three weeks in spring during the period of rapid shoot elongation.

Most species presented in this publication will initiate new shoots if cut. These shoots grow much faster than seedlings so they are often competitive again before conifers have responded to initial release. When a single shoot is severed it will typically give rise to multiple new shoots, so that it is possible to end up with more brush than before. If the original brush was dense, re-growth after manual tending may form a very dense canopy at a lower level, and be more competitive than the original brush canopy (Campbell 1981).

Chemical Treatments

For safety and economy, herbicidal chemicals should be used as sparingly and infrequently as possible to accomplish silvicultural objectives. Effective use requires that minimal amounts of herbicides be applied at the proper time of the year to obtain the maximum degree of control on undesirable species without damaging desirable tree species, wildlife browse or aesthetically desirable shrub species (Gratkowski 1975).

Susceptibility of a plant species to a given herbicide is primarily influenced by mode of action of the herbicide, genetics of the target species, time of year the herbicide is applied, and local environmental conditions (Boyd *et al.* 1985, King and Radosevich 1985). Proper timing of an application can significantly improve results. An understanding of the overall development and phenology of target vegetation is critical in developing and executing a best-possible treatment and matching it with relative vulnerability of target vegetation within a given level of herbicide application (Anon. 1981).

Comparisons of the relative susceptibility of different plants to a given chemical must be matched to specific time periods. A plant classified as susceptible to a particular herbicide during rapid shoot elongation may be relatively resistant following bud set. Since most herbicide applications for conifer release in Ontario are conducted in late August to early September, the relative susceptibility of plant species at this stage of their growth cycle needs to be known. Knowing the relative susceptibility of a species to herbicides licensed for vegetation management enables forest managers to knowledgeably select the herbicide which will provide the desired results.

Herbicides should control the non-crop vegetation without injuring the coniferous crop. Most conifers exhibit less injury when herbicides are applied in late summer or early fall than when applied in spring or summer (Willis *et al.* 1989). Herbicide injury to coniferous seedlings occurs most often when applications are made during periods of active growth, low water stress, and high photosynthetic activity (Radosevich *et al.* 1980, King and Radosevich 1985).

Desirable results include the diversion of site resources (such as soil moisture, nutrients and sunlight) from competing vegetation to conifer seedlings. Complete removal of a number of plant species from a plant community is not considered desirable for several reasons. For example, other species may invade the site and create serious competition problems or may be otherwise difficult to control (Vanden Born and Malik 1984). Sites without vegetation are also more subject to extremes in environmental conditions (MacKasey 1983).

Vegetation control using herbicides alone leaves a residue of standing dead or dying vegetation which may shelter animal and/ or other pests and allow them to proliferate (Sutton 1985). One or a few species in a weed population may be resistant to a herbicide treatment that is effective against most other species. These species may then develop into a major component of the competitive species population. Herbicides have little impact on the forest floor, resulting in a poor seedbed for most weeds, and reducing the incidence of "surprise weed problems" (Sutton 1985).

Mechanical and chemical site preparation are sometimes both conducted on the same site. To optimize vegetation control, adequate time must be given between the mechanical disturbance and the herbicide application (Anon. 1981, Burch and Zedaker 1988). If mechanical site preparation is done immediately before or after treatment with a foliar-absorbed, translocated herbicide, the value of the herbicide treatment will be minimal as the chemical will not be translocated to the roots of the plant. Mechanical site preparation, delayed after the herbicide treatment until translocation has taken place, will still stimulate weed growth from seed. Herbicide treatment delayed after mechanical treatment until regrowth has occurred will give maximum weed control, although dead vegetation may hinder planting or seeding (Campbell 1981).

If a soil-active herbicide is to be combined with mechanical site preparation, it will be most effective if applied after the mechanical treatment but before weed growth begins. Because most soil-active herbicides are more effective when applied to a stable surface, it is usually desirable to have a settling period between the mechanical and chemical treatments (Campbell 1981).

Under certain conditions, herbicides applied concurrent with planting may result in detrimental nutrient immobilization and an allelopathic effect on the planted trees by decomposing plant residues. Such undesirable effects might be eliminated by herbiciding well in advance of planting (Boyd 1982).

Herbicide treatments have much the same effect as fertilization treatments (Sutton 1969). Reduced competition for nutrients and decomposition of above and below ground tissues of killed plants results in a sudden mobilization of nutrients which tree seedlings can utilize.

Herbicides discussed in this handbook are: 2,4-D, hexazinone (Velpar®-L) and glyphosate (Vision™). For a detailed description of herbicide usage, users should consult chemical distributors, technical representatives, and original data sources. Manufacturer's recommendations (i.e., label information) give instructions for handling, storage, application procedures, and precautions to follow. Treatment regimes must be based on site-specific data, including weed species present, their competitiveness, and forest crops being managed.

2,4-D

The herbicide 2,4-D is produced as both ester and amine formulations, but only the ester is registered for forestry use. Used alone, 2,4-D is effective on species such as aspen, paper birch, hazel, cherry, and herbaceous broadleaf weeds. Resprouting is a problem with this chemical and retreatment may be needed. 2,4-D is not effective on species such as maples, oaks, certain herbaceous broadleaves and grasses. Using a selective herbicide such as 2,4-D can create certain problems. For example, brush may be replaced by raspberry or grass (Campbell 1981). Because of its relatively low level of effectiveness, 2,4-D has possible value in improving wildlife habitat by encouraging sprouting of hardwoods within reach of browsing animals (Anon. 1981).

All plants exhibit seasonal changes in susceptibility to 2,4-D. Since 2,4-D tends to translocate with carbohydrates in the plant, sprays applied after leaf development in late spring or early summer usually are more effective than sprays applied earlier or later (Miller 1978, Sajdak 1982). Susceptibilty is usually low during dormancy in late fall and winter, increases from time of bud-break throughout the active growing season, and decreases after shoot elongation has ceased (Gratkowski 1975).

The ester formulation may volatilize and move off site if subjected to temperatures >32°C, a situation which may occur following mid-summer applications (Boyd *et al.* 1985).

Hexazinone (Velpar®-L)

Hexazinone acts both as a foliage and soil-active herbicide in the liquid formulation (Velpar-L) and strictly as a soil-active chemical in the granular formulation (Boyd *et al.* 1985). Species controlled by concentrated applications of Velpar L include trembling aspen, cherry, white birch, ash (*Fraxinus* spp.) and maple (*Acer* spp.) (Dupont Canada 1987). It exhibits one to three month persistence in the soil (Sajdak 1982).

Hexazinone is absorbed by foliage and roots and is translocated upward through xylem to foliage where it blocks the photosynthetic process, slowly causing susceptible woody tissue to die (Anon. 1981, Sajdak 1982). Initial visible symptoms are browning leaves, followed by defoliation. Symptoms usually appear in herbaceous plants within two weeks after application under warm humid conditions, while four to six weeks may be required when weather is cooler. Symptoms usually appear within three weeks in actively growing woody plants after sufficient rainfall has carried the herbicide into the root zone (Dupont Canada 1987). Some trees will defoliate and refoliate during the first growing season following application. Other trees may refoliate and defoliate during the second growing season after application but ultimately these will die. Consequently, accurate evaluations on effectiveness of Velpar cannot be made until the third growing season after application (Sajdak 1982). Vegetation treated in late summer or fall will "green up" normally in the spring, then will die as the chemical is absorbed by the root system and translocated to the foliage (Boyd *et al.* 1985).

The degree of control and duration of effect will vary with amount of chemical applied, soil texture, soil moisture, soil organic matter content, rainfall, temperature, the weed and brush species involved, and other conditions. Applications to plants before leaves are fully expanded are generally more effective than later treatments (Dupont Canada 1987).

Weather conditions and soil properties influence the movement of hexazinone into the rooting zone. Post-treatment precipitation is necessary to "activate" hexazinone (Boyd *et al.* 1985). Effectiveness of root uptake applications is reduced on heavy clays and on soils with high organic content (Anon. 1981, Corcoran pers. comm. 1989). Lower rates are recommended on medium-textured soils with little organic content and higher rates on fine-textured soils with considerable organic content. Hexazinone is not licensed for used on coarse-textured soils (Dupont Canada 1987) (Figure 1) .

Glyphosate (Vision™)

Glyphosate is a systemic herbicide which enters through foliage and translocates throughout the plant, including roots. It is a broad spectrum and relatively non-selective herbicide, effective on woody vegetation as well as herbaceous broadleaved species and grasses (Sajdak 1982). It has no soil activity or persistence as the chemical is quickly adsorbed to soil particles (Sajdak 1982). The mechanism of action is through inhibition of plant amino acids (Anon. 1981).

Symptoms of glyphosate damage to vegetation are usually a gradual wilting and yellowing of foliage. For most annuals, this occurs within 2-4 days, and for perennials after 7 to 10 days. Cold or cloudy weather at the time of treatment may slow activity (Sutton 1978). The herbicidal effect of glyphosate does not reach a maximum until about two years after treatment (Vanden Born and Malik 1984).

Time of application to hardwoods is not critical provided the target vegetation is growing vigourously (Sutton 1978). However, optimum time of application ranges from August, after shoot elongation of competing vegetation is complete, to the beginning of leaf colour change (Sajdak 1982, LePage and Pollack 1988). Treatment of sprout-established plants soon after burning or cutting may not be effective due to the dilution of a relatively small amount of absorbed chemical in a large root system. Glyphosate may not be effective if target plants are stressed or damaged (Boyd *et al.* 1985).

Timing is important when the objective is to release conifers from hardwood competition. For conifer release, glyphosate should be sprayed late in the growing season, after bud-set on the conifers and before leaf fall by competitive species (Sutton 1978, Sajdak 1982). Although all conifers, except larch, are resistant to glyphosate once buds have been set and new foliage has hardened, late season flushes in all species will be damaged (Boyd *et al.* 1985). When applied immediately after planting, conifers should be carefully protected from direct contact with the chemical (Boyd 1982). Foliage condition is a better indicator of a safe phenological stage than is bud-set (Boyd *et al.* 1985).

Conifers and competing vegetation are rate-sensitive to glyphosate (Alm 1981), but interaction between seasonal timing and dose rates needed to optimize the performance of glyphosate is poorly documented (Perala 1985). There is some evidence that low concentrations of glyphosate may result in a greater herbicidal effect than high concentrations (Sutton 1978).

Several other factors influence herbicide efficacy. Because of the salt formulation of glyphosate, rain falling on treated vegetation within six hours of treatment will reduce effectiveness (Lund-Høie 1975, Boyd 1982). Biotests have shown, however, that not more than 25-50% of the herbicide is lost depending on the intensity of the rainfall (Lund-Høie 1975). Effectiveness of glyphosate is enhanced by an increase in relative air humidity (Lund-Høie 1975). Care must be taken to use clean water and clean spray equipment, because dirt will render the herbicide ineffective (Anon. 1981).

Fertilization

Positive growth responses of conifers to inorganic fertilization without subsequent weed control are difficult to obtain in young coniferous plantations (Sutton 1975). Established ground vegetation commonly responds to fertilization more rapidly than small conifers, especially those recently planted. In effect, weeds are helped to become even more competitive with the addition of fertilizer (Sutton 1975).

Competitive vegetation can have some positive effects, such as the protection against soil erosion (Valkova 1988). Soil binding capacities of some plants may improve following fertilization since roots grown under low nitrogen fertility levels tend to be long and sparsely branched while those with high nitrogen levels are short and well branched (Tiedemann and Klock 1974).

Competitive Mechanisms

Non-crop vegetation can cause deleterious effects on survival and growth of conifer regeneration by: directly competing for available light, moisture or nutrients; producing physical injury; smothering of seedlings by fallen leaves or snow-pressed non-woody vegetation; abrasive action; allelopathic effects; increasing fire potential; or, providing a favourable habitat for insects and animals with potential to damage or kill young seedlings (Sutton 1985). Most importantly, competition from associated vegetation can limit availability of site resources required for proper physiological functioning of planted seedlings. Without an adequate supply of moisture, nutrients, light, and space, seedlings may die or, at best, will grow at a rate well below their physiological optimum.

Actual levels of light reduction caused by vegetation and the effect it has on performance of seedlings is not well documented. However, it is known that survival and growth of conifer seedlings depends on the amount of assimilated carbon available for growth after deducting leaf fall and respiration by stems, twigs and roots. The amount of assimilated carbon is negatively related to competition for light. Results from a study in British Columbia indicate that at a 50% cover of fireweed (*Epilobium angustifolium* L.) and thimbleberry (*Rubus parviflorus* Nutt.) daily carbon dioxide assimilation of foliage of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*) seedlings was 74% that of fully exposed foliage; at 100% cover it was 50% that of fully exposed foliage; and at 150% cover foliage achieved only 19% of the rate of daily CO_2 assimilation of fully exposed foliage (Comeau 1988). Measure of percent vegetation cover provides a consistent estimate of light attenuation in certain plant communities (Comeau 1988) and is also considered to be the best predictor of seedling growth (Coates 1988).

Duration of the leaf area of deciduous canopies may influence growth and survival of conifer seedlings by influencing seasonal supplies of light. Conifer seedlings may be able to assimilate sufficient carbon to sustain good growth during spring and fall periods, when brush species are leafless (Comeau 1988).

Competition for soil water between non-crop vegetation and conifers can drastically affect the survival and growth of the conifer crop (Spittlehouse 1988). Because of evapotranspiration, large amounts of competing vegetation can rapidly dry the soil once spring rains have ended. Continued addition of vegetation to a site does not result in continued increase in the daily transpiration rate. The maximum transpiration rate from vegetation is limited by energy available to evaporate water. As more leaf material is added, the lower leaves of the canopy become shaded and their transpiration rate is reduced. Large leaf areas exist only on sites where a large water supply (through rainfall, seepage or a deep soil) is available to maintain transpiration levels through much of the summer (Spittlehouse 1988). It is important to note that competition for moisture does not end when conifers overtop competing vegetation (Spittlehouse 1988).

Physical damage can result in mortality due to smothering by dead foliage or reduced volume growth caused by whipping or other physical damage.

Allelopathy is the interference of one plant with the growth and development of another through chemicals produced by the plant and released into the environment. Allelopathic interactions may occur throughout the life of a stand, but are probably more common with conifer germinants than established conifers (Fisher 1980). This factor may be important if natural or artificial seeding is to be carried out. Seedlings generally become established on sites with allelopathic plants because distribution of the allelopathic plants is seldom continuous and their phytotoxic effects usually do not extend far from the source. Once established, conifers may shade phytotoxic plants, reducing their vigour and allelopathic activity (Fisher 1980).

Where non-crop vegetation is allowed to grow unchecked, accumulations of dry dead vegetation may constitute a fire hazard, especially in early spring before new growth commences (Estabrooks 1988).

Occasionally, plant species can be classified as non-desirable, not only because they are competing directly with conifer species, but also because they provide favourable habitats for small rodents and snowshoe hare (*Lepus americanus* Erxleben). Weeds and grasses provide a habitat for small rodents that chew and burrow around tree bases and in the rooting zone of the soil (Estabrooks 1988). Snowshoe hare cause damage to conifers by browsing on terminal and lateral buds of young regeneration. Browsing can result in retarded growth or mortality.

Stress on a seedling after outplanting is intensified by growth of non-crop vegetation, especially during the first two years after planting. This may result in decreasing seedling growth. Trees in this condition, sometimes referred to as "planting shock" or "check", are unlikely to show an immediate growth response following weed removal. The usual recovery time is two years (Estabrooks 1988).

Competing vegetation may benefit a site for several reasons, for example by: maintaining site productivity by reducing nutrient losses due to soil leaching; retarding soil erosion through stabilization of soil by their root systems; adding organic matter to the soil through leaf fall and root sloughing thereby improving soil moisture and cation exchange capacity of the soil; and protecting upper soil layers from temperature extremes (Anon. 1988). Competitive vegetation may also protect young trees in some circumstances by reducing extremes of summer air and soil temperatures by shading (Valkova 1988) and may benefit conifer seedling growth and survival by reducing moisture stress and respiration rates (Comeau 1988).

Responses of Conifers to Release

"Release is the removal or reduction of interference by weeds with the performance of established crop trees of any age after establishment" (Sutton 1985).

Reduction of competing vegetation has been observed to improve one or more of the following tree and stand attributes: tree survival; diameter, height, basal area growth, and individual tree and stand volume growth; crown length and width; bud size; needle number, colour, length and retentivity; nutrient status, tree vigour and resistance to damage from insects (Sutton 1985, Stewart 1987).

Stewart *et al.* (1984) published an extensive review of published and unpublished studies on the effects of competing vegetation on forest trees of the United States and Canada. They show that trees respond markedly to release from competing vegetation. Increased volume growth from 40% to 100% or more in the short term following treatment is common.

Long-term studies (15 years or more) of competition release suggest that tree growth responses after release at early ages persist or increase with time, continuing at least until crown closure. After crown closure, inter-tree competition begins to control growth (Stewart 1987).

Based on a literature review, Perala (1982) found that conifers in the Upper Great Lakes Region averaged 43% greater survival, 120% greater height growth, and 84% greater biomass growth after release from competing vegetation. Greater suppression prior to release and more complete release, resulted in larger contrast in growth between released and suppressed conifers. In addition, younger conifers showed a greater post-release relative height gain than older ones.

Perhaps the consequences of failure to release conifers are most dramatically shown in a survey of northern Lower Michigan's forest plantations (Stone and Chase 1962). At age 40, red pine (*Pinus resinosa* Ait.), white pine (*P. strobus* L.) and jack pine (*P. banksiana* Lamb.) plantations were 117%, 86% and 40% taller, respectively, without competing overstories. The average standing volume of red pine was 675% greater on sites free of competition.

There are two fundamental considerations for release (Sutton 1985). First, no matter how effective a treatment is in controlling weeds, it will not be effective unless applied while crop trees still have the vigour to respond to the increased resources made available. Secondly, if site resources are released at rates in excess of the ability of crop trees to use them, no benefit from the surplus accrues to the crop, and the site may be impoverished.

Wildlife Considerations

Management of broad-leaved woody species is carried out to reduce their impact on establishment and growth of conifer plantations. Vegetation management can have both beneficial and detrimental effects on wildlife habitat. Many shrub species targetted by vegetation management programs (e.g. beaked hazel and trembling aspen) are also important moose (*Alces alces* L.), and white-tailed deer (*Odocoileus virginianus* Zimmermann) browse. By identifying wildlife-plant interactions, forest managers may reduce detrimental effects and, in some instances enhance beneficial effects of vegetation management for wildlife. Potential use of competitive species by moose, white-tailed deer, woodland caribou (*Rangifera tarandus caribou*), snowshoe hare, ruffed grouse (*Bonasa umbellus* L.), and song birds is summarized in this publication.

A thorough review of literature describing moose habitat requirements is presented in Timmermann and McNicol (1988). Important browse species in eastern North American moose range are balsam fir (*Abies balsamea* L. Mill.), white birch, and trembling aspen. Beaked hazel, mountain maple (*Acer spicatum* Lam.), mountain ash (*Sorbus* spp.), willow, serviceberry (*Amelanchier* spp.), dogwood (*Cornus stolonifera* Michx.), and pin cherry are other common browse species (McNicol and Timmermann 1981, McNicol and Gilbert 1980). Large quantities of forage (18-25 kg/day) are necessary to maintain adult moose (Gasaway and Coady 1974).

Deer feed on leaves and branch tips of shrubs and trees including aspen, cherry, mountain maple, willow, bearberry (*Arctostaphylos* spp.), hazel, honeysuckle (*Diervilla* spp.), serviceberry, as well as the foliage of a great variety of herbaceous plants. In winter, deer browse on woody vegetation of trees and shrubs (McNicol and Timmermann 1981) and the average deer requires approximately 2.3 kg of quality browse per day (Smith and Borczon 1977).

Tree and ground lichens are important winter forage of woodland caribou, including 282 seed plant species, and 62 lichen species, as well as mushrooms. During summer, caribou feed on the leaves of deciduous trees and shrubs, especially willow, birch and blueberry. During fall, after leaf abscission, caribou browse on terrestrial lichens and leaves of coniferous species. In winter, caribou eat lichens (*Cladina* spp.), vascular plants, and fine twigs of browse species such as birch, willow, cherry and blueberry (McNicol and Timmermann 1981).

Snowshoe hare thrive in early successional vegetation interspersed with mature conifer stands used for shelter (Arnup *et al.* 1988). Snowshoe hare prefer jack pine, red pine, white pine, and white spruce (*Picea glauca* (Moench) Voss) (Aldous and Aldous 1944). Most damage is done to conifer plantations in or near areas of low lying, dense cover and the degree of damage is often in direct proportion to the size of the hare population. Hare populations typically follow a ten-year cycle; low populations persist for about six years, then a build-up occurs for about four years (Aldous and Aldous 1944). Although seedlings are not usually available to hares in years when snow levels exceed 30 to 50 cm, they are vulnerable in years of low snowfall, or in early spring and late fall (Bergeron and Tardif 1988).

Beaver (*Castor canadensis* Kuhl) feed upon leaves, twigs and bark of woody plants, particularly aspen, willow and balsam poplar (*Populus balsamifera* L.), as well as other aquatic and terrestrial herbs. Alder (*Alnus* spp.) is often used as construction materials by beavers (Arnup et al. 1988).

Ruffed grouse prefer aspen-birch mixed stands, or less frequently, pure aspen, lowland conifers, conifer-hardwood, jack pine, and red pine stands. These 7 stands types accounted for over 80% of the relative use of 16 stand types observed (Marshall and Winsness 1953). Of these, the aspen-birch stand type alone accounted for almost 25% of total use.

Critical Silvics of Selected Competitive Species

Acer spicatum Lam.	Mountain maple
Alnus crispa (Ait.) Pursh.	Green Alder
Alnus rugosa (Du Roi) Spreng.	Speckled Alder
Amelanchier spp.	Serviceberries
Betula papyrifera Marsh.	Paper Birch
Cornus stolonifera Michx.	Red Osier Dogwood
Corylus cornuta Marsh.	Beaked Hazel
Epilobium angustifolium L.	Fireweed
Graminoids	Grasses and Sedges
Ledum groenlandicum Oeder	Labrador Tea
Populus balsamifera L.	Balsam Poplar
Populus tremuloides Michx.	Trembling Aspen
Prunus pensylvanica L.f.	Pin Cherry
Prunus virginiana L.	Choke Cherry
Rosa acicularis Lindl.	Prickly Rose
Rubus idaeus L. var. *strigosus* (Michx.) Maxim.	Red Raspberry
Salix spp.	Willows
Vaccinium angustifolium Ait.	Lowbush Blueberry
Vaccinium myrtilloides Michx.	Velvet Leaf Blueberry
Viburnum spp.	Squashberry / Highbush Cranberry

Acer spicatum Lam.
Mountain Maple

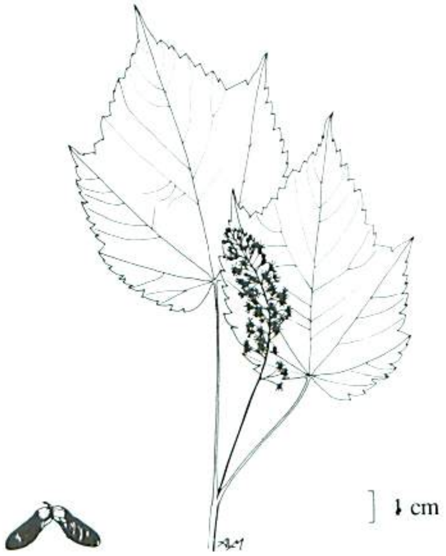
Description

General: erect shrub up to 3 m high; branchlets purplish-grey, minutely hairy, older branches greenish-grey to black; often forms thickets.

Leaves: opposite; with 3 prominent lobes and 2 obscure lobes near the base, the main lobes abruptly sharp-pointed; margins coarsely and irregularly toothed; lower surface with fine hairs, especially near the midrib.

Flowers: in dense, upright, long-stalked clusters at the branch ends; individual flowers small (<1 cm across), greenish-yellow; appearing in May and early June. Male flowers are borne near the tip of each cluster, the female flowers near the base.

Fruit: paired keys (each about 2 cm long), borne in clusters; July and August.



Habitat

Distribution in Ontario: Mountain maple is common throughout southern Ontario and northward to Lake Abitibi and to the southern end of James Bay; westward around Lake Superior; less common northwestward to the upper part of the Severn River drainage basin at about 53°N and reaching but not entering the Boreal Forest and Barren Region except in the Moose River drainage basin (Soper and Heimburger 1982).

Climate: Mountain maple thrives in a humid climate that has adequate precipitation in all seasons (Hosier 1974). The snow cover period ranges from 30 days in the southern part of the range to more than 120 days in the extreme northern part. The growing season lasts from less than 120 days to more than 170 days (Van Dersal 1938).

Site and Soil Relations: Mountain maple prefers rich soils, rocky slopes, cliff bases and flats. It occurs also along streams and in swamps (Vincent 1965a, Soper and Heimburger 1982), but grows well in drier or well-drained, acidic soils (Van Dersal 1938). In NW Ontario, mountain maple occurs more frequently on clay loams, silty clay loams and silty clays than finer or coarser textured soils.

Nutrient Requirements: Mountain maple prefers sites with abundant nutrients as indicated by its high frequency of occurrence on V-Types 2, 6, 8, 12 and 21. It occurs with relatively low frequency where nutrients are limiting and absent, on V-Types 37 and 38.

Distribution of **mountain maple** in Ontario
(Adapted from: Soper and Heimburger 1982)

Moisture Requirements: Mountain maple occurs across a wide range of soil moisture conditions. Nutrient levels appear to be a more limiting factor for growth than moisture levels. Mountain maple is more representative of mesic conifer and hardwood communities than of drier jack pine communities (Ohmann 1982).

Light Requirements: Mountain maple can grow well in either full sunlight or shade, but grows best in partial shade (Van Dersal 1938). It is about equal to balsam fir in light requirements (Post 1969). Although mountain maple is not sufficiently tolerant to thrive under dense overhead shade, it may survive for many years under this condition, taking advantage of any canopy openings (Vincent 1965a).

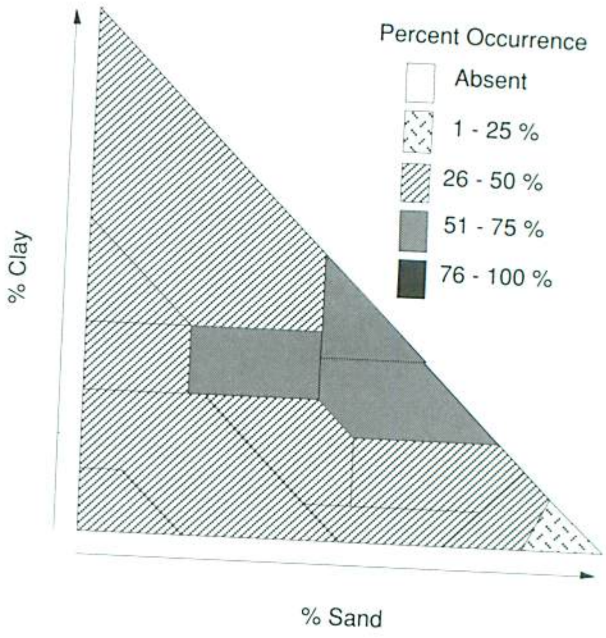
Reproduction

Sexual Reproduction: Although the species migrates and increases in number through seed propagation, seeding plays a minor role in maintaining established populations (Post 1965).

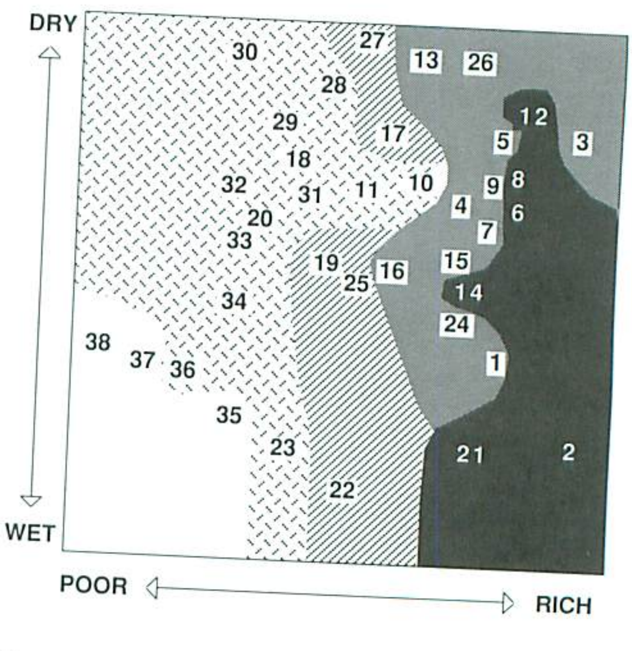
Seed Production and Dispersal: Information pertaining to the minimum seed-bearing age for mountain maple was not found in the literature. No data were found about the quantity of seed produced per tree. The number of cleaned seeds per kg varies from 33,700 to 61,300 with an average of 48,790 (Anon. 1974). Wind is the primary mode of seed dispersal (Hosier 1974, Anon. 1974). Seed dispersal by water occurs infrequently.

Seed Viability and Germination Requirements: Commercial seed was 93% pure and had a viability averaging 73% (range 57-84) (Hosier 1974). Seedlings of mountain maple do not become established in hardwood litter and survive in quantity only on mineral soil seedbeds (Post 1965).

Vegetative Reproduction: Reproduction occurs most commonly by sprouting from the stem near the root collar, including stems growing laterally underground, or from layering of branches in contact with the ground (Post 1965). Stems produce buds that tend to remain dormant until they are disturbed by cutting or browsing (Hosier 1974). Many stems are produced annually by vegetative reproduction but only a small proportion survive more than one or two years (Vincent 1965a). Dying mountain maple stems produce more new shoots, chiefly from the root collar region, than healthy, living ones (Vincent 1965a). Mountain maple does not form root suckers (Post 1969). Death of the terminal portion of a stem encourages prolific sprouting from the root collar (Post 1965). Branches of any age except current year's growth will produce adventitious roots (Post 1965). Layering, which may be mistaken for suckering, occurs frequently when stems are pressed against the ground; though common, layering is not important in the spread of this species (Post 1969). Propagation by root or shoot cuttings is difficult (Hosier 1974).



Frequency of occurrence of **mountain maple** by soil texture class



Frequency of occurrence of **mountain maple** by NWO FEC Vegetation Type

Growth and Development

Mountain maple is the smallest maple in eastern Canada (Plexman 1979). Mountain maple attains a maximum height of 9 m with a diameter of 15 to 20 cm in the Appalachian Mountains. It is generally smaller, about 6 m with a diameter of 8 to 10 cm further north (Hosier 1974). It has been shown to produce 2 to 4 m^2 of basal area per hectare when well developed (Vincent 1953). Annual height growth of mountain maple is usually less than 30 cm. The most rapid period of height growth for mountain maple stems appears to be between 5 and 10 years of age (Vincent 1965a). Shoots from the lower portion of parent stems grow faster than other types of shoots (Hosier 1974). It commonly forms clumps, each member having several upright branches which produce many branchlets (Hosier 1974). Mountain maple may form up to 7,900 clones/ha (Vincent 1965a). In Ontario and New Brunswick, senile mountain maple plants (40 to 50 years old) produced more new vegetative growth than younger plants (Hosier 1974).

Mountain maple's roots spread out and remain almost entirely along the interface between the organic and mineral soil layers (Post 1965). They do not appear to occupy the humus completely and are sparse in the mineral soil (Vincent 1965a). Penetration of mineral soil is limited to brush-like bundles of fibre-like rootlets, which themselves arise from very small rootlets (Post 1965). Mountain maple does not form root grafts (Post 1965).

Phenology

Root, Shoot and Foliage: Information regarding root, shoot or foliage phenology of mountain maple was not found in the scientific literature.

Reproductive Structures: Seeds ripen between mid-September and mid-October (Hosier 1974).

Response to Disturbance

Overstory Removal: The ability of mountain maple to survive under heavy suppression and to gain dominance upon release has been shown in widely different parts of its range (Post 1965). Selective cutting of timber creates openings that are favourable to mountain maple (Krefting 1953). Mountain maple spreads rapidly after cutting and is capable of forming a closed canopy ≥ 3 m above ground within 10 years (Vincent 1953, 1965a; Baskerville 1961). The aggressiveness of mountain maple after clearcutting is achieved mainly through sprouting at the root collar and subsequent spreading of the crown (Post 1965, Vincent 1965a). Few mountain maple seedlings are involved in the rapid takeover of an area following logging (Vincent 1965a). Since sprouting on the lower stem and not seeding is important in maintaining established stands, the key to mountain maple control is prevention of vegetative reproduction (Post 1969).

Fire: Burning can be used to suppress mountain maple (Hosier 1974). Since mountain maple does not produce root suckers, killing the stem-meristem will kill the plant. This characteristic suggests that fire may be an effective and efficient means of control (Post 1965). Intermittent burn survivors may vigourously sprout from the root collar. Sprouts can reach 30 to 80 cm in height within one year. Seed is soon produced again, propagating this species in the understory (Day and Harvey 1981).

Mechanical Site Preparation: Ground surface disturbance can eradicate mountain maple if entire plants are uprooted and the stems severed (Post 1969). However, if stems are simply tipped over or trampled, or if they are severed at the ground surface, sprouting will be stimulated (Post 1969). Disking without follow up treatments will increase the biomass of mountain maple (Ohmann 1982). Bulldozing can be used either for eradication or to stimulate new growth in an aging stand (Post 1969).

Cutting: Mountain maple has a tendency to grow in clumps if disturbed by cutting (Krefting *et al.* 1955). Cutting results in at least a temporary increase in stem numbers (Baskerville 1961, Ohmann 1982). Roots severed from mountain maple stems do not produce suckers and eventually die (Post 1969).

Chemical Treatments: The response of mountain maple to 2,4-D, hexazinone and glyphosate will be discussed separately.

***2,4-D*:** Mountain maple is resistant to, and not readily killed by, 2,4-D (Campbell 1981, Ohmann 1982, Kennedy and Jordan 1985). It can be controlled with 2,4-D but usually a high dosage must be used and it is only effective during the most susceptible period (Chemagro Corporation 1953). Summer applications of 2,4-D are moderately effective in killing aerial stems of mountain maple. Killing back of the tops can result in long-term reduction in the height of mountain maple stands (Post 1965, Ohmann 1982); however, increased number of stems is often associated with a decrease in height growth (Post 1965, Hosier 1974).

In order to effectively control overgrown stems of mountain maple and greatly increase the amount of regrowth available for deer browse, Krefting *et al.* (1955) recommend that 2,4-D in the ester form be applied to stems at breast height at a concentration of not less than 5.4 kg of acid per 380 l of diesel oil; applications should be conducted during the bud swelling stage.

***Hexazinone*:** Maples (*Acer* spp.) are rated as intermediately susceptible to Velpar-L. Approximately 14 l/ha are required to control maple on a medium- textured soil (Corcoran 1989).

Glyphosate: Glyphosate applied in mid- to late August at 2.24 to 4.48 kg a.i./ha will provide excellent control of mountain maple (Sutton 1978). Leaf drop is a pronounced sign of glyphosate damage to mountain maple (Sutton 1978).

Fertilization: Information pertaining to the response of mountain maple to applications of fertilizer was not found in the literature.

Effects on Conifers

Once mountain maple forms a tall shrub layer, it may suppress spruce and balsam fir for up to 35 years (Vincent 1965a). On good sites for mountain maple, a maple overstory may shade smaller softwoods, and shade and whip larger softwoods (Vincent 1953). Mountain maple has sufficiently numerous roots in the humus layer that it undoubtedly makes severe demands on available soil moisture. This demand for moisture offers severe competition to small spruce and fir seedlings which have initially small root systems. It also may contribute to establishment difficulties for naturally reproducing spruce and fir (Vincent 1965a).

Mountain maple leaf litter prevents or retards establishment of softwood seedlings (Post 1965), particularily spruce, and many regeneration surveys by the provincial government and industry have shown that advance reproduction on sites supporting mountain maple is usually inadequate to provide a satisfactory new stand (Vincent 1965a).

Uses by Wildlife

Mountain maple is an important browse species of moose in central and eastern North America (Peek 1974). Moose browse the bark and twigs of mountain maple (Hosier 1974). Mountain maple is browsed mainly during winter months but is also utilized during summer and autumn (Timmermann and McNicol 1988). Mountain maple is a staple and preferred white-tailed deer browse over much of its range (Krefting *et al.* 1955). Mountain maple is one of the most nutritious and palatable browse plants for deer. It withstands repeated and heavy browsing and actually produces the most browse when about 80% of the annual twig growth is removed each year (Aldous 1952). Mountain maple produces well even after being subjected to heavy browsing by deer for over 20 years, but it must be browsed at least moderately in order to remain available to deer (Aldous 1952). If not heavily browsed, it often grows out of the reach of deer within three years (Hosier 1974). Cottontail rabbits (*Sylvalagus floridanus* J. A. Allen) also browse mountain maple (Hosier 1974). Ruffed grouse eat the buds (Hosier 1974).

Alnus crispa (Ait.) Pursh
Green Alder

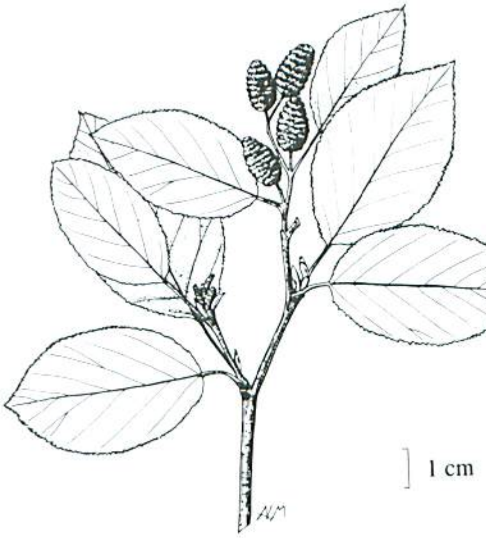
Description

General: erect shrub up to 3 m high; branchlets brownish, somewhat hairy, sticky, with few warty dots; older twigs reddish-brown to grey, hairless, not sticky, pith 3-sided; usually growing in clumps.

Leaves: alternate; egg-shaped to broadly oval, rounded to slightly heart-shaped at the base, blunt or pointed at the tip; margins somewhat wavy with many fine, sharp-pointed teeth.

Flowers: borne on catkins; male catkins slender, scaly, hanging in long-stalked clusters, elongating in the spring to 5-8 cm, opening in May and early June; female catkins smaller, cone-like, erect, in small clusters.

Fruit: winged seeds borne in small (1-2 cm long), dark, oval, woody cones on elongated stalks (2-4 cm long); cones persistent for a year or more after releasing the seeds.



Habitat

Distribution in Ontario: Green alder occurs throughout most of Ontario, but is rare south of 46°N and is absent in the area south of the Canadian Shield (Soper and Heimburger 1982).

Climate: Information pertaining to the influence of climate on green alder was not found in the literature.

Site and Soil Relations: Green alder occurs in wet depressions, along streams, on damp sandy or gravelly lakeshore, and bog or muskeg margins; on well-drained upland sites, rocky crests, sandy and gravelly slopes and cliffs (Furlow 1979, Soper and Heimburger 1982, Habgood 1983) and on well-drained upland soil such as glacial moraines (Habgood 1983). In NW Ontario, green alder occurs more frequently on coarse-textured soils such as sands and sandy loams than on fine-textured silts or clays.

Nutrient Requirements: Nutrient requirements are believed to be low (Habgood 1983). Green alder has been observed on nutrient deficient sites in Alberta (Moore 1964). In NW Ontario, it is most abundant in moderately rich stands (e.g., V-Types 10 and 17). Green alder appears to tolerate a wide pH range (Habgood 1983). It has a high tolerance of acidic conditions (Furlow 1979), but has been observed growing on alkaline (pH 8.0) glacial outwash (Watson *et al.* 1980).

Moisture Requirements: Green alder tolerates a range of soil moisture conditions, from well to poorly drained soils (Watson *et al.* 1980). It is better adapted to drier site conditions

Distribution of **green alder** in Ontario
(Adapted from: Soper and Heimburger 1982)

than most alders (Furlow 1979). In NW Ontario, it occurs with high frequency on moderately dry to dry sites, particularly V-Types 10 and 17. Green alder is also typical of drier sites in the Clay Belt region of NE Ontario (Carleton *et al.* 1985). It is relatively tolerant of spring flooding, but generally intolerant of stagnant water (Stanek and Orloci 1987) and drought (Watson *et al.* 1980).

Light Requirements: Green alder has a moderate to low shade tolerance (Watson *et al.* 1980).

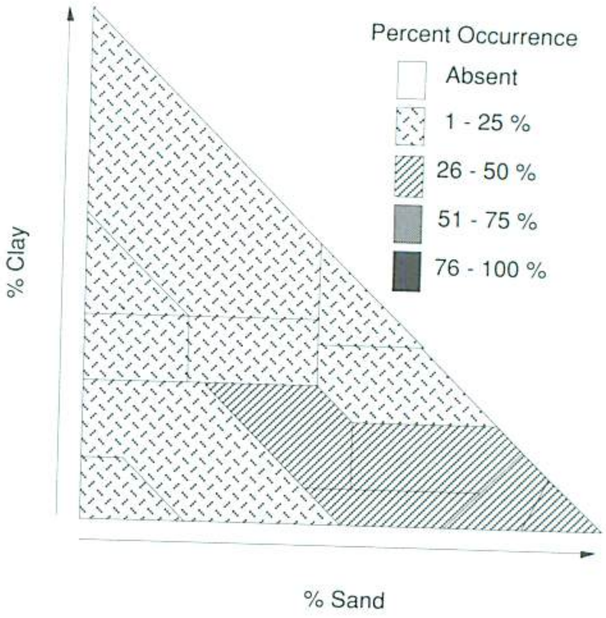
Reproduction

Sexual Reproduction: Green alder is monoecious, with both male and female catkins appearing on the same plant (Anon. 1974).

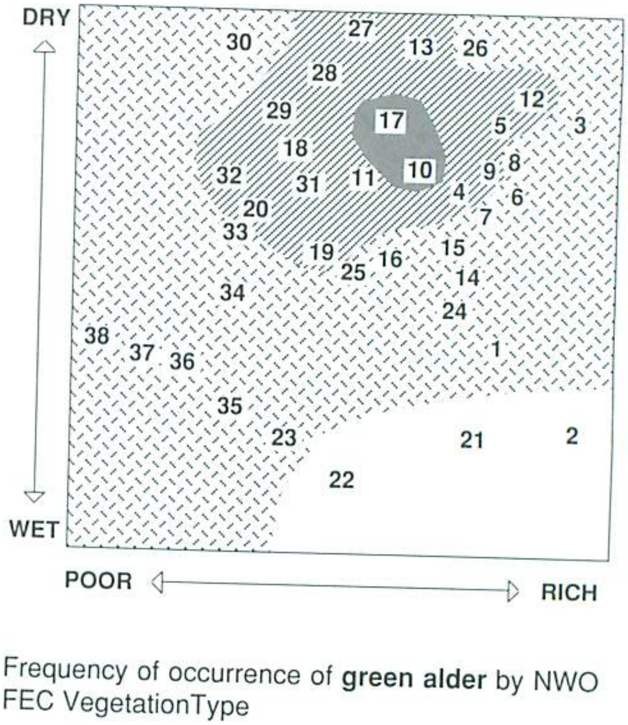
Seed Production and Dispersal: Green alder can produce seed at the age of five years (Furlow 1979). Farmer *et al.* (1985) estimated that the annual seed rain in individual alder stands varied from 0.14 to 2.40 million sound seeds per ha for understory alder stands and 9.5 million sound seeds per ha for open-grown stands. Green alder seeds average 2,821,900/kg; with a range of 1,534,400 to 4,109,400 (Anon. 1974). There are from 74 to 155 seeds per catkin (Farmer *et al.* 1985). Pollen is dispersed primarily by wind (Furlow 1979). Seeds are dispersed primarily by wind (Anon. 1974).

Seed Viability and Germination Requirements: A high percentage of seeds have abnormal, non-viable embryos (Farmer *et al.* 1985). Approximately 17-40% of seeds contain a viable embryo (Zasada *et al.* 1983, Farmer *et al.* 1985). Approximately 42-93% of cleaned seeds are also sound (Anon. 1974). At dispersal, green alder seeds exhibit conditional dormancy; a short chilling period (<30 days) is needed to promote germination under a wide range of conditions (Farmer *et al.* 1985). Germination of alder seed appears to be relatively independent of normal variation in light, temperature and pH but is sensitive to low oxygen and moisture levels (Furlow 1979). Green alder has not been observed to be a component of long-term soil seed banks (Farmer *et al.* 1985). Farmer *et al.* (1985) estimated that all green alder seeds in any single crop germinate or deteriorate within 10 months after fall or winter dispersal. Jobidon and Thibault (1982) noted root necrosis during the initial development of seedlings treated with leaf leachates and bud extracts of balsam poplar.

Vegetative Reproduction: Vegetative reproduction by sprouting is the dominant form of perpetuation of this species (Ahlgren 1960). Although both layering and cuttings are generally effective methods for propagating most alders (Furlow 1979), green alder cannot be readily propagated by means of stem cuttings (Holloway and Zasada 1979).



Frequency of occurrence of **green alder** by soil texture class



Frequency of occurrence of **green alder** by NWO FEC VegetationType

Growth and Development

Green alder usually grows to a height of 1 to 3 m, but it can occasionally grow to 8 m (Habgood 1983). It is a long-lived perennial (Watson *et al.* 1980) which often forms dense, extensive thickets (Habgood 1983).

The roots of green alder carry nodules with nitrogen fixing bacteria (Stanek and Orloci 1987).

Phenology

Root, Shoot and Foliage: Information regarding root, shoot or foliage phenology of green alder was not found in the literature.

Reproductive Structures: Both staminate and pistillate catkins are produced during the growing season prior to blooming (Furlow 1979). Elongation of male catkins begins during the first week in May (Farmer *et al.* 1985). Flowering occurs during the period when leaves unfold (Anon. 1974). Initial pollen dispersal occurs 18 to 20 days after the first sign of male catkin growth and after female catkins were clear of bud scales. Pollen dispersal continues for about 1 week. Clonal variation in these events ranges from 8 to 25 days. In a population north of Lake Superior anthesis and fertilization took place from mid-May to early June. By late August approximately 60-65% of the flower crop developed into mature catkins (Farmer *et al.* 1985). In the eastern United States fruit ripens between late-August and mid-October (Anon. 1974). Seed dispersal occurs shortly after ripening.

Response to Disturbance

Overstory Removal: Green alder is stimulated more by winter than summer logging. Three seasons after logging there were 3,600 stems/ha within a winter logged area compared to only 625 stems/ha within a summer logged area; prior to cutting there were 750 and 875 stems/ha within the two area respectively (Zasada *et al.* 1981).

Fire: Although fire is not carried through the crowns of green alder, the accumulation of leaves in the understory usually assures sufficient fire intensity to kill the cambium at the ground surface, thus killing all higher parts as well. Green alder is also occasionally pruned by low-intensity fires without total killing of branch tissue (Rowe 1983). Green alder will resprout from stumps if stems are killed by fire (Watson *et al.* 1980).

Mechanical Site Preparation: If scarification removes roots, alder competition should be reduced (Habgood 1983). Standing biomass of green alder tends to increase after rock raking (Ohmann 1982).

Cutting: Since green alder is capable of resprouting from the stump if cut (Watson *et al.* 1980), cutting may promote even denser growth of this species (Habgood 1983, Ohmann 1982).

Chemical Treatments: The response of green alder to 2,4-D, hexazinone and glyphosate will be discussed separately.

***2,4-D*:** Green alder can be easily controlled with a foliar application of 2,4-D (Chemagro Corporation 1953, Campbell 1981, Anon. 1986). Following a survey of plantations in northeastern Minnesota, Ohmann (1982) noted that green alder was absent from plantations that had been treated with 2,4-D. In some instances, green alder will resprout after spraying phenoxy herbicides (Lehela 1981, Anon. 1986).

***Hexazinone*:** Alders are rated as tolerant to Velpar-L (Corcoran 1989). More than 14 l/ha are required to control alders on a medium textured soil (Corcoran 1989). Green alder was only moderately affected by a mid-July foliar application of hexazinone even at 4 kg a.i./ha (Sutton 1984).

***Glyphosate*:** Green alder is very susceptible to glyphosate (Sutton 1984).

Fertilization: Information pertaining to the response of green alder to applications of fertilizers was not found in the literature.

Effects on Conifers

Green alder is believed to compete with conifer regeneration mainly by shading and competing for soil moisture. It may compete for nutrients other than nitrogen, although this impact may be outweighed by the nitrogen-enrichment alder creates. Alder could cause mechanical damage if bent down on seedlings by snow in winter. Alder competition is typically greatest in moderately well-drained (mesic) to imperfectly drained (subhygric) sites (Habgood 1983).

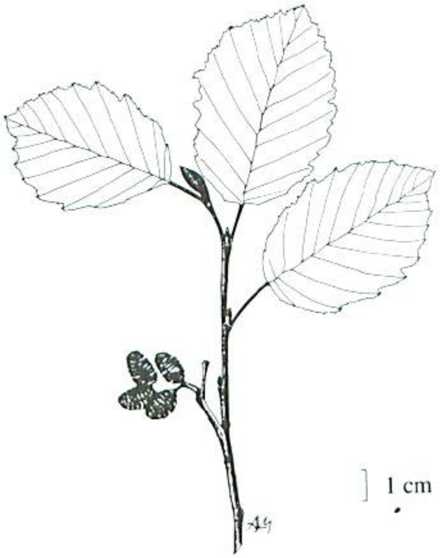
Green alder has potential as a nurse crop for timber production (Gordon and Dawson 1979). Its nitrogen-fixing capability helps improve soil nutrient regimes (Habgood 1983). Root nodules of green alder possess a symbiotic nitrogen-fixing organism (Dalton and Naylor 1975). Soil nitrogen measurements indicated that nitrogen fixation activity of green alder did not increase soil nitrogen above levels in adjacent areas (Dalton and Naylor 1975) because winds kept leaf litter from accumulating beneath alder clones. Lawrence (1958) found that nitrogen entering the soil originates mainly from dropped leaves rather than from the nodules themselves. Green alder may also benefit conifers by suppressing competition from *Calamagrostis* spp. and *Rubus* spp. (Habgood 1983). Green alder colonizing disturbed areas stabilizes soil, preventing soil erosion (Habgood 1983).

Uses by Wildlife

Although green alder is not a preferred food of moose, it is occasionally browsed (Habgood 1983, Timmermann and McNicol 1988). Woodland caribou browse leaves of green alder, for a brief period, when the leaves first appear, (Bergerud 1972). Foliar and floral buds of green alder are extremely rich in ether-soluble substances and are, therefore, less browsed by snowshoe hare than species such as trembling aspen (Radvanyi 1987).

Alnus rugosa (Du Roi) Spreng.
Speckled Alder

Description



General: shrub or small tree up to 4 m high; branchlets light reddish-brown, hairy, not sticky; older twigs dark brown to purplish-black, hairless, speckled with conspicuous, light warty dots, pith 3-sided; often growing in clumps or thickets, hummock-forming.

Leaves: alternate; egg-shaped to broadly oval, rounded to slightly heart-shaped at the base, pointed at the tip; margins coarsely and unevenly double-toothed; more or less hairy along the veins underneath.

Flowers: borne on catkins; male catkins slender, scaly, hanging on long stalks, elongating in the spring to 5-8 cm, opening in April or May; female catkins smaller, erect, cone-like, in small clusters at the branch ends.

Fruit: winged seeds borne in small (about 1 cm long), dark, roundish, woody cones; cones without stalks or on short (<1 cm) stalks; cones persistent for a year or more after releasing the seeds.

Habitat

Distribution in Ontario: Speckled alder is found throughout Ontario except in the counties near the west end of Lake Erie (Soper and Heimburger 1982).

Climate: Information pertaining to the climatic requirements of speckled alder was not found in the literature.

Site and Soil Relations: Speckled alder occurs along the edges of streams, rivers, bogs, swamps and lakes, in wet depressions and open woods (Furlow 1979, Soper and Heimburger 1982). It grows well on a variety of soils, including rocky till, sandy loam, grey forest soils and muck (Healy and Gill 1974). Brickman (1950) found that speckled alder grows best on well-drained clay soils.

Nutrient Requirements: The range of tolerance to alkalinity or acidity was not found in the literature, but it may be similar to that of European alder (*A. glutinosa* [L.] Gaertn.) and European speckled alder (*A. incana* [L.] Moench), which grow well on soils with a pH range of 3.4 to 7.7 (Healy and Gill 1974).

Moisture Requirements: Speckled alder most commonly occupies poorly drained soils (Healy and Gill 1974). Typically, it forms thickets where surface drainage is slow and the ground

Distribution of **speckled alder** in Ontario
(Adapted from: Soper and Heimburger 1982)

water level is near the surface during the early part of the growing season (Healy and Gill 1974, Jablanczy 1979). Some alder sites become relatively dry during late summer (Brickman 1950).

Light Requirements: Speckled alder grows more vigorously in full sunlight than shade and is considered to be intermediately intolerant to shade (Healy and Gill 1974). In general, sprouts are more tolerant of shade than seedlings (Brickman 1950).

Reproduction

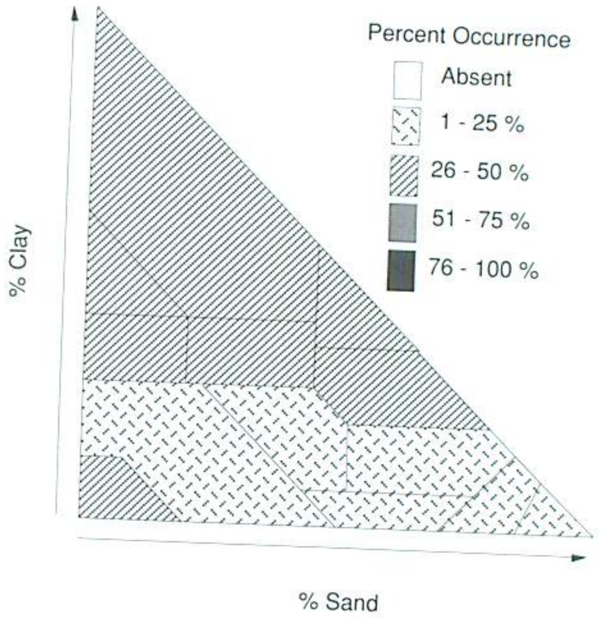
Sexual Reproduction: Speckled alder is monoecious (Brown and Hansen 1954), bearing male and female flowers on separate catkins (Healy and Gill 1974).

Seed Production and Dispersal: Speckled alder can produce abundant seed on stems older than seven years of age. It is a prolific seeder, producing seed each year (Brown 1953). The number of seeds produced per plant is not definitely known. Speckled alder seeds average 661,400/kg (Anon. 1974). Pollen and seed are wind dispersed (Healy and Gill 1974). Although some seed is dispersed to distances of 11-13 times the stem height, over 90% of seed falls within a distance of two to three times the stem height of the seed-bearing alder (Brown and Hansen 1954). Seed dissemination by water appears to play an important role in the spread of this species (Brown 1953).

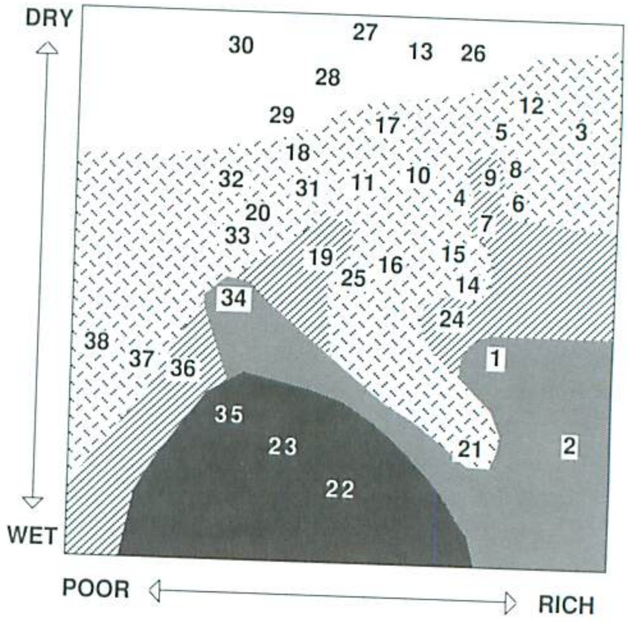
Seed Viability and Germination Requirements: Approximately 30-60% of cleaned seeds are sound (Anon. 1974). Cool, saturated soils appear to be required for seed germination (Brown 1953, Brickman 1950). Mineral soil is the preferred seedbed (Brown 1953).

Vegetative Reproduction: Alders reproduce vegetatively from sprouts, layering, underground stems and suckers (Brown and Hansen 1954). Perpetuation and spread of established stands results mainly from sprouting. As a seedling develops, lateral sprouts grow from its basal portion giving rise to a cluster of stems, thus forming a clone. Seedlings can produce such sprouts by five years of age.

The capacity of a branch to become layered is not restricted by age. Branches ranging from 2-17 years of age have been observed to layer. After becoming layered a branch will send up sprouts along its length (Brown 1953). Root suckers are found to such a limited extent that they are considered to be of minor importance in perpetuating the species (Brown and Hansen 1954). Although alder is capable of forming root suckers and sprouts, lateral expansion is apparently ineffective (Huenneke 1985).



Frequency of occurrence of **speckled alder** by soil texture class



Frequency of occurrence of **speckled alder** by NWO FEC Vegetation Type

Growth and Development

The largest recorded specimen of speckled alder occurred at Holland, Michigan, and had a height of 17 m, a trunk circumference of 80 cm and a spread of 8 m (Furlow 1979). Growth rates depend on many factors, including site conditions, competition, and type of growth (seedling or sprout) (Healy and Gill 1974). Thickets of speckled alder typically consist of numerous discrete clumps of stems (Huenneke 1985).

Phenology

Root, Shoot and Foliage: Shoot elongation commences shortly after pollination has occurred (Brown 1953) and ceases by about the middle of July. Leaves persist in their normal colour until freezing temperatures kill the foliage, at which time leaves turn dark brown and rapidly drop to the ground (Brown 1953).

Reproductive Structures: The formation of the next year's male flowers has been observed to begin from mid- to late July. Female catkins are formed between late July and the end of the growing season (Brown 1953). Speckled alder is one of the first species to flower in spring (Bassett *et al.* 1961). It flowers for a period of about one week within a given locality (Heinrich 1976). Flowering occurs in April-May (Bassett *et al.* 1961), approximately one to two weeks prior to leaf development (Brown 1953). For Ottawa, the average date of first flowering was about April 7 (Bassett *et al.* 1961). Staminate flowers occur before pistillate flowers (Brown 1953). Pollinated flowers develop throughout the summer, and by the beginning of August the cone-like fruit is quite discernible. Seeds are sufficiently developed to germinate by the latter part of August, although the bracts or scales are still tight and have not released the seed. By mid- September, cone scales begin to dry. As scales dry, seeds loosen in the cone and are dispersed. Most seed is released in early October. Some seeds remain in the cone and may not be released until the next spring or early summer (Brown 1953). Empty cones are very persistent, frequently remaining on branches until the following fall.

Response to Disturbance

Overstory Removal: Overstory removal may promote alder growth, not only through increased light, but also by raising the water table, especially in clay soils (Jablanczy 1979). Large stands of speckled alder commonly form after spruce and fir are logged in wet areas (Healy and Gill 1974). Vincent (1964a) studied eight speckled alder stands in Ontario that had originated after clearcutting of black spruce. Average height of speckled alder varied from 0.9 to 1.8 m and the annual height growth declined steadily after 9-10 years of age. Density of alder ranged from 39,500 to 74,000 stems/ha, averaging 65,500 stems/ha. Clearcutting one aspen-balsam poplar-speckled alder stand in northern Michigan resulted in a dense stand of alder sprouts, which reached a maximum height of 1.8 m the second year after cutting (Day 1956b). Layering will occur following logging operations which keep alder stems in contact with the ground by tops of fallen timber (Brown 1953). Vincent (1965b) observed that slash manipulation at the time of logging might prevent development of speckled alder on small areas and thus leave canopy openings. A vegetation survey in black spruce swamps and lowland brush areas in north-central Minnesota suggests that speckled alder usually develops from vegetative reproduction of shrubs already present at the time of logging and not by invasion from surrounding areas (Johnston 1968).

Fire: Reproduction of alder on moist, nutrient-rich sites can be vigorous following fire.

Mechanical Site Preparation: Stems that are only pushed in a horizontal position and not severed from the parent root system will sprout vigorously (Brown 1953). Stems that come in contact with, or are partially covered with soil will layer and produce new aerial shoots. Alders completely severed from the root system and left on the soil surface will die.

Cutting: Cutting of alder without subsequent chemical treatment will not eliminate it (Stoeckeler and Heinselman 1950). Rapid regrowth of alders may occur following mechanical brushcutting (Richardson 1979). Spring and winter cutting will result in the most rapid sprout growth; July and August cutting will produce the thinnest stands and least height growth (Stoeckeler and Heinselman 1950). Stoeckeler and Heinselman (1950) reported an increase of 65% in the number of stems after a May cutting, and 61% after an August cutting. Average heights were 0.9 and 0.8 m respectively.

Chemical Treatments: The response of speckled alder to 2,4-D, hexazinone and glyphosate will be discussed separately.

2,4-D: Speckled alder can be easily killed with an application of 2,4-D (Stoeckeler and Heinselman 1950, Johnston 1977, Campbell 1981); however, it seems to become most susceptible to aerially applied 2,4-D only at a relatively advanced stage of seasonal development [approaching full flush with expanded leaves] (Arnup 1986). In a herbicide trial in Newfoundland, spray application of 2,4-D provided good control of speckled alder with minimal damage to softwood seedlings. After alder was removed, dense bluejoint and raspberry competition developed (Richardson 1979).

***Hexazinone*:** Alders are rated as tolerant to Velpar-L (Corcoran 1989, Jensen and North 1987). More than 14 l/ha are required to control alder on a medium-textured soil (Corcoran 1989).

***Glyphosate*:** An application of 7.0 l/ha of Vision on July 25 in Minnesota killed 86% of alder in experimental plots (Butler-Fasteland 1987). Glyphosate applied at 2.1 kg/ha in mid-August provided effective control of speckled alder (Prasad 1983).

Fertilization: Information pertaining to the response of speckled alder to applications of fertilizers was not found in the literature.

Effects on Conifers

Speckled alder is often detrimental to conifer regeneration. Where dense, it casts shade which prevents or retards successful regeneration of valuable tree species (Stoeckeler and Heinselman 1950). Excessive competition from speckled alder generally occurs on fresh and moist sites (Stiell 1955).

Vincent (1964b) concluded that the overall effect of speckled alder on black spruce reproduction is beneficial and that it is not desirable to eliminate alder completely to make room for more conifers. However, some manipulation of the alder canopy seemed necessary if the full wood-producing potential of a site was to be realized. The availability of nitrogen to black spruce on some sites will be enhanced by alder (Watt and Heinselman 1965). Root nodules enable this species to fix nitrogen, which may be an important ecological factor (Brown and Hansen 1954). European foresters plant alders beneath conifers to increase soil nitrogen and stimulate growth of crop trees. Soil fertility increases result from nitrogen fixation by root nodules and from fallen leaves (Healy and Gill 1974). On favourable sites, soil nitrogen may accumulate under speckled alder thickets at rates in excess of 168 kg/ha per year (Daly 1966). In a study of natural speckled alder stands in Quebec, alder produced about 1,600 kg/ha/yr of leaf litter, equivalent to 43 kg ha/yr of nitrogen (Fortin *et al.* 1983). Under alder thickets, annual leaf fall decomposes extremely rapidly on the soil surface (Daly 1966). In vitro, the humus of alder soils produces significant quantities of mineral nitrogen even at pH as low as 3.9 (Fortin *et al.* 1983). A sparse overstory of alder may be beneficial to conifer regeneration by checking growth of grasses. Stoeckeler and Heinselman (1950) observed 10 times as many natural first-year seedlings of white cedar, balsam fir and spruce in plots where a partial kill of the alder overstory was attained, as compared to plots where all alder overstory was removed.

Uses by Wildlife

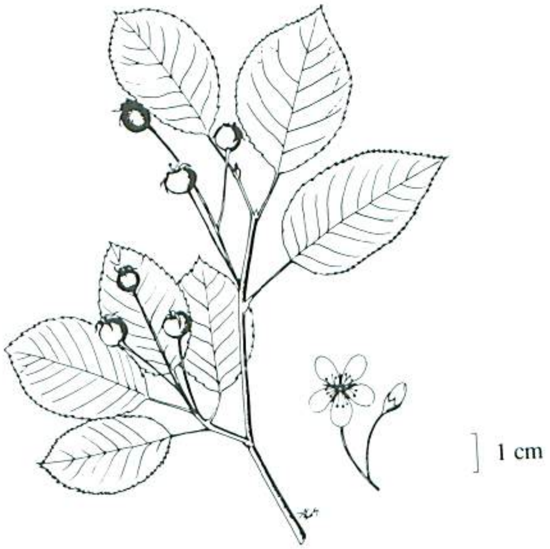
Moose, deer, muskrats (*Ondatra zibethica* L.), beavers, cottontail and snowshoe hare feed on twigs and foliage. Most investigators consider alder as low in preference for deer (Healy and Gill 1974). Beavers commonly use speckled alder for dam construction (Healy and Gill 1974).

Grouse eat small quantities of buds, catkins rabbit and seeds. Alder is an important cover plant for grouse and woodcock (*Philohela minor* Gmelin). Speckled alder provides high shrub cover needed around grouse drumming sites. Woodcock use alder cover from early spring through fall for nesting, feeding and resting. They prefer edges more than centres of large even-aged thickets (Healy and Gill 1974). Alder seeds are also eaten by some smaller birds, particularly red polls (*Acanthis* spp.), and to a lesser extent, goldfinches (*Spinus tristis* L.) (Healy and Gill 1974). Sapsuckers (*Sphyrapicus varius* L.) have been observed feeding on the inner bark (Brown 1953).

Amelanchier spp.
Serviceberries

Although there are numerous species of serviceberries in Ontario, they have been dealt with here as a single group because there is little ecological or biological information currently available for the individual species. Three of the most common serviceberries in NW Ontario are *A. bartramiana* (Taush) Roem., *A. humilis* Weig., and *A. sanguinea (Pursh)* DC. Less frequent species include *A. alnifolia* Nutt., *A. laevis* Wieg., and *A. stolonifera* Wieg..

Amelanchier bartramiana (Tausch) Roem.
Mountain Juneberry



Description

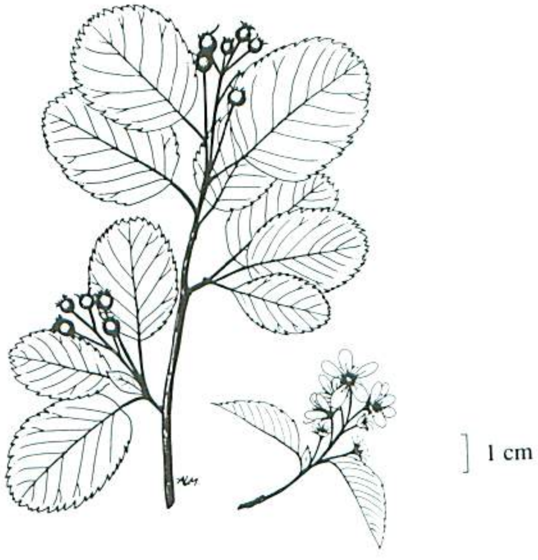
General: erect shrub up to 2 m high; branchlets purplish, hairless; often forming clumps.

Leaves: alternate; egg-shaped, elliptic or somewhat inversely egg-shaped, tapering at both ends; margins finely sharp-toothed almost to the base; no glands on the leafstalk; both surfaces hairless.

Flowers: solitary or fewer than 4 in a loose cluster; flower stalks hairless; individual flowers about 2 cm in diameter, with 5 white petals appearing in May and early June.

Fruit: berry-like, purplish-black, about 1 cm long; ripening in July and August.

Amelanchier humilis Wieg.
Shadbush



Description

General: stiff, upright shrub to 5 m high or straggling, low shrub (<1m) forming loose colonies; young branchlets very silky-hairy.

Leaves: alternate; broadly oval or elliptic, rounded to slightly heart-shaped at the base, rounded to bluntly pointed at the tip; margins coarsely toothed, often entire below the middle; hairless above, young leaves grey-woolly beneath usually becoming hairless; veins conspicuous, extending into the teeth.

Flowers: numerous in dense upright clusters; flower stalks silky-hairy; individual flowers about 2 cm in diameter, with 5 white petals; appearing in May and early June.

Fruit: berry-like, juicy, almost black, with a whitish, powdery coating, about 1 cm long; ripening in July and August.

Amelanchier sanguinea (Pursh) DC.
Red-twigged Serviceberry

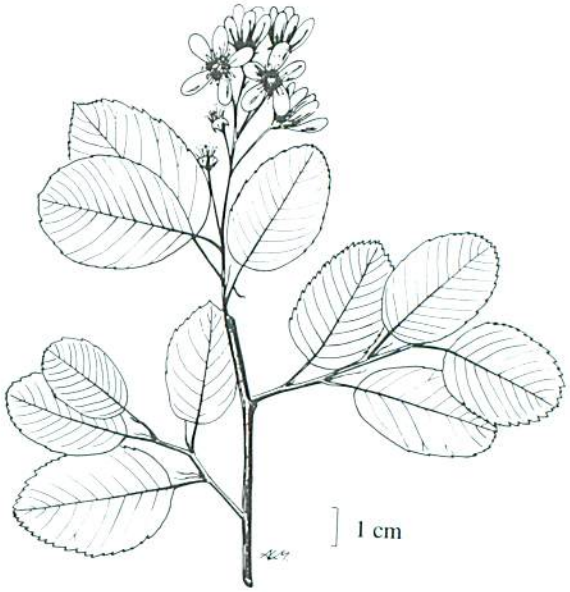
Description

General: straggling or erect shrub up to 3 m high; solitary or in small, loose clumps; branchlets bright reddish-brown.

Leaves: alternate; broadly elliptic to roundish, the base rounded to slightly heart-shaped, rounded or bluntly pointed at the tip; margins coarsely toothed; hairless above, young leaves grey-woolly beneath usually becoming hairless; veins conspicuous, straight, extending into the teeth.

Flowers: numerous in loose, drooping clusters; flower stalks hairless or sparsely hairy; individual flowers about 2 cm in diameter, with 5 white petals; appearing in May and early June.

Fruit: berry-like, dark purple, juicy, about 1 cm long; ripening in July and August.



Habitat

Distribution in Ontario: The range map presents the general range of all serviceberries in Ontario. Species specific information was obtained from Soper and Heimburger (1982). *A. alnifolia* is relatively rare. It is spreading from the prairies eastward into the northern and western parts of Ontario and along the north shore of Lake Superior. *A. bartramiana* is common from Lake Superior to the Hudson Bay Lowlands, less common in southern Ontario and rare off of the Canadian Shield. *A. humilis* is widely distributed throughout Ontario. *A. laevis* occurs throughout southern Ontario and northward to about 51°N. *A. sanguinea* occurs throughout southern Ontario and northward beyond Lake Superior to about 51°N. *A. stolonifera* occurs from Lake Erie to Lake Superior and northward to the Moose River drainage basin. It is absent in the extreme northern and western parts of Ontario.

Climate: Serviceberries are adapted to a wide range of climatic conditions (Harris 1972). The occurrence of *A. alnifolia* decreases with increasing precipitation and elevation (Klinka *et al.* 1989).

Site and Soil Relations: In general, serviceberries in NW Ontario occur more commonly on silts and clays than on sands. Species specific site and soil relations were obtained from (Watson et al. 1980, Soper and Heimburger 1982 and Klinka *et al.* 1989). *A. alnifolia* can be found in thickets, borders of woods, along rocky ridges and on stream banks. It is characteristic of seral forests and disturbed sites. It is adapted to a wide range of soil textures but prefers coarser-textured soils. *A. bartramiana* occurs primarily on acid soils, sandy lake shores, streambanks, peat bogs, swamps, boggy thickets and rocky ridges. *A. humilis* occurs on limestone flats, lakeshores, river banks, gravel fans,

Distribution of **serviceberries** in Ontario
(Adapted from: Soper and Heimburger 1982)

rocky hillsides, ridges and cliffs and in sandy areas, clearings, semi-open woods and ravines. *A. laevis* occurs in clearings and thickets, along the edges of woods, fencerows, and roadsides, and in coniferous and mixedwoods. *A. sanguinea* is found on gravelly and rocky soil ridges, slopes and lakeshores, in crevasses of open rock faces and cliffs, and in and along the edges of mixed forests. *A. stolonifera* occurs on rocky ground, bed rock crevasses of rocks (chiefly acidic), along shores, on ridges, in river gorges, on sandy soil clearings and in semi-open woods.

Nutrient Requirements: Serviceberries occur most frequently on slightly acid soils (pH 6.0 to 7.0) (Larson 1974). *A. alnifolia* is associated with soils that are moderately rich in nitrogen (Klinka *et al.* 1989) and is adapted to a range of soil pH from moderately acid to moderately alkaline (Plummer 1977). *A. humilis* is a common species in calcareous habitats (Soper and Heimburger 1982).

Moisture Requirements: *A. alnifolia* is relatively drought tolerant and occurs on dry to fresh soils (Monsen and Plummer 1978, Watson *et al.* 1980, Klinka *et al.* 1989). *A. spicata* typically occurs on drier sites in the Clay Belt region (Carleton *et al.* 1985).

Light Requirements: Growth and reproduction of serviceberries is best in full sunlight (Larson 1974, Watson *et al.* 1980). *A. alnifolia* is a shade-tolerant to shade-intolerant species (Klinka *et al.* 1989).

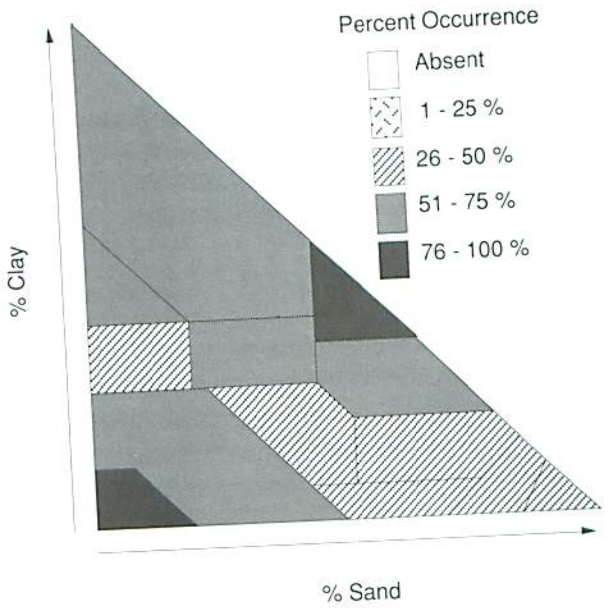
Reproduction

Sexual Reproduction: Seed production, dispersal, viability and germination are discussed.

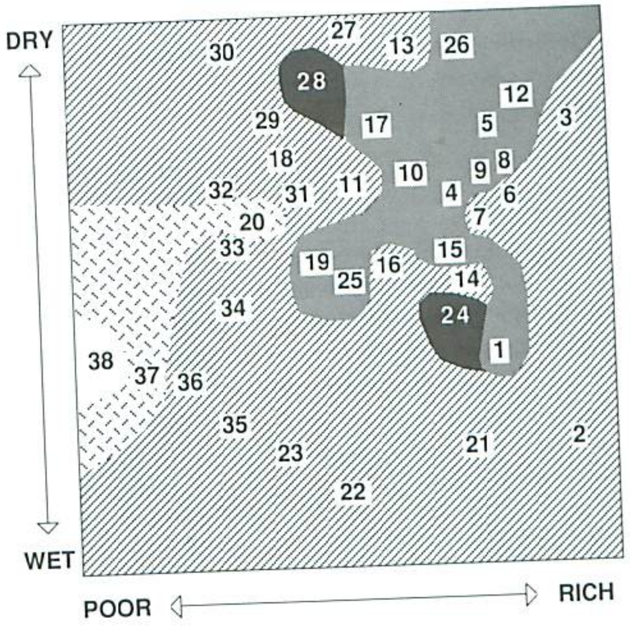
Seed Production and Dispersal: Yields of over 13 tonnes/ha of fruit can be obtained from managed stands of serviceberries (Harris 1972). The number of *A. alnifolia* seeds per kg varies from 79,000 to 250,900 with an average of about 180,800 (Anon. 1974). Seed dispersal occurs almost entirely via animals and birds and usually takes place soon after the fruit ripens (Larson 1974).

Seed Viability and Germination Requirements: Seeds of serviceberries are normally dormant (Watson *et al.* 1980). Seeds require cold stratification at 2-5 °C for 180 days (Watson *et al.* 1980). *A. alnifolia* does not appear to be a seed-banking species (Kramer and Johnson 1987).

Vegetatative Reproduction: Serviceberries reproduce from root suckers, sprouts or stolons to form dense thickets (Harris 1972, Watson *et al.* 1980). *A. alnifolia* can be reproduced from root cuttings (Harris 1972, Bishop and Nelson 1980).



Frequency of occurrence of **serviceberries** by soil texture class



Frequency of occurrence of **serviceberries** by NWO FEC Vegetation Type

Growth and Development

Serviceberries are deciduous, tall shrubs or small trees, growing 1 to 6 m in height (Watson *et al.* 1980). They generally grow in clusters (Harris 1972). Serviceberries are relatively long-lived perennials (Watson *et al.* 1980) capable of achieving 40 years of age (Brown 1953).

Phenology

Root, Shoot and Foliage: By mid-September about half of *A. alnifolia* leaves have dropped. Dormancy is induced and frost hardiness has increased considerably by this time (Kaurin *et al.* 1984).

Reproductive Structures: Time of flowering for most serviceberry species is late March to May (Larson 1974). Service berries are among the earliest woodland trees and shrubs to flower, with the white flowers often appearing before the leaves. Fruits ripen, depending on the species, from late June to August (Larson 1974).

Response to Disturbance

Overstory Removal: Information pertaining to the response of serviceberries to overstory removal was not found in the literature.

Fire: Serviceberries are relatively fire-resistant due to their massive, deep-rooting systems (Bradley 1984). For this reason, thick stands of sprouts can develop after fire (Gratkowski 1978). *A. alnifolia* increased in frequency, but decreased in percent cover after 24 years of repeated annual burning (Anderson and Bailey 1980). High soil moisture content may be involved in the destruction of underground parts of serviceberries during fires. Moisture in the uppermost layer of organic soil may form steam, which damages living tissue during intense fire (Ahlgren 1960). In a study contrasting spring and fall prescribed burns, a severe fall treatment killed 15% of the serviceberry plants on the site, while a less severe spring treatment killed only 5% (Noste 1982). Sprouting response in the first 2 years following fire was greater on the spring burn. In another study, Noste *et al.* (1987) noted that *A. alnifolia* plants did not resprout as well if burned just after leaves were fully developed or just after initial change in fruit colour, as compared to before bud burst or after first leaf colouring in fall.

Mechanical Site Preparation: Ohmann (1982), based on a survey of plantations in northeastern Minnesota, noted that sites that had been disked or received no site preparation had above-average biomass of serviceberries.

Cutting: Standing biomass of serviceberries increases following cutting (Gratkowski 1978, Ohmann 1982).

Chemical Treatments: The response of serviceberries to 2,4-D, hexazinone and glyphosate will be discussed separately.

2,4-D: Serviceberries are classified as both very susceptible to 2,4-D (Chemagro Corporation 1953, Larson 1974), and as resistant to 2,4-D (Benzie 1977). A 98% to 100% initial topkill of *A. alnifolia* can be achieved with between 2.2 and 4.5 kg/ha of 2,4-D ester (Boyd *et al.* 1985). The 2,4-D ester formulation is slightly more effective as a late foliar rather than an early foliar spray (Boyd *et al.* 1985). Basal sprouts are common after applications of 2,4-D (Gratkowski 1978).

Hexazinone: Velpar-L, applied at 2.2 to 3.4 kg/ha in late summer, provided less than an 11% kill of *A. alnifolia* provided two seasons after application (Boyd *et al.* 1985).

Glyphosate: Glyphosate applications are very damaging to serviceberries (Balfour 1989). An 87% to 100% initial topkill of *A. alnifolia* can be achieved with between 1.1 and 3.4 kg/ha of glyphosate applied as a late foliar spray (Boyd *et al.* 1985). Glyphosate applied in mid-August at rates of 1.1 and 1.4 kg a.i./ha was successful in controlling *A. alnifolia* for at least four years; no rate differences were detected (Thompson 1988).

Fertilization: Information pertaining to the response of serviceberries to applications of fertilizers was not found in the literature.

Effects on Conifers

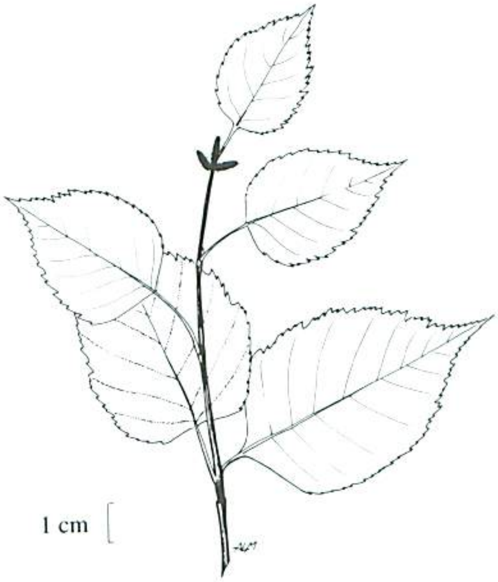
Serviceberries may seriously compete with young conifers. They produce masses of roots that fully occupy the soil surface layers beneath them (Gratkowski 1978). Serviceberries do not benefit conifers by fixing atmospheric nitrogen (Watson *et al.* 1980). Since serviceberries are rated "good" for soil stability (Plummer 1977) they may benefit sites susceptible to erosion.

Uses by Wildlife

Most serviceberries provide browse and edible fruits for wildlife (Anon. 1974). *A. alnifolia* is an important winter browse species of moose (Stevens 1970). Serviceberries are browsed by moose primarily in winter, but some browsing has been observed during summer and autumn (Timmermann and McNicol 1988). Serviceberry is an important winter food for whitetailed deer (Hemmer 1975), with twigs and foliage constituting 0.5% to 2% of their diet (Larson 1974). *A. bartramiana* is a relatively unimportant browse species of woodland caribou (Bergerud 1972). Many small mammals eat the fruit, and fruit and buds may constitute 0.5% to 2% of the diet of ruffed grouse (Larson 1974).

Betula papyrifera Marsh.
Paper Birch

Description



General: small to medium-sized (averaging 16 m high, up to 28 m), broadleaved hardwood tree with a rather small, open crown of spreading or ascending branches; branchlets slender, dark reddish-brown, buds with three scales; buds on older dwarf twigs with five to seven scales; trunk bark reddish-brown on young stems becoming distinctly white, papery, peeling easily into sheets, with long horizontal streaks.

Leaves: alternate but often appearing opposite or whorled on older, dwarf twigs; egg-shaped to almost triangular, tapering to a sharply pointed tip, rounded to wedge-shaped or occasionally heart-shaped (var. *cordifolia*) at the base; margins singly or doubly toothed, usually without teeth at the base within 1 cm of the leafstalk; hairless above, sparsely hairy in the vein angles beneath; variable in size and shape on young, vigorous shoots.

Flowers: borne on catkins; male catkins cylindric, visible at the tips of overwintering twigs, elongating in May before the foliage emerges; female catkins elongating in May to 3-5 cm long.

Fruit: two-winged seeds released from the female catkins in late May and early June; catkins are shed soon afterwards.

Habitat

Distribution in Ontario: Although paper birch is widely distributed throughout Ontario, it is absent from the region immediately north of Lake Erie and the Hudson Bay Site Region (1E) (Hills 1960, Hosie 1979).

Climate: Paper birch is adapted to a wide range of climates from humid to boreal. It tolerates wide variations in precipitation (Haeussler and Coates 1986).

Site and Soil Relations: Paper birch is frequently found on thin rocky soils (or otherwise poor sites), bogs, and may be found along streams and riverbanks (Watson *et al.* 1980). In general, paper birch is found on a wide variety of parent materials and on soil textures ranging from gravelly sands to loams, to organic soils (Haeussler and Coates 1986). In NW Ontario, paper birch occurs with greatest frequency on both deep and shallow morainal deposits. It is moderately frequent on glacio-fluvial, fluvial and lacustrine deposits, and infrequent on organic soils (Sims *et al.* 1990). Paper birch dominated stands are associated with deep, dry to fresh, coarse sandy, fine sandy and coarse loamy soils, as

Distribution of **paper birch** in Ontario
(Adapted from: Hosie 1979)

well as deep, moist, coarse loamy soils. Moderate distribution is found on shallow, moist soils over boulder pavement (Sims *et al.* 1990). Best growth occurs on fresh, well-drained sandy loams or silty soils; or on soils derived from limestone (Fowells 1965, Haeussler and Coates 1986). The poorest sites are extremely wet with poorly drained soils, or extremely dry with shallow to bedrock soils or coarse sands and gravels on glacial outwash deposits (Safford 1983).

Nutrient Requirements: Paper birch is associated with a wide range of soil nutrient conditions. Krajina *et al.* (1982) describe the nutritional requirements of birch as moderate to fairly high, especially for Ca and Mg. Paper birch grows on soils ranging from acidic to highly calcareous (Fowells 1965). In general it has a moderate acid tolerance (Watson *et al.* 1980). It has been observed growing on acid soils with elevated levels of N, Cu and Al near Sudbury, Ontario (Watson *et al.* 1980).

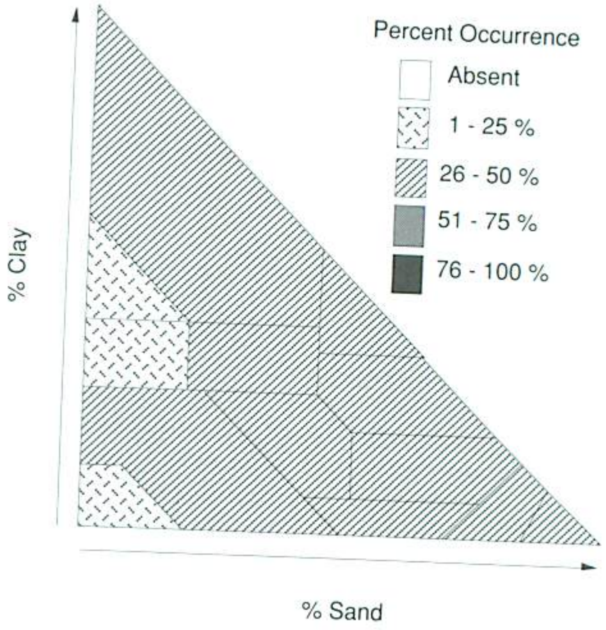
Moisture Requirements: Although paper birch is associated with a wide range of soil moisture conditions, it occurs most frequently on dry to fresh soils. It is infrequently associated with wet soils (Fowells 1965). Growth is better where soil is moist but well-drained (Haeussler and Coates 1986).

Light Requirements: Paper birch is intolerant of shade (Fowells 1965). It germinates best in partial shade, but subsequent growth is best under full sunlight. Logan (1965) grew paper birch seedlings for five years in 13%, 25%, 45%, and 100% of full sunlight. Shoot and root weights were greatest in 45% and 100% of full light. Greatest height growth was attained at 45% of full sunlight. Weight of foliage dropped significantly at light levels below 45% of full sunlight.

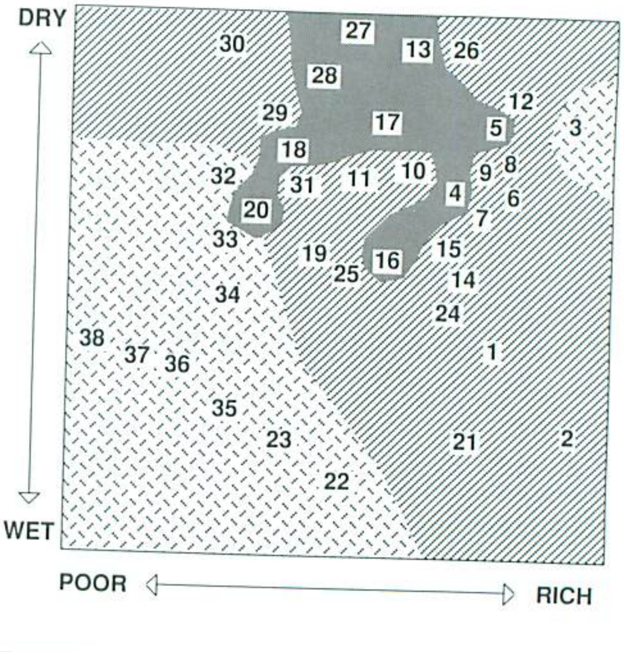
Reproduction

Sexual Reproduction: Paper birch is a monoecious species (Anon. 1974). Seed regeneration generally predominates over vegetative reproduction following disturbance (Zasada 1971, Watson *et al.* 1980).

Seed Production and Dispersal: Paper birch begins to bear seed at approximately 15 years of age; optimum seed-bearing age is from 40-70 years (Zasada 1971). Paper birch stands ranging from 45-100 years of age have been observed to produce large quantities of seed (Zasada 1971). Good seed crops, on at least some trees, occur almost every year (Fowells 1965). Relatively large quantities of seed appear to be produced annually, with excellent crops occurring every two to four years (Bjorkbom 1971, Zasada 1971) and a bumper crop occurring one year in 10 (Safford and Jacobs 1983). The average quantity of filled seed in four undisturbed Alaska stands for the period of 1958-1963 varied between 435,000 and 282,000,000 seeds/ha (Zasada



Frequency of occurrence of **paper birch** by soil texture class



Frequency of occurrence of **paper birch** by NWO FEC Vegetation Type

1971). In a study in Maine, seedfall varied from 3,212,300 seeds/ha in 1958, 1,976,800 in 1959 to 41,512,800 in 1960 (Bjorkbom 1967). Paper birch seed averages about 3,042,000 seeds/kg; ranging between 1,344,800 and 9,083,000 (Anon. 1974). The light, winged seeds are dispersed by wind and water (Haeussler and Coates 1986). Although seeds may be carried considerable distances by wind, (Fowells 1965), approximately 85% falls within twice the tree's height (Bjorkbom 1971, Zasada 1971). Seeds may be blown for some distance over crusted snow (Anon. 1974).

Seed Viability and Germination Requirements: The quality of paper birch seed is highly variable (Haeussler and Coates 1986). Seed viability is usually 15-20% (Watson *et al.* 1980). Seed quality in four undisturbed Alaska stands for the period of 1958-1963 varied between about 1% and 42% (average 17%). The quantity of filled seed varied between 434,900 to 281,694,000 seeds/ha (Zasada 1971). Seeds rapidly lose viability (Archibold 1980). Some seed may be stored in the forest floor for at least one year (Safford 1983). Seeds remain viable for up to two years if moisture content is low, but degenerate rapidly in moist conditions (Anon. 1974).

Seed stratification may not be necessary if seeds are germinated under light. Otherwise seed may need to be stratified at 5°C for 60-70 days (Watson *et al.* 1980). Because of the small size of paper birch seed, newly germinated seedlings are fragile. They are sensitive to moisture, light, and seedbed conditions. Mineral soil and rotten logs are best for germination and initial establishment. Leaf litter is especially poor (Fowells 1965). Shaded positions often have better initial survival (Marquis *et al.* 1964). Marquis *et al.* (1964) reported that, depending on seedbed and climatic conditions, between 20 and 400 birch seeds are required to produce a single one-year-old seedling. Seedlings require shade for two to three months in the first summer (Watson *et al.* 1980). The majority of seedlings in new stands become established during the first growing season following disturbance, but a small proportion may be added during the second and third years (Safford 1983).

Vegetative Reproduction: Paper birch can regenerate by sprouting from buds located beneath the bark at the base of the tree (Zasada 1971). Prolific sprouting will occur when birch are young, but sprouting vigour decreases with age (Haeussler and Coates 1986). Birch begin to lose their ability to sprout at approximately age 60 (Zasada and Argyle 1983). Paper birch can reproduce through layering, cuttings, budding and grafting (Watson *et al.* 1980).

Growth and Development

Paper birch is a fast growing, short-lived, deciduous tree (Ohmann 1982). Seedlings average 10 cm in height after the first growing season and 1 m after four growing seasons (Fowells 1965). Growth of sprouts is considerably more rapid than that of seedlings. Sprouts can grow up to 60 cm in the first year and are about twice the height of seedlings after four years (Haeussler and Coates 1986). Paper birch reach maximum heights of 30-40 m at maturity and diameters as large as 1 m at the base (Haeussler and Coates 1986). By the age of 60-90 years, paper birch are fully mature and vigour and quality have begun to decline. Dieback of crowns and death of many trees occur. Some individuals may reach ages over 100 years, with a maximum of 140 years (Safford 1983). Birch, in general, have deep, penetrating roots and high root to shoot ratios (Watson *et al.* 1980).

Phenology

Root, Shoot and Foliage: The onset of shoot expansion varies according to temperature (MacDonald *et al.* 1984). Seasonal height growth often begins while minimum temperatures are below freezing, rises gradually to a peak of maximum growth in mid-June and then gradually decreases (Fowells 1965). Diameter growth begins after maximum temperatures reach 22°C or more and minimum temperatures are above freezing. Temporary abrupt increases and decreases in diameter growth in the spring and fall are correlated with sudden fluctuations in temperature. Diameter growth ceases well before either moisture or temperature become limiting (Fowells 1965).

Preformed primordia are produced in mid-May to early August (MacDonald *et al.* 1984). By August these buds are determined, fully formed and entering dormancy. Bud burst is preceded by leaf expansion in mid-May. In the spring, at the time of bud break, vegetative long shoots form leaf primordia which quickly expand as leaves; these are true late leaves. Although late leaf production usually ends in early July, particularly vigorous shoots may continue to produce late leaves well into the growing season.

Reproductive Structures: Female flower induction takes place in late-June or early July during bud development (MacDonald and Mothersill 1983). Staminate catkins are formed in late summer or autumn, remain naked during winter, and open after considerable elongation in spring (Anon. 1974). Flowering occurs from mid-April until early June (Fowells 1965, Heinrich 1976), before leaves expand (Anon. 1974). Seed ripening occurs in late summer, from early August to mid-September. Seed dispersal occurs soon after ripening (Fowells 1965). Seed dispersal in southern parts of the species' range has been observed as early as July 4; however, peak dispersal normally occurs between August and October. Approximately one-half of the seed crop is dispersed in October and November (Bjorkbom 1971). More than 90% of seed is dispersed by December. After seed-fall, strobili slowly disintegrate on the trees with axes persisting on the branchlets (Anon. 1974).

Response to Disturbance

Overstory Removal: A condition known as post-logging decadence often develops where paper birch have been exposed by opening up of the stands (Baskerville 1961, Fowells 1965). Symptoms include lowered vigour, reduced growth, dying back of twigs and branches, and in many instances, eventual death (Fowells 1965). Sprouting may occur at the base of standing trees that were exposed by removal of nearby trees (Fowells 1965). Paper birch regeneration will normally be abundant where seed trees are left standing and logging disturbance has created a suitable seedbed. Logging with modern skidders during seasons when there is no snow and the soil is not frozen provides adequate scarification for paper birch (Safford 1983). In full-tree logging, skidding trees with branches attached ideally prepares the site for paper birch (Safford 1983).

Fire: Paper birch has very thin, flammable bark and is easily killed by fire (Watson *et al.* 1980). Burns of moderate intensity will kill even large paper birch (Fowells 1965). Paper birch stands have the highest flammability, with respect to surface fire, in spring. During spring, litter layers dry quickly, because they are completely exposed to the sun (Van Wagner 1983). Regeneration is frequently more abundant on burned than unburned areas. Birch sprouts from root crowns and seeds-in over time after a fire (Hamilton and Yearsley 1988b). Sprouting is common on trees damaged or killed by fire. New sprouts (i.e., buds at the base of parent tree) may be killed directly or indirectly by fire (Zasada 1971). Lutz (1956) reported that the average rate for seedling establishment within one year of a fire was 20,000 seedlings/ha, with maximum stocking of 300,000 seedlings/ha.

Mechanical Site Preparation: Scarification of soil by breaking up surface organic horizons and mixing them with surface mineral soils provides ideal seedbed conditions for germination and establishment of paper birch (Bjorkbom 1972, Safford 1983). Paper birch readily seeds into areas of mineral soil exposed during mechnical site preparation (Haeussler and Coates 1986). In Maine, stocking was two to three times greater on mechanically site prepared areas than on winter or summer logged areas that had received no treatment (Bjorkbom 1972). In NW Minnesota, site preparation by rock raking increased the biomass of paper birch in conifer plantations (Ohmann 1982).

Cutting: Paper birch can regenerate from sprouts from either the root collar or stump after cutting or browsing (Fowells 1965, Watson *et al.* 1980). Sprouting is believed to be more vigorous if stems are cut during the growing season. Prolific sprouting usually occurs where young, vigorous trees have been cut in the spring to stump heights of 15-30 cm. However, regeneration by sprouting after cutting merchantable-sized trees is rather uncertain; mortality of such sprouts is usually high (Fowells 1965).

Chemical Treatments: The response of paper birch to 2,4-D, hexazinone and glyphosate will be discussed separately.

2,4-D: Paper birch is susceptible to and easily killed by a foliar application of 2,4-D (Chemagro Corporation 1953, Campbell 1981, Ohmann 1982, Anon. 1986).

Hexazinone: Paper birch is rated as intermediately susceptible to Velpar-L and approximately 12-14 l/ha are required for control on a medium-textured soil (Corcoran 1989). Hexazinone applied in liquid spray, spot gun and granular forms has produced variable rates of defoliation and mortality (Expert Committee on Weeds 1984). Hexazinone (pure) injected with a hypohatchet at a rate of 2.0 ml per 7.5 cm dbh killed or seriously injured all paper birch in a New Brunswick study (Wile 1981).

Glyphosate: Paper birch is very susceptible to glyphosate (Sutton 1984). Vision was highly effective in killing paper birch when applied as a foliar spray at rates of 2.24 kg a.i./ha and greater (Sutton 1978). Glyphosate (20% solution) injected with a hypohatchet at a rate of 2.0 ml per 7.5 cm dbh gave satisfactory results; it was killed or seriously damaged and rated as susceptible (Wile 1981).

Fertilization: Paper birch is a nutrient-sensitive species that responds to increased levels of fertility. Adding N and/or P may substantially increase both height and diameter growth of paper birch (Safford 1983). Paper birch prefers nitrates to ammonium as a nitrogen source (Haeussler and Coates 1986). Response to an application of fertilizer lasts five to seven years (Safford 1983). Near Sudbury, Ontario, paper birch has been reported to be a pioneer on rocky, eroded hillsides with a few shallow soil pockets, particularly after these soils received amendments of lime and phosphate to raise pH and fertility (Watson *et al.* 1980).

Effects on Conifers

No direct beneficial effects of paper birch on conifer growth were described in the literature. Paper birch does not benefit conifers by fixing atmospheric nitrogen (Watson *et al.* 1980), but it may improve nutrient cycling. The deep rooting habit of the species, its relatively high demand for soil nutrients, and the rapid turnover of deciduous foliage suggest that soil organic matter content and associated levels of nutrients may be higher under birch mixedwoods than under pure conifer stands (Haeussler and Coates 1986). Paper birch may also improve soil stability. Roots of paper birch seedlings generally deeply penetrate the soil, providing good soil stabilization (Watson *et al.* 1980).

Birch usually does not pose problems for establishment and regeneration of conifers, but may affect growth and survival of conifer trees 5-10 years after birch is established (Mather 1988, Presslee 1989). Paper birch can be a serious competitor to conifers where there are concentrations of mature birch and where harvesting and silvicultural practices favour seeding-in (Haeussler and Coates 1986). Crushing and smothering beneath birch litter causes a high rate of mortality among spruce germinants (Gregory 1966).

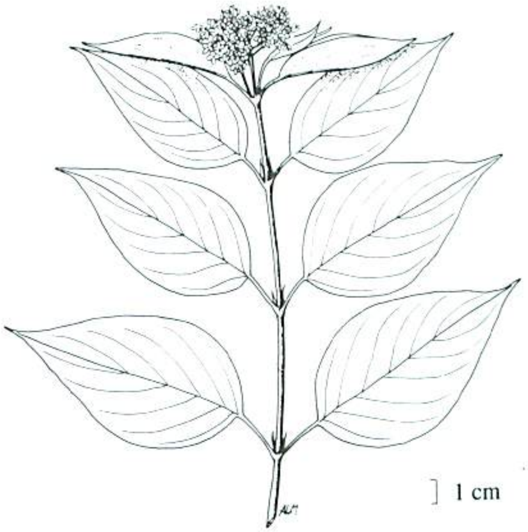
Uses by Wildlife

Young regenerating stands of paper birch and associated species provide prime browse and summer cover for deer and moose (Aldous 1952, Safford and Jacobs 1983). Moose browse paper birch throughout the year (Timmermann and McNicol 1988), which may constitute up to 31% of their winter diet (McNicol and Gilbert 1980). Loss of paper birch from herbicide treated mixedwood cutovers could significantly affect winter browsing activities by moose (McNicol and Timmermann 1981). If paper birch is being managed for timber, light browsing by deer can be tolerated, but heavier browsing will reduce height growth (Aldous 1952). Paper birch development may be greatly retarded if severely browsed by moose (Hatcher 1960). Paper birch can be browsed quite heavily by deer over a period of at least five or six years and must be used quite heavily if it is to remain within reach for deer (Aldous 1952). Paper birch is also an important food for beaver (Haeussler and Coates 1986). Buds, twigs and bark of birch are principle winter foods of snowshoe hare (Radvanyi 1987). Many small mammals nibble at the stem or bark, girdling or damaging trees (Stoeckeler 1955).

Paper birch is an important source of food for birds which feed on buds, catkins, and seed (Safford and Jacobs 1983, Haeussler and Coates 1986).

Cornus stolonifera Michx.
Red Osier Dogwood

Description



General: erect or loosely spreading shrub usually <2 m high, often forming dense thickets; stems often rooting at the nodes; branchlets purplish to bright red; pith large, white.

Leaves: opposite; egg-shaped to broadly lance-shaped, pointed and often tapered at the tip, rounded at the base; finely to densely soft-hairy beneath, often whitened; margins entire; veins distinct, 5-7 on each side, curving upward along the margins, unbranched.

Flowers: in flat-topped clusters; individual flowers small, creamy white; appearing in late June.

Fruit: in clusters, white, berry-like, about 6 mm in diameter; August and September.

Habitat

Distribution in Ontario: Red osier dogwood is common throughout southern Ontario, westward to the Manitoba boundary and northward to James Bay and Hudson Bay (Soper and Heimburger 1982).

Climate: Red osier dogwood is widespread in boreal, temperate and cool mesothermal climates (Klinka *et al.* 1989).

Site and Soil Relations: Red osier dogwood occurs on low damp ground, along shores, river flats, edges of marshes, in damp open woods and thickets, and along roadsides (Soper and Heimburger 1982). In NW Ontario, red osier dogwood is found across a wide range of soil textures, but occurs with higher frequencies on fine-textured soils than on coarser soils.

Nutrient Requirements: Red osier dogwood occurs on nitrogen-rich soils (Moder and Mull humus types) (Klinka *et al.* 1989), such as V-Types 1, 2 and 22. A Wisconsin sampling of vigourous stands led to the following soil fertility standards for nurseries growing red osier dogwood: pH 5.0-6.0, base exchange capacity 6.0 M.E./100g., total nitrogen 0.07%; and these amounts of nutrients in kg/ha: N-17, P_2O_5-84, K_2O-168, and replacable Ca-1,345 (Wilde 1946). Red osier dogwood is tolerant of alkaline soils and has been found in a wide range of pH values; 8.0 near lake outlets, 6.0 for sedge and northern white-cedar swamps, and 3.2 for sphagnum mats (Jewel and Brown 1929).

Distribution of **red osier dogwood** in Ontario
(Adapted from: Soper and Heimburger 1982)

Moisture Requirements: Red osier dogwood is associated with moist to wet soil conditions where it is not subject to significant moisture stress (Euler 1979, Haeussler and Coates 1986, Klinka *et al.* 1989). In NW Ontario, it occurs most often in V-Types 1, 2 and 22. Red osier dogwood tolerates fluctuating groundwater tables (Klinka *et al.* 1989). Because of its ability to live with roots often immersed in water (Conway 1949), it is often one of the earliest shrubby plants to become dominant in bogs and swamps. Its need for damp, open sites largely precludes its existence in timber stands or on well-drained areas (Aldous 1952), such as V-Types 13, 26, 27 and 30. Red osier dogwood grows best on freely draining soils with adequate available moisture (Watson *et al.* 1980). It has low drought tolerance (Watson *et al.* 1980).

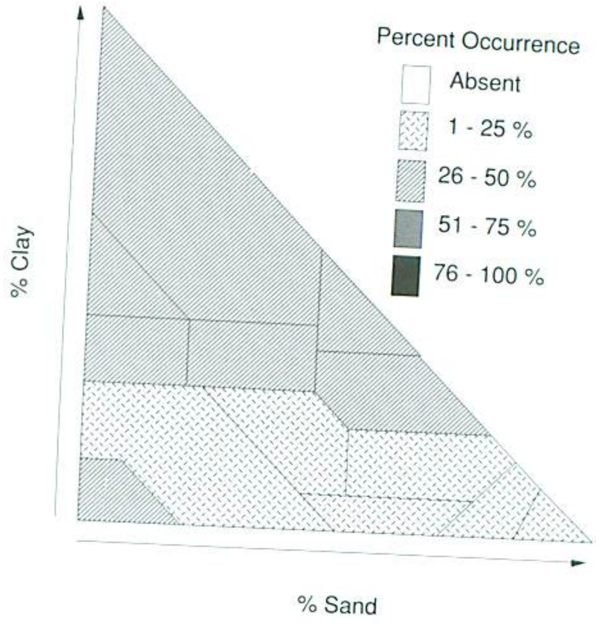
Light Requirements: Although red osier dogwood is shade-tolerant/intolerant (Rowe 1983, Klinka *et al.* 1989), it prefers full sunlight for best growth (Euler 1979). Sheppard and Pellet (1976) studied the effect of a range of light intensities on growth of red osier dogwood. Plants grown in full sun were dense and compact with many lateral branches and a high proportion of leaves, while those grown in 27% of full light were open and sprawling with fewer branches and leaves. Flowering was greatest at high light intensities. Although above-ground biomass was greatest at 75%, the authors speculated that some moisture stress may have occurred in the 100% light treatment.

Reproduction

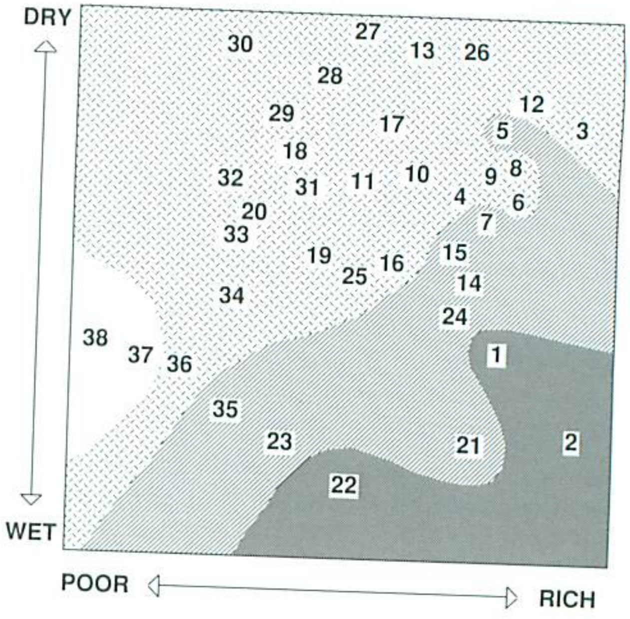
Sexual Reproduction: Seed production, dispersal, viability and gemination are discussed.

Seed Production and Dispersal: The typical age of first fruit-bearing, for unshaded or lightly shaded red osier dogwood is about 4 years (Smithberg 1974) with good seed crops are produced every 1-2 years (Watson *et al.* 1980). Red osier dogwood seed averages 40,800 seeds/kg; with a range of 30,400 to 58,900 (Anon. 1974). Because its seeds are spread mostly by birds and other animals (Smithberg 1974, Anon. 1974), seeds tend to be located in caches or dropping piles rather than randomly distributed (Rowe 1983).

Seed Viability and Germination Requirements: Red osier dogwood is a seed banking species (Rowe 1983) and seeds can remain dormant for several years until conditions become favourable for germination (Haeussler and Coates 1986). The seeds have a 60- to 90 days cold temperature requirement to break embryo dormancy, and normally germinate the following spring (Haeussler and Coates 1986). Some seed may have a hard seed-coat as well as embryo dormancy obstacles to germination, and may require mechanical scarification before stratification



Frequency of occurrence of **red osier dogwood** by soil texture class



Frequency of occurrence of **red osier dogwood** by NWO FEC Vegetation Type

(Smithberg 1974). Germination appears to be best when seeds are buried slightly beneath the soil surface (Watson *et al.* 1980).

Vegetative Reproduction: Red osier dogwood reproduces vegetatively through root sprouts, layering (Watson *et al.* 1980) and, as its specific name (*C. stolonifera*) denotes, it produces stolons (runners). In a study in various habitats, reproduction from stolons was noted primarily on very moist or wet sites (Smithberg 1974). Vegetative reproduction also occurs from stems touching or growing under the ground and from root suckers (Smithberg 1974). Red osier dogwood can be readily propagated by stem and root cuttings (Chen and Li 1978, Watson *et al.* 1980).

Growth and Development

Red osier dogwood is a deciduous, relatively long-lived, perennial shrub (Watson *et al.* 1980). Because layering and suckering occur readily, the plant is usually shrubby with many stems (Hauessler and Coates 1986). When found in meadows with dense grass cover, the species tends to remain in single large plants, because layering cannot occur (Smithberg 1974). Red osier dogwood averages 1 to 2 m in height, but can grow up to 5 m (Watson *et al.* 1980). Under adequate environmental conditions, early growth of red osier dogwood is rapid. An average plant can be 1 m tall and put on 1.1 m of branches by the end of the first growing season in the northeastern United States (Smithberg 1974). Mature plants vary considerably in height, ranging from 1 to 5 m (Haeussler and Coates 1986). Under shaded conditions red osier dogwood often reaches a height of more than 3 m (Smithberg 1974).

Phenology

Root, Shoot and Foliage: Spring bud break occurs at about the same time for all clones (Smithberg and Weiser 1968). In all clones, rest occurs first, followed by red colouring of the bark and finally leaf abscission (Smithberg and Weiser 1968). Dates at which the current year's bark changed from green to red in the fall were generally related to dates of onset of rest. The rest period was described as that part of dormancy during which plants would not grow, even when provided with a favourable environment. Observations of winter bud formation in clones of red osier dogwood indicated that clones from Manitoba, Ontario, Saskatchewan, North Dakota and Alaska entered a rest period by August 10 or earlier, and had lost 50% of their leaves by late October (Smithberg and Weiser 1968).

On the central British Columbia coast, flushing occurred during middle to late April and leaves were fully expanded by mid-May. The first leaves began to change colour in early August. By mid-September most leaves were coloured; most shrubs retained some leaves until mid-October (Haeussler and Coates 1986).

Reproductive Structures: Flowering occurs during May-June, but second flushes of blooms are common in late summer (Smithberg 1974). McWilliams and Ludwig (1972) noted flowering from May 10 to September 20 at a site near the University of Michigan. In general, fruits ripen from July to October and may persist over winter (Anon. 1974).

Response to Disturbance

Overstory Removal: Removal of the tree canopy will enhance red osier dogwood, especially near wetter areas (Harcombe *et al.* 1983).

Fire: Red osier dogwood may benefit from the removal of senescent shoots by fire, allowing the plant to channel most of its resources into new growth (Smith and James 1978b). Fires of low intensity will stimulate sprouting and rejuvenate the shrub (Archibold 1979), but will not necessarily result in a rapid increase in abundance or cover (Coates and Haeussler 1986). Severe fires that destroy underground parts can dramatically set back dogwood and recovery will be slow (Coates and Haeussler 1986). Germination of stored seed is favoured most by fires of low severity and of short duration that partially remove the surface organic matter (Rowe 1983). However, prolific germination of stored seed is unlikely to occur (Coates and Haeussler 1986). Areas dominated by red osier dogwood may not burn completely due to relatively low quantities of surface litter and dead standing material (Smith and James 1978a).

Mechanical Site Preparation: Plants damaged during mechanical site preparation can be expected to sprout or sucker from roots and stem bases (Haeussler and Coates 1986). Exposure of mineral soil may stimulate germination of buried seed.

Cutting: Red osier dogwood stems are especially prone to rooting when they are cut during the dormant season (Smithberg 1974). Therefore, care should be taken to ensure that fresh cut branches are not touching moist soil or they may form a new plant. In general, early to mid-summer cutting of dogwoods produced shorter and narrower sprout clumps than winter cutting 3 years after disturbance (Buell 1940). Clipping will produce a slight increase in total twig production of red osier dogwood (Aldous 1952).

Chemical Treatments: The response of red oiser dogwood to 2,4-D, hexazinone and glyphosate will be discussed separately.

2,4-D: Red osier dogwood can be killed with 2,4-D usually with one application at the time when the plant is most susceptible (Chemagro Corporation 1953). Dogwoods are rated as susceptible to intermediately susceptible to 2,4-D (Anon. 1986). For maximum effectiveness, 2,4-D must be applied prior to the onset of vegetative maturity (Crabtree and Fuchigami 1979). Red osier dogwood will show typical signs of 2,4-D damage (chlorosis and necrosis of leaves) within two weeks after herbicide application.

Hexazinone: Velpar-L provides moderate control of red osier dogwood (Coates and Haeussler 1986). Spring spot treatments and maximum rate treatments cause low to moderate damage; dormant season and low rate treatments cause low to no damage (Balfour 1989).

Glyphosate: The limited data available on the effects of glyphosate on dogwood suggest moderate to severe damage for late summer applications and light damage for all applications at rates of >1.1 and <2.2 kg a.i./ha (Balfour 1989). Red osier dogwood appears to be quite tolerant of glyphosate (Expert Committe on Weeds 1984). However, an application of 7 l/ha applied on July 25 in Minnesota killed 87% of red osier dogwood in experimental plots (Butler-Fasteland 1987).

Fertilization: Information pertaining to the response of red osier dogwood to applications of fertilizers was not found in the literature.

Effects on Conifers

Red osier dogwood can be a significant competitor with coniferous trees on imperfectly drained to poorly drained sites that have a well- established, diverse brush community. These sites are often very productive for tree growth (Haeussler and Coates 1986). Red osier dogwood does not fix atmospheric nitrogen (Watson *et al.* 1980) and therefore does not benefit conifers in this manner.

Uses by Wildlife

Red osier dogwood is an important and preferred winter browse species for moose (Stevens 1970, Zach *et al.* 1982, Timmermann and McNicol 1988). It is used by moose primarily in fall, after twigs redden, and decreases in value as winter progresses (Peek 1974). Snow depth appears to be critical in use of red-osier dogwood by moose, since many plants disappear under 1 m of snow. Dogwood is a favourite food of deer (Aldous 1952), but it does not hold up under repeated heavy browsing by deer. Under such circumstances, bushes become spiny and growth is retarded. Black bear (*Ursus americanus* Pallus), beaver, cottontail rabbit, snowshoe hare and many other mammals forage on the twigs or fruit of red-osier dogwood (Smithberg 1974, Haeussler and Coates 1986).

Red osier dogwood provides food for many songbirds and upland game birds (Smithberg 1974, Euler 1979). It is a favourite fall food of ruffed grouse (Bump *et al.* 1947). Red osier dogwood is also an important cover species for birds such as grouse and woodcock (Smithberg 1974, Euler 1979).

Red osier dogwood is recommended for stream bank planting to stabilize eroding banks and to provide shade and thermoregulate water for summer protection of fish habitat (Smithberg 1974,

Corylus cornuta Marsh.
Beaked Hazel

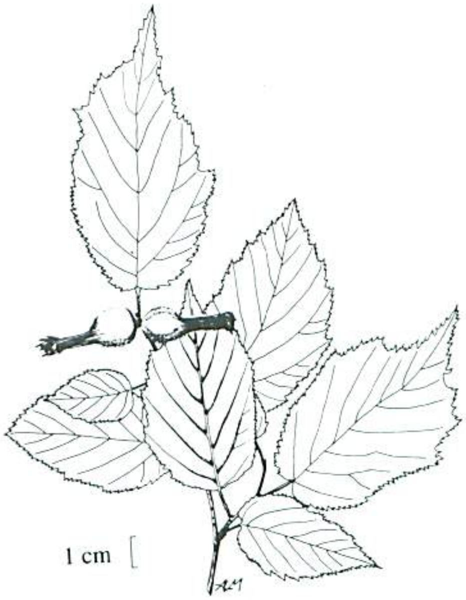
Description

General: coarse shrub up to 3 m high, often forming dense thickets; branchlets sparsely hairy; older twigs smooth, grey, often appearing somewhat mottled or striped; without conspicuous warty dots.

Leaves: alternate; egg-shaped to broadly oval, tapering to a point at the tip, rounded or heart-shaped at the base; margins irregularly and coarsely double-toothed, often with distinctive "shoulders" below the middle; usually somewhat hairy beneath.

Flowers: male flowers borne on catkins, female flowers in small clusters; male catkins elongating to about 5 cm; female flowers concealed in buds with crimson, hair-like styles protruding; opening in late April and May.

Fruit: solitary or in small clusters; a round, hard-shelled nut enclosed in a bristly husk with an elongated beak.



Habitat

Distribution in Ontario: Beaked hazel occurs from Lake Erie throughout most of southern and southwestern Ontario northward to about 50°N (Soper and Heimburger 1982).

Climate: Range of beaked hazel in North America implies that this species is not well adapted to high summer temperatures nor to the extreme northern boreal climate (Stearns 1974). It occurs in cool temperate and cool mesothermal climates (Klinka *et al.* 1989).

Site and Soil Relations: Beaked hazel occurs in thickets, clearings, and borders of woods and is a typical understory plant of mixed conifer-hardwood forests (Soper and Heimburger 1982). Well-aerated loamy sands, sandy loams, and loams support vigorous growth of beaked hazel (Hsiung 1951). In the Clay Belt Region, beaked hazel is associated with forests on nutrient-rich clays and silts (Carleton *et al.* 1985). The general range of silt-plus-clay content within which hazel is distributed is from 15-65%. The optimum range of silt-plus-clay content falls between 27% and 47% (Hsiung 1951). Hazel does not grow well on poorly drained mineral or organic soils, nor on very dry coarse sands (Hsiung 1951).

Nutrient Requirements: Beaked hazel occurs with higher frequencies on nutrient-rich than nutrient-poor soils. It prefers Ca- and N-rich soils (Moder and Mull humus types) (Klinka *et*


Distribution of **beaked hazel** in Ontario
(Adapted from: Soper and Heimburger 1982)

al. 1989), and grows best on slightly acidic (pH 5.3-6.1) soils (Hsiung 1951). Very acidic or near neutral soils seem unfavourable for development of beaked hazel (Hsiung 1951).

Moisture Requirements: Hazel occurs across a wide range of soil moisture regimes. Beaked hazel favours sites that are moist but well-drained (Krajina *et al.* 1982, Haeussler and Coates 1986). It does not grow successfully in wet, poorly aerated soils (Hsiung 1951, Stearns 1974). Krajina *et al.* (1982) note that beaked hazel does, however, have a high tolerance to flooding.

Light Requirements: Hazel prefers 8-35% of full sunlight (Hsiung 1951). Although hazel does not grow successfully under dense shade, it will grow vigorously under an open overstory of red or jack pine, aspen, or aspen-birch and conifer-hardwood mixtures (Hsiung 1951). Dense shade diminishes seed production of beaked hazel; many stems growing at low light levels never produce seeds (Stearns 1974).

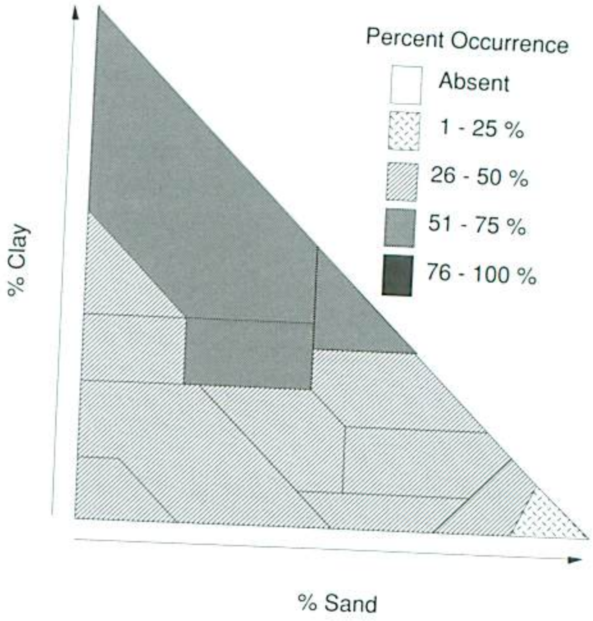
Reproduction

Sexual Reproduction: Beaked hazel is a monoecious species, male and female flowers are borne separately on 1-year-old lateral twigs of the same plant (Anon. 1974).

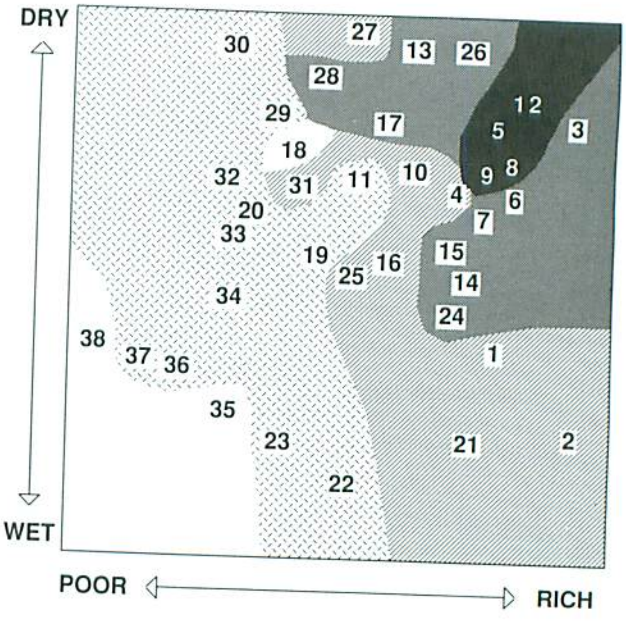
Seedlings are not abundant in nature because seeds are destroyed by rodents or occasionally by insects and fungi (Stearns 1974).

Seed Production and Dispersal: Male flowers may develop on one-year-old stems, but female flowers do not occur until stems are two years of age (Hsiung 1951). Flowering increases with stem age, reaching a maximum at 10-11 years, after which it diminishes gradually and ceases at about 18 years (Hsiung 1951). Beaked hazel has good seed yields about every five years (Anon. 1974, Haeussler and Coates 1986). Seed production is not well documented, but may fluctuate greatly between years. In an aspen stand near Rochester, Alberta with 75% beaked hazel cover, numbers of beaked hazel nuts per ha varied from 32,100 in 1968 to only 109 in 1969 (Stearns 1974). Numbers of cleaned seed averages 1,210 seeds/kg, with a range of 937 to 1,490 (Anon. 1974). Nuts are disseminated primarily by small rodents such as chipmunks and red squirrels (Hsiung 1951). Hazel produces large, wingless seed within 1.5-5.0 m of the ground; seeds are not windborne and neither water nor gravity are effective disseminators of hazel seed on flat surfaces (Hsiung 1951).

Seed Viability and Germination Requirements: Germination of beaked hazel seed is poor (Stearns 1974). Most data indicate relatively low germination, between 30 and 60 percent, after cold stratification (Stearns 1974). Beaked hazel seeds require two to



Frequency of occurrence of **beaked hazel** by soil texture class



Frequency of occurrence of **beaked hazel** by NWO FEC Vegetation Type six months of pre-chilling before germination will occur (Anon. 1974). Germination is highest where nuts are sufficiently covered to prevent drying during winter (Hsiung 1951). Beaked hazel will not germinate or grow successfully on wet sites or under dense shade (Stearns 1974). Hsiung (1951) obtained 30% germination in an upland soil, 56% on a black spruce-tamarack site and 0% in a wet swamp. Seedling establishment requires a good seed source and (temporarily, at least) a low rodent population (Tappeiner 1971).

Vegetative Reproduction: Beaked hazel can reproduce by layering and sprouting from either aerial or underground stems (Hsiung 1951). The latter method is most important in expansion and regeneration of colonies. One-year-old hazel stems are capable of producing sprouts from buds formed in the axils of cotyledons. Sprout formation increases following damage to the main stem and/or after the plant is well established. Underground stems are initiated, from buds formed in the axils of cotyledons, when the seedling is between seven and twelve years of age. The average maximum distance of aerial stems from the original stem of a 38-year-old colony was reported to be 3.0 m. Additional new stems develop vegetatively from aerial stems, underground stems and layers, creating dense thickets of hazel perpetuated by sprouting. Older clones produce larger and more vigorous sprouts. Field observations indicate that vegetative propagation of beaked hazel by layering rarely occurs in nature (Hsiung 1951).

Growth and Development

Beaked hazel is a relatively long-lived perennial shrub which can live to 60 years of age (Brown 1953).

Following germination from seed, hazel produces a deeply-penetrating taproot (Hsiung 1951). If the newly established plant receives considerable light and grows on well-drained soils, it generally produces a vigorous system of tap and lateral roots. Normally, the growth rate of seedlings is slow (less than 0.6 m in 10 years) (Hsiung 1951). At 7-12 years, seedlings start developing an underground stem. Over 90% of underground stems and roots are found within the top 15 cm of soil, often along the boundary between humus and mineral soil (Hsiung 1951, Johnston and Woodard 1985). Underground stems usually run prostrate and differ from ordinary rhizomes by their irregular production of roots and sprouts (Hsiung 1951). Growth is usually rapid following sprout formation. Vigorous sprouts may reach heights of over 0.6 m in two years and over 1.8 m in 10 years (Hsiung 1951). Average stem height at 15-20 years is about 2.5 m. Growth declines as stems age; annual growth is often less than 2.5 cm/yr in decadent stems (Hsiung 1951). Hazel often forms a very dense, multi-layered canopy that allows little light to penetrate. In one study, total leaf area over a 0.4 ha plot equalled 2.8 ha (Waldron 1959). Dense hazel undergrowths are formed by the coalescence of underground and aerial stems of many clones. In dense stands, up to 4,600 clones/ha may exist (Tappeiner 1971). Vegetative spread of hazel clones is slow but accelerates with age. At Cloquet, Minnesota, six-year-old clones had one or two sprouts, while 38-year-old clones had 25 living aerial stems (Hsiung 1951).

Phenology

Root, Shoot and Foliage: Shoot elongation begins slowly during early May, but is rapid until early July, and ceases by late July (Hsiung 1951). Leaves unfold 5-15 days later than flowers, reaching full size within three or four weeks. Leaves begin to change colour in late August, usually a week earlier in the open than under a forest canopy, and start to fall when the colour becomes yellow or yellow-brown. Leaf fall is usually complete by late September.

Reproductive Structures: Male, or staminate, flower buds are initiated early in the growing season and are visible as early as mid-June of the year prior to pollen dispersal (Hsiung 1951). They continue to develop slowly until growth ceases in September; catkins are then evident as elongated buds (Stearns 1974). Female, or pistillate, flower buds are initiated about six weeks later than male flowers and appear somewhat larger than leaf buds (Stearns 1974). Warm, relatively dry late summer and autumn weather is favourable for flower bud initiation (Hsiung 1951). Flower buds swell and elongate rapidly before leaves unfold in spring (Hsiung 1951). In the northern Lake States, female flowers appear during late April to early May (Hsiung 1951). Red, slender stigmas appear at the top of pistillate buds when the scales open. The length of time required for development of flowers depends chiefly upon weather conditions of the current year. In average spring weather at Cloquet, Minnesota, it takes 10-15 days from appearance of female flowers before pollination begins. After pollination, seeds develop slowly and are still at the "milky stage" in early August. Subsequently, fruits gradually change in colour from green, to yellowish-green, to greenish-yellow, and finally, yellow-brown upon seed maturation. By early September seeds cease to elongate.

Response to Disturbance

Overstory Removal: Beaked hazel is well adapted to open conditions created by clearcuts and will often rapidly colonize a site after harvest (Chapeskie *et al.* 1989). Reduction of overhead competition increases stem vigour and stimulates both fruit production and vegetative growth (Stearns 1974). Rapid expansion of hazel colonies has been noted after logging of spruce or mortality of decadent aspen (Haeussler and Coates 1986). Increased hazel growth has been observed following thinning of red pine (Tappeiner 1971).

Fire: Although the above-ground parts of hazel are extremely susceptible to fire (Johnston and Woodard 1985), sprouting is often stimulated by fire, which kills the above-ground parts without destroying the underground system (Buckman 1964). Sporadic burn survivors may sprout from the root collar and reach 0.25-0.5 m in the first year (Day and Harvey 1981). A light fire may increase stem density two to four times that of the original unburned stand (Buckman 1964). Since nearly all of the underground stem systems of hazel lie at or very close to the contact zone between the humus and the mineral soil (usually about 5-10 cm below the duff surface) hazel is susceptible to fire when humus is dry (moisture content of 16-48%) and combustible (Johnston and Woodard 1985). Attempts to eliminate hazel by prescribed burning in spring are unlikely to be successful. Although the above-ground portions of the plants are easily killed, even with low intensity fires, high spring duff moisture contents will prevent mortality of underground reproductive organs (Johnston and Woodard 1985). Only slow, hot, summer fires, which consume duff and kill underground stem systems, will eliminate hazel (Buckman 1964). High soil moisture content may be involved in the destruction of underground parts of hazel during fires. Moisture in the uppermost layer of organic soil may form steam, damaging living tissue during intense fire (Ahlgren 1960). Eradication will only occur if summer burning is repeated many times (Haeussler and Coates 1986). Buckman (1964) found that four annual summer burns reduced numbers of aerial stems to less than half the preburn number (49,000 stems/ha). Repeated summer fires destroy hazel's ability to resprout by exposing and destroying underground stem systems and probably exhausting stored food reserves (Buckman 1964).

Mechanical Site Preparation: As long as underground stems are not destroyed or removed during mechanical site preparation, hazel will sprout back and the number of aerial stems will be increased in the long term (Haeussler and Coates 1986). Both disc trenching and deep scarification with a brush blade have been successful in reducing abundance and cover of hazel (Coates and Haeussler 1986). Disking may expose underground parts of shrubs, setting back growth for several years (Eyre and Zehngraff 1948).

Cutting: Clipping stimulates the production of sprouts by beaked hazel (Aldous 1952).

Chemical Treatments: The response of beaked hazel to 2,4-D, hexasinone and glyphosate will be discussed separately.

2,4-D: Occurrence of beaked hazel generally decreases after spraying 2,4-D (Schacht and Hansen 1963). 2,4-D produces heavy top-kill of hazel, but resprouting can be vigorous (Haeussler and Coates 1986). Roe and Buchman (1963) tested effects of 0.6, 1.1 and 2.2 kg/ha of 2,4-D applied at various times throughout summer. Sprays conducted between late June and late August gave satisfactory top-kill; however, plots sprayed in July resprouted less than those sprayed in mid-June or August (Roe and Buchman 1963). The average recovery from the 0.6, 1.1 and 2.2 kg/ha, mid-July foliar sprays were 62%, 55% and 18% respectively. Recovery was greater for earlier and later treatments. From tests at the Quetico-Superior Wilderness Research Center in northern Wisconsin, Hansen and Ahlgren (1950) concluded that June and July sprays of 2,4-D gave 90-100% control, while August treatments were only 31-61% effective. Zehngraff and von Bargen (1949) concluded that best control of hazel with 2,4-D was obtained from applications made during July 1 to August 15. Waldron (1959) found that resprouting was delayed for two years following a mid-summer foliage spray. Waldron (1959) also reported a mean height of 0.9 m for hazel six years after treatment with 2,4-D; untreated hazel on the same site increased from 1.2-1.6 m. Zehngraff and von Bargen (1949) reported nearly complete elimination of old hazel stems using 2,4-D at a rate of 2.8 kg/ha.

Basal dormant-season application of 2,4-D at a concentration of about 2.3 kg per acid per 380 l of oil diluent will effectively kill hazel (Klug and Hansen 1960).

Hexazinone: Hazel is rated as intermediate/resistant to Velpar-L. More than 14 l/ha may be required to control hazel on a medium-textured soil (Corcoran 1989).

Glyphosate: There is little published information pertaining to seasonal susceptibility of beaked hazel to glyphosate. European experience has shown that hazel (*Corylus avellana*) is rate-sensitive to glyphosate. Lund Høie (1975) showed that hazel can be controlled (<90% top-kill with no regrowth) with as little as 0.5 kg a.i./ha of glyphosate. Canadian experience has shown that glyphosate applied at 2.2 kg a.i./ha, in late August, can be highly effective against six-year-old beaked hazel (Sutton 1978).

Fertilization: Information of the response of beaked hazel to applications of fertilizers was not found in the literature.

Effects on Conifers

Hazel is a very aggressive competitor and a major deterrent to successful regeneration of conifers and other plant species (Haeussler and Coates 1986). The primary impact of hazel on conifers is believed to be shading, caused by its aggressive growth and densely layered habit (Haeussler and Coates 1986). Below a dense hazel stand the light intensity may be only two to seven percent of full sun (Hsiung 1951). Cheyney (1928) stated that pines and other conifers do not reproduce under beaked hazel because of the lack of light, or the lack of soil moisture. Hazels, by virtue of an extensive and shallow root system, provide considerable competition for moisture in the upper soil layers (Stearns 1974). Tappeiner and John (1973) indicated that a dense layer of hazel can tie up a significant component of total site nutrients in their above-ground biomass. Although hazel biomass stores a significant quantity of nutrients, most of these nutrients are annually recycled through the ecosystem following leaf fall, where they can become available to coniferous trees (Haeussler and Coates 1986).

Uses by Wildlife

"Foresters would like to see this species utilized more heavily by deer, but because of its low palatability rating, such usage would require a deer herd so large that the more desirable browse and timber species would be seriously affected before the hazel would be properly controlled" (Aldous 1952). On upland sites hazel may compete with preferred browse species and undoubtedly reduce their numbers (Aldous 1952). Winter browsing by deer may be severe, and young hazel thickets may be browsed to the snowline. Although hazel is not a highly preferred browse species for white-tailed deer (Aldous 1952), stems and twigs are generally a major component of winter browse (Stearns 1974). More often, browsing is moderate to light and scattered because deer prefer new sprouts and vigorous growth. Heavy browsing by deer may stimulate sprouting (Hsiung 1951). In order to obtain maximum browse production from hazel, moderate to heavy usage is desirable (Aldous 1952). Because of beaked hazel's low growth form, it does not often grow out of reach of deer (Aldous 1952). Deer may also eat the nuts if any remain after rodents have finished their harvest (Stearns 1974).

Moose browse hazel more heavily in winter than summer months (Timmermann and McNicol 1988). Hazel nuts are a major food item for chipmunks (*Eutamias minimus* Bachman) and squirrels. Squirrels have been known to consume entire crops of hazelnuts before they ripen (Anon. 1974).

Male catkins provide a rich protein source for ruffed grouse, especially in late winters (Stearns 1974). Hazel clumps provide cover for both woodcock and grouse, especially in vigorous and well developed stands. Dense hazel thickets with closely spaced stems serve as upland brood range and drumming habitat for ruffed grouse (Gullion *et al*. 1962).

Epilobium angustifolium L.
Fireweed

Description

General: tall, erect perennial from a thickened rootstalk; stems usually unbranched, often > 1 m high.

Leaves: alternate; long, narrowly lance-shaped, tapering at the base; margins entire or slightly toothed; densely crowded on the stem; veins conspicuous beneath.

Flowers: in a long, dense, terminal spike; individual flowers large (about 2 cm across), showy, with 4 magenta (occasionally white) petals; lowest flowers opening first, often exceeded by the accompanying stem leaves; appearing in late July and August.

Fruit: a long (up to 7 cm), narrow, green to purple pod opening to release numerous silky-haired seeds; ripening in August and September.

Habitat

Distribution in Ontario: Fireweed is distributed throughout Ontario (Hultén 1968).

Climate: The extremely broad range of fireweed indicates that it can tolerate a wide range of climatic extremes (Haeussler and Coates 1986). In northern climates, fireweed is confined to warm sunny locales and south-facing slopes; towards the central portion of its range, it occurs on a wide range of slopes and aspects; at the southern end of its distribution, in hot, dry climates, it favours cool, moist, shaded locales (Myerscough 1980).

New, emergent shoots tolerate some frost in spring, but exposed leaf tips and margins sometimes subsequently become necrotic (Myerscough 1980).

Site and Soil Relations: Fireweed occurs on a range of soils from those with little organic matter, such as mobile dune sands, to purely organic peats (Myerscough 1980). Fireweed is found on a wide range of soil textures and commonly occurs on sandy, loamy, and fine-textured soils (Myerscough 1980).

Nutrient Requirements: Fireweed is often reported as a nitrogen-demanding species (Haeussler and Coates 1986). However, experiments by van Andel (1976) suggest that while the plant has great adaptability to high levels of N, K, P and Ca, it does not appear to depend on them. Fireweed is capable of persisting under poor N, P and K conditions (van Andel and Neilsson 1979). Fireweed occurs over a wide range of pH values (pH 3-9) (Van Andel *et al.* 1978, Myerscough 1980).

Distribution of **fireweed** in Ontario
(Adapted from: Hultén 1968)

Moisture Requirements: Usually fireweed occurs on soils whose surface layers are at least freely draining, but it is occasionally found in periodically waterlogged sites (Myerscough 1980). Fireweed is generally intolerant of flooding; total wilting will occur within 12 hours of flooding (Etherington 1984).

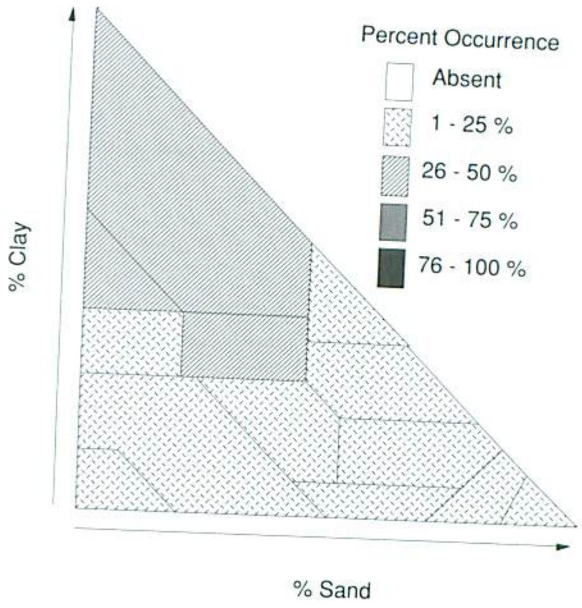
Light Requirements: Fireweed is very shade-intolerant (Klinka *et al.* 1989) and is seldom found growing in mature forests (Foster 1985). In shade, fireweed does not flower, although it sometimes forms flower buds which it sheds unopened (Myerscough 1980).

Reproduction

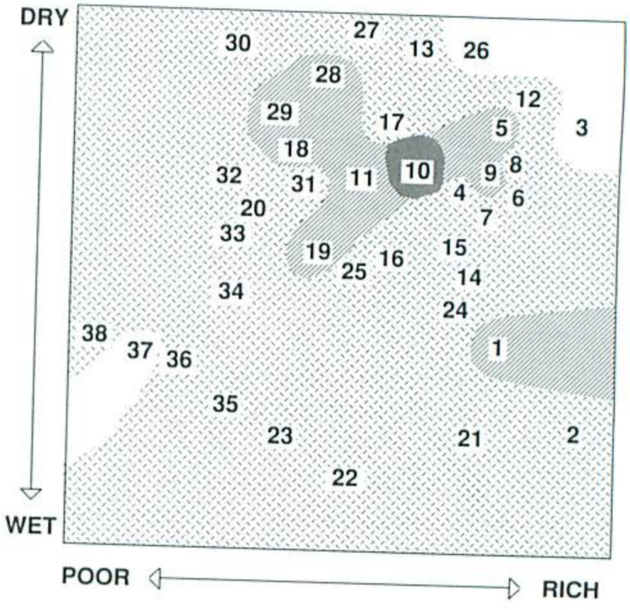
Sexual Reproduction: Seed production, dispersal, viability and germination of fireweed are discussed.

Seed Production and Dispersal: Fireweed is capable of flowering from the first year onward (van Andel and Jager 1981). Seed production is dependent upon availability of nutrients (van Andel and Vera 1977). Estimates of numbers of seeds per capsule range from 250 to 500 with an average of 380, and annual production per plant is about 76,000 seeds (Myerscough 1980). Archibold (1980) estimated that fireweed released 5.66 million seed per ha during the first season after fire. Pollination is by insects and wind (Myerscough 1980). Seed of fireweed is dispersed by wind and small mammals (Ahlgren 1960). The plumed seeds are wind-dispersed and have low rates of fall even in still air (Myerscough 1980).

Seed Viability and Germination Requirements: Viability of fresh seed is high; Granstrom (1987) reported 89% viability. Seeds usually lose viability after about 18 months when stored dry at normal room temperature (Myerscough 1980). Seeds of fireweed do not exhibit any innate seed dormancy (Granstrom 1987) and do not develop a buried seed bank (Isaac 1982). Fresh seeds of fireweed germinate promptly and completely within six days (Granstrom 1987). Mineral soil provides ideal conditions for germination of fireweed seeds (Viereck 1983). If mineral soil is exposed when fireweed seed is dispersed, germination on it is almost complete and very few dormant seeds overwinter (Myerscough and Whitehead 1967). Seedlings emerge successfully only from seeds germinated on or close to the soil surface (Myerscough 1980). Germination is stimulated by light, but not blue light. Temperatures between 15°C and 35°C appear optimal for germination. Fireweed seed germination is strongly inhibited by leachates from needles of balsam fir, jack pine and black spruce (Jobidon 1986). Successful establishment of fireweed seedlings appears to be confined to open moist sites with at least moderate fertility and few initial competitors (Myerscough 1980).



Frequency of occurrence of **fireweed** by soil texture class



Frequency of occurrence of **fireweed** by NWO FEC Vegetation Type

Vegetative Reproduction: Vegetative reproduction is from perennial, horizontally spreading, fleshy roots which, with old stem bases, give rise to shoot buds (Myerscough 1980). In established colonies of fireweed, vegetative reproduction has clear priority over reproduction by seed (Haeussler and Coates 1986), especially in terms of nutrient allocation (van Andel and Vera 1977, van Andel and Jager 1981). The buds on the rhizomes of fireweed do not develop immediately after initiation; they remain dormant until the next growing season (Vodolazsky 1979). Most buds are located at depths of 2 to 8 cm, and rarely in the surface layer of soil (Moss 1936).

Growth and Development

Fireweed is a perennial, which persists for many years (van Andel and Vera 1977). Fireweed has a rhizome system that grows mostly from 2 to 8 cm below the mineral soil surface (Moss 1936, McLean 1969). Perennial roots are most abundant at 5 to 20 cm depth, with some descending deeper than 40 cm. Large, dense colonies several meters wide occur in many habitats. Up to 120 shoots per m^2 have been observed (Myerscough 1980). The perennating organ, root and pseudo-rhizome may attain a considerable age (the root 20 years or more) and may still give rise to aerial shoots (Moss 1936). A thick but open litter of dead stems may develop where dense colonies of fireweed persist (Myerscough 1980).

Fireweed may accumulate its maximum dry weight at about 17 weeks after germination and maximum leaf area at about 14 to 15 weeks (van Andel and Jager 1981). Emergent living shoots may reach a maximum biomass of 600 - 900 g/m^2. Fireweed often overtops lower growing plants by late May or early June (Myerscough 1980). Observations made in July, and extending for more than 20 years, of a colony of fireweed indicated a progressive increase in aboveground biomass for about seven years. This was followed by a period of fairly steady height and biomass growth for about 12 years. Subsequently there was a sharp decline in both height and shoot biomass, some die-back being noted near the center of the colony (Myerscough 1980). van Andel (1976) found that the lateral spread of one colony in a particular direction was approximately one meter per year over several years.

van Andel and Vera (1977) studied nutrient allocation within fireweed. They found that from the rosette stage onwards, the amount of nutrients absorbed increases considerably due to its continued increase in biomass. The rosette stage is characterized by a large allocation of nutrients to leaves (68% to 83%). During stem elongation there is also a considerable increase in the production of both roots and leaves. Fireweed allocates about 40% to 60% of its nutrient uptake into its overwintering tissues i.e. the roots and rhizomes.

Phenology

Root, Shoot and Foliage: Aerial shoots first begin to emerge from late March to early June at mid-latitude, but most emerge in May (Haeussler and Coates 1986). Roots may grow before shoot buds begin to emerge and elongate. New shoot buds may already be apparent on some roots in early May. Shoots emerge in spring and reach maximum biomass between the middle of June and end of August. The leaf canopy expands most rapidly between the beginning of April and middle of June (Moss 1936). Approximately half of its maximum percent coverage is completed by the beginning of June and its foliage development is completed by about Julian Day 174 (DeLong 1988). As aerial shoots senesce in autumn a periderm in each stem base separates the shoot from living tissues below ground (Moss 1936).

Reproductive Structures: Fireweed blooms between early July and late August (Heinrich 1976). The flowering season extends over several months because the inflorescence begins to flower at the base, and continues to elongate during summer, producing blossoms at the tip of the plant long after the basal fruits have ripened and released their seed (Clark 1976). Seeds are released throughout late summer until after the aerial shoots have withered in autumn (Haeussler and Coates 1986). The elapsed time between the development of a flower bud and the release of ripe seed is about 7 to 8 weeks (van Andel and Vera 1977).

Response to Disturbance

Overstory Removal: Fireweed is an aggressive invader of logged sites (Dyrness 1973). Colonization is primarily by seeding in, but where fireweed already exists prior to canopy removal, it may expand by its spreading root systems (Haeussler and Coates 1986). The first few seeds may arrive in fall of the first year following winter logging and germinate in spring of the second year. Depending on their ability to produce seed, fireweed may appear in great numbers during the fourth year (Eis 1981). Summer logging may stimulate fireweed reproduction more than winter logging (Zasada *et al.* 1981).

Fire: Fireweed is rated as moderately resistant to fire because of its shallow root system (McLean 1969). Actively growing fireweed has a very low flammability and acts as a heat sink because of its high moisture content (Haeussler and Coates 1986). Fireweed is a common invader of moist to wet, burned sites (Ahlgren 1960, Dyrness 1973, Rowe 1983, Comeau 1988). This species may occur as a minor component in an undisturbed community, but is typically abundant within weeks after fires (Wein and Bliss 1973, Auclair 1983). In one study, fireweed constituted only 4% of the total pre-burn understory production of an aspen stand; however, it increased dramatically by the first post-burn year and by the third post-burn year it averaged 45% of the understory (Bartos and Mueggler 1981). Fireweed invades rapidly by means of wind-borne seeds and is more abundant on moderately and severely burned sites than on lightly burned sites (Archibold 1980, Bartos and Mueggler 1981, Hamilton and Yearsley 1988b). Fireweed loses vigour and does not survive well under regimes of regular, repeated burning (Myerscough 1980).

Fireweed takes up the available nutrients immediately following a fire and recycles them quickly through their dead and decaying plant parts (Viereck 1983). Foliar concentrations of N, P, K, Ca and Mg in fireweed do not appear to be related to burn intensity (Dyrness and Norum 1983).

Mechanical Site Preparation: Site preparation appears to reduce competition from other species and provides a suitable seedbed for fireweed (Watson *et al.* 1980, Hamilton and Yearsley 1988a).

Cutting: Fireweed does not survive under regimes of continued mowing or grazing (Myerscough 1980).

Chemical Treatments: The response of fireweed to 2,4-D, hexazinone and glyphosate will be discussed separately.

2,4-D: Information pertaining to the response of fireweed to applications of 2,4-D was not found in the literature.

***Hexazinone*:** Fireweed is rated as intermediate/resistant to Velpar-L (Corcoran 1989). More than 14 l/ha of Velpar-L may be required to control fireweed on a medium-textured soil (Corcoran 1989). The results of hexazinone, applied as a liquid at rates of 2.2 to 4.3 kg/ha, have ranged from nearly complete control to little control (Expert Committee on Weeds 1984). Velpar-L, aerially applied in late June at 2 kg a.i./ha, will effectively control fireweed (over 90% cover reduction) for one year (Pitt *et al.* 1989).

***Glyphosate*:** Fireweed was reduced by 71% in both cover and height one growing season after glyphosate was applied at 2.25 kg/ha (Expert Committee on Weeds 1984). Two years after glyphosate was applied with a Micron Herbi applicator at 0.5 kg a.i./ha the majority of fireweed shoots were dwarfed and deformed (Haeussler and Coates 1986). Fireweed can quickly dominate aspen sites where complete control of the aspen has been achieved with Vision (Perala 1985).

Fertilization: Fireweed may increase in abundance where fertilizers have been used (Myerscough 1980). Fertilization increases flowering and seed production of fireweed (van Andel and Vera 1977). Germination is also improved on fertilized sites (Myerscough and Whitehead 1967).

Effects on Conifers

Fireweed can be an important competitor with coniferous trees within two years of site preparation (Haeussler and Coates 1986) and its competition is most serious on moist, nutrient rich soils (Presslee 1989). Fireweed may contribute to seedling snow press damage (Haeussler and Coates 1986) and to reduced soil temperatures due to shading on mesic and wetter sites (Hamilton and Yearsley 1988a). On submesic sites, the species does not appear to have sufficient volume or density to cause appreciable snow press damage to species such as lodgepole pine, which is capable of growing fast enough to avoid light competition or mechanical damage from fireweed (Hamilton and Yearsley 1988a). Root competition for soil moisture and nutrients can be significant (Haeussler and Coates 1986). A canopy of fireweed may reduce the quality of sunlight reaching small conifer seedlings and reduce the quantity of carbon dioxide assimilation of conifer foliage (Comeau 1988). In general, competition for light is relatively minor because the aerial shoots must grow from the ground up each spring, and the mature fireweed canopy allows considerable light to penetrate (Eis 1981). Neither the importance of moisture competition between conifer seedlings and fireweed on drier sites nor the potential effects of shading and other positive contributions of the species, which absorbs nutrients released after burning and thus maintains them on site, have been determined (Hamilton and Yearsley 1989).

Herbaceous vegetation, such as fireweed, may slow down the rate of growth of spruce seedlings for a few years, but rarely causes significant mortality and failure of conifer regeneration (Eis 1981).

An important benefit of a fireweed cover is that it may delay development of shrubby vegetation on cleared or burned areas, thus allowing planted conifers to gain dominance of a site once they outgrow the fireweed (Haeussler and Coates 1986). Fireweed does not benefit conifers by fixing atmospheric nitrogen (Watson *et al.* 1980). Fireweed's extensive root system helps to bind soil and reduce erosion (Watson *et al.* 1980).

Uses by Wildlife

Fireweed is grazed by deer and moose (Haeussler and Coates 1986) throughout the growing season, but particularly when plants are in flower (McLean 1979). Small mammals use fireweed seed (Watson *et al.* 1980).

Graminoids
Grasses and Sedges

Although there are numerous grass and sedge species on forested and cutover sites of NW Ontario, they are dealt with here as a group because they are generally difficult to identify and there is little ecological or biological information on individual species.

A few of the grass species found in NW Ontario include: *Agropyron repens* (L.) Beauv., *A. trachycaulum* (Link) Malte, *Agrostis hiemalis* (Walter) Britton, *A. borealis* Hartman, *A. perlennans* (Walt.) Tuckem., *A. scabra* Willd., and *A. stolonifera* L., *Bromus ciliatus* L., *Calamagrostis canadensis* (Michx.) Beauv., *Cinna latifolia* (Trev.) Griseb., *Deschampsia flexuosa* (L.) Trin., *Oryzopsis asperifolia* Michx., *O. canadensis* (Poir.) Trin., *O. pungens* (Torr.) Hitchc.,and *Phleum pratense* L.

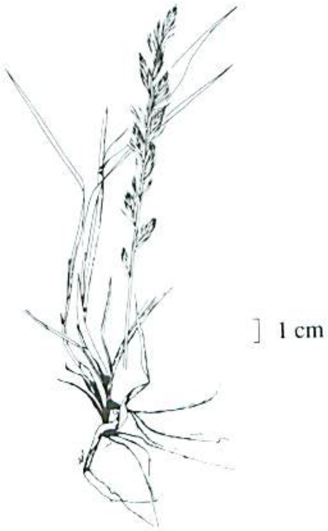
A few of the sedge species found in forested and cutover sites of NW Ontario include: *Carex aenea* Fern., *C. adusta* Boott, *C. arctata* Boott, *C. brunnescens* (Pers.) Poir., *C. canescens* L., *C. castanea* Wahl., *C. crawfordii* Fern., *C. cristatella* Britt., *C. deflexa* Hornem., *C. deweyana* Schw., *C. disperma* Dew., *C. gracillima* Schw., *C. interior* Bailey, *C. intumescens* Rudge, *C. leptalea* Wahl., *C. leptonervia* Fern., *C. nigro-marginata* Schw., *C. pauciflora* Lightf., *C. paupercula* Michx., *C. peckii* Howe, *C. pedunculata* Muhl., *C. projecta* Mackenzie, *C. retrorsa* Schw. *C. trisperma* Dew., and *C. vaginata* Tausch.

In order to recognize some of the common species, it is essential to gain at least a rudimentary knowledge of the flower parts and the main distinguishing features of the different genera. One of the first steps in identification is to differentiate between grasses and sedges. Smith (1981) and Roberts (1983) summarize some features that will help separate plants from the two families. Angrove and Bancroft (1983) provide a short list of distinguishing characteristics between different genera of grasses.

The following text is organized by subject and five broad groups of species: *Agropyron* spp., *Agrostis* spp., *Calamagrostis* spp., *Carex* spp. and *Phleum* spp.

Agropyron repens (L.) Beauv.
Quack Grass

Description



General: tall, coarse perennial with long, wiry, yellowish-white rhizomes; plants spreading or loosely tufted; flowering stems up to 1 m high.

Leaves: blades flat, soft, lax, 5-10 mm wide, with numerous fine veins; slightly roughened and sparsely hairy above, smooth and hairless beneath; leaf sheaths open, usually hairy, often with a prominent "collar" at the top; ligule inconspicuous.

Inflorescence: a single, slender, contracted spike; spikelets numerous, flattened, overlapping, alternate, positioned sideways against the stem; several florets per spikelet; individual florets with distinct nerves, with or without awns; at maturity the entire spikelet falls from the stem.

Agrostis scabra Willd.
Tickle Grass

Description

General: delicate, erect, tufted perennial without rhizomes or stolons; flowering stem up to 60 cm high, with a large, broad inflorescence which occupies 1/3 to 2/3 the height of the plant; inflorescence often detaching after flowering and blowing around like a tumbleweed.

Leaves: leaves mainly basal; blades narrow (usually < 2 mm wide), often inrolled and appearing hairlike, roughened on both surfaces.

Inflorescence: a large, diffuse, panicle with spreading, roughened, hairlike branches which rebranch at or above the middle; the panicle appearing tinged with pink or purple; small (< 4 mm), shiny, purplish spikelets crowded near the tips of the panicle branches; one floret per spikelet.

Calamagrostis canadensis (Michx.) Beauv.
Canada Blue-joint Grass

Description

General: a large, robust grass with numerous creeping rhizomes; stems in clumps, often extensive; flowering stems often 1 m high or more; stems not hairy, often purplish around the joints.

Leaves: blades flat, 4-8 mm wide, gradually tapering to a long point; roughened on both surfaces as well as along the margins; leaves slightly drooping; ligule long, membranous, with a ragged top.

Inflorescence: a large, open panicle, occasionally somewhat drooping, densely crowded or not, often purple-tinged; many spikelets per branch, one floret per spikelet; each floret with a dense tuft of hairs at the base, about as long as the floret; straight, delicate awn is short and inconspicuous.

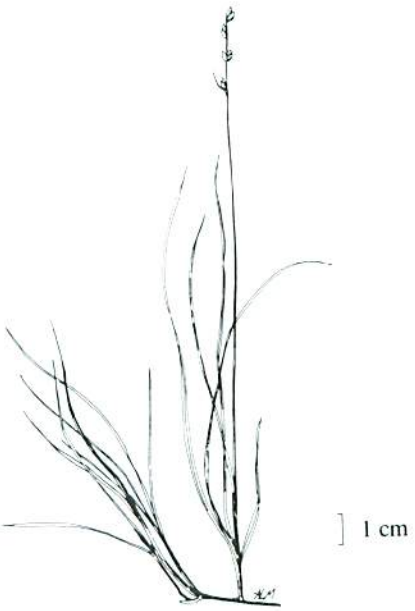
Carex disperma Dewey
Soft-leaved Sedge

Description

General: solitary or in loose, narrow-leaved tufts with both rhizomes and stolons; flowering stems usually <40 cm high, exceeding the leaves, more or less zig-zagging within the inflorescence.

Leaves: principal blades 1-2 mm wide; weakly ascending to drooping; usually rough-margined to the base.

Inflorescence: two to five small, stalkless spikelets spread loosely along a central axis; each spikelet with one to five (usually one or two) flowers; perigynium of each flower elliptical, round in cross section, with a minute beak, turning from green to dark brown or black upon ripening; bract at the base of the inflorescence either missing or very short.



Carex trisperma Dewey
Three-fruited Sedge

Description

General: solitary or in loose, narrow-leaved tufts with stolons; flowering stems usually <40 cm high, exceeding the leaves, slender and lax.

Leaves: principal blades 1-2 mm wide; usually drooping; rough-margined to the base; many dead leaves at the base of the plant.

Inflorescence: one to three (usually three) small, stalkless spikelets spread 1-4 cm apart on a slender, central axis; each spikelet with one to five (usually two or three) flowers; perigynium of each flower flattened on one side, greenish, with a smooth minute beak; bract at the base of the inflorescence bristle-like, several times as long as its spikelet.

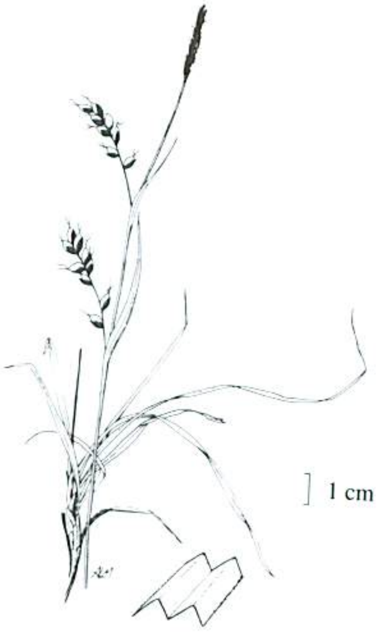
Carex vaginata Tausch
Sheathed Sedge

Description

General: medium-sized plants usually with a dense tuft of leaves; solitary or in loose (often extensive) clumps from rhizomes; flowering stems usually <40 cm high, equalling or exceeding the leaves, often nodding.

Leaves: principal blades 2-5 mm wide, doubly folded in cross section (forming an 'M'); turning with age from light to dark green with brown tips; rough-margined for the top 1/3.

Inflorescence: one to four elongated, cylindrical spikelets; the terminal spikelet on an erect stalk, 1-2 cm long, consisting only of male (staminate) flowers; the lateral spikelets on weak stalks, 0.5-3 cm long, loosely flowered, usually drooping; leaf-like bracts on the flowering stalk with loose, inflated sheaths, usually 1-2 cm long.



Phleum pratense L.
Timothy

Description

General: tall, erect, perennial without rhizomes or stolons; stems solitary or in clumps, growing from a swollen, bulbous base; flowering stems up to 1 m high; stem and foliage hairless.

Leaves: blades flat, 5-8 mm wide, distinctly veined, roughened along the margins; ligule membranous, white, up to 3 mm long.

Inflorescence: a single, elongated, cylindrical spike; spikelets flattened, densely crowded on the spike; 1 floret per spikelet; glumes compressed, bristly, of equal length, fully enclosing the floret, terminating in a short awn.

Habitat

Distribution in Ontario

Agropyron - Quack grass is an introduced grass found in all provinces of Canada and the Northwest Territories (Werner and Rioux 1977).

Agrostis - *A. scabra* extends throughout Ontario (Dore and McNeill 1980).

Calamagrostis - Canada blue-joint is a common species throughout Ontario, except in the extreme north (Dore and McNeill 1980). Canada blue-joint is especially abundant in the boreal forest.

Phleum - Timothy is an introduced grass from Europe, of high adaptability (Dore and McNeill 1980, Watson *et al.* 1980). It has escaped from cultivation throughout the settled parts of Ontario (Dore and McNeill 1980).

Climate

Agropyron - *A. trachycaulum* requires the equivalent of 35 mm of precipitation annually, depending on evapotranspiration (Watson *et al.* 1980).

Agrostis - *Agrostis* spp. are adapted to a wide range of climatic conditions.

Calamagrostis - Canada blue-joint seems to be particularly well adapted to a harsh northern climate and it reaches its greatest abundance and best growth in Alaska and northern Canada (Haeussler and Coates 1986).

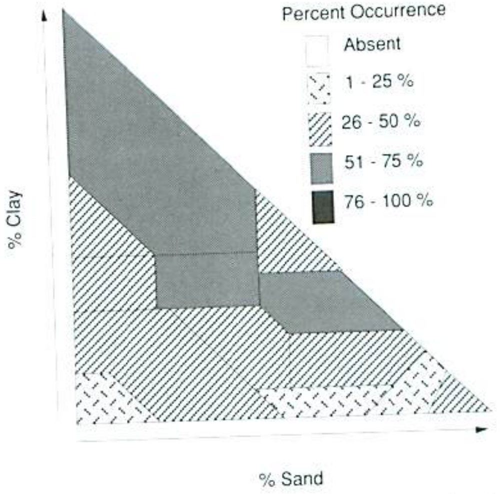
Carex - The wide geographic range of sedges indicates that they can tolerate a wide range of climatic extremes.

Phleum - Although timothy is very adaptable, it does best under rather cool and moist climatic conditions (Grant and Burgess 1978). Timothy grows best where annual precipitation exceeds 45 cm (Watson *et al.* 1980).

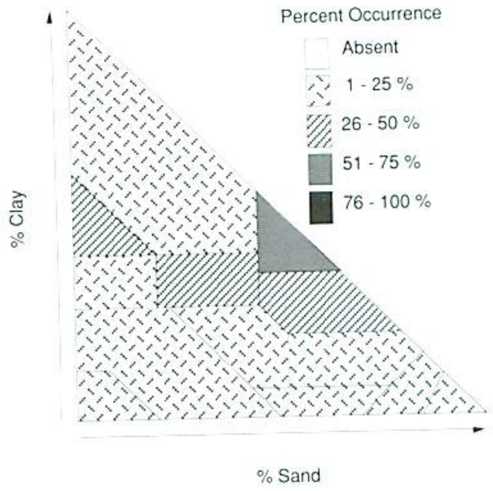
Site and Soil Relations

Agropyron - Quack grass has been reported growing on a wide variety of soils, from dry sand to wet alluvium (Werner and Rioux 1977). Quack grass has a high salt tolerance of 70-95 mg/100 g of soil (Tesu *et al.* 1972). Rhizome growth of quack grass is reduced in compacted soil (Wolcott and Carlson 1947). *A. trachycaulum* prefers medium-textured and well-drained soils (Watson *et al.* 1980).

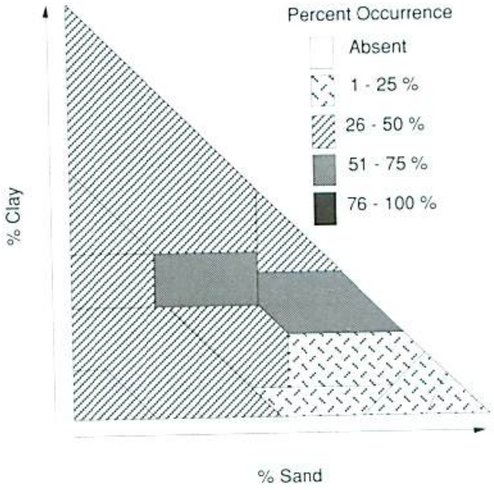
Agrostis - *A. scabra* is one of the most characteristic plants of open sites, where the soil tends to become periodically dry, such as on shallow rock or recently burned-over areas (Dore and McNeill 1980). In the far north of Ontario, where it is the only *Agrostis* species represented, it is abundant on the drier beach ridges of James Bay, and on eroded river banks. On exposed rocks along Lake Superior, it is widespread and common (Dore and McNeill 1980).



All grass species except *C. canadensis*



C. canadenis



***Carex* spp.**

Calamagrostis - In southern Ontario extensive stands of Canada blue-joint are found in swamps, bogs, ditches and shorelines. In the northern half of the province, however, Canada blue-joint also grows on well-drained soils, rock outcrops, and sandy tracts, showing less habitat preference (Dore and McNeill 1980). Canada blue-joint prefers very moist forest conditions and is common in swamps, marshes, fens, moist woodlands, wet meadows and floodplains (Habgood 1983, Haeussler and Coates 1986, Klinka *et al.* 1989). It is adapted to a wide range of soil textures, occurring on both mineral and peaty soils, but more often on peat (Watson *et al.* 1980).

Carex - In NW Ontario, sedges occur more commonly on fine-textured, silt and clay soils than on coarser-textured, sandy soils.

Phleum - Timothy persists on roadsides, open fields, and vacant land (Dore and McNeill 1980). Timothy can grow successfully under a wide range of soil conditions (Grant and Burgess 1978). Fair growth has been achieved on sandy soils, good growth on loamy and clayey soils and timothy is tolerant of organic soils. The optimum slope for growth is < 9% and the optimum soil depth is more than 60 cm (Watson *et al.* 1980).

Nutrient Requirements

Agropyron - Quack grass has been reported in pH ranges from 4.5 to 8.0; however, it is most vigorous in neutral to alkaline soils (pH 6.5-8.0) (Werner and Rioux 1977). *A. trachycaulum* occurs naturally under a variety of nutrient conditions (Watson *et al.* 1980).

Agrostis - *A. scabra* is adapted to soils of low nutrient status and tolerates soils of low pH. It is an early colonizer of barren, acid (pH 4.0) soils near Coniston, Ontario (Watson *et al.* 1980).

Calamagrostis - Canada blue-joint occurs on sites that are moderately rich in nitrogen (Klinka *et al.* 1989). The optimum pH range is 5.0-5.9, but Canada blue-joint tolerates very acid soils with pH values as low as 3.5 (Watson *et al.* 1980).

Carex - In NW Ontario, sedges occur across the full range of nutrient regimes. Their distribution appears to be controlled more by soil moisture regime than soil nutrients.

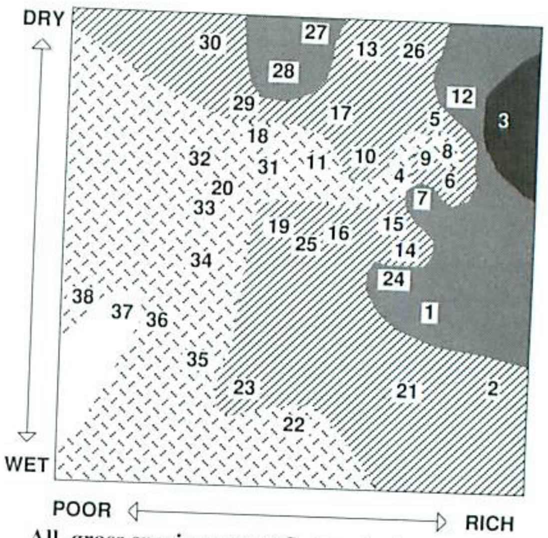
Phleum - Timothy is regarded as a species with high nutrient requirements (Watson *et al.* 1980). It is also acid tolerant. The lower pH limit for growth has been identified at 4.5 (Watson *et al.* 1980). Timothy grows best at a pH of 6.0 or above.

Moisture Requirements

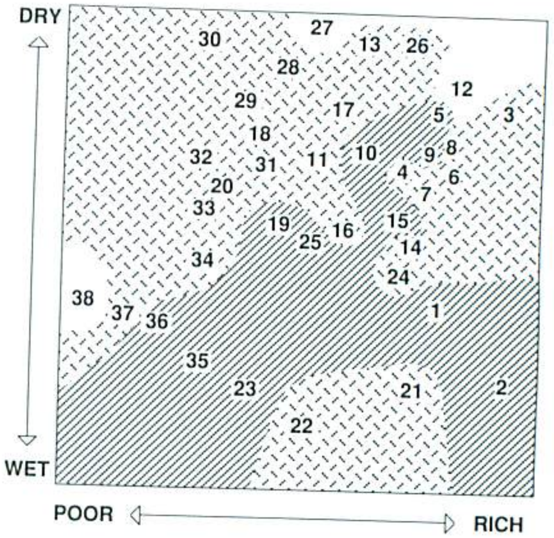
Agropyron - Quack grass shows no drainage preference, but does best on fine-textured soils (Dale *et al.* 1965). *A. trachycaulum* prefers moist to dry sites (Watson *et al.* 1980).

Agrostis - Information pertaining to moisture requirements of *Agrostis* spp. was not found in the published literature.

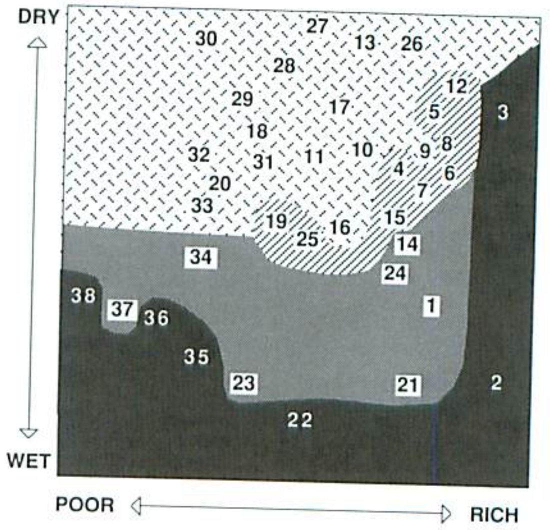
Calamagrostis - Canada blue-joint prefers very moist to wet sites (Klinka *et al.* 1989), but can survive on imperfectly to moderately well-drained soils and, once established, is also very drought tolerant (Watson *et al.* 1980). Canada blue-joint is found



All grass species except *C. canadenis*



C. canadensis



***Carex* spp.**

predominantly on fine-textured soils with good water-holding capacity and on sandy soils with high water tables (Mueller-Dombois and Sims 1966).

Carex - In NW Ontario, sedges show a strong preference for very moist to wet sites. Most sedges are found on moist or swampy areas, although some species are associated with dry, open ground (Habgood 1983).

Phleum - Timothy is not drought resistant (Grant and Burgess 1978) and requires considerable moisture to maintain itself (Watson *et al.* 1980).

Light Requirements

Agropyron - Quack grass is not found under a continuous cover of shrubs and trees (Palmer and Sagar 1963). During long photoperiods, quack grass produces more numerous, thicker and heavier rhizomes (Werner and Rioux 1977). The level of above-ground illumination affects the rhizomes more than it does the aerial shoots (Werner and Rioux 1977). A reduction in light level produces an increase in the percentage of rhizome buds developing as shoots (Werner and Rioux 1977).

Agrostis - *A. scabra* is generally found in open sunny locations, so it is presumed to be shade intolerant (Watson *et al.* 1980).

Calamagrostis - Canada blue-joint is shade-tolerant/intolerant (Klinka *et al.* 1989). It is most abundant and better developed on open sites but will tolerate partial shade (Watson *et al.* 1980, Habgood 1983).

Carex - Assumed to be shade intolerant.

Phleum - Timothy is shade-tolerant (Watson *et al.* 1980).

Reproduction

Sexual Reproduction

Seed Production and Dispersal

Agropyron - The amount of seed produced by quack grass is highly variable. Reports range from 15-400 seeds per plant stem, with 25-40 most common (Werner and Rioux 1977). Quack grass is wind pollinated (Werner and Rioux 1977). Seeds of quack grass possess no special morphological adaptations for dispersal, but fall passively from the parent plant (Werner and Rioux 1977). *A. trachycaulum* is noted for its high production of seed (Watson *et al.* 1980).

Agrostis - *A. scabra* is very efficient at seed dispersal, using a tumbling mechanism; at maturity, the inflorescence breaks away and is carried off by wind like a tumble weed. This facilitates dispersal to areas far removed from the place of origin (Watson *et al.* 1980).

Calamagrostis - Seed is produced annually, when environmental conditions are favourable (Haeussler and Coates 1986). Seed yields are generally low (Watson *et al.* 1980). Canada blue-joint is adapted to wind pollination (Haeussler and Coates 1986). Blue-joint seeds are small and easily windborne (Ahlgren 1960).

Phleum - Timothy has a moderate ability to reseed naturally (Watson *et al.* 1980). Timothy seeds resist digestion by large herbivores and thereby get transported to remote habitats (Dore and McNeil 1980).

Seed Viability and Germination Requirements

Agropyron - Buried quack grass seeds may lie dormant for two to three years (Carder 1961) and may retain their viability for a maximum of about four years (Brackney and Seely 1966). Seeds generally germinate in the spring (Werner and Rioux 1977). Alternating temperatures are a requirement for germination (Werner and Rioux 1977). Germination will not occur under drought conditions (Wein and McLean 1973). *A. trachycaulum* seed retained 70% viability over six years under cool, dry warehouse storage (Watson *et al.* 1980). Seeds generally have high germination rates and quack grass seedlings are vigorous (Watson *et al.* 1980).

Agrostis - Information regarding seed viability and germination requirements of *Agrostis* spp. was not found in the published literature.

Calamagrostis - Seed viability is initially greater than 70% (Conn and Farris 1987). Seeds normally lose their viability after 18 months, but germination continues at reduced rates for up to two years. Seed viability is reported to be higher for seed buried for 21 months at 15 cm below the soil surface than for seed buried for a similar length of time at 2 cm depth: percent germination was 50% and 4% respectively (Conn and Farris 1987). Germination of Canada blue-joint seeds occurs without cold stratification (Haeussler and Coates 1986). Blue-joint seed may germinate on sandy soils; however, germinants stand little chance of survival on such media, because the surface soil will periodically dry below the wilting point during the growing season (Mueller-Dombois and Sims 1966).

Carex - Most sedges are monoecious, with staminate and pistillate flowers on separate spikes of the same plant or on different parts of the same spike (Habgood 1983). *C. brunnescens* appears to develop a buried seed bank (Isaac 1982).

Phleum - Timothy does not develop a buried seed bank (Kramer and Johnson 1987). Timothy seed germination is slightly affected by leachates from needles of black spruce and jack pine, and greatly delayed by balsam fir extracts (Jobidon 1986).

Vegetative Reproduction

Agropyron - Rhizome growth of quack grass is renewed annually from axillary buds at the base of aerial shoots (Werner and Rioux 1977). Most axillary buds along the rhizomes are dormant due to strong apical dominance exerted by the terminal bud. Aerial shoots are formed mainly at the end of the growing season when a rhizome tip becomes erect; they are also formed from both terminal and axillary buds any time a rhizome becomes detached from the parent plant. Adventitious roots form at nodes of the rhizome; roots are short in length relative to other grasses (Werner and Rioux 1977). Given the relatively low number of seeds produced, and the generally higher probability of survival of vegetatively produced plants relative to seedlings, vegetative cloning is much more important than sexual reproduction in maintaining a population on a site (Werner and Rioux 1977). *A. trachycaulum* is somewhat rhizomatous, and produces numerous productive tillers (Watson *et al.* 1980).

Agrostis - Information regarding vegetative reproduction of *Agrostis* spp. was not found in the literature.

Calamagrostis - Once it has seeded in and become established in an area, Canada blue-joint spreads primarily by rhizomes (Habgood 1983, Haeussler and Coates 1986).

Carex - Sedges spread by means of rhizomes or stolon-like rootstocks (Habgood 1983). Vegetative reproduction is the primary means of perpetuation of *C. disperma* and many other sedges (Ahlgren 1960).

Phleum - Timothy is a perennial grass with a unique method of vegetatively renewing itself each year (Grant and Burgess 1978). In the seeding year, timothy forms only a single shoot and overwinters. In succeeding years, a seed head is formed near the base of the plant and gradually elevates to first appear as a swelling at the top of the shoot (boot stage); it then emerges, elongates, and begins to flower. As this is happening, a corm is formed at the base of the shoot. The corm is a small, onion-like bulb containing food reserves in the form of sugars. About the time that the head elongates, the corm is well-formed, and small buds, usually at the base of the corm, can be seen. These buds are the beginning of the second crop. The food reserves in the corm provide nutrition for initial growth of the second crop. As shoots for the second crop develop; they, in turn, take root and form small secondary corms. A third set of shoots rise from corms as an overwintering stage for the plant.

Growth and Development

Agropyron - Seedlings of quack grass begin to produce tillers in the 4- to 6-leaf stage and rhizomes in the 6- to 8-leaf stage (Palmer and Sagar 1963). The latter stage is usually reached two to three months after seedling emergence. In contrast, new rhizomes start to develop at the 3- to 4-leaf stage in plants that have developed from rhizome buds (Fiveland *et al.* 1972). In open habitats, individual plants form a clump during the first growing season due to extensive subtillering of primary tillers. Also, as many as 150 rhizomes or rhizome branches are produced. In the second season the clump develops into a patch as other clumps develop from the erected tips of the first season's rhizomes. Later, adjacent patches coalesce to form a continuous ground cover, sometimes limited by the presence of other species (Palmer and Sagar 1963). During spring and summer the tip of each rhizome grows in a horizontal direction below the soil surface, but becomes erect in autumn to form a primary aerial shoot. This shoot develops into a mature plant during the following year (Werner and Rioux 1977). Raleigh *et al.* (1962) reported that the diameter of spread of 14 rhizomes from one parent quack grass plant was 3.04 m. The total length of rhizomes was 154 m, with 206 shoots arising from them.

Agrostis - *A. scabra* is a perennial grass which forms dense tufts 30-70 cm high (Watson *et al.* 1980).

Calamagrostis - Canada blue-joint is a tall, long-lived perennial grass. A well-developed stand of blue-joint may persist for long periods, possibly as long as 100 years (Watson *et al.* 1980). It can attain heights of 1.1 m to over 1.5 m within a six-week growing period (Mitchell 1974). In shaded sites, as in bottomland thickets of alder, the plants are lanky, growing often to a height of 2 m (Watson *et al.* 1980). In open sunny sites the plants are usually shorter, up to about 1 m. Plants have numerous leaves and creeping rhizomes, forming tussocks (Watson *et al.* 1980). Yields of 34-56 tons/ha (dry matter) have been estimated in native, undisturbed stands of bluejoint.

Carex - Little is known about the growth and development of sedge species.

Phleum - Timothy is a short-lived perennial bunchgrass. Under favourable conditions timothy will produce about 9 tons/ha of dry matter (Grant and Burgess 1978). Timothy has fibrous roots which may extend more than 1.2 m (Watson *et al.* 1980).

Phenology

Root, Shoot and Foliage

Agropyron - Quack grass is most active in sexual reproduction and rhizome formation in the middle of summer, and in tillering and photosynthesis in spring and autumn (Werner and Rioux 1977). Johnson and Buckholtz (1962) reported seasonal activity of rhizome buds; there was a steady decrease in activity from mid-April to June, dormancy during June and increased activity from July onward. New rhizomes of quack grass develop underground in greatest numbers during June, July and August (Evans and Ely 1935). The pattern of translocation of carbohydrates within quack grass varies with seasonal time. In one study, total soluble sugars increased, reached an early season high (8%) in late May, decreased to 3% from June until early October, followed by an increase to about 8% in November (Arny 1932). Carbohydrate reserves in the rhizomes are lower in spring and up to the first part of July than at any later time (Arny 1932).

Agrostis - Where abundant, *A. scabra* casts a pinkish haze over the landscape in mid- to late summer (Watson *et al.* 1980).

Calamagrostis - Canada blue-joint, in south central Alaska, completes its height growth by mid-July (Mitchell 1974). Different variants of Canada blue-joint are best separated in August (Watson *et al.* 1980).

Carex - Information pertaining to the shoot and root growth of sedges was not found in the literature.

Phleum - In most parts of eastern Canada, the "jointing stage" is reached in early to mid-June, but the time varies with the variety and local climate (Grant and Burgess 1978). The full head stage begins about five days after heads first appear and lasts about five days (Grant and Burgess 1978). McWilliams and Ludwig (1972) noted flowering of timothy from late May to mid-August at a site in mid-Michigan.

Reproductive Structures

Agropyron - Flowering of quack grass occurs in late June to July (Frankton and Mulligan 1971). Seeds ripen in early August to early September and drop from parent plants by late September.

Agrostis - Information regarding the phenology of reproductive structures of *Agrostis* species was not found in the literature.

Calamagrostis - Canada blue-joint, in south central Alaska, has fully-developed heads by mid-August (Mitchell and Evans 1966).

Carex - At the Matthaei Botanical Gardens of the University of Michigan, the majority of sedges flower between early June and late July (McWilliams and Ludwig 1972).

Phleum - The average date of first flowering of timothy near Ottawa, Ontario was June 25, and the earliest and latest dates were June 18 and June 30 respectively (Bassett *et al.* 1961).

Response to Disturbance

Overstory Removal

Agropyron - Information pertaining to the response of quack grass to overstory removal was not found in the literature.

Agrostis - Information pertaining to the response of *Agrostis* spp. to overstory removal was not found in the literature.

Calamagrostis - Canada blue-joint may develop into continuous mats within three or four years after logging (Frisque *et al.* 1978). A vegetation survey in black spruce swamp and lowland brush areas in north-central Minnesota suggests that Canada blue-joint increases in frequency from 5-29% in the swamp type, and from 15-71% in the brush type after logging (Johnston 1968). However, a decrease in frequency may occur where heavy competition from poplar root suckers follows logging (Zasada *et al.* 1981). A winter harvest of the overstory, which disturbs the soil less than a summer harvest, should result in less competition from blue-joint (Campbell 1981).

Carex - Areas dominated by sedges can have large amounts of surface litter and standing dead material and consequently can be thoroughly burned (Smith and James 1978b). Even wet meadows of sedge have been observed to burn (Auclair 1983). Sedges are known to reproduce abundantly, often within weeks after a fire (Ahlgren 1979a, Auclair 1983). Within two years of the removal of the canopy by fire, sedges can fully occupy a site to the exclusion of almost all other vegetation, including jack pine (Rouse 1986b). *C. disperma* is a common invader of moist to wet, burned sites (Alhgren 1960). Growth of sedges may be encouraged by the removal of litter accumulations. On recent burns, sedge seeds may be abundant and plant frequency relatively high. On older burns, although plant frequencies are generally much lower, seed quantities are still high indicating maintenance of a seed source (Ahlgren 1979a).

Phleum - In the days of horse-power, when some grains were dropped from the hay feed and others were carried far along wood roads in manure, timothy was one of the first grasses to appear in any new clearing (Dore and McNeill 1980).

Fire

Agropyron - Information pertaining to the response of quack grass to fire was not found in the literature.

Agrostis - *Agrostis* spp. produce large numbers of light seeds and are typically abundant immediately (within weeks) after fire (Auclair 1983).

Calamagrostis - Sylvester and Wein (1981) pointed out that fire spreads rapidly through stands of blue-joint because of the presence of large volumes of fine, dry litter. Live plant material is very resistant to burning but does not slow the rate of fire spread. Canada blue-joint colonizes burned sites more rapidly than unburned sites. It is a common invader of moist to wet, burned sites (Rowe 1983) and is typically abundant immediately (within weeks) after burning (Auclair 1983, Hamilton and Yearsley 1988b). Rhizomes survive and increase in abundance after burning and the species also rapidly seeds-in to burned sites (Wein and Bliss 1973). In undisturbed communities, blue-joint may have low vegetative vigour and a lack of seed heads (Wein and Bliss 1973). Burning tends to stimulate the flowering of blue-joint grass (Bliss and Wein 1972). The development from vegetative reproduction of almost-pure stands of blue-joint during the first post-fire season may effectively suppress less-vigorous competitors (Smith and James 1978b). Burning intensity does not appear to affect the rate at which blue-joint spreads on a site (Ahlgren 1960). Light to moderate burns stimulate rhizomatous sprouting and may create favourable seedbeds (Viereck 1983). More intense fires which expose mineral soil create favourable seedbeds. Since seeds are easily wind-borne, blue-joint is able to quickly invade burned-over sites if a seed source is nearby (Dyrness and Norum 1983). Three years may be required before blue-joint forms thick stands following a severe fire (Dyrness and Norum 1983). Blue-joint takes up the available nutrients immediately following a fire and recycles them quickly via dead and decaying plant parts (Viereck 1983). The foliar concentrations of N, P, Ca and Mg in blue-joint grass increase with the degree of burning, while concentrations of K remain relatively unchanged (Dyrness and Norum 1983).

Carex - Sedges develop well following fire in all but the unburned and heavily burned sites within a burned area (Archibold 1979). Sedges such as *C. deflexa* and *C. peckii* decreased in frequency and percent cover after 24 years of annual spring burning (Anderson and Bailey 1980).

Phleum - Timothy is described as a meadow grass that can be used to provide ground cover on burned-over land (Tiedemann and Klock 1974). It is generally more abundant on burned than unburned sites (Ahlgren 1960).

Mechanical Site Preparation

Agropyron - Axillary buds on the rhizomes of quack grass are released from inhibition when the rhizome apex is severed from the parent plant (Rogan and Smith 1976). Careful and repeated tillage from the beginning of August until the ground becomes frozen often gives excellent control of quack grass (Godbout 1960). Since carbohydrate reserves in the rhizome are lowest in the first part of July, this may be the opportune time to begin eradication through soil disturbance (Arny 1932). Growth may be retarded by a single tilling or scarification (Estabrooks 1988).

Agrostis - Information pertaining to the response of *Agrostis* spp. to mechanical site preparation was not found in the literature.

Calamagrostis - Soil disturbance has positive effects on both growth and vigour of Canada blue-joint; plants growing on disturbed soil showed more shoots per clone, more flowering heads, more seeds produced per head, greater plant height and higher tissue concentrations of N and P than plants of undisturbed areas (Habgood 1983). Arlidge (1967) found that within two to three years following scarification, blue-joint was a serious competitor on mounded microsites within wet depressional areas. Heavy cultivation may control established plants, but areas of newly exposed soil may be rapidly reinvaded by adjacent, undisturbed plants.

Carex - Information regarding the response of sedges to mechanical site preparation was not found in the literature. However, treatments which cut up the sedges' rhizomes should increase the abundance of these species.

Phleum - Timothy is well adapted to disturbance. It will spread from cultivated fields into adjacent rangelands (Watson *et al.* 1980).

Cutting: Mowing of grasses eliminates immediate competition to tree foliage and reduces the fire hazard. One mowing of grasses gives adequate control on most sites. Two or more mowings are usually necessary for satisfactory control (Estabrooks 1988).

Agropyron - Since carbohydrate reserves in the rhizome are lowest in the first part of July, it appears that this is the opportune time to begin control methods through cutting (Arny 1932). *A. trachycaulum* is presumably tolerant to grazing and mowing (Watson *et al.* 1980).

Agrostis - Many *Agrostis* spp. are used for putting greens of golf courses because of their tolerance to very close mowing (Watson *et al.* 1980).

Calamagrostis - Cutting Canada blue-joint more than once during the growing season will result in lower biomass yields; recovery after cutting is slow (Habgood 1983). Yields decreased by 15-20% when the grass was cut two to four times during the growing season, and by about 70% when cut seven times, in relation to plots cut once at the end of the growing season (Watson *et al.* 1980).

Carex - Information pertaining to the response of sedges to cutting was not found in the literature. However, if one assumes that grasses and sedges are similar in this characteristic, repeated cuttings would reduce the abundance and vigour of most sedges.

Phleum - Timothy is not sensitive to close, continuous grazing (Watson *et al.* 1980) and numbers will decline with close mowing (Dore and McNeill 1980). Cutting timothy during the two-week period before the seed heads emerge (i.e., the jointing stage) greatly weakens the original plant. The cycle of regeneration is interrupted because the corms and buds for the second shoot are not properly formed (Grant and Burgess 1978).

Chemical Treatments: There is very little herbicide research which divides grasses on the basis of species (Balfour 1989).The response of grasses and sedges to 2,4-D, hexazinone and glyphosate will be discussed separately.

***2,4-D*:** Boyd *et al.* (1985) found that applications of 2,4-D throughout the growing season caused little or no injury to grasses. Applied at 4.7 to 28.1 l/ha, 2,4-D was not effective in killing grasses (Johnson 1987).

Agropyron - Quack grass is thought to be encouraged by phenoxy herbicides (Werner and Rioux 1977).

Agrostis - *Agrostis* spp. can be controlled or killed with 2,4-D but usually a high dosage must be used and then only during the most susceptible period. Repeated treatments may be required (Chemagro Corporation 1953).

Calamagrostis - 2,4-D does not control Canada blue-joint (Campbell 1981).

Carex - Density of sedges may markedly increase following 2,4-D treatments (Lehela 1981, Posner 1984). Response to 2,4-D can be variable (Chemagro Corporation 1953).

Phleum - Control of timothy by 2,4-D is not feasible (Chemagro Corporation 1953).

***Hexazinone*:** Grasses are rated as susceptible to Velpar-L (Corcoran 1989). Excellent first-year control of grasses can be obtained with rates of 8-10 l/ha (Cocoran 1989) or 1.7-4.5 kg/ha (Boyd *et al.* 1985). Average percent controls of 42%, 74%, 84%, 91% and 98% were obtained with rates of 1.1, 1.7, 2.2, 3.4 and 4.5 kg/ha respectively (Boyd *et al.* 1985). Applications made during the dormant season provide slightly better control than applications made after the foliage appears (Boyd et al. 1985). Velpar-L applied in May at a rate of 1.0-1.5 kg a.i./ha usually gives adequate control of grasses (Estabrooks 1988).

Severe damage by hexazinone to grasses has been found to persist into the second year (Balfour 1989). Grasses can be controlled for at least two to four growing seasons after spring application with treatment rates of 9.38 l/ha and greater. Root competition is lower in treated blocks than controls even after four years (Anon. 1989a). Neither Velpar-L applied at 4.7-28.0 l/ha nor Pronone 10G applied at 6.5-9.4 kg/ha were effective in killing grasses. However, early top-kill caused by Velpar-L and Pronone granules indicates that these herbicides may be effective at higher rates (Johnson 1987).

Agropyron - Information pertaining to the response of quack grass to applications of Velpar-L was not found in the literature.

Agrostis - Information pertaining to the response of *Agrostis* spp. to applications of Velpar-L was not found in the literature.

Calamagrostis - Lehela and Campbell (1981) reported excellent control of Canada blue-joint grass with 4.5 kg/ha of hexazinone used for site preparation in early spring in Ontario. Hexazinone applied as a liquid spray at rates of 1.1-4.3 kg/ha has provided excellent control of blue-joint; however, with increasing organic matter depths, results may be less consistent (Expert Committee on Weeds 1984). Blue-joint can be controlled by broadcast applications of Velpar-L (Dupont Canada 1987).

Carex - Sedges are rated as tolerant to Velpar-L; more than 14 l/ha are required to control sedges on a medium-textured soil (Corcoran 1989). Excellent first-year control of sedges is dependent upon the rate of application. Average percent controls of 27%, 73%, 85% and 90% were obtained with rates of 1.1, 1.7, 2.2 and 4.5 kg/ha respectively (Boyd *et al.* 1985). Applications made during the dormant season provide better control than after foliage appears. Regrowth from seed may reduce the efficacy by approximately 30% by the second post-spray season.

Phleum - Information pertaining to the response of timothy to applications of Velpar-L was not found in the literature.

***Glyphosate*:** The limited surface area of grasses, combined with their variable growth forms, are likely causes of efficacy variation for a leaf uptake herbicide such as glyphosate (Balfour 1989). Excellent first year control of grasses can be obtained with rates of 1.12-1.68 kg a.i./ha (Anon. 1988); however, by the end of the second year grasses re-establish themselves from the residual seed source. Glyphosate controls grasses, provided they are sprayed prior to turning brown in late August (Presslee 1989). Where glyphosate is to be used, new grass should be allowed to reach a height of about 20 cm before spraying (Estabrooks 1988). Glyphosate does not provide residual control for grasses that have already shed seed prior to time of herbicide application. In glyphosate treated plantations, grasses are often very abundant (Kennedy and Jordan 1985).

Agropyron - Glyphosate is rapidly absorbed by quack grass after surface-spraying, with a large portion transmitted to the rhizomes and untreated shoots (Sprankle *et al.* 1975). Glyphosate has been shown to provide a high degree of quack grass control in fall and spring applications (Baird and Begeman 1972). However, quack grass appears to be more susceptible to glyphosate in mid- to late August than in June or July (Lund-Høie 1975). Rates greater than 2.0 kg a.i./ha can provide greater than 80% control if applied between mid-June and late August; lower rates (e.g., 0.5 and 1.0 kg a.i./ha) are most effective if applied in mid- to late August (Lund-Høie 1975). When quack grass is actively growing and has three to four new leaves on each shoot, glyphosate applied at 1.7-2.5 kg/ha is recommended for control (Anon. 1986). For glyphosate to be most effective, quack grass should be 15-20 cm high (Estabrooks 1988).

Agrostis - Information pertaining to the response of *Agrostis* spp. to applications of glyphosate was not found in the literature.

Calamagrostis - In terms of initial kill of Canada blue-joint, August applications of glyphosate are more effective than June applications (Blackmore and Corns 1979); however, in one study, grass reinvasion was complete within two years, although not as tall or as dense as the controls for either spray time. Glyphosate does not provide residual control for grasses that have already shed seed prior to time of herbicide application. Blackmore and Corns (1979) suggest using 3.0-3.5 kg a.i./ha for blue-joint control.

Carex - Glyphosate severely damages sedges, except when applied during the dormant season (Balfour 1989). Only two trials from Boyd *et al.* (1985) had both year one and year two results. One trial found 100% damage in year one and 53% damage in year two; the other found 88% damage in year one and 50% damage in year two. These results suggest a healthy recovery (Balfour 1989).

Phleum - Information pertaining to the response of timothy to applications of glyphosate was not found in the literature.

Fertilization

Agropyron - Information pertaining to the response of *Agropyron* spp. to applications of fertilizer was not found in the literature.

Agrostis - *Agrostis* spp. produce very lush growth the first year, if fertilized. The thick thatch formed in the first year may retard regrowth in the second year (Watson *et al.* 1980).

Calamagrostis - Blue-joint has moderate fertilizer requirements (Watson *et al.* 1980), but responds well to fertilization with N, P and K, becoming denser (Laughlin *et al.* 1984). Fertilizer additions on tundra sites caused marked stimulation and an increase in the number of flowering spikes (Habgood 1983).

Carex - Information pertaining to the response of sedges to applications of fertilizers was not found in the literature.

Phleum - It has been observed on many soils that the application of N without K leads to a weakening of timothy and its replacement by bluegrass and bentgrass (Grant and Burgess 1978).

Effects on Conifers

Grasses often hinder establishment of conifers in plantations by preempting resources, chemically excluding natural seedlings (allelopathy), attracting insects and animals, and increasing fire potential. Grasses are generally not desirable in conifer plantations less than five years old, but after approximately five years, they can aid conifer seedling growth by physically and chemically excluding more competitive vegetation (Stiell 1976, McDonald 1986).

Spruce seeds that fall into a thick mat of grass in the fall become suspended and, as the dead blades of grass dry out in the spring, most germinants dessicate before their roots penetrate into soil. Those germinants that do make contact with mineral soil are either shaded out in summer by rapidly growing grass or smothered by dead grass compressed by snow during the next winter (Arlidge 1967).

Grass can rapidly reduce available soil moisture, which can lead to the early death of tree seedlings with poorly distributed roots when planted on grassy sites (Lambert *et al.* 1971, Lane and McComb 1948). In areas with heavy grass competition, the wilting point may be reached before roots of seedlings have extended into the deeper soil layers having fewer roots (Lane and McComb 1948). Soil water stress caused by heavy grass competition can be sufficient to inhibit tree growth (Lambert *et al.* 1972). Tall grasses with medium blade width such as *Calamagrostis* create more problems than fine-bladed grasses of the genera *Poa, Panicum* or *Muhlenbergi* even though approximately 1,000 stems of medium grass occupy the same space as 40,000 stems of fine grass (Lehela 1981). Fine-bladed grasses do not have the same smothering effect on conifers as medium-bladed grasses (Lehela 1981). Grass competition around established trees causes needles to drop from lower branches (Estabrooks 1988).

Planting is difficult on sites with heavy sod cover. The rate of planting is reduced and the effort is increased when planting in tightly-bound soil. Planting slits in sod are difficult to close initially, and they have a tendency to reopen as the ground surface dries, thereby increasing the likelihood of serious moisture deficiency in the root zone of the seedling (Estabrooks 1988). Grass cover also reduces soil surface temperatures (Lambert *et al.* 1971).

Grasses may help spruce plantations by providing protective cover and insulation from frosts, especially finer-bladed grasses (R. Sims, pers comm., 1990).

Agropyron - The ability of quack grass to maintain high growth rates through very cool periods of the year, coupled with rapid vegetative reproduction, and possibly allelochemic toxins, make it a potentially strong competitor (Werner and Rioux 1977). Although quack grass reportedly is an allelopathic plant, living quack grass material has failed to produce inhibitory effects in numerous experiments; it may be that only dead materials produce an inhibitory effect. The allelopathic effect is probably through chemical means, although it is not clear whether the inhibitor is leached from quack grass itself or is a product of microbial activity (Werner and Rioux 1977). Quack grass is a luxury consumer of key nutrients. By mid-July a stand of quack grass can tie up approximately 55%, 45% and 68% of the total N, P and K respectively, which it removes from the soil for the entire season (Werner and Rioux 1977). Because of its rapid establishment, high emergence success and rapid spreading ability, the species is a good choice for use in a short-term erosion control programs. It is a moderately good soil stabilizer (Watson *et al.* 1980). *Agropyron* spp. do not benefit conifers by fixing atmospheric nitrogen (Watson *et al.* 1980).

Agrostis - *A. scabra* does not benefit conifers by fixing atmospheric nitrogen (Watson *et al.* 1980).

Calamagrostis - Blue-joint is a major concern as a competitor of spruce regeneration (Habgood 1983). Root competition with young seedlings is considered to be the dominant mode of competition (Haeussler and Coates 1986). It competes with tree seedlings for moisture because it is a shallow rooter, growing in the same soil stratum as seedlings (Habgood 1983). Tall and luxuriant growth also causes mechanical damage to conifer seedlings by crushing and smothering the seedlings in the winter when the grass collapses on top of them (Stiell 1976). This is a problem for tree seedlings below the grass canopy (Habgood 1983). Canada blue-joint may indirectly reduce seedling growth by preventing soils from warming up during the growing season (Haeussler and Coates 1986). Mitchell (1974) noted that the thick layer of litter and mulch that develops under a blue-joint cover has a significant insulating effect on the soil. Blue-joint could be a problem to conifer regeneration within two years of site preparation on moist, nutrient-rich sites which are naturally or artificially seeded or planted (Presslee 1989). Sims and Mueller-Dombois (1968) showed that the effect on tree growth was most severe not on the driest sites and sandiest soils, but on relatively moist, loamy soils where Canada blue-joint was not vigorous. On the driest sites, young seedlings were able to get their roots below the shallow, poorly developed grass sod. Control of grasses either before or concurrent with planting is often necessary for adequate survival of conifers (Vanden Born and Malik 1984).

Blackmore and Corns (1979) speculate that a light growth of blue-joint on a scalped area of soil may be beneficial in reducing frost-heaving of seedling conifers. A cover of Canada blue-joint can also limit invasion of larger brush species that may have a longer-lasting and more serious impact on crop tree growth (Haeussler and Coates 1986).

Canada blue-joint does not benefit conifers by fixing atmospheric nitrogen (Watson *et al.* 1980). Canada blue-joint's ability to colonize disturbed sites makes it a useful soil stabilizer and erosion controller (Habgood 1983).

Carex - Sedges may compete with conifer seedlings for soil moisture and nutrients, since sedges often root within the same soil strata as seedlings. Tall sedge species may shade seedlings, and cause mechanical damage by crushing when the sedges die back in fall and are weighted down by snow (Habgood 1983). Sedges may compete with conifer seedlings on open, very moist to wet sites (Habgood 1983). Graminoid species have a relatively high rate of vegetative decomposition (Auclair 1983). Some sedge species may be of value on land reclamation and erosion stabilization (Habgood 1983).

Phleum - Timothy does not benefit conifers by fixing atmospheric nitrogen, but has some erosion control capacity (Watson *et a*l. 1980).

Uses by Wildlife

Little information pertaining to the use of grasses and sedges by wildlife could be found in the literature. Grasses were not found to be important browse species for moose (Stevens 1970).

Agropyron - Information pertaining to the use of *Agropyron* spp. by wildlife was not found in the literature.

Agrostis - Information pertaining to the use of *Agrostis* spp. by wildlife was not found in the literature.

Calamagrostis - Canada blue-joint is probably most utilized by ungulates in the spring (Habgood 1983).

Carex - Sedges are browsed by caribou and moose (Robertson 1984). They are important as a constituent of the spring diet of woodland caribou (Bergerud 1972). Sedges provide a good seed source for small birds and rodents (Robertson 1984).

Phleum - Foliage of timothy is used as forage by some grazing ungulates; seeds are used by birds (Watson *et al.* 1980).

Ledum groenlandicum Oeder
Labrador Tea

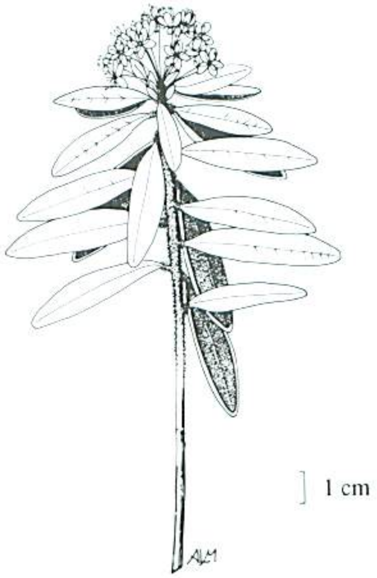
Description

General: low, spreading, evergreen shrub to 1 m high; often forming extensive patches; branchlets densely covered with curly brown hairs.

Leaves: alternate; firm, leathery, fragrant when crushed; oval to narrowly elliptic; upper surface dark green, somewhat wrinkled, hairless; lower surface densely covered with brown, woolly hairs; margins entire, inrolled.

Flowers: in dense, showy clusters at the branch ends; individual flowers small (approx. 1 cm across), on slender stalks, with five separate, white petals; appearing in late May and June.

Fruit: a small (5-7 mm long), brown capsule with a protruding, hair-like style; splitting from the base; appearing in late July and August.



Habitat

Distribution in Ontario: Labrador tea is widely distributed from Lake Ontario to Hudson Bay and from the Ottawa and St. Lawrence Valleys to Lake-of-the-Woods; it is absent from the region immediately north of Lake Erie (Soper and Heimburger 1982).

Climate: Labrador tea occurs within cool temperate and cool mesothermal climates; its occurrence decreases with increasing mean annual temperature (Klinka *et al.* 1989).

Site and Soil Relations: Labrador tea occurs in and around Sphagnum bogs, swamps and wet woods (Soper and Heimburger 1982). In NW Ontario, it occurs more frequently on coarse-textured than on fine-textured soils.

Nutrient Requirements: Labrador tea is generally found on acidic (Stanek and Orloci 1987), nitrogen poor soils (Reader 1980, Klinka *et al.* 1989). In NW Ontario, it occurs most frequently on nutrient poor sites such as V-Types 22, 23, and 34-38.

Moisture Requirements: Labrador tea is generally found on wet to very wet soils and is common on sites with a stagnant water table (Klinka *et al.* 1989). In NW Ontario, it occurs most frequently on wet sites such as V-Types 22, 23, and 34-38.

Light Requirements: Labrador tea is shade tolerant (Bakuzis and Hansen 1959).

Distribution of **labrador tea** in Ontario
(Adapted from: Soper and Heimburger 1982)

Reproduction

There is very little information in the published literature regarding the reproduction of Labrador tea.

Sexual Reproduction: Pollinating agents of Labrador tea include bees and flies (Pojar 1974). Seeds exhibit shallow or conditional dormancy and exhibit a marked light requirement for germination (Calmes and Zasada 1982).

Vegetative Reproduction: Plants of Labrador tea expand mainly through growth of above-ground shoots. Decumbent stems eventually become covered by moss growth and organic matter accumulation, with rooting occurring along the buried stem (Calmes and Zasada 1982). Sprouts generally originate in the lower half of the organic matter. No rhizomes have been observed on Labrador tea (Calmes and Zasada 1982). Stem cuttings of Labrador tea can be rooted (Holloway and Zasada 1979).

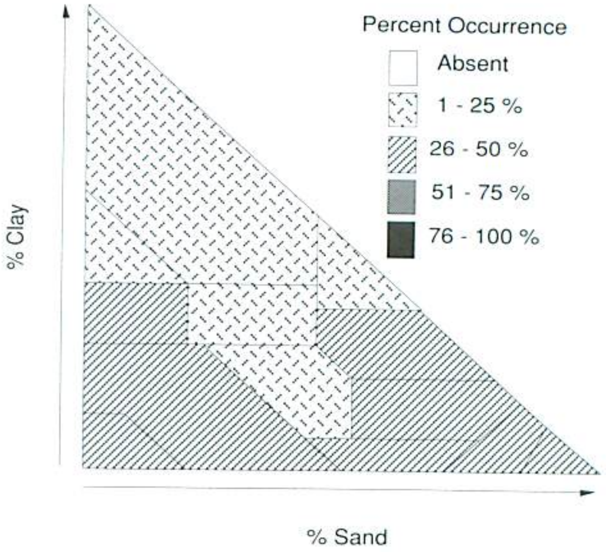
Growth and Development

Plants of Labrador tea normally retain individual leaves for two growing seasons (Reader 1980, Prudhomme 1983). New Labrador tea tissues develop serially, with currently-produced shoots being initiated at the apex of the previous year's shoot. This pattern allows separation of leaves into age classes by virtue of their attachments to shoots of a given age. During the growing season three age classes of leaves can be found: leaves currently being produced, those produced the previous year and those that are two years old.

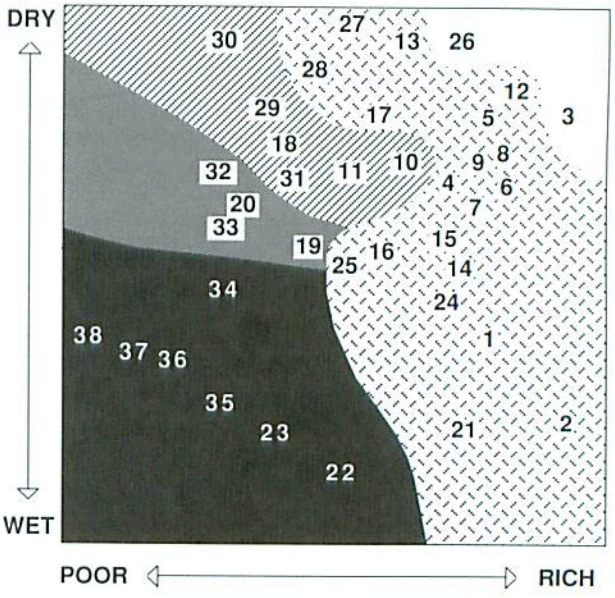
Underground parts generally occur in the surface organic layers. Growth of underground parts into subjacent mineral soil is uncommon (Calmes and Zasada 1982).

Phenology

Root, Shoot and Foliage: Overwintering one and two-year-old Labrador tea leaves become active as soon as spring thaw occurs. A dark brown colour after emerging from the snow, leaves turn a characteristic green colour within two weeks, depending on weather conditions. Buds on terminal shoots begin to swell after leaves become green. Shoot elongation and new leaf development occur within an additional two weeks. Leaf expansion and new shoot growth continue until early August. New overwintering primordia are then formed (Prudhomme 1983). Mortality of leaves that have survived two winters begins in May (Reader 1980). Senescence is closely



Frequency of occurrence of **Labrador tea** by soil texture class



Frequency of occurrence of **Labrador tea** by NWO FEC Vegetation Type timed with initiation of bud swelling. Most remaining two-year-old leaves turn red at this time (Prudhomme 1983). By mid-August approximately 40% of leaves have fallen, and the majority of remaining two-year-old leaves fall during September (Reader 1980).

Reproductive Structures: Labrador tea flowers sometime between May 30 and July 10 in southwestern British Columbia (Pojar 1974).

Response to Disturbance

Overstory Removal: Information pertaining to the response of Labrador tea to overstory removal was not found in the published literature.

Fire: Labrador tea thrives in the frequently burned forest ecosystems of the boreal and subarctic (Rowe 1983). Light fires which kill aboveground plant parts, char and kill the moss layer, and leave underground parts intact encourage the proliferation of Labrador tea (Viereck 1983). After a fire, initial sprouting occurs at the base of fire-pruned aerial stems. Sprouts from buried stems become evident later than those arising from fire-pruned aerial stems (Lotan *et al.* 1981). Sprouting may be delayed on severely burned sites as a result of heat damage to underground parts (Ahlgren 1960). Labrador tea can flower profusely from young sprouts soon after burning (Auclair 1983). In areas where fire has burned the ground surface and exposed mineral soil, Labrador tea can regenerate from seed (Calmes and Zasada 1982).

Low ericaceous shrubs such as *Ledum* spp. have a high percentage of ether extractives, and a relatively high lipid content and lipid-free caloric values. The result is relatively high flammability (i.e., low temperature for ignition) and high heats of combustion (Auclair 1983). The species also form a continuous complex of fine fuels allowing for the spread of fires.

Mechanical Site Preparation: Information pertaining to the response of Labrador tea to mechanical site preparation was not found in the literature.

Cutting: Information pertaining to the response of Labrador tea to cutting was not found in the literature.

Chemical Treatments: The efficacy of 2,4-D, hexazinone and glyphosate on labrador tea does not appear to have been well studied. Very little information could be found in the published literature.

2,4-D: Labrador tea can be killed with a foliar application of 2,4-D at the time when the plant is most susceptible (Chemagro Corporation 1953).

Hexazinone: Information pertaining to the response of Labrador tea to applications of Velpar-L was not found in the literature.

Glyphosate: Labrador tea is controlled only by relatively high rates of glyphosate. In a study analysing 1.12, 2.24 and 3.36 kg a.i./ha, Labrador tea was only effectively controlled for three years at the 3.36 kg a.i./ha rate (Anon. 1988).

Fertilization: Labrador tea responds well to nitrogen or phosphorus fertilization. In a black spruce fertilization study, Labrador tea coverage was about three times as great on fertilized plots as on controls (Alban and Watt 1981). The chemical composition of the Labrador tea leaves showed the effects of fertilization up to 10 years after treatment. Fertilization with a nitrogen-phosphorus combination, and phosphorus alone, resulted in higher levels of macronutrients in fertilized Labrador tea than in the controls; whereas fertilization with nitrogen resulted in no significant difference from controls (Alban and Watt 1981).

Effects on Conifers

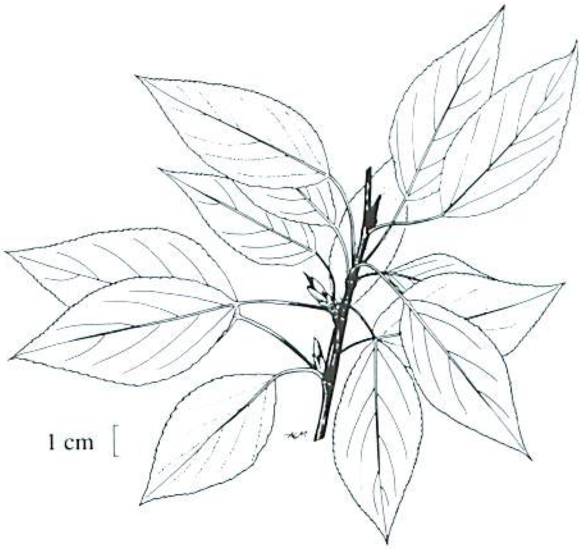
Labrador tea successfully competes with conifers, such as black spruce, for nitrogen and phosphorus because it has a higher uptake capacity per mass of roots compared to black spruce. As well, it has a shallower rooting depth and therefore earlier spring uptake than black spruce (Chapin 1983). Black spruce and Labrador tea are similar to one another in magnitude and seasonal pattern of phosphate absorption (Chapin and Tryon 1983), being high in June and September and low in May and July. Labrador tea is the alternate host of some needle rusts (*Chrysomyxa* spp.) which may cause moderate to heavy defoliation of spruce (Pendrel and Renault 1984).

Uses by Wildlife

Evergreen shrubs such as Labrador tea are an important browse species of woodland caribou from the time of leaf fall of deciduous shrubs until green sedges appear in the spring (Bergerud 1972).

Populus balsamifera L.
Balsam Poplar

Description



General: a medium to large-sized (averaging 20 m high, up to 30 m), broadleaved hardwood tree with a narrow, open crown of thick, ascending branches; branchlets stout, hairless, reddish-brown with large (1.5-2.5 cm long), sticky, fragrant, sharp-pointed buds; trunk bark smooth and greenish on young trees, soon becoming grey and deeply furrowed into long ridges.

Leaves: alternate; egg-shaped to broadly lance-shaped, always longer than wide, tapering gradually to a pointed tip, rounded at the base; margins finely toothed; dark bronzy-green above and pale beneath; leafstalk not flattened, leaves not fluttering in light breezes (see *P. tremuloides*).

Flowers: borne on catkins; male and female catkins, on separate trees; appearing in May before leaves have emerged.

Fruit: capsules (5-8 mm long) on female catkins, splitting to discharge tiny seeds with long, silky hairs before the leaves are fully expanded at the end, of May and early June.

Habitat

Distribution in Ontario: Balsam poplar is found throughout Ontario, except in the Hudson Bay Lowlands (Hills 1960, Hosie 1979).

Climate: Balsam poplar is primarily a species of boreal climates, although it ranges from arctic to temperate climates (Haeussler and Coates 1986).

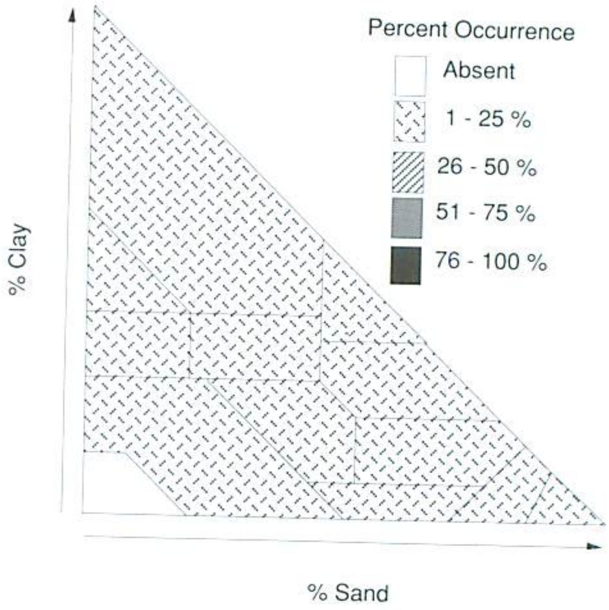
Site and Soil Relations: In general, balsam poplar occurs on low, often inundated, alluvial bottom lands or river flats, sand bars, streambanks and borders of lakes and swamps (Fowells 1965, Brayshaw 1976). It is generally of minor importance on upland sites (Zasada and Argyle 1983). In NW Ontario, balsam poplar occurs on moist alluvial soils, lacustrine deposits, and fine-textured tills with a calcareous C horizon (Sims *et al* 1990). In NW Ontario, balsam poplar dominated stands occur primarily on lacustrine deposits with local occurrences on morainal tills (Sims *et al.* 1990). Soils supporting balsam poplar vary widely and include gravels, deep sands, clay loams, silts, silt loams and shallow organic soils, but not deep peats (Haeussler and Coates 1986). In NW Ontario, it occurs on a wide range of soil types with slightly higher frequency on deep, moist to wet fine loamy and clayey soils (S10) and deep, fresh, clay soils (S6). Balsam poplar is not associated with very shallow soils (Sims *et al.* 1990).

Distribution of **balsam poplar** in Ontario
(Adapted from: Hosie 1979)

Nutrient Requirements: Nutrient requirements of balsam poplar are moderate to high (Watson *et al.* 1980, Haeussler and Coates 1986). It requires a good supply of Ca and Mg and prefers nitrate to ammonium forms of nitrogen (Krajina *et al.* 1982). It often occurs on river terraces described as having a rich nutrient status (Haeussler and Coates 1986). Balsam poplar has a low tolerance to acid soils (Watson *et al.* 1980). It does not tolerate acidic Mor humus forms where nutrients are slowly released (Haeussler and Coates 1986).

Moisture Requirements: Although balsam poplar requires abundant moisture, it will not grow in areas of excess moisture; it seldom grows on dry exposed soils (Crist and Schlaegel 1979). Balsam poplar will tolerate flooding (Fowells 1965), but does not tolerate brackish water (Haeussler and Coates 1986). In NW Ontario, balsam poplar dominated stands occur on soils with very fresh to very moist moisture regimes. Soil texture is not as important for growth as abundant moisture; excellent development occurs on deep sandy soils and gravelly soils that are subirrigated (Fowells 1965).

Light Requirements: Balsam poplar is a shade-intolerant species, requiring full sunlight for best growth and development. It will not grow competitively with other species unless it is in a dominant position (Fowells 1965).



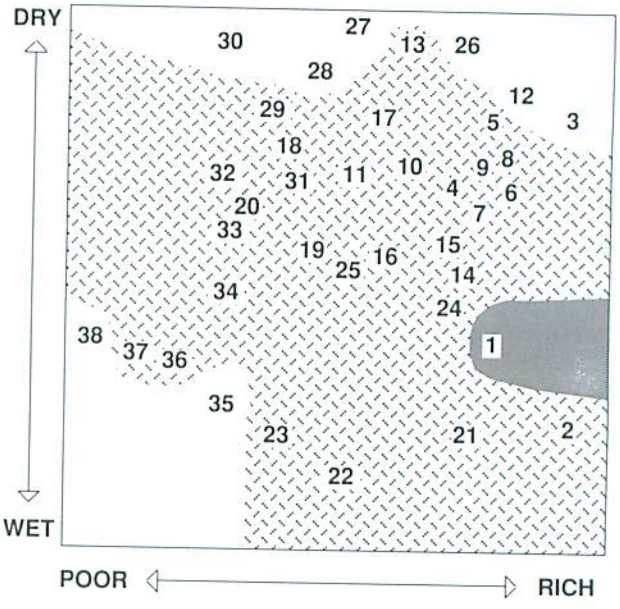
Frequency of occurrence of **balsam poplar** by soil texture class

Reproduction

Sexual Reproduction: Balsam poplar is dioecious. Reproduction from seed is important in the colonization of areas where the species did not occur before, but it is much less important than vegetative reproduction in restocking fire-killed or logged stands (Fowells 1965).

Seed Production and Dispersal: Balsam poplar begins to bear seed between 8 and 10 years of age (Anon. 1974). Balsam poplar is believed to produce seed in large quantities on an annual basis (Zasada 1971). Although the white cottony mass containing seed is dispersed for great distances by wind (Crist and Schlaegel 1979), seed deposition is greatly reduced at distances greater than 100-200 m from the seed source (Zasada *et al.* 1981).

Seed Viability and Germination Requirements: Seed viability is initially about 90% (Zasada *et al.* 1983); however, seed remains viable for only a few days unless given special storage conditions (Fowells 1965). Seed does not exhibit dormancy and germinates immediately after dispersal (May to early June) if seedbed conditions are favourable (Fowells 1965). For best establishment, seedbeds should be continuously moist for a week or two following germination (Fowells 1965). Lutz (1956) reported that balsam poplar seedlings were abundant wherever mineral soil had been exposed and a seed source was present.



Frequency of occurrence of **balsam poplar** by NWO FEC Vegetation Type

Moist mineral soil, such as recently deposited alluvium along streams and valleys subjected to overflow or soil exposed by recent fires, provide an excellent seedbed (Fowells 1965). Young balsam poplar seedlings are extremely susceptible to drying, rain damage and soil fungi (Haeussler and Coates 1986). They need at least one month of abundant moisture to ensure survival (Anon. 1974).

Vegetative Reproduction: Balsam poplar commonly reproduces from root suckers, stump sprouts and cuttings (Crist and Schaegel 1979). Sucker regeneration is believed to be more important than seed regeneration (Zasada 1971). Most suckers grow from roots in the top 2 cm of the soil. Stump sprouts are not very effective, because sprouts usually break off at an early age (Fowells 1965). Balsam poplar will propagate from stem cuttings (Holloway and Zasada 1979).

Growth and Development

Balsam poplar is a medium-sized, deciduous tree, usually 9 to 25 m in height and 30 to 70 cm in diameter (Watson *et al.* 1980). It may occasionally reach heights of over 30 m and diameters greater than 1 m (Watson *et al.* 1980). It is characterized by rapid early growth that allows it to establish and maintain dominance above competing vegetation. Rapid growth can be maintained for the first 40-50 years of life by which time it can reach heights of 25 m and diameters of over 45 cm. Balsam poplar is relatively long-lived, surviving up to 200 years (Haeussler and Coates 1986).

Phenology

Root, Shoot and Foliage: In Marquette County, Michigan, the average dates for swelling of leaf buds, beginning leaf expansion and full leaf were May 2, May 13 and June 10, respectively (Fowells 1965).

Reproductive Structures: Flowers mature in April and May before leaves appear, but dates vary from year to year depending on climatic factors (Crist and Schlaegel 1979). Seed-bearing capsules mature during May or June when leaves are about two-thirds grown (Fowells 1965). Seed dispersal occurs shortly thereafter. In Marquette County, Michigan, the average date for flowering to begin is May 2, with full bloom reached on May 9 (Fowells 1965).

Response to Disturbance

Overstory Removal: Reproduction of balsam poplar is far greater after summer logging than winter logging (Zasada *et al.* 1981). Root sucker formation benefits from the removal of the forest floor (Zasada *et al.* 1981). Seed germination will likely occur on areas of exposed mineral soil if a seed source is available (Haeussler and Coates 1986).

Fire: Burning will stimulate abundant root suckering and prepare a good seedbed for seedling establishment (Fowells 1965). Bailey and Anderson (1979) noted that the majority of suckering occurred during the second season following spring burning of a 15-year-old balsam poplar stand. Density was greater on burned areas than on unburned areas. In general, mature poplar stands are more resistant to fire than young stands. Young, thin-barked trees are more easily killed by fire while older, thick-barked trees are quite fire-resistant (Crist and Schlaegel 1979). Mature stands also tend to have lower quantities of fine fuels (Fowells 1965).

Mechanical Site Preparation: Mechanical site preparation generally promotes suckering by increasing soil temperatures (Haeussler and Coates 1986) and provides a favourable seedbed by exposing mineral soil (Sims *et al.* 1989). Branch fragments buried as a result of soil disturbance have a high likelihood of regenerating, but they must be well buried in soil to produce aerial shoots (Zasada *et al.* 1981).

Cutting: Trees cut or damaged during logging will sprout from stumps or sucker from roots (Haeussler and Coates 1986). Concentrating logging during the snow-free periods will increase the probability of reproduction from seed, root suckers or branch segments (Zasada *et al.* 1981). Zasada *et al.* (1981) observed that more than 50% of mature balsam poplar cut during the summer, fall and winter produced sprouts from callus tissue and dormant buds located in the stump. Many stumps had more than 25 sprouts after the first growing season.

Chemical Treatments: The response of balsam poplar to 2,4-D, hexazinone and glyphosate will be discussed separately.

2,4-D: Balsam poplar is not readily killed by 2,4-D (Johnston 1977, Campbell 1981), although 1- or 2-year-old suckers are more susceptible than older stems. High mortality was recorded for one year-old balsam poplar sprayed with 2.2 kg/ha of 2,4-D as a mid-summer foliar spray, with resuckering occurring in the following year (Bailey and Anderson 1979).

Hexazinone: Balsam poplar is rated as intermediately susceptible to Velpar-L; approximately 12 to 14 l/ha are required to control balsam poplar on a medium-textured soil (Corcoran 1989). Hexazinone, applied as a liquid, spray, by soil injection or through granular applications will provide good control of balsam poplar (Expert Committee on Weeds 1984). However, results may be variable on sites with deep organic layers.

Glyphosate: Vision applied by either backpack spray or aerially at 2.4-3.0 kg/ha has provided good to excellent control of balsam poplar. The majority of stems were completely killed with little subsequent suckering (Haeussler and Coates 1986). An application of 7 l/ha on July 25 in Minnesota killed 98% of the balsam poplar in experimental plots (Butler-Fasteland 1987).

Fertilization: Information pertaining to the response of balsam poplar to applications of fertilizers was not found in the literature.

Effects on Conifers

There are no quantitative data on the effects of balsam poplar competition on conifers (Haeussler and Coates 1986). Balsam poplar does not fix atmospheric nitrogen (Watson *et al.* 1980).

Uses by Wildlife

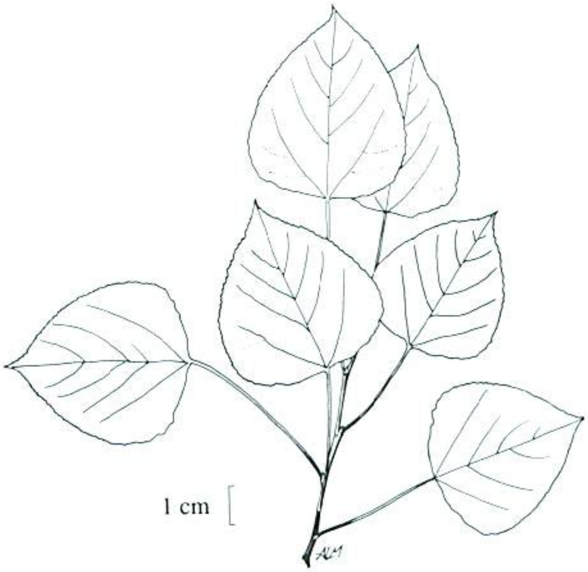
Balsam poplar has been identified as an important browse species for moose in central and eastern Canada (Zach *et al.* 1982). Following a review of the literature, Timmermann and McNichol (1988) reported that balsam poplar is only browsed during winter months. Since foliar and floral buds of balsam poplar are extremely rich in ether-soluble substances, it is browsed less by snowshoe hares than other species such as trembling aspen (Radvanyi 1987). Balsam poplar is used extensively by beaver for food and construction material (Watson *et al.* 1980).

Populus tremuloides Michx.
Trembling Aspen

Description

General: medium to large-sized (averaging 21 m high, up to 34 m), broadleaved hardwood tree with a relatively small, diffuse crown; branches spreading; trunk with little taper, essentially branchless below the crown; branchlets and end buds slender, shiny, reddish-brown; buds small (5-7 mm), sharp-pointed; trunk bark smooth, pale green to chalk white with diamond-shaped indentations and dark patches, becoming darkened, rough and furrowed into ridges.

Leaves: alternate; broadly egg-shaped to almost round, often wider than long, sharp-pointed at the tip, rounded or squared at the base; margins wavy, finely toothed or almost entire; leafstalk long, slender, flattened, permitting the leaf to "tremble" in the slightest breeze.



Flowers: borne on catkins; male and female catkins on separate trees; appearing in May before leaves have emerged.

Fruit: capsules (6 mm long) on the female catkins, splitting to discharge tiny seeds with long, silky hairs before leaves are fully expanded at the end of May and early June.

Habitat

Distribution in Ontario: Trembling aspen is found throughout Ontario, from the southern agricultural area to the northern portion of the Hudson Bay Lowlands, and from the Quebec border in the east to the Manitoba border in the west (Hosie 1979, Davidson *et al.* 1988). Seventy-eight percent of Ontario's commercial natural aspen, mainly trembling aspen with some largetoothed aspen, occurs within a 160-320 km wide strip across northern Ontario from Red Lake-Kenora to the Chapleau-Cochrane area (Heeney *et al.* 1980).

Distribution of **trembling aspen** in Ontario
(Adapted from: Hosie 1979)

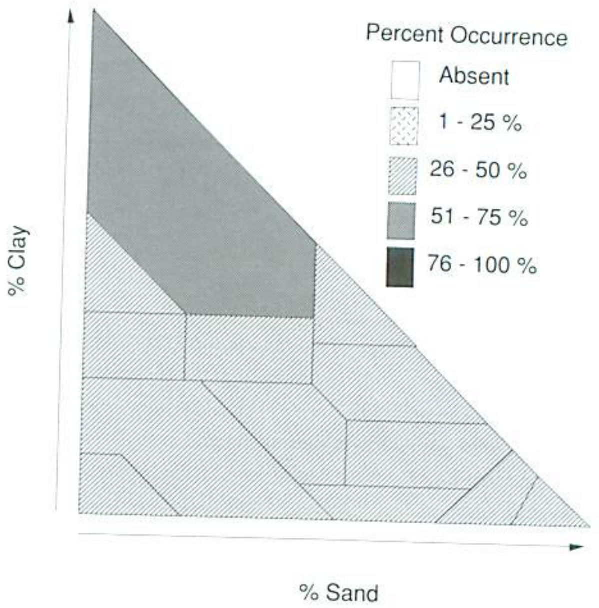
Climate: Trembling aspen occurs over a wide range of climatic conditions (Haeussler and Coates 1986), such as continental boreal and cool temperate climates (Klinka *et al.* 1989). Key gradients that affect the range and growth of aspen are temperature and moisture (Davidson *et al.* 1988). Within its commercial range in Ontario, mean annual growing season varies between 150 and 170 days, mean daily temperature in July from 18°C to 22°C and mean annual precipitation from 40 cm in western to over 75 cm in eastern locations (Heeney *et al.* 1980).

Site and Soil Relations: Trembling aspen can tolerate a wide range of sites, from dry sands to wet clays. Growth is generally best on fresh to moist loams and moist sandy loams that have good drainage. Growth on sandy soils is often poor because of low moisture and nutrient levels (Fowells 1965), while clays do not permit best growth because of poor aeration (Fowells 1965). Rockiness greatly limits stand development (Shepperd and Engelby 1983). In NW Ontario, trembling aspen dominated stands occur on morainal deposits. Trembling aspen are commonly found on deep glaciofluvial deposits and lacustrine soils as well. These stands do not occur on organic soils. In the NC Region, trembling aspen dominated stands typically occur on deep, dry to fresh coarse loamy (S3), medium sand (S1), fine sand (S2), or silt (S4) soils. They are less common on moist sandy soils (S7) (Sims et al. 1990). In the Clay Belt area of NE Ontario, trembling aspen is associated with forests on nutrient-rich clays and silts (Carleton *et al.* 1985).

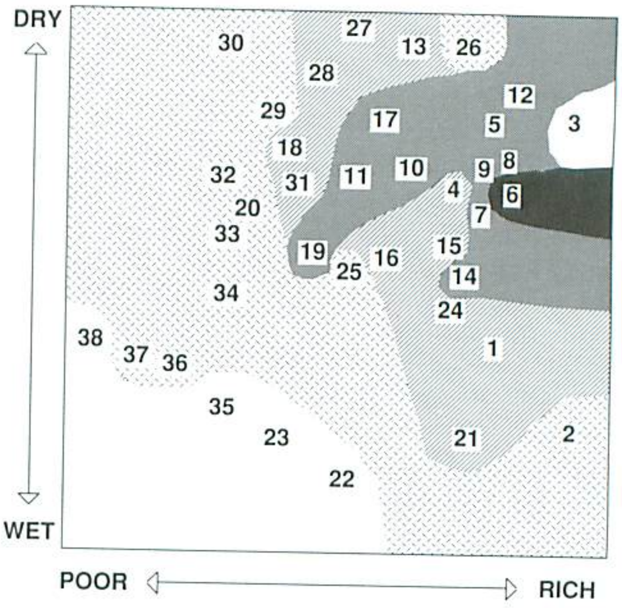
Nutrient Requirements: Trembling aspen grows on soils with a wide range of soil fertility. Good aspen sites are characterized by a markedly high content of Ca, Mg, K and N (usually Moder and Mull humus forms) (Fowells 1965, Klinka *et al.* 1989). Soils which have free lime, or have an otherwise high content of Ca, seem to produce the best aspen (Heeney *et al.* 1980). Average annual growth of trembling aspen on soils containing high levels of Ca, Mg, K and N was more than four times that on soils in which the levels of these elements were low (Voigt *et al.* 1957). Aspen is adapted to soils of intermediate to high pH, yet has been observed as a successional species on flat, barren sand areas near Sudbury, Ontario where the soils are very acidic (pH 3.2 - 4.5).

Moisture Requirements: Trembling aspen is tolerant of sites ranging from xeric to hygric (Haeussler and Coates 1986). Growth rate varies with soil fertility and available moisture (Parker 1978, Heeney *et al.* 1980). Soil moisture is the most important factor in trembling aspen productivity because of its relatively poor stomatal control (Davidson *et al.* 1988). Best aspen growth typically occurs on very fresh sites (Moisture Regime (MR) 3) consisting of well structured clay or silt loam. Good growth occurs on fresh sites (MR 2-3) of clay to fine sand. Poorest growth is normally found on dry sandy soils (MR 0-1) and moist clays (MR 4-5) (Parker 1978). Moist fertile loams can produce large sawlog and veneer-quality trees, but deep dry sand and some rocky areas will produce only limited yields of pulpwood. Growth on sandy soils is better where the water table is between 46 and 152 cm deep; a higher water table may be detrimental (Wilde and Zicker 1948, Wilde and Pronin 1949).

Light Requirements: Trembling aspen is a shade-intolerant species (Klinka *et al.* 1989) requiring full sunlight for survival and growth (Parker 1978). Aspen cannot reproduce successfully under its own shade (Ohmann 1982). High light levels are required to stimulate production of root suckers and ensure their continued, vigorous growth (Haeussler and Coates 1986).



Frequency of occurrence of **trembling aspen** by soil texture class



Frequency of occurrence of **trembling aspen** by NWO FEC Vegetation Type

Reproduction

Sexual Reproduction: Flowers are typically unisexual, with male and female flowers occurring on separate trees (Zasada 1971). Reproduction from seed is rare, primarily because the short period of viability rarely coincides with environmental conditions that are sufficiently moist to allow seedling establishment (Haeussler and Coates 1986).

Seed Production and Dispersal: Trembling aspen usually begins to bear seed between 10 and 20 years of age (Anon. 1974). Flowers have been observed on suckers that were only four years old (Pregitzer and Barnes 1980). The minimum commercial seed-bearing age is 20 years, and the optimum range is 50 to 70 years (Zasada 1971). Good seed crops are produced every four to five years with light crops in intervening years after age 10 to 20 (Zasada 1971, Perala and Russell 1983). Individual trees are capable of producing large quantities of seed (Heeney *et al.* 1980). A mature aspen tree can produce up to 1.6 million seeds in a single year (Shepperd and Engelby 1983). Seeds are light, averaging from 5.5 to 6.6 million seed/kg (Fowells 1965). Pollen and seeds are wind dispersed (Haeussler and Coates 1986). Long, silky hairs attached to aspen seed allow dispersal by wind for distances of several kilometres (Fowells 1965). Water also serves as an agent for seed dispersal.

Seed Viability and Germination Requirements: Initial seed viability can be over 75% (Heeney *et al.* 1980, Zasada *et al.* 1983). Under favourable natural conditions, seeds are believed to remain viable for a period of only two to three weeks after maturity (Zasada 1971). Seedbed and microenvironment requirements for seedling establishment are stringent (Perala and Russell 1983). Trembling aspen seed is not dormant and will germinate immediately after dispersal (Perala and Russell 1983). If required seedbed conditions are present in the two to three weeks during which aspen seeds retain their viability, seedling production can be prolific (Peterson *et al.* 1989). Seed germination and seedling survival are best on moist mineral soil or humus seedbeds with moderate temperatures, good drainage, and little competition from other vegetation (Barnes 1966, Steneker 1976). On moist seedbeds, germination is completed within a few days.

Vegetative Reproduction: Most regeneration of aspen is by root suckers, although stump sprouts and root collar sprouts occur if the harvested trees are relatively young (Peterson *et al.* 1989). The majority of lateral roots of aspen may be 25 m long, enabling sprouts to occur some distance from the parent (Rouse 1986b). More commonly, however, aspen suckers occur within 10 m of the base of the parent tree (Baker 1989). Aspen suckers usually originate along horizontal lateral roots that have diameters between 0.5 and 2.5 cm (Heeney *et al.* 1980). These roots occur predominantly in the upper 60 cm of soil and most suckering occurs along roots 4-12 cm below surface. Most suckers are formed during the first growing season after a major disturbance such as fire or harvesting, although others originate during the second or third growing seasons. Suckering may be as much as 20 times greater in some clones than others. Maximum sucker production occurs at soil temperatures between 22°C and 25°C. Soil conditions directly affect suckering. Flooded and saturated soils may inhibit suckering and reduce survival (Heeney *et al.* 1980). Suckers can arise both from roots of badly decayed trees as well as from healthy trees (Fowells 1965).

Growth and Development

Trembling aspen is a small to medium-sized deciduous tree, averaging 13-20 m in height and 20-25 cm in diameter. It may attain heights of 30 m and diameters of 60 cm (Watson *et al.* 1980). Aspen is relatively long-lived, reaching maturity in 80-120 years (Steneker 1976, Bartos and Mueggler 1981). Stands usually break up much earlier, due to extensive decay and loss in vigour. Stands often reach an advanced state of decay between 55 and 90 years (Haeussler and Coates 1986). When overmature aspen stands break up, shrub vegetation, particularly beaked hazel and alder, commonly increase and inhibit aspen suckering (Steneker 1976).

Aspen is characterized by rapid early shoot growth. Because suckers are supported by a large pre-established root system, vigorous suckers may grow as much as two metres in height their first year (Steneker 1976, Parker 1978). Subsequent height growth averages between 30 and 60 cm annually, depending on site (Steneker 1976, Hamilton and Yearsley 1988a). Growth of aspen seedlings is relatively slow for the first two to three years. First-year growth is generally less than 15 cm; second year, 15-30 cm; and, under favourable conditions, seedlings may reach a total height of 1 - 1.3 m after three years (Heeney *et al.* 1980). During early establishment, trembling aspen cannot compete with grasses for moisture, particularly during dry years (Watson *et al.* 1980).

An important aspect of vegetative regeneration is the formation of clones. Suckers which develop from the root sytem of one parent tree are genetically identical and together are called a clone. Individual clones can have very distinctive growth and defect characteristics. Although stems within a clone are indistinguishable, clones can often be recognized from their neighbours by leaf shape and size, bark character, branching habit, stem form, suckering ability, time of flushing and autumn leaf colour (Morgan 1969). Clones can be identified easily in the spring and autumn because of interclonal differences in timing of leaf flush and leaf fall. Clones vary in size and may cover up to several hectares (Steneker 1976). Adjacent clones of the same age may differ in height by six metres (Parker 1978).

Initial density of suckers after a disturbance may vary substantially, but is often between 24,700 and 37,100 stems/ha (Parker 1978). Densities can exceed 70,100 stems/ha. However, tree dominance is quickly established and high stocking levels are significantly reduced in the first few years through natural mortality (Steneker 1976).

The root system of aspen is shallow and wide-spreading. Roots typically extend 1.0-1.5 m into the soil, but can penetrate to a depth of 2.2 m and may extend as far as 14 m from the stem base (Haeussler and Coates 1986). An excavated root system of a 35 year-old aspen had more than 111 m of lateral roots, the longest root being 17 m. A lateral root from another aspen was more than 31 m long.

Phenology

Roots, Shoot and Foliage: Aspens produce both seasonally determinate and seasonally indeterminate shoots (Pregitzer and Barnes 1980). A typical determinate shoot (4-12 cm long) in winter condition has one terminal vegetative bud, one or more lateral vegetative buds and several flower buds (Pregitzer and Barnes 1980). Earliest and latest flushing clones within a given area may be one to three weeks apart in their phenological development (Haeussler and Coates 1986). Leaf phenology is identical for all trees within the same clone. In the Upper Peninsula of Michigan, the average date of leaf buds swelling, bud flush and full leaf were May 6, May 15 and June 5 respectively, with start of leaf fall, maximum leaf colouring and completion of leaf fall occurring Oct. 2, Oct. 4 and Oct 17 respectively (Fowells 1965). Clonal differences are most evident in the spring, when trees of some clones can be seen leafing out while adjacent trees are still dormant.

In the Upper Peninsula of Michigan, height growth begins around May 23 and ends approximately August 10 (Fowells 1965). In the same location the average dates of the start and end of cambial growth were May 19 and August 13, respectively.

Van Wagner's (1967) study of foliage moisture content showed that the foliage of trembling aspen flushed with a high moisture content (>245%) in the third week of May, fell rapidly to 160% by mid-June and levelled off at approximately 140% in mid-July. A rise to 150% occurred in mid-August followed by a drop to 135% in early September. A sharp rise to 160% occurred after autumn colour change.

Reproductive Structures: Flower buds differentiate in the axils of leaves during the growing season prior to flowering (Pregitzer and Barnes 1980). Flowering occurs early in spring, generally late April and early May (Heeney *et al.* 1980). Since all trees within a clone develop their flowers simultaneously (Haeussler and Coates 1986), it is usually impossible in the field to distinguish differences in flowering times between ramets within a clone (Pregitzer and Barnes 1980). In one study in southeastern Lower Michigan, pollen was discharged for a period of 12 days beginning April 15. Peak pollen discharge occurred between April 19 and April 22 and the last pollen was released April 26 (Pregitzer and Barnes 1980).

Fruits mature as leaves expand, and are normally ripe during May or June, about 4-6 weeks after flowering (Heeney *et al.* 1980, Haeussler and Coates 1986). Seed dispersal occurs within a few days of ripening. In northern Ontario, seed dispersal takes place from late May through mid-June (Heeney *et al.* 1980).

Response to Disturbance

Overstory Removal: Aspen suckers grow rapidly following clearcutting, particularly in the second growing season, and may begin to suppress production of undergrowth within a few years. Aspen sucker density in clearcut stands has been reported to be greater than 20,000 stems/ha (Davidson *et al.* 1988). The full-tree harvest method presents the greatest potential for regenerating aspen stands, as it leaves the site relatively clear of slash. In contrast, residual slash from short-wood and tree-length harvest methods may inhibit good aspen suckering (Davidson *et al.* 1988). Season of cutting exerts some influence on the number and vigour of aspen suckers. Winter logging may result in at least four times as many suckers as summer or spring logging (Zehngraff 1946). Logging during the period when bark can be peeled by hand, early May to early June, will result in the least amount of suckering. Overall, however, the effect of cutting season on number of suckers is generally negligible after two or three years (Peterson *et al.* 1989). Overstory trees left after logging restrict development of young aspen. Trees cut or damaged during logging, and even those remaining undamaged, are stimulated into sucker production by increased light and heat on the forest floor (Fowells 1965, Haeussler and Coates 1986, Baker 1989). There are indications that mixedwood stands with only 4.7 m^2/ha of aspen basal area will produce 12,400 to 14,800 root suckers/ha following clearcutting (Perala 1972).

On fresh and moist sites, residual slash after clearcutting (using shortwood harvesting techniques) has not proved to be a significant hindrance to sucker formation and growth. On wet sites, however, slash may keep soil temperatures below the optimum range for suckering (Steneker 1976).

Fire: Fire will favour aspen over seed-reproducing conifers (Rouse 1986a). Early growth after forest fires is extremely rapid, giving aspen an advantage over trees that regenerate from seeds, as well as an advantage over competing grasses and herbs (Peterson *et al.* 1989) Thus, if a change in species composition from conifers to aspen is desired, fire can be used (Rouse 1986a). Even a few aspen in a coniferous stand maintain root systems sufficient to restock the area with aspen after a serious fire (DeByle and Winokur 1985).

Increased soil temperature and light conditions after a fire stimulate aspen suckering (Rouse 1986a). Most suckers will arise in the first year following a burn (Bailey and Anderson 1979). Burns that occur in early June will fill with poplar suckers one metre tall by the end of the growing season. In contrast, burns in late July sucker very lightly or not at all in the same season (Davidson *et al.* 1988). Prolific regeneration resulting from light and medium burns is nearly always of sucker origin. A moderate burn that kills the aspen tops and undergrowth and destroys the litter and part of the duff will produce more suckers than either a light or severe fire (Horton and Hopkins 1966, Heeney *et al.* 1980). Spring fires that occur before leaf flushing and suckering take place result in the greatest stimulation of suckering (Heeney *et al.* 1980).

It takes a very hot fire under favourable burning conditions to remove the duff, expose mineral soil and provide a suitable seedbed for aspen (Heeney *et al.* 1980). Although natural regeneration by seed is possible after a fire, the seeds require an open but moist seedbed. Fires often produce open seed beds but rarely moist ones (Rouse 1986a). The report of dispersal of aspen seed in June indicates that seed are probably available for regenerating burns occurring in June or July (Zasada 1971).

Burning to arrest aspen suckering has not always been successful because of the discontinuous coverage of fuels and the difficulty in obtaining suitable burning conditions (Perala 1974). Aspen stands are generally low in flammability, unless there is slash on the ground. Consequently, they form a fuel break and fires in aspen stands can be extinguished relatively easily (Perala and Russell 1983). Since pure aspen stands do not burn readily (Shepperd and Engelby 1983), low intensity surface wildfires are most common (Rouse 1986a). Trembling aspen stands have the highest flammability, with respect to surface fire, in the spring. During the spring, the litter layers dry quickly because they are completely exposed to the sun (Van Wagner 1983). Winter cuts may be difficult to burn the following spring due to the high moisture content in the fuel (Heeney *et al.* 1980). Bulldozing, piling and burning brush leaves sufficient roots in the soil to permit rapid re-establishment of aspen (Bowes 1975). However, dry slash piles may burn so intensely that aspen sucker growth is reduced (Heeney *et al.* 1980). Successive fires will increase aspen density (Kittredge 1938, Shirley 1941, Anderson and Bailey 1980), but decrease quality and vigour (Buckman and Blakenship 1965).

Direct loss of aspen due to fire may be small in proportion to trees lost later due to disease. Early stand senescence and breakup may result from fire due to mechanical damage and/or attacks by insects and disease that physically weaken trees (Rouse 1986a).

Mechanical Site Preparation: Aspen appears to respond most vigorously to soil disturbance when the organic mat is disturbed but not completely removed and the root systems remain intact (Zasada and Argyle 1983). Ground disturbance improves sucker production by reducing understory competition, litter and duff, and opening the forest floor to solar radiation (Perala 1972). A high level of cultivation that eliminates the aspen root system is needed for effective control of aspen (Haeussler and Coates 1986). Since damaged aspen root systems are more susceptible to disease, suckering may be reduced when aspen root systems are injured by mechanical site preparation treatments. Deep plowing techniques that tear up roots will reduce suckering (Haeussler and Coates 1986). However, rows of suckers often form along plowed furrows (Haeussler and Coates 1986). Site preparation techniques such as rock raking, drag scarification or disc trenching generally increase suckering (Ohmann 1982, Baker 1989). Shearblading on frozen soils will also result in profuse aspen sucker production (Davidson *et al.* 1988).

Scarification or disking in early spring or late fall results in greater survival and height growth of aspen suckers than summer scarification (Perala 1972, Heeney *et al.* 1980). Scarification with barrels and chains prior to suckering increases both the percent stocking and density of aspen suckers, with the greatest increase resulting from heavy scarification (Weingartner 1980). Scarification of 3-year-old aspen stands results in wounding of the parent root thereby inhibiting sucker growth. Survivors continue to develop, but with abnormally high levels of internal stem and root rot (Basham 1982).

Cutting: Sucker production is generally proportional to the degree of cutting (Fowells 1965). The silvicultural clearcut, which involves the harvesting of all merchantable stems and the additional removal of most of the residual trees, creates the most desirable conditions for aspen sucker regeneration. A commercial clearcut, which leaves residual stems, is not conducive to optimum regeneration, development or growth of aspen stands (Davidson *et al.* 1988). Young aspen stands, 2, 4, and 8 years old when cut, produced 74,100, 86,500 and 101,300 new suckers/ha respectively (Perala 1972).

Girdling prevents or reduces root suckering (Davidson *et al.* 1988). Aspen that was cut and girdled with an axe during the winter, spring, summer, or fall months of the year suckered rather prolifically regardless of the season treated, although the density and vigour of the suckers was somewhat lower from trees cut during the summer months after full leaf development (Arend 1953). Cutting in June is far more effective in reducing the initial number of suckers than cutting in August, December or April. Bella and DeFranceschi (1972) reported on experiments at Hudson Bay, Saskatchewan, and concluded that summer logging destroyed ground vegetation, including brush, which helped to increase soil temperature and the number of suckers. However, six years after cutting, the summer-logged areas had sufficient suckers to be considered well-stocked.

Inspections of operational work in Geraldton, Ontario, where aspen were cut halfway through the stem and pushed to the ground, showed that most aspen resumed their normal growth except for an S-shaped crook where cuts were made (Jovic 1981). This study recommended complete cutting of aspen as close to the ground as possible. A less common practice is to break poplar suckers by hand. However, suckers are usually too small at age one for this practice to be feasible, and when they are beyond age two they are usually too large to be broken easily by hand (Lemon 1981).

Compared to conifer stands, aspen allows greater ground water recharge and streamflow due to lower seasonal use and smaller interception loss (Perala and Russell 1983). Clearcutting entire small watersheds may temporarily increase streamflow up to 60%, but with rapid sucker regrowth, preharvest water yields are restored in about 10 years.

Chemical Treatments: The response of trembling aspen to 2,4-D, hexazinone and glyphosate will be discussed separately.

2,4-D: Aspen is usually rated as susceptible to 2,4-D, but experience has shown that it is variable in response and often quite resistant (Anon. 1986). For example, Basham (1982) found that after being sprayed with 1.4 kg/ha of 2,4-D, surviving aspen had reduced height and diameter growth, but within six years had resumed normal growth rates. Root suckering is common after spraying 2,4-D and it may be necessary to spray more than once. Bowes (1975) reports that an application of 2,4-D in two consecutive years at 2.2 kg/ha can give more than 90% control of aspen, but delaying the second application for two years may give only 80% control.

Trembling aspen is generally more susceptible to early summer than mid- or late summer applications (Chemagro Corporation 1953). Sharma and Vanden Born (1970) measured effects of stage of growth on penetration of 2,4-D amine and ester forms into leaves of trembling aspen from June to September. There were no time-related differences in absorption of 2,4-D ester, but 2,4-D amine had a period of maximum absorption in July. Steneker (1976) reports that 2,4-D applied to foliage from the air or ground during mid-July to mid-August will kill all above-ground tree parts but will not prevent resuckering.

2,4-D has been used successfully in the Lake States to control unmerchantable residuals and brush to promote aspen regeneration. Aerial spraying with 3.3 kg/ha of 2,4-D, applied prior to the initiation of new aspen suckers, has successfully controlled white birch and aspen residuals. Aspen suckering was evident during the year following treatment and resulted in a well-stocked stand (Perala 1977).

Spraying 2,4-D to control aspen suckering after prescribed burning should be delayed until the second season after burning for best results (Bailey and Anderson 1979).

If undiluted 2,4-D amine is applied to fresh cuts in the bark during the peak of the growing season (June-August), root systems may be killed, preventing later sucker production (Arend 1953, Worley *et al.* 1954).

Where aspen has been completely killed by 2,4-D the sites will become invaded with grasses and/or raspberries (Dennis 1984).

Hexazinone: Trembling aspen is rated as intermediately susceptible to Velpar-L, and approximately 12-14 l/ha are required to control aspen on a medium-textured soil (Corcoran 1989). Hexazinone applied as a liquid spray or in granular form will control aspen. Results are variable in areas with deep organic layers. Standish (1981) tested liquid and gridball pellets of hexazinone at 1.2 to 2.4 kg/ha on an old, cutover, boreal forest site overgrown with dense aspen. Both formulations resulted in excellent control of aspen with no significant differences between the two application methods. Sutton (1984) reported that aspen was not completely controlled by a mid-July foliar application of hexazinone at rates of 2.0 and 4.0 kg a.i./ha, and resprouting was common six years after treatment.

Glyphosate: Trembling aspen is very susceptible to glyphosate (Sutton 1984). Glyphosate dosages greater than 1.0 kg a.i./ha are generally required to control aspen (Lehela 1981). At a rate of 2.2 kg a.i./ha glyphosate is highly effective against 6-year-old aspen (Sutton 1978). Glyphosate appears to be more effective if applied in mid-July to late August than in September (Sutton 1984, Perala 1985). Applied at 1.0 kg a.i./ha in mid-July, glyphosate provided 50% control of aspen three years after treatment (Sutton 1984). An application of 7.0 l/ha on July 25 in Minnesota killed 88% of trembling aspen in experimental plots (Butler-Fasteland 1987). Applied as a foliar spray between August 8 and September 2, glyphosate provided more than 90% reduction of aspen biomass at rates between 1.12 and 2.24 kg a.i./ha (Perala 1985). Applied on September 17, the same rates provided less than 50% reduction. Control of aspen after the first week or so of September may be unreliable unless limiting climatic or physiological factors are identified (Perala 1985).

Vision (20% solution) injected with a hypohatchet at a rate of 2.0 ml/cm in diameter at breast height gave satisfactory results, i.e., the aspen was killed or seriously damaged (Wile 1981).

Fertilization: Information on the effects of fertilization of aspen stands is limited (Peterson *et al.* 1989). Interprovincial forest fertilization trials indicated notable 5-year responses to fertilization in a 35-year-old stand in Saskatchewan. Responses ranged from an extra 6% of 5-year increment, when nitrogen only was added at 112 kg/ha, to an extra 111% when N at 224 kg/ha and P and K at 112 kg/ha were added (Peterson *et al.* 1989).

Effects on Conifers

Trembling aspen generally does not cause problems for conifer plantations until 5-10 years after site preparation (Presslee 1989). Aspen regenerates abundantly from root suckers which quickly form a dense shrub layer and suppress growth of shade-intolerant conifers (Klinka *et al.* 1989). Conifers growing beneath an overstory of aspen are subjected to significant mechanical damage. "Whipping" damage is particularly severe at approximately 55-75 years when understory trees begin to pass through the aspen overstory (Lees 1966). Because aspen trees killed by herbicides can remain standing for up to 10 years, there must be a sufficient height differential between the two canopies to prevent leader whipping and ensure rapid growth. In stands where the softwood understory is just below aspen crowns, mechanical damage cannot be avoided unless the aspen overstory is removed (Steneker 1976).

Aspen can benefit conifer reproduction in several ways. A sparse overstory of aspen can be beneficial in reducing weevil damage (Heeney *et al.* 1980). Trembling aspen has been rated as very good in promoting soil stability (Plummer 1977) and is also regarded as a soil improver (Haeussler and Coates 1986, Klinka *et al.* 1989). Nutrient content of leaf litter under aspen stands is higher than coniferous litter (Daubenmire 1953). In addition, aspen litter decomposes rapidly, recycling nutrients to the soil, especially Ca, Mg, N (Bartos and DeByle 1981, Haeussler and Coates 1986). Trembling aspen does not fix atmospheric nitrogen (Watson *et al.* 1980), and cannot benefit conifers in this manner.

Uses by Wildlife

Aspen stands typically yield more understory herbaceous biomass than adjoining coniferous stands (Anon. 1976) and provide habitat for numerous wildlife species (Shepperd and Engelby 1983). Both deer and moose browse on aspen (Heeney *et al.* 1980). Immature stands of trembling aspen provide an important source of browse for moose in central and eastern Canada (Peek 1974). Most aspen use occurs in late winter after more palatable species have been heavily utilized (Stevens 1970, Timmermann and McNicol 1988). Spring and summer use of foliage by moose has been noted (Stevens 1970, Timmermann and McNicol 1988). During autumn, moose may feed heavily on aspen litter which is more digestible and higher in nutrient content than woody browse (Renecker and Hudson 1985). Repeated browsing can cause severe deformity of young stems and may retard height growth of aspen for several years (Heeney *et al.* 1980). Mature stands of aspen have value for energy conservation for moose during winter, as these stands allow the sun to reach the ground even during early morning and late afternoon periods, while still providing shelter from wind and a supply of browse (Davidson *et al.* 1988). Aspen is a fair source of browse for deer in early or late summer, and provides some summer shelter. It is of little value as thermoregulatory cover or protection from deep snow for deer (Davidson *et al.* 1988). Snowshoe hare and cottontail rabbit feed on young aspen regeneration (Heeney *et al.* 1980). Buds, twigs and bark of trembling aspen are principle winter foods of snowshoe hare (Radvanyi 1987). Snowshoe hare are fond of fresh, green, aspen bark when it is lying on the ground. There are some indications that this food supply within or adjacent to plantations may divert the animals' attentions from conifer seedlings to aspen (Aldous and Aldous 1944). Poplar stands often support a diversity of food-producing shrubs such as blueberries, cherries, raspberries, and strawberries (*Fragaria virginiana* Duchesne) which are important sources of food for black bear. Young aspen stands can provide substantial food in the early spring, when black bears feed on swollen aspen buds (Davidson *et al.* 1988). Beaver use aspen both as construction materials for dams and lodges and as a preferred food (Heeney *et al.* 1980). Porcupines (*Erethizon dorsatum* L.) feed on aspen leaves and twigs in summer. During winter, porcupines eat bark from branches and trunks (Heeney *et al.* 1980).

Ruffled grouse consume aspen buds, catkins and leaves during the entire year (Heeney *et al.* 1980). Male reproductive buds of aspen constitute a high proportion of the December and March diet of ruffed grouse in northern Ontario. Buds of female aspen are seldom eaten and are of minor importance to grouse. Aspens of both sexes are important in spring, as 59% of the April and May diet of the grouse is composed of young aspen leaves (Davidson *et al.* 1988). Although aspen snags deteriorate rapidly, they are important for cavity-nesting ducks and other hole-nesting species (Perala and Russell 1983).

Prunus pensylvanica L.f.
Pin Cherry

Description

General: erect shrub or small tree to approximately 5 m high; branchlets smooth, usually reddish-brown, with scattered pale brown, warty dots; bark on older stems splitting horizontally into papery strips; twigs bitter to taste.

Leaves: alternate; lance-shaped or narrowly egg-shaped (more than 2 times as long as wide); pointed to taper-pointed at the tip, blunt to rounded at the base; margins irregularly toothed with fine, rounded teeth; upper surface bright green and shiny; leafstalks glandular near the junction with the blade.

Flowers: in small clusters scattered along the branches; individual flowers small (about 1 cm across), with 5 white petals; appearing in May and early June.

Fruit: a bright red cherry with a large central stone; ripening in August and September.

Habitat

Distribution in Ontario: Pin cherry is common throughout Ontario from Lake Erie to Lake Superior and in the Hudson Bay Lowlands to 54° 30'N (Soper and Heimburger 1982).

Climate: Throughout its range, the period of snow cover varies from 1-10 days in the south to 120 days or more in the north, and the growing season ranges from 100 to 210 days (Fulton 1974).

Site and Soil Relations: Pin cherry is found in dry woods, clearings, recent burns, thickets, on sandy and gravelly banks and shores of rivers and lakes, along trails, roadsides, fencerows, rocky ridges, cliffs, and on limestone pavement (Soper and Heimburger 1982). Pin cherry grows on many kinds of soils, from infertile sands to nutrient-rich loams (Fulton 1974). In NW Ontario, pin cherry occurs with low frequency across a wide range of soil textures.

Nutrient Requirements: In NW Ontario, pin cherry occurs most frequently on soils with low to medium nutrient regimes. Optimum soil pH is about 5.0-6.0 (Spurway 1941).

Moisture Requirements: In NW Ontario, pin cherry occurs on dry to moist soils and is absent on wet soils.

Light Requirements: Pin cherry is a shade-intolerant species (Fulton 1974). Although it prefers full sunlight, it will persist in semi-shade (Euler 1979).

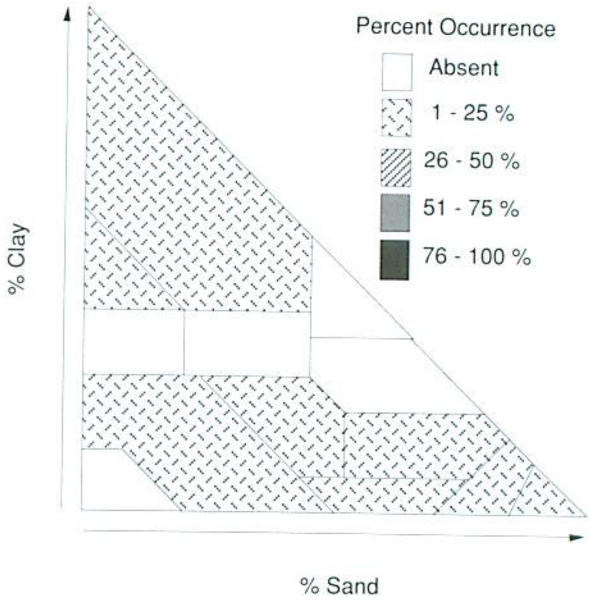
Distribution of **pin cherry** in Ontario
(Adapted from: Soper and Heimburger 1982)

Reproduction

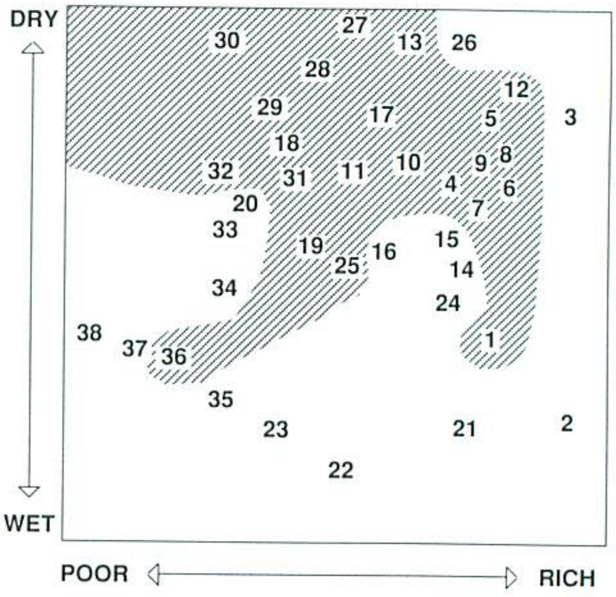
Sexual Reproduction: Seed production, dispersal, viability and germination are discussed.

Seed Production and Dispersal: Sexual maturity is attained by dominant individuals during their fourth growing season; however, fruits are not produced in large quantities until several years later (Marks 1971). A 25-year old pin cherry stand is capable of producing 2,323,500 seeds/ha/yr. By age 25 or 30, when pin cherry individuals are dying rapidly, sufficient numbers of seeds have been produced and disseminated for pin cherry to renew itself following a major disturbance. For a single open-grown tree, judged to be 15 years old and producing a good crop of fruit, Marks (1974) measured fruit production per unit area of ground surface and found 1,300 fruits over an area of 4.5 m^2 (or approximately 2,761,500 fruit per ha per year, assuming a pure stand of pin cherry). From age 10 to 25 years, about 16 million fruits per ha would be produced by a pure stand of pin cherry. Cleaned seed averages 31,300 seeds/kg with a range of 17,600 to 48,100 (Anon. 1974). Seed dispersal by birds, mammals and gravity occurs from July into the winter months (Fulton 1974). Small mammals are important for distribution of pin cherry seeds on a local scale, and birds scatter seeds over a much wider range (Marks 1971). The distribution of pin cherry seeds on the forest floor is influenced by: (1) prior colonization of the site by pin cherry (2) dissemination of fruits by birds that excrete or regurgitate the endocarp and seed at a distance from their source and (3) small mammals that tend to shift the distribution of seeds toward more or less discrete aggregations of caches (Ahlgren 1966).

Seed Viability and Germination Requirements: Pin cherry is a seed banking species (Marks 1974, Auchmoody 1979, Rowe 1983). Seeds of pin cherry have very hard coats and accumulate in the humus layer of the forest floor (Fulton 1974). *Prunus* spp. seeds also have embryo dormancy, and require a period of after-ripening in the presence of moisture and oxygen to overcome dormancy (Anon. 1974, Auchmoody 1979). The presence of the endocarp limits germination of newly ripened seeds (Marks 1974). As a result, large quantities of seed may be present 30 years or more after pin cherry has died out of the overstory (Marquis 1975). Very few seeds germinate beneath a closed canopy. Estimates of dormant pin cherry seed contained in the duff of certain middle-aged northeastern deciduous forests range from 250,000 to more than 4,500,000 seeds/ha (Auchmoody 1979). Marquis (1975) estimated that there were nearly 4.9 million pin cherry seeds/ha in the forest floor of one stand. Germination occurs predominantly in response to major disturbances (Marks 1974). The density of pin cherry stems in part depends upon the population of buried, viable seeds.



Frequency of occurrence of **pin cherry** by soil texture class



Frequency of occurrence of **pin cherry** by NWO FEC Vegetation Type

Vegetative Reproduction: Once established, pin cherry will reproduce by suckering and basal sprouting (Fulton 1974).

Growth and Development

Pin cherry is a fast growing, short-lived species. It usually occurs as a tree 9.5 to 12 m tall at maturity, but in the southern Appalachians specimens up to 28 m tall and 1.6 m in circumference have been found (Stupka 1964). In dense stands, pin cherry grows rapidly to attain canopy closure (high leaf area index) and high values of net annual production and nutrient accumulation by the end of the fourth growing season (Marks 1974). On a unit area basis, the amount of foliage in a dense stand of pin cherry increases rapidly to about its maximum value of 220 g/m^2 at four years and then remains relatively constant until about age 14 (Marks 1974). By age 25 or 30, pin cherry individuals rapidly senesce (Marks 1974).

Phenology

Root, Shoot and Foliage: Information regarding root, shoot or foliage phenology of pin cherry was not found in the literature.

Reproductive Structures: Pin cherry flowers from April to early June, when the leaves are half-grown (Heinrich 1976). Fruits ripen from late-July to mid-August and may persist on trees until October or later (Fulton 1974, Marks 1971).

Response to Disturbance

Overstory Removal: Pin cherry aggressively invades cleared areas (Fulton 1974). It grows from buried seed remaining in the forest floor from prior colonization (Ohmann 1982). A winter harvest that disturbs the soil less than a summer harvest should result in less competition from pin cherry (Campbell 1981). Marks (1971) noted that pin cherry can rapidly capture nutrients that are released after cutting. In one study pin cherry had incorporated more than 90% of its maximum requirements of N, K, and Mg levels within six years after cutting.

Fire: Pin cherry is generally more frequent on burned than unburned sites (Ahlgren 1960). Seeds that accumulate within humus layers beneath the forest floor germinate profusely when influenced by fire (Fulton 1974). In general, pin cherry is more abundant after logging and burning than after logging only (Bjorkbom 1972). Percent frequency and cover of pin cherry remain relatively unchanged by repeated annual spring fires (Anderson and Bailey 1980).

Mechanical Site Preparation: Pin cherry was more abundant after disking than after logging only (Bjorkbom 1972). In northeastern Minnesota, Ohmann (1982) noted above-average biomass of pin cherry in conifer plantations that had been disked or rock-raked and below average biomass in plantations that had received no site preparation.

Cutting: Pin cherry responds well to heavy clipping. Four successive years of clipping after an initial cut produced increases varying from 88% to 121% (Aldous 1952).

Chemical Treatments: The response of pin cherry to 2,4-D, hexazinone and glyphosate will be discussed separately.

2,4-D: Pin cherry is very susceptible to and can be easily controlled by an application of 2,4-D (Chemagro Corporation 1953, Campbell 1981, Fulton 1974).

Hexazinone: Pin cherry was only moderately affected by a mid-July foliar application of hexazinone at 4 kg a.i./ha (Sutton 1984).

Glyphosate: Pin cherry is susceptible to glyphosate, but not as susceptible as trembling aspen or white birch (Sutton 1984). Glyphosate applied at rates between 0.56 and 2.24 kg a.i./ha will provide excellent control of pin cherry for the first year after treatment (Anon. 1988). Pin cherry cover increased dramatically for the 0.56 kg a.i./ha rate, whereas control was maintained with rates of 1.12 and 2.24 kg/ha for up to four years (Anon. 1988). Glyphosate applied at rates between 2.2 and 4.5 kg/ha will provide over 90% defoliation of pin cherry (MacKasey 1983). Pin cherry can resprout following applications of 2.24 to 13.42 kg a.i./ha (Sutton 1978). Six years after a foliar application of glyphosate at 4.0 kg a.i./ha, pin cherry sprouts were about 50 cm high (Sutton 1984).

Fertilization: Nitrogen fertilizers, such as urea, triggered the germination of dormant pin cherry seed that were naturally buried in the forest floor of a 60-year-old yellow birch-maple stand (Auchmoody 1979). Nitrate was apparently responsible for breaking seed dormancy. The addition of P or PK with urea does not further influence germination (Auchmoody 1979).

Effects on Conifers

This species causes severe competition for young conifers if not removed (Jablanczy 1979). Roots and crowns of pin cherry compete directly with those of planted conifers for moisture, nutrients and light (Bailey 1984). Pin cherry provides excellent cover for rabbits which are capable of destroying or severely retarding the growth of planted conifers (Bailey 1984).

Uses by Wildlife

Pin cherry may be heavily browsed by moose (McNicol and Gilbert 1980). Browsing by moose typically occurs more frequently during the winter than at other times of the year (Timmermann and McNicol 1988). Pin cherry is used moderately by deer (Aldous 1952). It is used by deer primarily during late winter and spring after the deer move from winter concentration areas (Aldous 1952). Both foliage and twigs are browsed by deer; although, one study showed the foliage to have an undesirably high calcium to phosphorous ratio (Fulton 1974). Pin cherry also provides excellent cover and browse for rabbits (Bailey 1984). Beaver will cut pin cherry, and sometimes completely remove small stands (Fulton 1974). Small mammals eat the berries and bark (Euler 1979).

The fruit is eaten in summer and fall by at least 25 species of non-game birds (e.g., waxwings (*Bombycilla cedrorum* Vieillot), robins (*Turdus migratorius* L.), grosbeaks (*Hesperiphora vespertina* Cooper) and thrushes (*Catharus* spp.)) and several upland game birds (Marks 1974, Fulton 1974). Flower buds are eaten by sharptailed (*Pedioecetes phasianellus* L.) and ruffed grouse (Fulton 1974). Pin cherry provides only fair nesting cover and materials for birds, but this value is probably greater where pin cherries form dense thickets (Fulton 1974).

Prunus virginiana L.
Choke Cherry

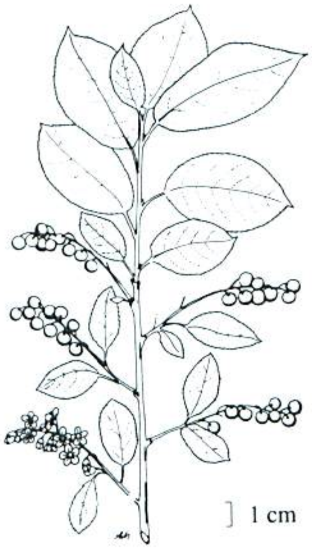
Description

General: erect shrub up to 3 m high; often forming clumps; branchlets, reddish-brown to purplish-grey, bitter to taste with an acrid odour when bruised.

Leaves: alternate; broadly oblong or egg-shaped, usually widest at or above the middle; pointed or short pointed at the tip, rounded to tapered at the base; margins finely toothed with narrow, spreading teeth; leafstalks with 1 to several glands at or near the base of the blade.

Flowers: in elongated clusters at the ends of the branches; individual flowers small (<1 cm across), with 5 white petals; appearing in May and early June.

Fruit: a dark red or nearly black cherry with a large central stone; ripening in August and September.



Habitat

Distribution in Ontario: Choke cherry is common throughout southern Ontario, and northward to James Bay reaching its northern limit at about 53°N (Soper and Heimburger 1982).

Climate: The wide range of choke cherry implies a wide-ranging adaptation to temperature and precipitation (Mulligan and Munro 1981). It occurs within continental cool temperate and cool semiarid climates (Klinka *et al.* 1989). Its occurrence increases with increasing temperature, and decreases with increasing precipitation and latitude (Klinka *et al.* 1989). Choke cherry will grow in frost pockets where the temperatures drop to as low as -40°C (Vilkitis 1974). Choke cherry is reported to grow best in areas receiving at least 40 cm mean annual precipitation (Watson *et al.* 1980).

Site and Soil Relations: Choke cherry occurs along river banks, roadsides, fencerows, lakeshores, and the edges of woods and swamps, and on hillsides, talus slopes, rocky ridges, open ledges, and gravelly and sandy soils (Soper and Heimburger 1982), granite and limestone soils, glacial tills and sand dunes (Mulligan and Munro 1981). Choke cherry grows best in rich, well-drained, moist soils (Vilkitis 1974, Mulligan and Munro 1981), with loamy soil textures (Watson *et al.* 1980). In NW Ontario, choke cherry occurs more frequently on fine-textured than on coarse-textured soils.

Distribution of **choke cherry** in Ontario
(Adapted from: Soper and Heimburger 1982)

Nutrient Requirements: Choke cherry is commonly found and grows best on nitrogen-rich soils (Mulligan and Munro 1981, Klinka *et al.* 1989). In NW Ontario, choke cherry occurs most frequently within V-Types 2 and 3 and is absent on poor sites such as V-Types 30, 37 and 38. Optimum soil pH ranges from 6.0 to 8.0 (Spurway 1941).

Moisture Requirements: Choke cherry is found across a wide range of soil moisture regimes, but commonly occurs on moderately dry to fresh soils (Klinka *et al.* 1989). Although choke cherry requires adequate moisture for establishment (Euler 1979), it does not tolerate moisture stress (Watson *et al.* 1980).

Light Requirements: Choke cherry is shade-intolerant (Watson *et al.* 1980, Klinka *et al.* 1989). Although optimum growth occurs in full sunlight, choke cherry will grow in partial shade (Euler 1979).

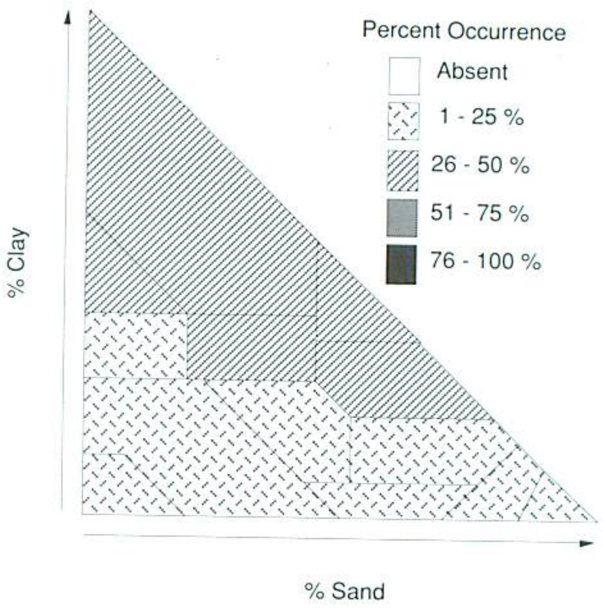
Reproduction

Sexual Reproduction: Primary reproduction of choke cherry is through seed (Vilkitis 1974). Choke cherry will flower after 2 years (Mulligan and Munro 1981). Good crops of fruit are borne in most years by mature plants (Mulligan and Munro 1981). Fruit production is abundant in most years (Vilkitis 1974). Cleaned seed averages 10,560 sees/kg and ranges from 6,640 to 18,500 (Anon. 1974). Birds and mammals are the chief means of seed dispersal (Vilkitis 1974). *Prunus* spp. seeds have embryo dormancy, and require a period of after-ripening in the presence of moisture and oxygen to overcome dormancy (Anon. 1974).

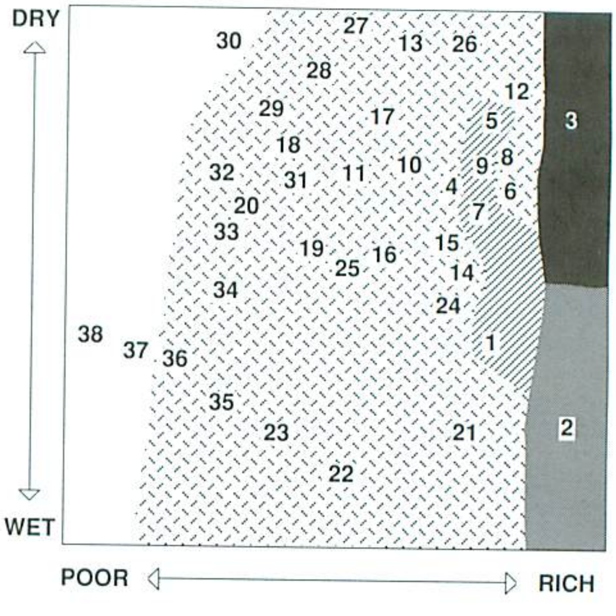
Vegetative Reproduction: Once established, choke cherry often forms dense thickets of suckers and sprouts from extensive lateral root systems (Vilkitis 1974). Choke cherry will readily sprout from damaged trunks (Mulligan and Munro 1981). *Prunus* spp. can be artificially established by budding, grafting, suckering or root cutting (Watson *et al.* 1980).

Growth and Development

Choke cherry is a relatively long-lived, perennial shrub or small tree 0.6 to 6 m tall (Watson *et al.* 1980). In favourable circumstances, it may reach a height of 10 m, and a diameter of 15 cm (Watson *et al.* 1980). It rarely reaches full size; more commonly it is a multi-branched, low- to medium-sized shrub (Mulligan and Munro 1981).



Frequency of occurrence of **choke cherry** by soil texture class



Frequency of occurrence of **choke cherry** by NWO FEC Vegetation Type

Phenology

Root, Shoot and Foliage: The leaves are nearly fully developed at the time of flowering in late spring (Mulligan and Munro 1981).

Reproductive Structures: In general, flowering occurs from April to June (Heinrich 1976). In northern areas of its range, flowers may open later (Vilkitis 1974, Mulligan and Munro 1981). McWilliams and Ludwig (1972) noted flowering between May 5 and June 10 at a site near the University of Michigan. Anthesis occurs from mid- to late May and fruit ripens during late June to early July in southwestern Ontario (Mulligan and Munro 1981). The maturation process of choke cherry fruit lasts about 10 weeks and is characterized by three distinct stages: periods of rapid growth (at the beginning and end of ripening) are separated by a retarded growth period (Labrecque *et al.* 1985). Seeds remain astringent until ripe (Vilkitis 1974). The clusters of red or amber fruit turn dark red to purplish black at maturity (Vilkitis 1974).

Response to Disturbance

Overstory Removal: Information pertaining to the response of choke cherry to overstory removal was not found in the literature.

Fire: Choke cherry increased in percent frequency, but percent cover remained unchanged, after 24 years of repeated annual spring burning (Anderson and Bailey 1980).

Mechanical Site Preparation: Choke cherry can be controlled in fields by plowing-in seedlings and young saplings (Mulligan and Munro 1981).

Cutting: Choke cherry sprouts readily if cut back (Mulligan and Munro 1981).

Chemical Treatments: Choke cherry is difficult to eradicate without the use of herbicides, especially when mature (Mulligan and Munro 1981). The response of choke cherry to 2,4-D, hexazinone and glyphosate will be discussed separately.

2,4-D: Choke cherry is rated as moderately to strongly susceptible to 2,4-D amine or low-volatile ester (Chemagro Corporation 1953, Mulligan and Munro 1981, Anon. 1986). Frequency of occurrence generally increases following 2,4-D applications (Schacht and Hansen 1963). Basal-bark treatments are effective for choke cherry over 3 m tall (Mulligan and Munro 1981).

Hexazinone: Information pertaining to the response of choke cherry to applications of Velpar-L was not found in the literature.

Glyphosate: Information pertaining to the response of choke cherry to applications of glyphosate was not found in the literature.

Fertilization: Information pertaining to the response of choke cherry to applications of fertilizers was not found in the literature.

Effects on Conifers

There are no quantitative data on effects of choke cherry competition on conifers. Choke cherry is very competitive with other plant species (Vilkitis 1974). Choke cherry does not fix atmospheric nitrogen (Watson *et al.* 1980) and does not benefit conifers in this manner. Since choke cherry is considered to be a good soil stabilizer (Watson *et al.* 1980), it may be of some benefit on sites that are susceptible to erosion.

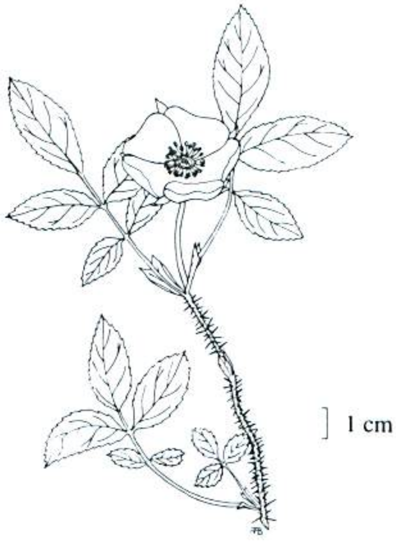
Uses by Wildlife

Choke cherry is a preferred winter browse species of moose (Harry 1957, Stevens 1970). White-tailed deer eat choke cherry, but utilization differs with locality (Vilkitis 1974). Rabbits do not prefer the bitter twigs of choke cherry, but will readily eat the bark (Vilkitis 1974, Euler 1979). Small mammals eat the fruit and bark (Euler 1979). Choke cherry has fair cover value for small mammals (Vilkitis 1974).

About 70 species of game and songbirds seek out choke cherry fruits as soon as they become available (Vilkitis 1974). Choke cherry fruit is readily eaten by ruffed grouse through autumn until December, but may be less important locally than pin cherry fruit (Edminster 1947). During winter, ruffed grouse browse the buds and twigs (Phillips 1967).

Rosa acicularis Lindl.
Prickly Wild Rose

Description



General: low, bushy shrub, <1 m high; branches reddish, densely covered with straight, slender thorns.

Leaves: alternate; compound with 5 or 7 sharply toothed, oval to oblong leaflets; axis of leaf minutely hairy, usually glandular; a pair of leaf-like stipules at the leaf base.

Flowers: usually solitary at the branch ends; large (5-7 cm diameter), showy flowers with 5 pink petals; appearing in June and July.

Fruit: a bright red, many-seeded 'rose hip'; ripening in late August and September.

Habitat

Distribution in Ontario: Prickly rose occurs throughout Ontario, but is less common southeast of Lake Huron (Soper and Heimburger 1982).

Climate: Prickly rose occurs in continental boreal and cool temperate climates (Klinka *et al.* 1989).

Site and Soil Relations: Prickly rose is found in meadows, clearings, and open woods, on rocky shelves and ridges, limestone flats, talus slopes, clay and sand banks, and along roadsides, lakeshores and river banks (Soper and Heimburger 1982). In NW Ontario, prickly rose is found on a range of soil textures, but most commonly on fine-textured soils.

Nutrient Requirements: In NW Ontario, prickly rose occurs on soils that are moderately rich in nutrients. Prickly rose has a high acid tolerance (Watson *et al.* 1980).

Moisture Requirements: Prickly rose is adapted to a range of soil drainage classes, from well to poorly drained soils (Watson *et al.* 1980). It occurs most commonly on soils that have a dry to fresh moisture regime (Klinka *et al.* 1989). Prickly rose has moderate drought resistance and can withstand flooding during the growing season (Watson *et al.* 1980).

Light Requirements: Prickly rose is shade-intolerant (Klinka *et al.* 1989). All roses grow more vigorously and produce more fruit in full sunlight than in shade (Smithberg and Gill 1974).

Distribution of **prickly rose** in Ontario
(Adapted from: Soper and Heimburger 1982)

Reproduction

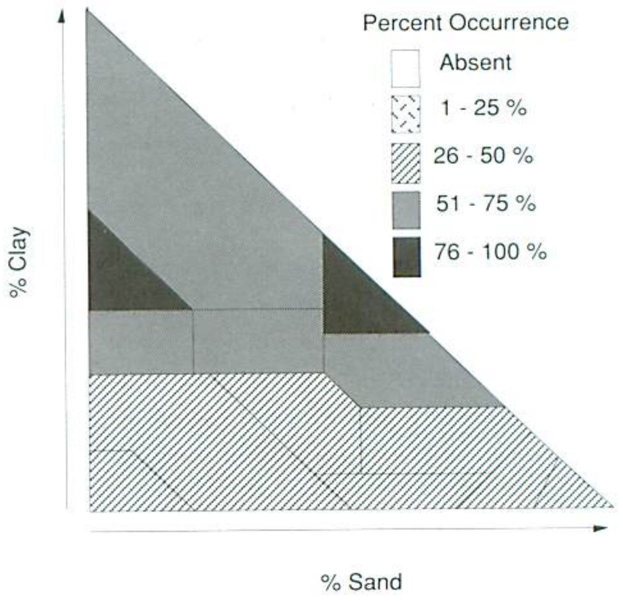
Sexual Reproduction: Seed production, dispersal, viability, and germination are discussed.

Seed Production and Dispersal: Rose species may produce flowers and fruits at 2 years of age (Smithberg and Gill 1974). Prickly rose produces a relatively small number of seeds (Densmore and Zasada 1977). Flowers are pollinated by insects (Smithberg and Gill 1974). Considerable energy is allocated to the edible hip to provide for animal dispersal, which increases the chances that seeds will be dispersed to suitable habitats (Densmore and Zasada 1977). Many seeds are dispersed by small mammals, songbirds and grouse that eat the fruit and pass the seeds (Ahlgren 1960, Densmore and Zasada 1977).

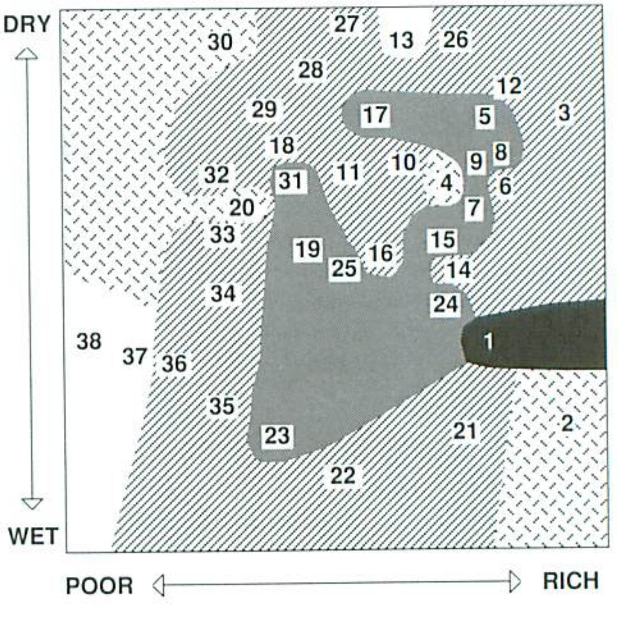
Seed Viability and Germination Requirements: The small number of seeds produced is compensated for by the large seed size (Densmore and Zasada 1977). The large seeds have enough stored food to rapidly produce a large root system and a vigorously growing seedling. Rose seeds exhibit dormancy primarily due to conditions in the seedcoat rather than the embryo (Anon. 1974). Most seeds require 2 years to germinate. Seeds develop and mature the first growing season, warm stratify the next growing season, cold stratify the following winter and finally germinate in spring following snow melt (Densmore and Zasada 1977, Calmes and Zasada 1982). The complex dormancy mechanisms provide for germination and seedling establishment under suitable conditions, and may spread germination of a single seed crop over several years (Densmore and Zasada 1977).

After stratification, seeds are capable of germination over a wide range of temperatures (Densmore and Zasada 1977). In prickly rose the pericarp does not inhibit imbibation of moisture and offers little resistance to embryo growth. In many seeds, the pericarp is split open and may fall off, but the seed remains dormant. After stratification, germination generally occurs after snowmelt the following spring. The ability of prickly rose to germinate and grow at low temperatures enables the species to establish in a variety of habitats and take advantage of optimum moisture conditions in spring.

Vegetative Reproduction: Prickly rose seedlings, once established, spread vegetatively by rhizomes over wide areas (Densmore and Zasada 1977). The species also reproduces by sprouting (Ahlgren 1960). Rhizome cuttings from prickly rose are capable of producing both roots and shoots (Calmes and Zasada 1982). Prickly rose can be reproduced from both softwood cuttings (McTavish 1986) and rhizome cuttings (Calmes and Zasada 1982).



Frequency of occurrence of **prickly rose** by soil texture type



Frequency of occurrence of **prickly rose** by NWO FEC Vegetation Type

Growth and Development

Prickly rose is a relatively long-lived, perennial shrub that typically grows to 30-120 cm in height (McTavish 1986) and up to 2.5 m in shaded conditions (Watson *et al.* 1980). Prickly rose clones can cover an area of 10 to 20 m^2 (Calmes and Zasada 1982). Prickly rose rhizomes are located predominantly in the mineral soil, and typically about 20 to 30 cm below the surface. (Calmes and Zasada 1982).

Phenology

Root, Shoot and Foliage: Information regarding root, shoot or foliage phenology of prickly rose was not found in the literature.

Reproductive Structures: Prickly rose flowers prolifically throughout the summer months (McTavish 1986). Many seeds are freed from the fruit and dispersed prior to snowmelt. Some seeds overwinter in the fruit, often attached to the plant. These fruits are usually shed when new leaves appear in late spring (Densmore and Zasada 1977).

Response to Disturbance

Overstory Removal: Reproduction of prickly rose is stimulated more by summer logging than by winter logging (Zasada *et al.* 1981). Three seasons after logging there were 19,250 stems/ha within a summer logged area and 2,500 stems in a winter logged area. Frequency of occurrence was 60% and 20% respectively.

Fire: Prickly rose spreads rapidly after disturbance (Lotan *et al.* 1981). Since rhizomes are located within the mineral soil, prickly rose is relatively resistant to fire (Calmes and Zasada 1982). Light to moderate burns stimulate vegetative reproduction (Viereck 1983). More severe fires may kill rhizomes and reduce the abundance of prickly rose (Ahlgren 1960). Prickly rose produces new shoots at intervals along rhizomes after fire, as well as from bases of fire-killed aboveground stems (Lotan *et al.* 1981). Where fire has consumed all of the duff layer and exposed mineral soil, a good seedbed is provided for prickly rose regeneration from seed (Calmes and Zasada 1982).

Mechanical Site Preparation: Prickly rose was more abundant in nonscarified than in scarified conifer regeneration plots in interior Alaska (Zasada and Grigal 1978). Following a survey of plantations in northeastern Minnesota, Ohmann (1982) noted that above average biomass was present on sites that had been rock-raked. Bowes (1981) reports that even three passes of a heavy-duty disk will not kill all rhizomes of prickly rose.

Cutting: Severing of the aerial stems of prickly rose increases sprout production (Ohmann 1982).

Chemical Treatments: The response of prickly rose to 2,4-D, hexazinone and glyphosate will be discussed separately.

***2,4-D*:** Roses are classified as resistant to 2,4-D (Benzie 1977, Balfour 1989). 2,4-D amine does not effectively control prickly rose (Bowes 1976). Applications of 2,4-D at 1.1 and 2.2 kg/ha applied in mid-June provided a 35 and 23% reduction respectively, in numbers of shoots three years following spraying (Bowes 1976).

***Hexazinone*:** Hexazinone causes severe injury to roses, except after spring and summer application at rates of less than 2.2 kg a.i./ha (Balfour 1989). The Expert Committee on Weeds (1984) reported that spot-gun treatments of Velpar-L provide excellent control of roses.

***Glyphosate*:** For application rates of >1.1 and <2.2 kg a.i./ha, glyphosate causes moderate to severe damage to rose species regardless of season of application (Balfour 1989). Summer applications exhibit damage that persists into the following growing season (Balfour 1989).

Fertilization: Information pertaining to the response of prickly rose to applications of fertilizers was not found in the literature.

Effects on Conifers

There are no quantitative data on effects of prickly rose competition on conifers. Prickly rose does not benefit conifers by fixing atmospheric nitrogen (Watson *et al.* 1980).

Uses by Wildlife

Prickly rose is an important food source for many animals including rodents, grouse and snowshoe hares (Densmore and Zasada 1977). Rose hips are eaten by grouse and other birds during fall and winter (Viereck and Little 1972). Buds and twigs of rose are principle winter foods of snowshoe hare (Radvanyi 1987). The twigs are covered with straight bristles which may discourage browsing by some animals (Budd and Best 1969).

Rubus idaeus L. var. *strigosus* (Michx.) Maxim. Wild Red Raspberry

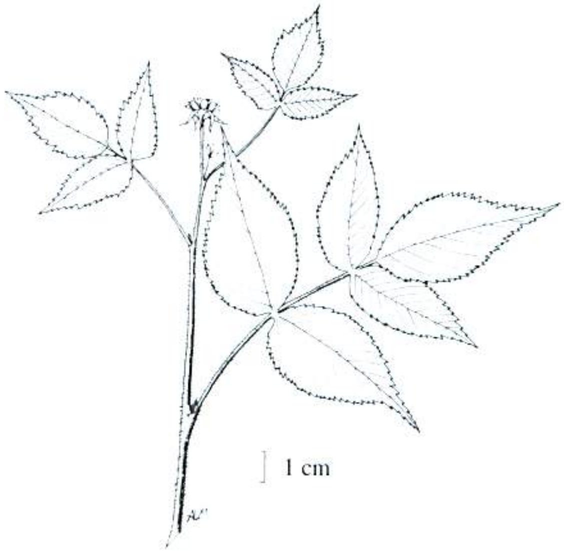
Description

General: spreading shrub with erect or arching stems up to 2 m long; branchlets covered with slender spines and stiff bristles; papery bark shredding from older stems.

Leaves: alternate; compound with 3, 5 or 7 egg-shaped or elongated, irregulary toothed, pointed leaflets; dark green above, softly grey- hairy beneath.

Flowers: in clusters of two to five at the branch ends; five narrow, white or greenish-white petals; appearing in June and July.

Fruit: a red raspberry; ripening in July and August.



Habitat

Distribution in Ontario: Red raspberry is widespread throughout Ontario from Lake Erie northward to Lake Superior and Lake of the Woods; less common in the Hudson Bay drainage basin (Soper and Heimburger 1982).

Climate: The broad distribution of red raspberry across continental North America indicates that it is tolerant of a wide range of northern temperate climates, and not limited by the short growing season and cold winter temperatures of the boreal forest (Haeussler and Coates 1986). It occurs in both continental boreal and wet temperate climates (Klinka *et al.* 1989).

Site and Soil Relations: Red raspberry is chiefly found in open areas, talus slopes, edges of woods, thickets, roadsides, clearings, burns, and waste places (Soper and Heimburger 1982). Red raspberry occurs on a wide variety of soil types ranging from sandy loam to silty clay loam (Watson *et al.* 1980). In NW Ontario, red raspberry occurs most frequently on fine-textured soils.

Nutrient Requirements: Red raspberry prefers nitrogen rich soils (Klinka *et al.* 1989). It is abundant where soil nutrients are plentiful, due to high nutrient demands (Wright 1972). In NW Ontario, it occurs most frequently on moderately rich sites such as V-Types 1, 2, 5, 9, 15, 17, 23, 24, 26, 28 and 35. Red raspberry has moderate tolerance to soil acidity (Watson *et al.* 1980).

Moisture Requirements: Red raspberry occurs across a wide range of soil moisture regimes, but prefers fresh to very moist soils (Klinka *et al.* 1989). Best growth typically occurs on moist (subhygric) sites (Haeussler and Coates 1986). Adequate

Distribution of **red raspberry** in Ontario
(Adapted from: Soper and Heimburger 1982)

moisture is necessary for fruit production (Rogers 1974) and for establishment (Euler 1979). Late summer drought reduces stored carbohydrate levels in the plant (Crandall *et al.* 1974), and may result in lower plant vigour. In drier locations, red raspberry is restricted to sites where seepage water augments the supply of soil moisture (Haeussler and Coates 1986).

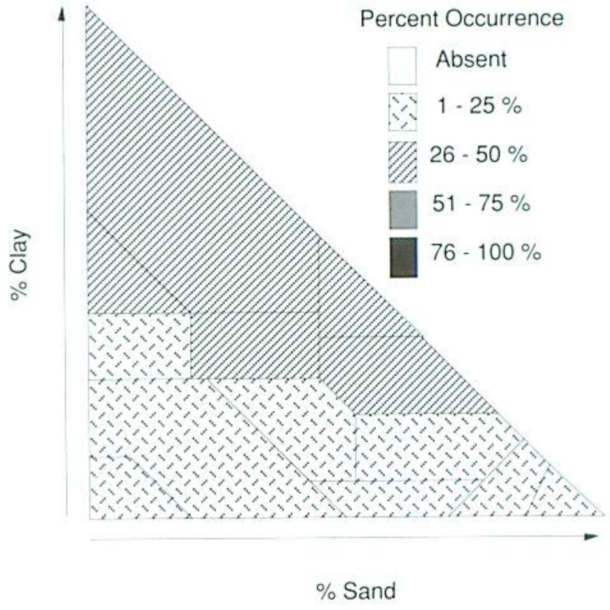
Light Requirements: Red raspberry is shade-intolerant (Klinka *et al.* 1989). It is rarely found within undisturbed, mature forests (Haeussler and Coates 1986). Growth is more vigorous in full sunlight than in partial shade (Core 1974). It devotes more energy into seed production as it becomes shaded (Whitney 1982).

Reproduction

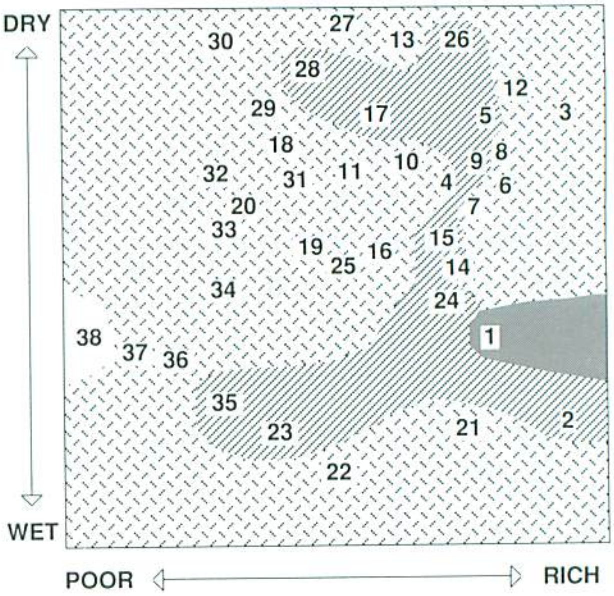
Sexual Reproduction: Once the initial colonizers have been established, seedling recruitment plays a relatively minor role in the maintenance of numbers of plants on a site (Whitney 1978). Once established, red raspberry's ability to rapidly colonize a site depends primarily on its ability to reproduce vegetatively (Haeussler and Coates 1986).

Seed Production and Dispersal: Flowers occur on two-year-old canes referred to as 'floricanes' (Whitney 1982). Good seed crops occur nearly every year (Anon. 1974). Fruit set is often successful; 70-90% of the flowers eventually mature into fruits (Whitney 1982). Red raspberry seed production starts at a low of approximately 700 seeds/m^2 two years after disturbance and climbs to a high of more than 14,000 seeds/m^2 during year four (Whitney 1978). Total seed production during the first four year period after disturbance can exceed 26,000 seeds/m^2 and average 6,500 seeds/m^2/year (Whitney 1978). Cleaned seeds average 723,000 seeds/kg with a range of 668,000-847,000 (Anon. 1974). Pollination is carried out predominantly by solitary bees and bumblebees (Whitney 1978). Natural seed dispersal occurs primarily by birds, small mammals and bears (Ahlgren 1960).

Seed Viability and Germination Requirements: Red raspberry is a seed banking species (Isaac 1982, Rowe 1983). A small number of seeds may germinate the year after dispersal, but many remain dormant for a long time, probably in excess of 50-100 years (Whitney 1978, 1982). Seed decay is extremely slow (Whitney 1978). Granstrom (1987) found that after two years in soil, 4% germinated; after three years, 12%; and after five years, 16% germinated. Seed viability ranged from 92-99% for six seed lots collected in northern Alberta (Watson *et al.* 1980). The lengthy period of viability allows the species to bank seeds in the soil where they can remain dormant until conditions become suitable for germination and seedling survival (Haeussler and



Frequency of occurrence of **red raspberry** by soil texture class



Frequency of occurrence of **red raspberry** by NWO FEC Vegetation Type

Coates 1986). Germination of stored or recently deposited seed is the primary means by which raspberry is able to become established on recently disturbed sites, but one year after stand initiation, further seedling establishment is almost non-existent (Hauessler and Coates 1986). The 2,500,000-5,000,000 seeds/ ha (if partially viable) found in old pine forest and older burns, could be important in early revegetation should a disturbance occur (Alhgren 1979a). Germination is largely limited to a 1.5 month period from early June to mid-July during the first year after a disturbance (Whitney 1978). Raspberry seeds require a lengthy period of chilling (approximately 120 days) before they will germinate (Haeussler and Coates 1986). Light helps to stimulate germination following chilling (Haeussler and Coates 1986). Temperatures of between 10°C and 25°C are favourable for germination (Haeussler and Coates 1986). Seeds must be treated so that water can penetrate the seed coat (Rogers 1974). Alterations in the soil water nitrate concentration levels or changes in the spectral quality of light reaching the forest floor are probable factors triggering the germination of red raspberry (Whitney 1978).

Vegetative Reproduction: Raspberry shoots arise in three distinct ways: 1) as root suckers from buds on roots, 2) as stem sprouts from axillary buds (usually basal buds borne near ground level), or 3) more rarely, as lateral branches from axillary buds well above ground level (Hudson 1959, Core 1974). Vegetative propagation is the primary source of development of the dense colonies often seen in old fields (Core 1974). Nurseries propagate raspberries vegetatively from tip layers, root cuttings and suckers (Rogers 1974). Raspberry regenerates readily from root cuttings taken during the dormant season, while cuttings taken between May and August usually fail to regenerate successfully (Williams 1959).

Growth and Development

Raspberries appear, flourish, complete their life cycles and decline in importance all within the first few years after disturbance (Marks 1974). Like many other members of the genus *Rubus*, red raspberry possesses a biennial cane system on a long-lived perennial root system (Hudson 1959, Whitney 1982). Red raspberry frequently forms an almost monospecific shrub layer or stand during the first three to five years following large scale disturbances (Whitney 1982). The natural habit of this species is to form dense colonies of shoots, which originate from the roots or stems of the parent plant. Many young shoots die from overcrowding, but surviving stools subsequently develop to be long-lived and sparsely branched, and often become separated from the parent plant by the death of the parent roots from which they grew (Hudson 1959).

Shoots arising from root buds pass through nine distinct phases of growth and development (Hudson 1959): 1) initiation of the root bud, 2) development of a subterranean sucker, 3) emergence of the sucker, 4) overwinter dormancy of new cane, 5) shoot elongation in the second growing season, 6) initiation of flower buds, 7) overwinter dormancy of one-year-old cane during which time dormancy of flower buds is broken, 8) flowering and fruiting of the two-year-old cane, and 9) senescence and death of the two-year-old cane. From phase one to six the plant is referred to as a "primocane" and from seven to nine it is referred to as a "floricane."

There are two phases involved with the development of a raspberry stand: 1) a building phase and 2) a self-thinning phase (Whitney 1982). The first two years, designated as the building phase, are characterized by a rapid increase in the number of individuals present in the stand. Seedling establishment is responsible for the initiation of the stand. After the first year, however, seedling establishment is almost non-existent. Production of root suckers, formed 0-5 cm below the duff surface (Johnston and Woodard 1985), soon dominates the stand's pattern of growth. Phase two, the self-thinning phase, generally commences at year three, and represents a period of biomass accumulation and high net productivity. Net productivity (g/m^2 per year) peaks during the first two years of the self thinning phase. At three years of age, the leaf area index (LAI) levels off at a maximum value of approximately 4.6. This approaches the LAI of mature *Acer-Betula-Fagus* communities. The self-thinning phase is also accompanied by decreased sucker production and establishment as well as increased seed production (Whitney 1982).

In summary, stems live for only two years; one-year-old stems are usually sterile and have leaves that are unlike those of the two-year-old stems; flowers and fruit are borne on the two-year-old stems; vegetative reproductive output for a stand reaches a high during year two and declines thereafter; and seed reproductive output does not peak until year four (Whitney 1978).

Phenology

Root, Shoot and Foliage: Floricanes leaf out rapidly in the spring, build up a large leaf biomass by late June, transfer their photosynthate to the developing fruits from mid-June to late August, initiate leaf senescence in late June, and fade away gradually from late June to early October. The decrease in floricane LAI is balanced by a developing primocane LAI. Frost-hardy primocanes maintain a high leaf area index well into October, extending the time available for the production of photosynthate and the regeneration of the overwintering carbohydrate root reserves (Whitney 1982). Carbohydrate transfer to the root system is relatively low in May, increases gradually through June and July, increases very rapidly in early August and remains at a high level from August to November (Whitney 1982).

Production of a new group of vegetative canes arising from dormant buds at the base of the stem occurs simultaneously with the maturation and death of the floricane (Whitney 1978).

Reproductive Structures: Although floral initiation occurs in the autumn, production of fruiting branches or laterals is usually delayed until the following season (Waister *et al.* 1977). Although red raspberry has a relatively long flowering period (from late May to early October), the peak of the flowering season occurs in the first two weeks of June. Thereafter it decreases to an occasional flower per m^2 during the latter part of the summer (Heinrich 1976, Whitney 1978). Fruit bearing season extends from early July to late August (Whitney 1978), and seed dispersal occurs from July to October (Anon. 1974). Fruiting is followed by the death of fruiting canes (i.e., the floricanes) (Whitney 1978).

Response to Disturbance

Overstory Removal: Red raspberry is a pioneer species that depends on forest openings for establishment and survival (Haeussler and Coates 1986). Dense fields of raspberry frequently become established following clearcutting (Johnston 1968, Whitney 1982, Fox 1986). Red raspberry, which re-establishes through resprouting and germination of stored seed, is continually present after site disturbance (Hatcher 1960, Moore and Wein 1977, Hamilton and Yearsley 1988a). Winter harvest disturbs the soil less than a summer harvest and should result in less competition from raspberry (Campbell 1981). Red raspberry does not compete well with established understory vegetation and will not invade moist sites where a diverse shrub layer is already well established prior to canopy removal (Zasada *et al.* 1981, Haeussler and Coates 1986). From a study in New Brunswick, Baskerville (1961) observed a rapid influx of raspberry following manual removal of a mountain maple overstory.

Fire: Red raspberry is usually more abundant on burned than on unburned sites (Ahlgren 1960). Burning stimulates sprouting and suckering of existing plants, stimulates germination of buried seed, and provides a suitable seedbed for germination of newly deposited seed (Hamilton and Yearsley 1988a). Raspberry is frequently found in great abundance on sterile mineral soil that has been exposed by a severe burn (Haeussler and Coates 1986).

Johnston and Woodard (1985) studied the effect of fire severity on raspberry by artificially adjusting fuel loading on small plots within a single large burn. They found that above-ground plant parts were killed even by low severity fires and that some below-ground mortality occurred under plots with heavy fuel loads.

Foote (1983) found that red raspberry invaded black and white spruce sites the first year after burning in Alaska, but that raspberry plant numbers then declined once spruce was established. Ahlgren (1960) reported that red raspberry took at least five years to become dominant on jack pine sites in northern Minnesota, then declined in abundance.

Mechanical Site Preparation: Scarification generally increases the abundance of red raspberry (Zasada and Grigal 1978). Where mechanical site preparation is used within existing stands of raspberry, soil disturbance can fragment the root system, creating new independent stools (Hudson 1959), and stimulate root suckering (Haeussler and Coates 1986). Deep cultivation (15-23 cm) cuts the roots of existing raspberries and causes the formation of many suckers (Rogers 1974). Mechanical site preparation following a chemical treatment may increase raspberry cover (Reynolds *et al.* 1989) Repeated cultivation of the soil will control the spread of raspberry by root suckering, but will be accompanied by an increase in the vigour of adjacent undisturbed plants (Lawson and Waister 1972).

Cutting: Due to the prolific sprouting capability of raspberry, manual weeding may increase rather than decrease the quantity of raspberry on a site (Rogers 1974, Anon. 1989a). New shoots are rapidly produced from suckers and stools (Core 1974). Raspberries resprout from root crowns if cut (Watson *et al.* 1980). Most people have experienced the rapid regrowth and increase in density of backyard raspberry patches after cutting the mature canes (Bailey 1984). Any treatment that reduces the cane density will serve to improve the vigour of remaining canes (Haeussler and Coates 1986). Repeated heavy cutting will probably result in depletion of stored food reserves and an eventual decline in the number and vigour of canes produced (Haeussler and Coates 1986).

Chemical Treatments: Raspberry tends to be more vulnerable to chemical treatment during the first two years after a disturbance, while it is still young and developing (Anon. 1981). Beyond the third year it becomes well established and may require more thorough treatment and higher application rates of herbicides. The response of red raspberry to 2,4-D, hexazinone and glyphosate are discussed separately.

2,4-D: This herbicide has little effect on raspberry (Chemagro Corporation 1953, Sutton 1969, Campbell 1981, Anon. 1986). Following a survey of plantations in NW Minnesota, Ohmann (1982) found that above-average raspberry biomass occurred where 2,4-D was used for site preparation. Raspberry may develop into a dense stand following the removal of an alder or aspen overstory by this chemical (Coulter 1955, Schacht and Hansen 1963).

Hexazinone: Raspberry is rated as susceptible to Velpar-L; approximately 8-10 l/ha will control raspberry on a medium-textured soil (Corcoran 1989). Although hexazinone causes severe damage to red raspberry, results have been highly variable (Balfour 1989). Red raspberry appears to be quite sensitive to hexazinone applied at rates of 2.0-5.0 kg/ha (Expert Committee on Weeds 1984). Raspberry can be controlled with treatment rates of 9.38 l/ha and greater for at least four growing seasons after treatment (Anon. 1989a). Lehela and Campbell (1981) reported excellent control of red raspberry with 4.5 kg/ha of hexazinone used for site preparation in early spring in Ontario.

Both liquid (Velpar-L) and dry flowable formulations (Velpar ULW) of hexazinone aerially applied in late June at 2.0 kg a.i./ha effectively controlled raspberry with a 70% and 50% cover reduction respectively (Pitt *et al.* 1989).

Velpar-L has little effect on the germination of raspberry whereas hexazinone such as Pronone 10G strongly decreases germination (Morash and Freedman 1989).

Glyphosate: Glyphosate dosages greater than 1.0 kg a.i./ha are required to control raspberry (Lehela 1981). Glyphosate provides excellent control of raspberry, even when well established on good sites, for at least four years after application, at application rates between 2.24 and 3.36 kg a.i./ha (Anon. 1981, MacKasey 1983, Anon. 1988). Results may be variable with rates as low as 0.56 kg a.i./ha (Anon. 1988). In a Nova Scotia experiment (Bailey and McNally 1983), raspberry treated with glyphosate via backpack sprayers was effectively controlled with rates of 3.1, 6.2, and 9.3 l/ha. Control persisted for four to five years. Red raspberry was found to be moderately tolerant of glyphosate applied as a foliar spray at 2.25 kg/ha (Haeussler and Coates 1986). Red raspberry appears to be less sensitive to applications of glyphosate made during mid-July than to applications made before or after this period. The middle of July typically coincides with the end of flowering and the beginning of fruit set (Lund-Høie 1975).

Since glyphosate has little effect on the germination of raspberry (Morash and Freedman 1989), raspberry may increase in abundance one to two years after glyphosate application (Kennedy and Jordan 1985, Balfour 1989). Large decreases in germination occur only at concentrations that are unrealistically large in comparison with herbicide residues than actually occur after a silvicultural treatment of herbicides (Morash and Freedman 1989).

Reduction in the cover of raspberry following an application of glyphosate may be accompanied by an immediate increase in the cover of a variety of species in the lower vegetation strata including ferns, grasses, dogwood and goldenrod (Bailey 1984).

Chemical applications of glyphosate are typically made in mid- to late summer when raspberries are fully ripe. Uptake studies by Roy *et al.* (1989) near Matheson, Ontario indicated that less than 10% of glyphosate penetrated the fruit in the first nine hours after application. Results of persistence studies showed a gradual decline in residue levels in the fruit with time. Initial residue levels dissipated to approximately 6% after 33 days.

Fertilization: Application of nitrogen fertilizer to red raspberry can either increase suckering and have no effect on height growth, or increase growth without affecting stand density (Lawson and Waister 1972). Lawson and Waister (1972) also observed increased levels of winter mortality following fertilization.

Effects on Conifers

Red raspberry can cause serious problems in conifer plantations within two to five years of site preparation. These problems are more acute on moist, nutrient-rich soils (Whitney 1982, Presslee 1989) and sites where site preparation has mixed the organic layer with mineral soil (Chapeskie *et al.* 1989). Competition is limited to the early stages of conifer stand establishment, since raspberry colonies are quickly eliminated once trees and shrubs begin to cast overhead shade (Haeussler and Coates 1986). Roots and crowns of raspberry compete directly with those of planted conifers for moisture, nutrients and light (Bailey 1984). Competition from raspberry plants reduces diameter growth and adversely affects the nutrient budget of conifer seedlings (Fox 1986). A dense cover of raspberries can suppress small spruce and fir seedlings (Fox 1986). On moist sites, *Rubus* spp. may present serious competition to young pine plantations (Stiell 1955). Raspberries provide excellent cover for rabbits which are capable of destroying or severely retarding the growth of planted conifers (Bailey 1984).

A possible beneficial effect of red raspberry is its ability to limit invasion of taller, longer-lived deciduous species during early stages of succession (Haeussler and Coates 1986). Since red raspberry does not fix atmospheric nitrogen (Watson *et al.* 1980), it cannot benefit conifers in this manner. Raspberries have great erosion control value (Rogers 1974).

Uses by Wildlife

Because of their habit of forming extensive colonies, raspberries have much value as cover for wildlife. Although the thorny canes create nearly impenetrable thickets where birds, rabbits, and other animals find shelter (Rogers 1974, Euler 1979), the thorns may prevent excessive use by other wildlife species (Watson *et al.* 1980). Red raspberry provides excellent summer food for wildlife. Many birds, raccoons (*Pyocyon lotor* L.), chipmunks, and squirrels eat the fruit; rabbits and deer eat the stems. Bears browse on the fruit and foliage (Ahlgren 1960).

Salix spp.
Willows

Although there are numerous species of willows in Ontario, they have been dealt with as a single group because there is little ecological or biological information currently available for the individual species. Three of the most common willows in NW Ontario are *Salix bebbiana* Sarg., *Salix discolor* Muhl. and *Salix humilis* Marsh.

Salix bebbiana Sarg.
Bebb's or Beaked Willow

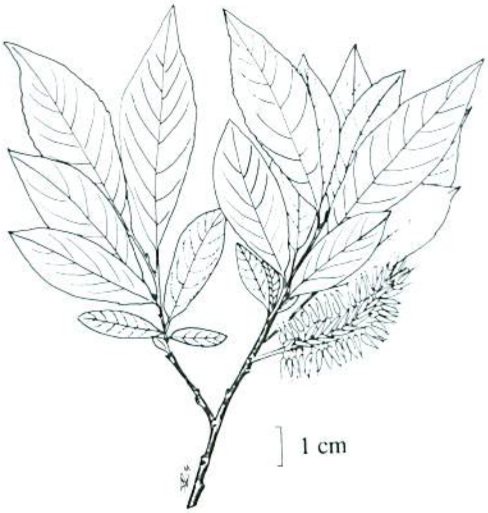
Description

General: large shrub or small tree, 2-6 m high; branches and branchlets ascending, spreading, grey-hairy and reddish brown when young.

Leaves: alternate; elliptic to inversely egg-shaped, pointed at the tip, pointed or rounded at the base; young leaves usually grey-hairy above and below; mature leaves dull green above, whitish, sometimes hairy, with prominent ridged veins beneath; margins smooth, wavy or sparsely toothed.

Flowers: borne on catkins; male and female catkins on separate plants; appearing at the same time as the leaves in May and early June.

Fruit: capsules (5-9 mm long) on the female catkins, usually finely hairy, on a relatively long stalk (2-5 mm long); maturing in June.



Salix discolor Muhl.
Pussy Willow

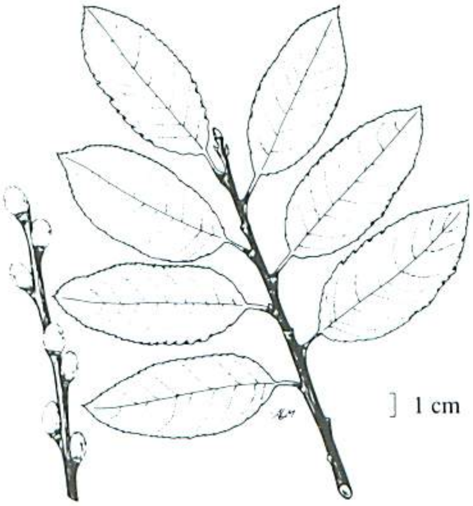
Description

General: large shrub or small tree, 2-6 m high: older branches dark, reddish-brown, often shiny or with a layer of waxy powder; young branchlets usually hairy.

Leaves: alternate; elliptical to inversely egg-shaped or elongated; tip either pointed or blunt, base tapered; bright green, hairless above, whitish, sometimes hairy beneath; margins irregularly wavy or toothed.

Flowers: borne on catkins; male and female catkins on separate plants; appearing before the leaves in May or early June.

Fruit: long-beaked capsules (7-12 mm long) on the female catkins, finely grey-hairy; maturing in June.



Salix humilis Marsh.
Upland Willow

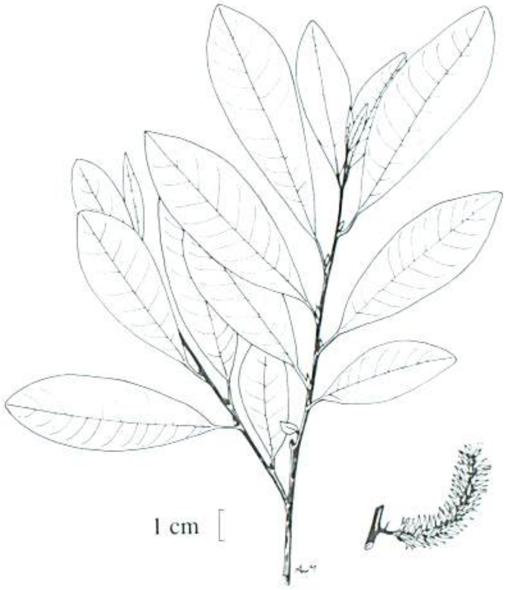
Description

General: low to medium-sized shrub, 1-3 m high; branchlets yellow to brown, hairy or smooth but never shiny.

Leaves: alternate; inversely egg- or lance shaped, tip with a short point, base tapered; young leaves hairy (often rust-coloured hairs), mature leaves grey-green above, whitish and usually hairy beneath; margins entire or undulating, often curled under.

Flowers: borne on catkins; male and female catkins on separate plants; appearing before leaves in May or early June.

Fruit: slender capsules (6-9 mm long) on female catkins, finely grey-hairy; maturing in June.



Habitat

Distribution in Ontario: The range map presents the general Ontario distributions of the 3 willows discussed in this report. Species specific information was obtained from Soper and Heimburger (1982). Bebb's willow is one of the most common and most widely distributed of the willows found in Ontario. It is found from Lake Erie to Hudson Bay and from the Ottawa-St. Lawrence lowlands to the Manitoba border. Pussy willow is common throughout southern and central Ontario and northward from Lake Superior to James Bay. Upland willow is common throughout southern Ontario, along the north shore of Lake Superior and northward in the Boreal Forest Region, becoming rare north of 54°N.

Climate: Willows grow throughout the world, but are best adapted to a cool, moist northern climate (Brayshaw 1976). In temperate and warmer climates willows are often most prevalent in locations with a cool microclimate (Haeussler and Coates 1986). Bebb's willow occurs in subcontinental to continental boreal and cool temperate climates (Klinka *et al.* 1989).

Site and Soil Relations: In NW Ontario, willows occur with relatively low frequency across a wide range of soil textures. Bebb's willow is usually found in moist to wet habitats, sandy or gravelly, rich soils (Rawson 1974, Soper and Heimburger 1982). Within Ontario, willow habitat includes sedge meadows, swamps, bogs, lakeshores, river banks, alluvial flats, deciduous and coniferous forest, limestone flats and sandy jack pine woods. It is a common upland, forest species (Brayshaw 1976, Soper and Heimburger 1982). Pussy willow commonly occurs in moist meadows and along lakes and streams, in alder swamps, cedar woods, wet thickets, and flooded ditches (Rawson 1974, Soper and Heimburger 1982). Upland willow occurs on dry sandy

Distribution of **Bebb's, upland, and pussy willow** in Ontario
(Adapted from: Soper and Heimburger 1982)

uplands, in aspen, jack pine, or oak-pine woods, on outwash deltas and moraines, also on lakeshores and in boggy woods and alder swamps (Soper and Heimburger 1982).

Nutrient Requirements: Willows will tolerate moderately alkaline soils, but do poorly on extremely alkaline or acidic soils (Rawson 1974). The general pH range for willows is 5.5 to 7.5 (Rawson 1974). Bebb's willow is found mainly on medium to nutrient-rich sites within British Columbia (Haeussler and Coates 1986). This species has been noted as a pioneer species on very acidic soil (pH 3.2-4.5) near Sudbury, Ontario (Watson *et al.* 1980). Upland willow is associated with nutrient-poor sites (Kurmis *et al.* 1970).

Moisture Requirements: Although willow species are adapted to the full range of moisture conditions, the majority are found on moist, subhygric and wet sites (Haeussler and Coates 1986). Willow requires a continuous supply of moisture during the growing season (Fowells 1965). Bebb's willow is adapted to a range of soil moisture conditions ranging from well-drained to poorly drained, water logged soils, and can withstand flooding; however, it has a low drought tolerance (Watson *et al.* 1980).

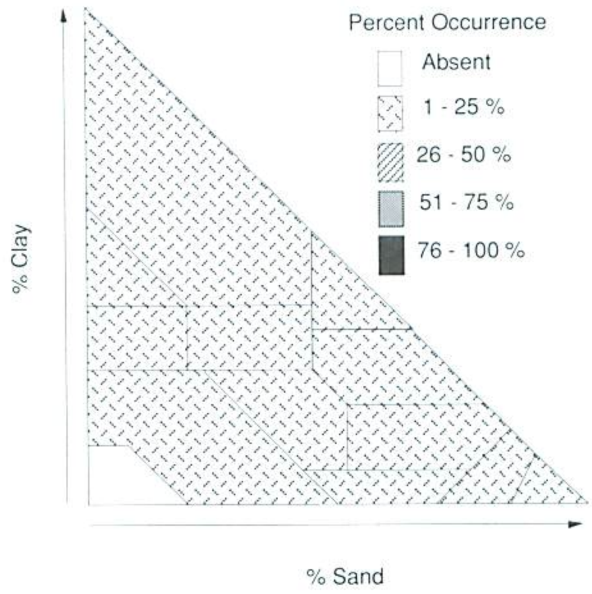
Light Requirements: Willows are moderately to very intolerant of shade and do not compete well where shading occurs. Willows grow rapidly in good soils and full sunlight; under such conditions, they often dominate other species (Rawson 1974, Watson *et al.* 1980). Bebb's willow is a shade-intolerant species (Klinka *et al.* 1989).

Reproduction

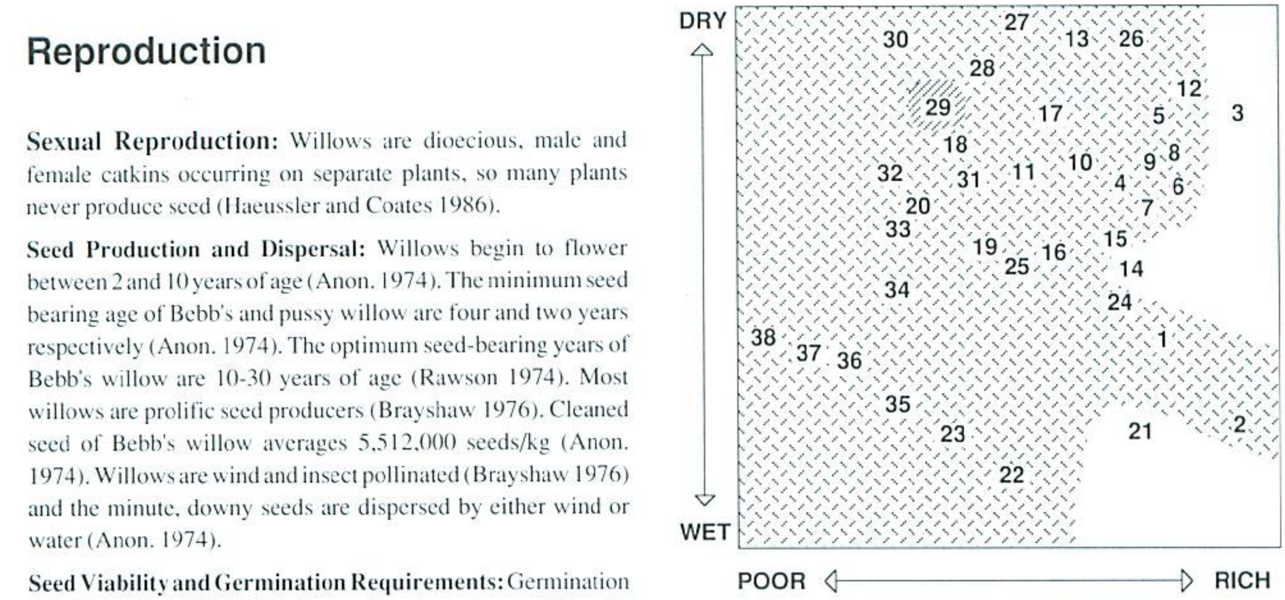
Sexual Reproduction: Willows are dioecious, male and female catkins occurring on separate plants, so many plants never produce seed (Haeussler and Coates 1986).

Seed Production and Dispersal: Willows begin to flower between 2 and 10 years of age (Anon. 1974). The minimum seed bearing age of Bebb's and pussy willow are four and two years respectively (Anon. 1974). The optimum seed-bearing years of Bebb's willow are 10-30 years of age (Rawson 1974). Most willows are prolific seed producers (Brayshaw 1976). Cleaned seed of Bebb's willow averages 5,512,000 seeds/kg (Anon. 1974). Willows are wind and insect pollinated (Brayshaw 1976) and the minute, downy seeds are dispersed by either wind or water (Anon. 1974).

Seed Viability and Germination Requirements: Germination is initially high (70-100%), but tends to decreases rapidly with seed age (Rawson 1974, Zasada *et al.* 1983). Under natural conditions, willow seeds remain viable for only a few days. Seed dormancy is absent in most willow species (Haeussler and



Frequency of occurrence of **Bebb's, upland, and pussy willow** by NWO FEC soil texture type



Frequency of occurrence of **Bebb's, upland, and pussy willow** by NWO FEC vegetation type

Coates 1986). Germination of Bebb's willow seed is rapid and can be 80% complete within two weeks after artificial seeding (Zasada *et al.* 1983).

Seeds normally germinate within 12-24 hours after landing on a suitable seedbed (Rawson 1974). Germination is best under conditions at high relative humidity and full sunlight (Anon. 1974). Exposed mineral soil provides the best seedbed for many willow species, and germination of the small seed is inhibited on sites with a continuous cover of tree litter (Grime 1979).

Vegetative Reproduction: Damaged or cut stems produce numerous sprouts from the stem base or root collar (Haeussler and Coates 1986). Layering occurs readily if branches are buried in moist soil (Hauessler and Coates 1986). Stem cuttings of Bebb's willow, taken during the growing season, root particularly well (Holloway and Zasada 1979).

Growth and Development

Willow species normally have relatively short lifespans (40-60 years on a good site) and, except for a dozen species which grow into timber-sized trees, they are shrub-like (Cayford and Bickerstaff 1968, Ericsson 1984). Many species form dense thickets on wet sites, but upland willows often occur as scattered individuals (Haeussler and Coates 1986). Willows exhibit rapid early growth from both seeds or sprouts (Rawson 1974). Sprout growth exceeds that of seedlings and can exceed two metres in one year (Haeussler and Coates 1986). Willows in general have shallow, dense root systems (Watson *et al.* 1980). Upland willow has been observed to live up to 43 years (Brown 1953).

Phenology

Root, Shoot and Foliage: Information regarding root, shoot or foliage phenology of willows was not found in the literature.

Reproductive Structures: Willow species typically have an early flowering phenology (Haeussler and Coates 1986) and often complete anthesis in a few days (McWilliams and Ludwig 1972). Bebb's willow flowers from April to June. The fruit ripens soon after flowering and seed dispersal occurs from May to June (Anon. 1974). Pussy willow flowers from April to early May (McWilliams and Ludwig 1972) and blooms for a period of about two weeks within a given locality (Heinrich 1976). The capsules ripen soon after flowering in late May- early June, before the leaves expand (Soper and Heimburger 1982). Upland willow catkins are fully developed (May to early June) before the leaves expand. Capsules are present in June and July (Soper and Heimburger 1982).

Response to Disturbance

Overstory Removal: Frequency of occurrence and percent cover generally increase following overstory removal. Mueggler (1965) found that crown cover of willow was 10 times greater on areas with low overstory cover than under a closed canopy. Increased sunlight following overstory removal is very favourable to willow (Haeussler and Coates 1986). Cut or damaged willow will sprout vigorously (Haeussler and Coates 1986). Willows seed into clearcuts after disturbance, particularly on wetter sites (Hamilton and Yearsley 1988a).

Fire: Although aerial parts of willow are easily killed by fire, eradication of willows through fire is highly unlikely; willows have been known to survive even the most intense forest fires. Comparisons of burned and unburned sites show that willows are favoured by burning. They resprout readily from the root crown after fire (Hamilton and Yearsley 1988b). The vigour and intensity of spouting may be affected by the intensity and duration of the burn. A quick, hot fire maximizes sprouting, while a slower, longer burn causes extensive damage and reduces sprouting (Haeussler and Coates 1986).

Soon after burning, willows can flower profusely from young sprouts and produce large quantities of seed (Auclair 1983). The most receptive seedbeds are those that are burned severely (Zasada *et al.* 1983). Leaving only a very small amount of residual organic matter seems to make a significant difference in germination success (Zasada *et al.* 1983). Bebb's willow is a common invader of dry to fresh, burned sites (Rowe 1983).

Prescribed fire is widely used as a wildlife management tool to rejuvenate decadent willow and stimulate sprouting (Haeussler and Coates 1986).

Mechanical Site Preparation: If scarification removes the root system, willow competition should be reduced (Habgood 1983). Following a survey of plantations in NW Minnesota, Ohmann (1982) found that above-average willow biomass occurred on sites that had received a disk treatment prior to planting conifers and a below-average biomass on sites that had received a rock-rake treatment. Windrowing has been used to stimulate willow browse production because mechanical damage to stems stimulates prolific sprouting (Haeussler and Coates 1986). Branch parts incorporated into the mineral soil during mechanical treatments have the potential to root and subsequently regenerate new plants. Exposure of mineral soil following site preparation favours the germination of willow seed.

Cutting: Manual treatments are usually used to increase production of willow browse and are not considered an effective means of reducing frequency and cover. It is possible for individual cut stems to produce 50 to 60 sprouts after cutting, but sprout number is quite variable (Haeussler and Coates 1986).

Although willows sprout vigorously if cut, regardless of the cutting season, willows cut during the dormant season will sprout most vigorously.

Heavy clipping increases twig production (Aldous 1952). Over five years of cutting, annual production increased steadily to 855% of initial production.

Chemical Treatments: Herbicide response in willows is difficult to monitor because of the difficulty of identifying willow species (Haeussler and Coates 1986). Because willow is one of the most important forage species for ungulates, trials are necessary to determine response on a species level (Balfour 1989). The response of willows to 2,4-D, hexazinone and glyphosate are discussed separately.

2,4-D: Willows are rated as susceptible to 2,4-D (Anon 1986, Rawson 1974). Adequate control of most willow species can be obtained with a single application of 2,4-D (Chemagro Corporation 1953, Sutton 1969). 2,4-D is most effective if applied early in the growing season while the new growth is still succulent. Upland and Bebb's willow are easily killed by 2,4-D, but they resprout vigorously and generally increase in frequency of occurrence. Height growth following treatment tends to be retarded (Schacht and Hansen 1963).

Hexazinone: Willows are rated as intermediately susceptible to Velpar-L; approximately 12-14 l/ha are required to control willow on medium-textured soils (Corcoran 1989). Hexazinone has demonstrated the ability to seriously injure willow and these injuries may be persistent; however, the results have been highly variable (Balfour 1989).

Glyphosate: Willows are susceptible to glyphosate, but are not as susceptible as trembling aspen or white birch (Sutton 1984). Results with glyphosate have been highly variable (Balfour 1989). Applications of glyphosate have resulted in varying degrees of defoliation and have generally been followed by sprouting. Applications of 1.7, 2.2 and 3.4 kg/ha have resulted in 45 (range 0-80%), 60 (range 21 to 100%) and 63 (range 15 to 100%) percent control of willow in the second post-spray season (Boyd *et al.* 1985). At a site near Dawson Creek, B.C. an aerial application at 3.0 kg a.i./ha to Bebb's willow resulted in a 70% defoliation after the first growing season, but few coppice stools were completely killed (Haeussler and Coates 1986). An application of 7 l/ha on July 25 in Minnesota did not reduce the number of willow stems (Butler-Fasteland 1987). However, Sutton (1984) noted that willows were controlled by glyphosate applied at 4.0 kg a.i./ha in mid-July.

Fertilization: Bebb's willow has been observed invading barren acid soils near Sudbury, particularly after such soils received amendments of lime and phosphate (Watson *et al.* 1980).

Effects on Conifers

Rapid early growth, especially by plants of sprout origin, allows willow to quickly outgrow competitors (Rawson 1974). Willows compete with conifer regeneration by shading and competing for soil moisture and nutrients; and they could cause mechanical damage if bent down by snow on top of seedlings (Habgood 1983). The canopy of mature willow seldom creates deep shade, but juvenile growth may have larger leaves and dense sprouts can produce a solid canopy (Haeussler and Coates 1986, Klinka *et al.* 1989). Willows are likely to be strong competitors for soil moisture because they transpire large quantities of water (Kozlowski 1972). The evapotranspiration in young willow stands located in southern Sweden on hot, clear days can be as high as 5 mm/day (Grip and Perttu 1982). Since willows do not fix atmospheric nitrogen (Watson *et al.* 1980), they cannot benefit conifers in this manner. Willows are useful for soil stabilization (Watson *et al.* 1980).

Snowshoe hare, which consume twigs and bark of willows during the winter, may also cause damage to conifer seedlings by nipping shoots (Habgood 1983).

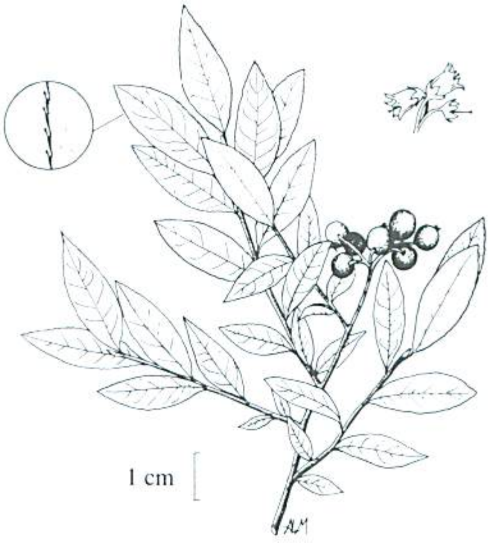
Uses by Wildlife

Willows are a major and preferred browse species throughout most of their range and a prime source of food for moose and deer (Rawson 1974, Peek 1974, Zach *et al.* 1982). Willow are browsed all year by moose, but receive greatest use in September through December (Stevens 1970, Peek 1974, Timmermann and McNicol 1988). Bebb's and pussy willow are preferred willow species (Peek 1974). Willows are more important as summer food for deer (Aldous 1952). Willows tolerate relatively high levels of browsing and must be browsed at least moderately to stay within the reach of deer (Aldous 1952). Willow shoots and buds are eaten by many rodents, including muskrats and beaver as well as rabbits and hare (Rawson 1974). Following heavy browsing, willows revert to a juvenility stage by producing adventitious shoots (Radvanyi 1987). These new juvenile growths have increased production of phenolic substances and resins that serve as defensive functions against additional snowshoe hare browsing (Radvanyi 1987). Snowshoe hare almost totally avoid eating adventitious shoots of willow if the growth is less than four years old. After that, the shoots are highly palatable (Radvanyi 1987).

Willow buds and twigs are utilized to varying degrees by several members of the grouse family (Rawson 1974). Certain ducks and waterbirds feed on willow catkins and leaves (Rawson 1974). Because of their abundance and thicket-forming habits, willows provide cover and protection for many wild birds and mammals (Rawson 1974).

Vaccinium angustifolium Ait.
Lowbush Blueberry

Description



General: low, branching shrub <50 cm high, usually forming large patches (often in association with *V. myrtilloides*); branchlets greenish with small warty dots, essentially hairless.

Leaves: alternate; oval to narrowly elliptic or even lance-shaped, tapering at both ends; thin, bright green, hairless or with a few hairs along the veins beneath; margins minutely toothed with glandular teeth.

Flowers: in crowded clusters; individual flowers bell- or urn-shaped with 5 fused lobes, white or pale pink, <6 mm long; appearing in May and early June.

Fruit: a bright blue berry with a whitish, powdery coating; ripening in late July and August.

Habitat

Distribution in Ontario: Lowbush blueberry is widely distributed from Lake Erie northward to the Lake Superior Region, becoming less frequent north of 50°N (Soper and Heimburger 1982).

Climate: Lowbush blueberry tolerates a wide range of climatic conditions. In eastern Canada, winter temperatures are generally ameliorated by snow cover. Inadequate snow cover may be followed by shoot dieback to ground level (Hall *et al.* 1979). One of the most important factors limiting flowering and fruit development is the occurrence of late spring frosts, especially in low-lying areas (Hall *et al.* 1979). Although lowbush blueberry borders the tundra in Canada, for optimum growth this species requires at least a 125 day growing season (Chandler 1943).

Site and Soil Relations: Lowbush blueberry is found in dry, sandy or rocky clearings and open woods, along roadsides, in and around Sphagnum bogs (Soper and Heimburger 1982). It is not characteristic of wet habitats such as marshes or lake margins (Hall *et al.* 1979). In NW Ontario, lowbush blueberry occurs more frequently on sandy soils than on silts or clays. Blueberries achieve their best growth on coarse-textured, well-drained, acidic soils with high organic matter content (Rogers 1974). Fine-textured soils with poor drainage prevent root penetration and thereby increase the probability of frost heaving. Coarse sandy soils may present droughty and poor growing conditions for lowbush blueberry during summer months (Rogers 1974).

Distribution of **lowbush blueberry** in Ontario
(Adapted from: Soper and Heimburger 1982)

Nutrient Requirements: In NW Ontario, lowbush blueberry occurs most frequently on nutrient poor sites. Blueberries, like most members of the Heath family, prefer acidic soils (Rogers 1974). Optimum growth of blueberries occurs when soil pH is between 4.3 and 4.8 (Kender and Brightwell 1966). However, blueberries are commonly found on soils with pH values ranging from 3.5 to 5.5 (Ballinger 1966).

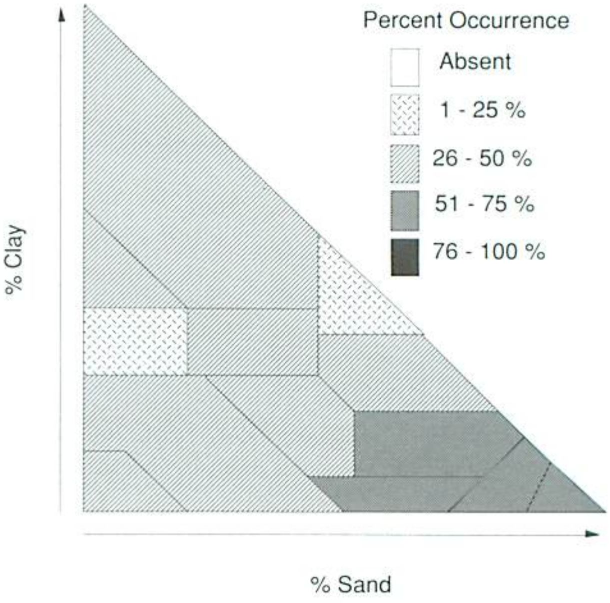
Moisture Requirements: In NW Ontario, lowbush blueberry occurs most frequently on dry to fresh soils. Prolonged drought conditions may result in reduced shoot growth, reduced flower bud formation and/or shrivelling of fruit (Hall *et al.* 1979). During dry periods, blueberries are hindered in water uptake because they lack root hairs (Rogers 1974). During the dormant period lowbush blueberry can withstand flooding, such as that which occurs in many bogs (Hall *et al.* 1979).

Light Requirements: Blueberries are relatively intolerant of shade (Rogers 1974). Shading reduces vegetative growth and flower bud formation (Smith 1962, Rogers 1974). Hall (1955) found that 0.5% of full sunlight under a red spruce-balsam fir canopy gave minimum growth, 10% sunlight under a birch canopy gave moderate vegetative growth but no flowering, and 50% sunlight (openings in canopy) resulted in flowering and fruiting.

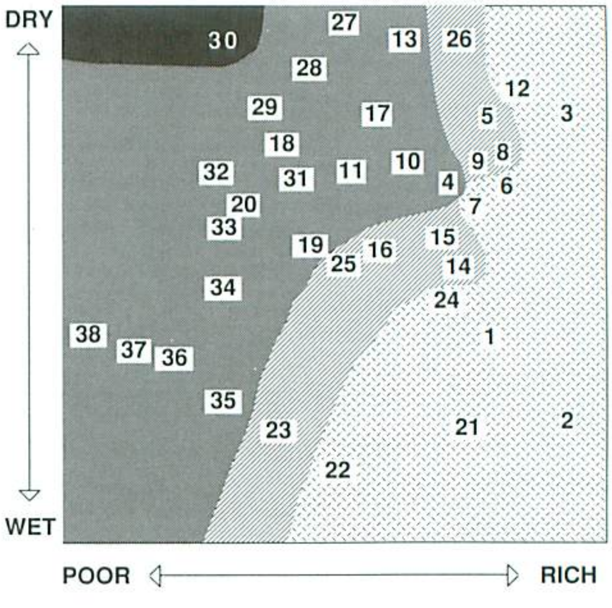
Reproduction

Sexual Reproduction: Sexual reproduction predominates in areas where the soil has recently been denuded by cultivation, flooding, or blowdown of forest trees (Hall *et al.* 1979).

Seed Production and Dispersal: Plants rarely flower until four years after germination (Hall *et al.* 1979). The number of seeds (up to 64) found in a berry depends on genetic factors and environmental conditions (Hall *et al.* 1979). If velvet leaf blueberry is present in the stand, lowbush blueberry pollen will be diluted and fruit production will be reduced (Aalders and Hall 1961). Velvet leaf blueberry pollen is incompatible with lowbush blueberry pollen. The number of cleaned seed/kg of fruit for lowbush blueberry is 4,348,000; range 4,000,100 to 4,762,000 (Anon. 1974). Insects, specifically honeybees, are the chief pollinating agents of lowbush blueberries (Rogers 1974, Hall *et al.* 1979). Both fruit yield and fruit size are a function of the bee population in a given area (Rogers 1974). Seed is disseminated primarily by birds, small mammals, bears and raccoons from June through September (Rogers 1974, Hall *et al.* 1979). The American robin is a major seed disperser in SW New Brunswick (Eaton 1957).



Frequency of occurrence of **lowbush blueberry** by soil texture class



Frequency of occurrence of **lowbush blueberry** by NWO FEC Vegetation Type

Seed Viability and Germination Requirements: Seed germination occurs only after periods of prolonged rainfall in late summer or early fall (Hall *et al.* 1979). Loamy and sandy loam soils with a high percentage of stone or gravel provide conditions most favourable to the emergence, growth and development of blueberry seedlings (Jackson *et al.* 1972). Germination is greater in light than in dark (Hall *et al.* 1979). Fresh seeds of lowbush blueberry extracted from well-ripened berries, germinate readily at 21°C under 16 h light per 24 h period and usually take 21 days. Seedling mortality is very high, ie. >99% of germinating seeds die even under partially controlled conditions (Hall *et al.* 1979).

Vegetative Reproduction: Blueberries reproduce from sprouts, underground stems and suckers (Rogers 1974). Asexual reproduction occurs when rhizomes are cut or killed (Hall *et al.* 1979). Plants rarely produce rhizomes until 4 years after germination (Hall *et al.* 1979). Plants may be propagated from either rhizome or stem cuttings (Hall *et al.* 1979).

Growth and Development

The maximum height of lowbush blueberry is about 0.6 m (Rogers 1974). Growth of lowbush blueberry is relatively slow, even with optimal site conditions (Rogers 1974). During prolonged drought in early summer, shoot growth is reduced (Hall *et al.* 1979). The ability of lowbush blueberry to grow on very poor soils and at the same time produce a heavy crop of fruit may be due to its extensive tap root system. Tap roots of older plants have been found 0.9 m below ground level (Hall 1957). Lowbush blueberries may form extensive colonies by means of underground stems (Camp 1945) on both mineral and organic soils (Hall *et al.* 1979). In soils with much humus, most rhizomes grow in the top 5 cm of mineral soil (Trevett 1956, Hall *et al.* 1979). Lowbush blueberries may form extensive colonies by means of underground stems (Rogers 1974). Clones may attain both a significant size (>10 m diameter) and age (>150 years) (Hall *et al. 1*979). After plants reach a total width of 30 cm and rhizome growth occurs in several directions, clones expand more rapidly. Rhizomes may grow up to 10 cm/year in mineral soils and up to 50 cm/year in organic soils. Clones with intact rhizomes 10 m long have been excavated.

Phenology

Root, Shoot and Foliage: Kender (1968) found that growth potential of rhizome buds was greater in early spring and late summer than in July. Termination of shoot growth, as evidenced by a black tip in the apical meristem, occurs in early July (Hall *et al.* 1979). Leaf development may occur before, with or after flowering depending on the particular clone. Leaves harden by mid-July, turn a brilliant red or yellow in late August to mid-October with about 50% abscission by the first of October. Lowbush blueberry overwinters in a leafless stage, with yellow to reddish brown twigs.

Reproductive Structures: Flower buds are formed during the previous year. Flower primordia begin to develop shortly after cessation of vegetative growth, but continue until late October if air temperatures remain >0°C with extended periods greater than 10°C. By winter, primordia of the floral organs are microscopically recognizable (Bell and Burchill 1955a). Lowbush blueberry flowers appear with the leaves from April to June (Rogers 1974, Anon. 1974). At Kentville, Ontario flower buds swell in early May if air temperatures have exceeded 10°C for three to four days (Hall *et al.* 1979). Lowbush blueberry fruit mature from July to August, 90 to 120 days after blooming (Rogers 1974, Anon. 1974).

Response to Disturbance

Overstory Removal: Removal of the overstory will stimulate the lowbush blueberry root system and increase the vigour, abundance and fruit yields of the plants (Rogers 1974). Complete removal of overstory vegetation will result in maximum flowering and fruiting of blueberries (Rogers 1974).

Fire: The vegetative parts of lowbush blueberry are remarkably fire tolerant (Ahlgren 1960). Initial sprouting after a fire occurs at the base of fire-pruned aerial stems. Sprouts from buried stems become evident later than those from fire-pruned aerial stems (Lotan *et al.* 1981). Resprouting may be observed within two weeks after a fire (Martin 1955). Sprouting may be delayed on severely burned sites as a result of heat damage to underground parts (Ahlgren 1960). Blueberries can flower profusely from young sprouts soon after burning (Auclair 1983). There are no significant differences between fall- and spring-burned plants with respect to amount of shoot growth and number of flower buds per shoot (Hall *et al.* 1979). Burning after the plants are in full leaf is detrimental to new shoot growth and flower bud formation (Eaton and White 1960).

As an agricultural crop, blueberry fields are burned in early spring, while the soil is still frozen or thoroughly wet so as to minimize the detrimental effects burning might have on the surface soil horizons and blueberry rhizomes (Black 1963). Commercial stands are burn-pruned every second year resulting generally in unbranched stems which have more flower buds per stem and more flowers per bud than older stems.

Low ericaceous shrubs such as blueberries have high percentages of ether extractives, and relatively high lipid contents and lipid-free caloric values. This results in relatively high flammability (i.e. low temperature for ignition) and high heats of combustion (Auclair 1983). Blueberry plants also may form a continuous complex of fine fuels on the forest floor, thus allowing for the rapid spread of fires (Auclair 1983).

Mechanical Site Preparation: Lowbush blueberry can readily colonize abandoned farm fields (Hall *et al.* 1979).

Cutting: Removal of shoot tips results in increased lateral branching (Hall *et al.* 1979) and increased fruit production (Rogers 1974). Fruit is produced in greater quantities on 1-year old shoots than on older mature branches (Rogers 1974).

Chemical Treatments: The response of lowbush blueberry to 2,4-D, hexazinone, glyphosate will be discussed separately.

2,4-D: Lowbush blueberry can be killed with a moderate foliar application of 2,4-D at the time when it is most susceptible (Chemagro Corporation 1953). The response of lowbush blueberry to 2,4-D is dependent on the date of application. When applied during mid-September, 2,4-D significantly reduces the number of fruiting and non-fruiting stems produced in the following year. Tolerance to 2,4-D increases linearly with applications made after mid-September applications and is related to the senescence and abscission of the blueberry foliage (Jensen and North 1987). 2, 4-D causes a twisting of the terminal growth followed by browning and leaf fall (Hall *et al.* 1979). Although blueberries are killed by foliar applications of 2,4-D, partially selective treatments have been developed based on roller or wiper applications, spot treatments or applications made during blueberry dormancy (Jensen and North 1987).

Hexazinone: Blueberries are rated as very tolerant to Velpar-L; more than 14 l/ha are required to control blueberries on medium-textured soils (Corcoran 1989). Velpar-L is licensed for use in the commercial production of lowbush blueberries (Dupont Canada 1987). Velpar-L can be applied to control competing vegetation in blueberry plantations. Applications of 6.0 to 8.0 l/ha in the spring, after burning operations but before blueberry leaves emerge, resulting in little harm to blueberries. Blueberries seem to be unaffected by mid-July foliar applications of hexazinone, even at 4.0 kg a.i./ha (Sutton 1984). Some clones of lowbush blueberry are sensitive to Velpar-L. Temporary defoliation of the lower leaves will occur, but plants recover (Dupont Canada 1987).

Glyphosate: Rates of 1.12 to 3.36 kg a.i./ha provide effective control of lowbush blueberry for at least three years (Anon. 1988). At the beginning of the fourth year, the degree of control provided by the 1.12 kg a.i./ha rate may decrease markedly.

Fertilization: Information pertaining to the response of lowbush blueberry to applications of fertilizers was not found in the literature.

Effects on Conifers

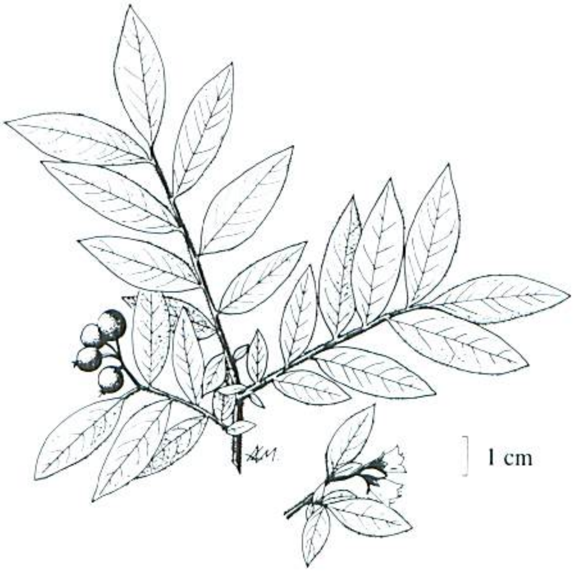
The high concentration of roots and rhizomes near the soil surface allow lowbush blueberry to absorb considerable water from light rains (Laycock 1967). Lowbush blueberry does not appear to have allelopathic effects, either as it relates to germination or growth, of jack pine (Brown 1967).

Uses by Wildlife

White-tailed deer browse the branches and foliage and eat the fruit (Rogers 1974). Woodland caribou heavily browse lowbush blueberry in the spring (Bergerud 1972). Fruits are eaten by a number of mammals (Hall *et al.* 1979). Fur and game mammals such as black bear, red fox, cottontail rabbit and skunk utilize the fruit, twigs and/or foliage of lowbush blueberry (Rogers 1974). For several species of grouse, blueberries are among the most important summer and early fall foods. Many song birds, including bluebird and thrush also feed on blueberries (Rogers 1974).

Vaccinium myrtilloides Michx.
Velvet Leaf Blueberry

Description



General: low, branching shrub <50 cm high, often forming large patches (usually in association with *V. angustifolium*; branchlets densely velvety hairy, bark often peeling from older stems revealing crowded warty dots.

Leaves: alternate; oval to narrowly elliptic, tapering at both ends; thin, soft, covered by downy hairs (at least the lower surface); margins entire and finely hairy.

Flowers: in crowded clusters; individual flowers bell-shaped or cylindrical with 5 fused lobes, white or tinged with pink, <6 mm long; appearing in May and early June.

Fruit: a dark blue berry with a whitish, powdery coating; ripening in late July and August.

Habitat

Distribution in Ontario: Velvet leaf blueberry is widely distributed throughout Ontario, except for the northernmost areas near Hudson Bay (Soper and Heimburger 1982).

Climate: Since velvet leaf blueberry occurs throughout several of Rowe's (1972) Forest Regions, viz., Subalpine, Boreal, Great Lakes-St.Lawrence and Acadian, the species is obviously adapted to a wide range of climatic conditions (Vander Kloet and Hall 1981). It tolerates a potential growing season of 200 days in the south and 100 days in the north (Vander Kloet and Hall 1981).

Site and Soil Relations: Velvet leaf blueberry is found in dry or moist, sandy or rocky clearings and open woods, and also in Sphagnum bogs and swamps (Soper and Heimburger 1982). Velvet leaf blueberry achieves its highest abundance on well-drained sandy sites dominated by pines (Vander Kloet and Hall 1981). In NW Ontario, velvet leaf blueberry occurs more frequently on silty and sandy soils than on clays.

The thickness of the soil organic layer influences the abundance of velvet leaf blueberry. An increase in numbers of this species accompanies an increase in the thickness of the organic layer (Smith 1962).

Nutrient Requirements: In NW Ontario, velvet leaf blueberry occurs most frequently on soils of low nutrient status. The nutrient occurring in the greatest amount in mature leaves of velvet leaf blueberry is nitrogen, generally in the concentration range of 1.5-2.0%. Phosphorus is lowest at about 0.1% (Vander

Distribution of **velvet leaf blueberry** in Ontario
(Adapted from: Soper and Heimburger 1982)

Kloet and Hall 1981). Velvetleaf blueberry has been observed on soils with pH values ranging from 3.0 to 5.6 (Vander Kloet and Hall 1981).

Moisture Requirements: Velvet leaf blueberry prefers sites with good soil moisture conditions (Smith 1962). Maycock and Curtis (1960) have shown that velvet leaf blueberry has a bimodal distribution along the moisture gradient in the forests of the Upper Great Lakes Region, i.e., it has peaks of presence and abundance on dry sites and wet sites. This bimodal distribution also occurs in NW Ontario. Velvet leaf blueberry occurs most frequently on V-Types 11, 18, 27-32, and 35. Jeglum (1971) found that the presence of velvet leaf blueberry in the peatlands of Saskatchewan indicated that the water level was more than 80 cm below the ground surface.

Light Requirements: Velvet leaf blueberry is shade-tolerant/ intolerant (Klinka *et al.* 1989). Heavy shade is detrimental to its growth and production. Vander Kloet and Hall (1981) have observed plants just surviving in closed canopy white spruce-balsam fir stands. However, numbers of shoots may be higher under heavy shade conditions than under exposed conditions. Velvet leaf blueberry may increase potential leaf surface in reduced light (Smith 1962).

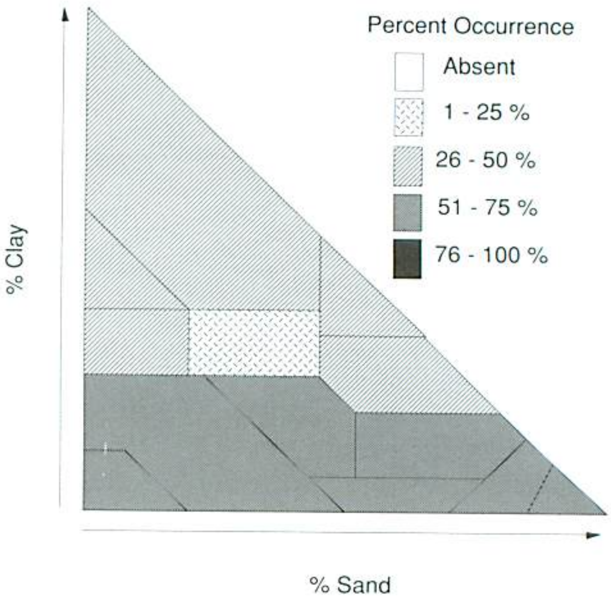
Reproduction

Sexual Reproduction: Seed production, dispersal, viability and germination are discussed.

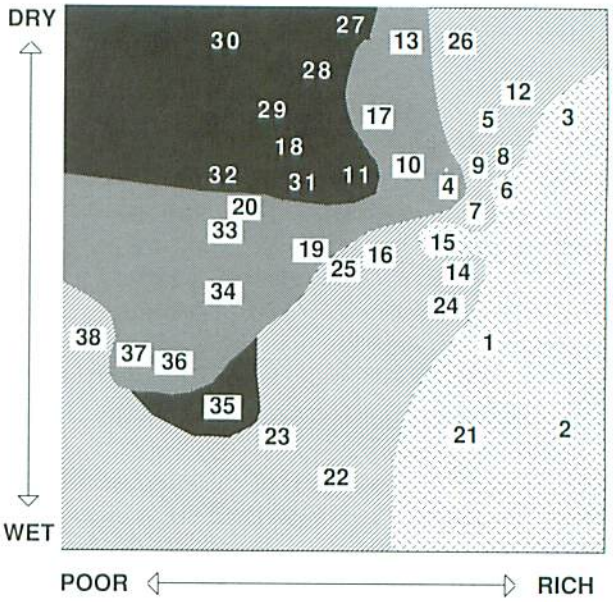
Seed Production and Dispersal: The number of viable seeds per berry in the field is 16 ± 10. Seed weights are 26 ± 7 mg/100 seeds (Vander Kloet and Hall 1981). The American robin is a major seed disperser in New Brunswick (Vander Kloet and Hall 1981).

Seed Viability and Germination Requirements: Nichols (1934) reported a germination success of 20% and Vander Kloet and Hall (1981) obtained 30%. Viability is reduced by at least 10% after excretion by birds and mammals (Krefting and Roe 1949).

Vegetative Reproduction: Velvet leaf blueberry reproduces well by rhizomes on both mineral and organic soils, provided adequate moisture and aeration are available (Vander Kloet and Hall 1981). Stallard (1929) found that the rhizomes of velvet leaf blueberry often exceed several metres in length. Asexual reproduction occurs when the older rhizomes senesce, are cut by slope creep, or where partial kill results from fire, shading, or frost heaving (Vander Kloet and Hall 1981).



Frequency of occurrence of **velvet leaf blueberry** by soil texture class



Frequency of occurrence of **velvet leaf blueberry** by NWO FEC Vegetation Type

Growth and Development

Smith (1962) found that rhizome length of mature velvet leaf blueberry plants ranged from 100 to 1400 cm. Rhizomes produced an average of one to two shoots for each 100 cm of rhizome length, depending on the density of the overstory. Lateral growth of the rhizome system below ground is a means of continuous advancement of a particular clone. Branching of rhizomes is strongly dichotomous following the cessation of growth in the dormant period (Vander Kloet and Hall 1981). Injury to the growing point of a rhizome will produce a similar effect, as two lateral buds are then stimulated to grow one on either side of the original growing point (Vander Kloet and Hall 1981). Once the plant has attained a diameter of about 20-30 cm and rhizome growth occurs in several directions, expansion of the clone is rapid (Vander Kloet and Hall 1981). Rhizomes of individual clones differ considerably in the number of shoots, rhizome growing points, major shoot locations, dead shoots and the number of decayed rhizome ends. There are also wide variations in the depth, total length and radial growth of rhizomes as well as in depth of shoot origin, shoot position and numbers of shoots (Smith 1962).

Organic horizons of the soil contain the bulk of the rhizomes because these layers provide a favourable physical, chemical and biological environment and a path of least resistance to growth (Trevett 1956). The thickness of the soil organic layer influences the abundance of velvet leaf blueberry. An increase in numbers of this species accompanies an increase in the thickness of the organic layer (Smith 1962). Smith (1962) found that the depth of the rhizomes varied from 4.5 ± 0.9 to 9.0 ± 2.8 cm, depending on the thickness of the organic horizon. The thicker the organic horizon, the shallower the rhizome system. All rhizomes have numerous small roots scattered along their entire length which extend into the surrounding organic and mineral soil horizons. Often several large or major roots are found per clone and range in diameter from 0.01 to 0.05 cm. These major roots extend deeper into the soil and branch frequently.

For velvet leaf blueberry, 72% of aerial shoots are located terminally on the rhizome and 28% arise from mid-rhizome locations (Smith 1962). The current growth of a rhizome growing point is characterized by the presence of leaf scales or modified leaves which are absent from older rhizome growth. Shoots of velvet leaf blueberry have been found to originate from depths as far as 11 cm below the ground surface.

Once a plant becomes established, it takes a major change in vegetation, such as the development of a multilayered overstory, to destroy the clone. In the 25-30 years that are often required for the forest canopy to develop, the clone may grow up to 10 m in diameter and spread to adjoining areas (Vander Kloet and Hall 1981). Velvet leaf blueberry has a much higher survival potential than lowbush blueberry in a mature forest (Hall *et al.* 1979). Under heavy competition in old fields, seedling growth is slow, requiring at least five years for a plant to reach 15 cm in diameter (Vander Kloet and Hall 1981). Rhizome growth will continue as long as a few shoots grow and translocate carbohydrates back to storage tissues in the rhizomes.

Phenology

Root, Shoot and Foliage: Leaf and vegetative shoot development may occur before, with, or after flowering depending on the particular clone. The formation of a black tip at the apical meristem indicates cessation of shoot growth (Vander Kloet and Hall 1981). Velvet leaf blueberry overwinters in a leafless state, with greenish, yellowish or brown twigs.

Reproductive Structures: Flower primordia are formed in the previous summer, shortly after the cessation of vegetative growth. Flower primordia may continue to be formed until late October if air temperatures remain >0°C with extended periods greater than 10°C (Bell and Burchill 1955a). In eastern Ontario, the vegetative and flower buds begin to swell in late April or early May, if night air temperatures have exceeded 6°C for 4 to 5 days. Anthesis usually occurs between May 22 and May 28 (Wood 1965). In northern Quebec, Labrador, Ungava, northern Ontario, northern Manitoba, Saskatchewan, northern Alberta and the Northwest Territories, flowering usually occurs from late May to early July (Vander Kloet and Hall 1981). Berries generally ripen 49-68 days after flowering (Vander Kloet and Hall 1981).

Response to Disturbance

Overstory Removal: Clearcutting of balsam fir and red spruce in the Maritime Provinces stimulated velvet leaf blueberry to produce vigorous shoots (Hall 1955).

Fire: Velvet leaf blueberry thrives in frequently burned forest ecosystems (Rowe 1983), responding best to light burns (Archibold 1979). Rhizomes usually survive even the most severe burns if the rhizomes are deep enough in the soil (Vander Kloet and Hall 1981). Since blossoms and fruit are borne on the previous season's growth, a large proportion of strong, new shoots is required for fruit production. The results of a 9-year rotational burning study indicated that total fruit production was greater from burning every second year than from every third year (Black 1963). Spring fires that occur after the snow has gone, but before the frost is out of the ground, enhance blueberry fruit production (Black 1963). On relatively infertile and dry sandy sites, where competition from herbs is not intense, velvet leaf blueberry populations expand rapidly, with peak flower and fruit production usually occurring 10 to 20 years after fire and prior to tree canopy closure, after which they decline in cover and fruit production (Vander Kloet and Hall 1981).

Mechanical Site Preparation: Cultivation may increase the abundance of velvet leaf blueberry since it cuts the rhizome into segments that may continue to grow and produce shoots (Hall 1963).

Cutting: Destruction of the terminal growing point of either the shoot or rhizome will destroy apical dominance and result in the development of one or more new growing sites (Vander Kloet and Hall 1981).

Chemical Treatments: The response of velvet leaf blueberry to 2,4-D, hexazinone and glyphosate will be discussed separately.

***2,4-D*:** Information pertaining to the response of velvet leaf blueberry to applications of 2,4-D was not found in the literature.

***Hexazinone*:** Velvet leaf blueberry is sensitive to Velpar -L (Dupont Canada 1987).

***Glyphosate*:** Chemical applications of glyphosate are typically made in mid-to late summer when the fruit is fully ripe (Roy *et al.* 1989). Uptake studies near Matheson, Ontario indicated that less than 10% of glyphosate penetrated the fruit in the first 9 hours after application. Results of persistence studies showed a gradual decline in residue levels with time. Initial residue levels dissipated to approximately 4% after 61 days.

Fertilization: Information pertaining to the response of velvet leaf blueberry to applications of fertilizers was not found in the literature.

Effects on Conifers

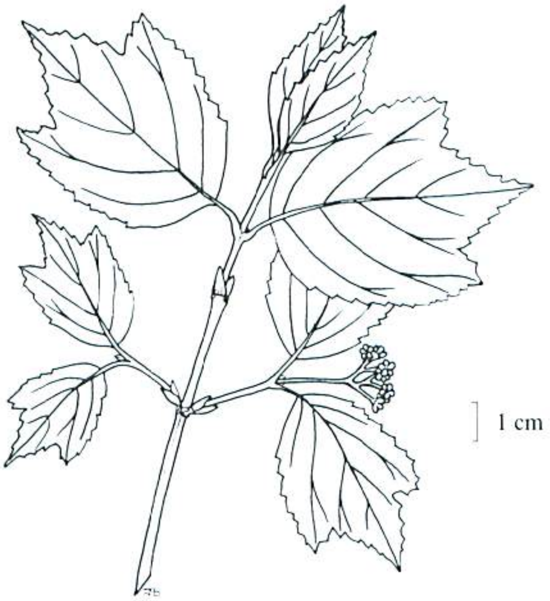
Velvet leaf blueberries may cause a loss in the expected volume of merchantable timber on sandy sites through competition for moisture (Wilde *et al.* 1968). The rhizome system of velvet leaf blueberry, once established, plays an important role in preventing slope erosion. Should soil particles be washed into the network of rhizomes and shoots, new roots and shoots develop in the additional soil, favouring the plant and retaining the soil (Vander Kloet and Hall 1981).

Uses by Wildlife

Foliage and twigs of velvet leaf blueberry are eaten by a number of mammals, chief of which are white-tailed deer and eastern cottontail. Fruits are eaten by raccoon, white-tailed deer, red fox, black bear and porcupine (Vander Kloet and Hall 1981). Fruits are eaten by several birds, most notably the American robin.

Viburnum spp.
Squashberry/Highbush Cranberry

Viburnum edule (Michx.) Raf.
Squashberry



Description

General: erect or straggling shrub usually <1.5 m high; branchlets smooth, hairless, purplish-brown, often angled with longitudinal ridges.

Leaves: opposite; egg-shaped and unlobed (often at the branch ends) to rounded with 3 shallow lobes; sharp-pointed at the tip of the leaf; hairy beneath in the angles of the veins; margins sharp-toothed, often with several glandular teeth where the blade joins the leafstalk.

Flowers: in few-flowered, open clusters on short, 2-leaved lateral branches; individual flowers small (approx. 7 mm across), creamy white and alike in a cluster; appearing in June and early July.

Fruit: orange or red, berry-like, containing a flat stone; ripening in July and August.

Note: Highbush cranberry (*V. trilobum* Marsh.) is a taller shrub than squashberry with stipules at the leafstalk bases and 2 different types of flowers in the inflorescence.

Habitat

Distribution in Ontario: Squashberry is widely distributed in northern Ontario from the north shore of Lake Superior to Hudson Bay and James Bay. It is rare south of 48°N and absent in southern Ontario (Soper and Heimburger 1982). Highbush cranberry is common in southern Ontario, north to James Bay and northwest to Lake Superior and Lake of the Woods. Highbush cranberry reaches its northern limit at about 52°N (Soper and Heimburger 1982).

Climate: *Viburnum* spp. occur in continental boreal and cool temperate climates (squashberry) or cool mesothermal climates (highbush cranberry); their occurrence increases with increasing continentality. Highbush cranberry is found throughout North America but is primarily a species of the boreal climatic region (Haeussler and Coates 1986).

Site and Soil Relations: Squashberry is found in damp woods, swampy clearings, bogs along lakeshores and stream banks (Soper and Heimburger 1982). Highbush cranberry is

Distribution of ***Viburnum* spp.** in Ontario
(Adapted from: Soper and Heimburger 1982)

generally characteristic of good soil and moisture conditions (Habgood 1983) and is found in damp soil around swamps and bogs and along streams or in cool open woods and thickets (Soper and Heimburger 1982). Its best development occurs on floodplains (Haeussler and Coates 1986). In NW Ontario, *Viburnum* spp. occur more frequently on fine-textured than coarse-textured soils.

Nutrient Requirements: Highbush cranberry is typically found on sites characterized as moderate to very rich in nutrients (Euler 1979, Haeussler and Coates 1986). It is characteristic of Moder and Mull humus forms (Klinka *et al.* 1989). A Wisconsin sampling of vigorous stands led to the following soil fertility standards for nurseries growing highbush cranberry: pH 5.5-6.0, base exchange capacity 6.5 M.E./100g., total nitrogen 0.10%; and these amounts of nutrients in kg/ha: N - 28, P_2O_5 - 134, K_2O - 196, and replaceable Ca - 2240 (Wilde 1946). *Viburnum* spp. occur on both acid and alkaline soils (Euler 1979).

Moisture Requirements: *Viburnum* spp. usually occur on fresh to very moist soils (Klinka *et al.* 1989). Greatest growth occurs on moderately well-drained (mesic) to imperfectly drained (subhygric) soils (Euler 1979, Habgood 1983). *Viburnum* spp. do not appear to tolerate poorly drained or dry soil (Habgood 1983).

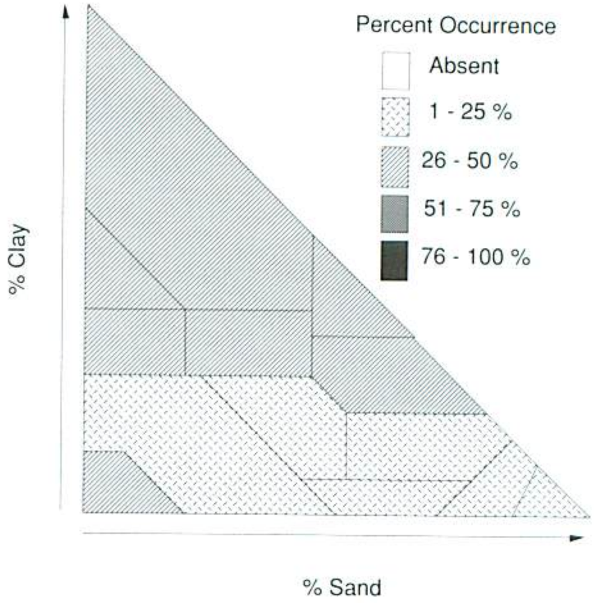
Light Requirements: *Viburnum* spp. are shade-tolerant/intolerant (Klinka *et al.* 1989). Highbush cranberry does well in full light, but will also grow under shaded conditions (Euler 1979). It is a common understory species in deciduous and coniferous forests (Haeussler and Coates 1986).

Reproduction

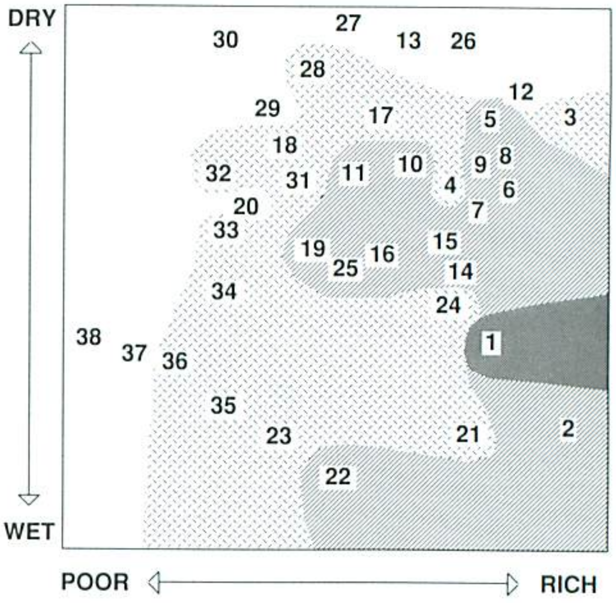
Sexual Reproduction: Seed production, dispersal, viability and germination are discussed.

Seed Production and Dispersal: The minimum seed bearing age of highbush cranberry 3 to 5 years (Anon. 1974). Fruits are produced in quantity nearly every year (Haeussler and Coates 1986). Cleaned seeds of highbush cranberry average 30,000 seeds/kg with a range of 20,700 to 39,200 (Anon. 1974). Seed dispersal is by animals and birds which feed on the fruit throughout winter (Habgood 1983, Haeussler and Coates 1986) and by gravity (Anon. 1974).

Seed Viability and Germination Requirements: *Viburnum* spp. are seed banking species (Rowe 1983). Seeds of highbush cranberry remain viable in storage for up to 10 years (U.B.C. Bot. Garden 1977). Seeds seldom germinate until the second spring after dispersal. Before germination is completed, seeds require a warm period (summer) to stimulate root development followed by a cold period to stimulate shoot development (Anon. 1974).



Frequency of occurrence of ***Viburnum* spp.** by soil texture class



Frequency of occurrence of ***Viburnum* spp.** by NWO FEC Vegetation Type

Vegetative Reproduction: Highbush cranberry regenerates vegetatively by natural layering and by sprouting from damaged root stocks and stem bases (Haeussler and Coates 1986). Stem cuttings of highbush cranberry can be readily rooted (Holloway and Zasada 1979). Treating cuttings with hormones will significantly increase rooting. Softwood cuttings whose leaves have fallen and hardwood cuttings do not produce roots; rhizome cuttings can be readily propagated (Holloway and Zasada 1979).

Growth and Development

Highbush cranberry is a multi-stemmed shrub with a rather scraggly habit because of frequent natural layering (Haeussler and Coates 1986). At maturity it averages between 0.75 and 2 m (Clark 1976). It can reach a height of 1 m in 4 years (Haeussler and Coates 1986).

Phenology

Root, Shoot and Foliage: In central British Columbia, leaf flush occurs in April or early May, but leaves are not fully expanded until late May (Haeussler and Coates 1986).

Reproductive Structures: In general, flowering occurs from late May to July. Fruits of highbush cranberry are ripe from late August to October, but may remain on the twigs throughout winter (UBC Bot. Garden 1977).

Response to Disturbance

Overstory Removal: Eis (1981) and Haeussler and Coates (1986) report a decrease in percent cover following logging. Zasada *et al.* (1981) reports an increase in density of *Viburnum* spp. following logging of a balsam poplar stand in Alaska. Highbush cranberry had fewer numbers on a winter logged balsam poplar stand than a summer-logged stand (Zasada *et al.* 1981). Three years after logging, the winter-logged site had 13,900 stems/ha while the summer-logged site had 16,000 stems/ha (Zasada *et al.* 1981).

Fire: Low impact fires stimulate germination of highbush cranberry seeds and resprouting of stems in the boreal forest (Rowe 1983). Shallow burns do not kill rhizomes and sprouting may occur at the base of stems after fires (Hamilton and Yearsley 1988b).

Mechanical Site Preparation: Information pertaining to the responses of highbush cranberry and squashberry to mechanical site preparation was not found in the literature.

Cutting: Information pertaining to the responses of highbush cranberry and squashberry to cutting was not found in the literature.

Chemical Treatments The response of *Viburnum* spp. to 2,4-D, hexazinone and glyphosate will be discussed separately.

2,4-D: *Viburnum* spp. are rated as resistant to 2,4-D (Anon. 1986).

Hexazinone: Hexazinone does not appear to give significant control of highbush cranberry (Expert Committee on Weeds 1984). In spring trials, highbush cranberry demonstrated tolerance to hexazinone. Individual applications during this season resulted in less than 39% damage. Applications of less than 2.2 kg a.i./ha generally resulted in low damage. Applications at rates between 2.2 and 4.3 kg a.i./ha resulted in 9-60% damage to highbush cranberry (Balfour 1989).

Glyphosate: Highbush cranberry can suffer heavy mortality following an aerial spray in June with 3 kg a.i./ha glyphosate (Expert Committee on Weeds 1984). Glyphosate generally provides excellent control of highbush cranberry (Balfour 1989).

Fertilization: Information pertaining to the responses of highbush cranberry and squashberry to applications of fertilizers was not found in the literature.

Effects on Conifers

In southeast Manitoba, *Viburnum* spp. were noted as soil-moisture competitors with established white spruce in mature stands because they root in the same stratum as the trees (Habgood 1983). Highbush cranberry is not considered to be a primary competitor of coniferous trees because it is a low shrub and rarely forms a dense cover (Habgood 1983, Haeussler and Coates 1986).

Uses by Wildlife

Fruits of *Viburnum* spp. are eaten by deer, bear, rabbits, chipmunks, squirrels, mice and skunks (Anon. 1974, Habgood 1983). The twigs, bark and leaves are eaten by deer, moose, rabbits and beaver (Anon. 1974). *Viburnum* is spp. of low value for moose (Habgood 1983).

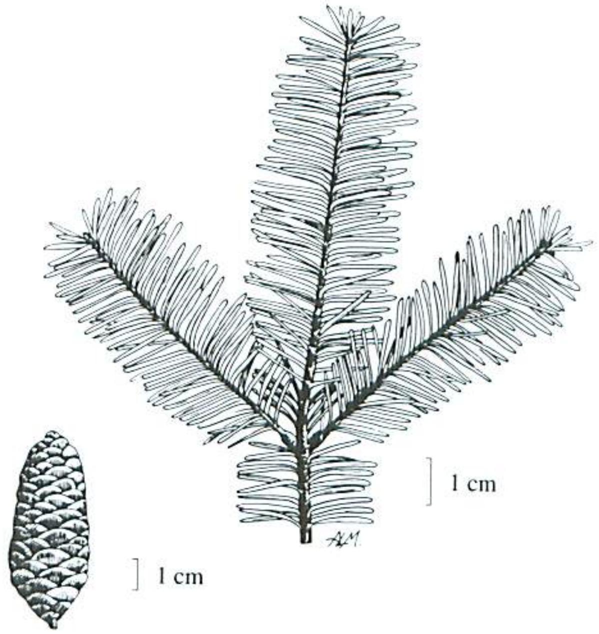
Fruits of most *Viburnum* spp. are eaten by grouse and many song birds (Anon. 1974).

Critical Silvics of Selected Conifer Species

***Abies balsamea* (L.) Mill.**	Balsam Fir
***Picea glauca* (Moench) Voss.**	White Spruce
***Picea mariana* (Mill.) B.S.P.**	Black Spruce
***Pinus banksiana* Lamb.**	Jack Pine
***Pinus resinosa* Ait.**	Red Pine

Abies balsamea (L.) Mill.
Balsam Fir

Description



General: small to medium-sized (averaging <15 m high), evergreen conifer tree with a dense, symmetrical, spire-like crown; branches usually distinctly whorled, persistent below the crown when dead; branchlets essentially opposite, arranged in flat sprays, minutely hairy; bark of branchlets smooth and waxy, with circular leaf scars when needles are removed; trunk bark smooth with raised resin blisters when young, becoming scaly with age.

Leaves: needle-like, 2-3 cm long, flat, with a blunt or minutely notched tip and 2 white bands beneath; unstalked, attached spirally to the stem but twisted at the base to appear in 2 rows (giving the spray a flattened appearance).

Flowers: male and female flowers separate on the same tree; male flowers tiny, conelike, deciduous, short-lived, hanging from the angles of the previous year's leaves; female flowers 5 to 10 cm long, purplish to green, upright, fleshy cones with broadly rounded cone scales; appearing in May.

Fruit: winged seeds enclosed by the woody scales of the mature female cone; the scales and seeds fall away from the central stalk which persists on the branch.

Habitat

Distribution in Ontario: Balsam fir is found throughout Ontario, except for the Hudson Bay Site Region (1E) (Hills 1960).

Climate: Balsam fir grows under a variety of climatic conditions (Bakuzis and Hansen 1965). Since balsam fir flushes relatively early in the season, it is only moderately resistant to frost.

Site and Soil Relations: Balsam fir grows on a wide range of mineral and organic soils (Johnston 1986). In NW Ontario, balsam fir dominated stands occur on deep, fresh, fine sands, coarse sands, coarse loams, silts and clays (S1, S2, S3, S4 and S6) and deep, moist to wet sands, coarse loams and fine loams/clays (S7, S8 and S10). Balsam fir occurs less frequently on shallow soils, but does occupy those with a coarse loamy parent material (SS6) (Sims *et al.* 1990).

Nutrient Requirements: Balsam fir grows on sites with a wide range of soil acidity (Bakuzis and Hansen 1965). Optimum growth for balsam fir occurs between soil pH 4.0 and 6.0.

Distribution of **balsam fir** in Ontario
(Adapted from: Hosie 1979)

Moisture Requirements: Balsam fir is found over most of the moisture gradient, from wet to dry sites (Johnston 1986). Stands are primarily associated with a fresh soil moisture regime, but occur on moderately moist soils as well. Balsam fir dominated stands are not found on wet sites (Sims *et al.* 1990).

Light Requirements: Balsam fir is very tolerant of overstory competition. Seedlings can become establish with only 10% of full sunlight (Benzie *et al.* 1983).

Early growth is determined by the amount of overhead shade. Balsam fir can grow at low light levels for the first 6 to 8 years and will survive for many years. After the first few years, however, best growth is obtained in approximately 45% or more of full sunlight (Logan 1969, Benzie *et al.* 1983).

Reproduction

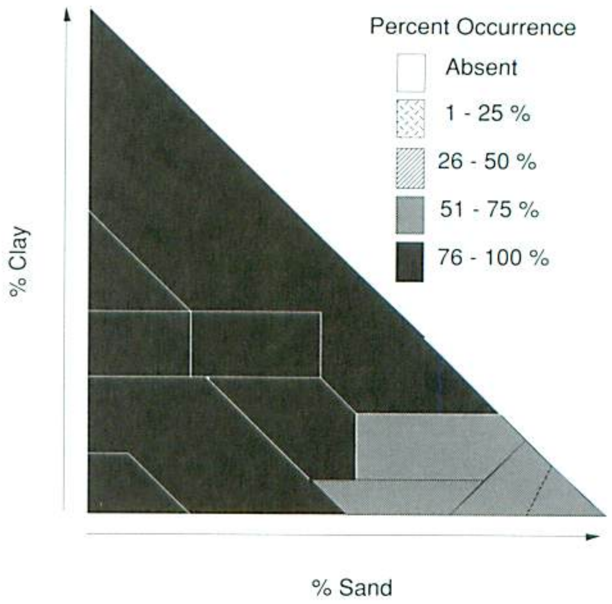
Sexual Reproduction: Male and female flowers are found on the same tree (Bakuzis and Hansen 1965). Female strobili are found on uppermost branches, where they occur singly or in small groups on the upper side of the previous year's twig growth. Male strobili cluster densely along the undersides of 1-year-old twigs and generally occur lower in the crown than female strobili, although both male and female are occasionally found on the same branchlet (Anon. 1974).

Seed Bearing Age: Balsam fir begins to bear seed at about 20 years of age, or when trees reach a height of 4.6 m. Regular seed production starts at 30 to 35 years of age (Bakuzis and Hansen 1965).

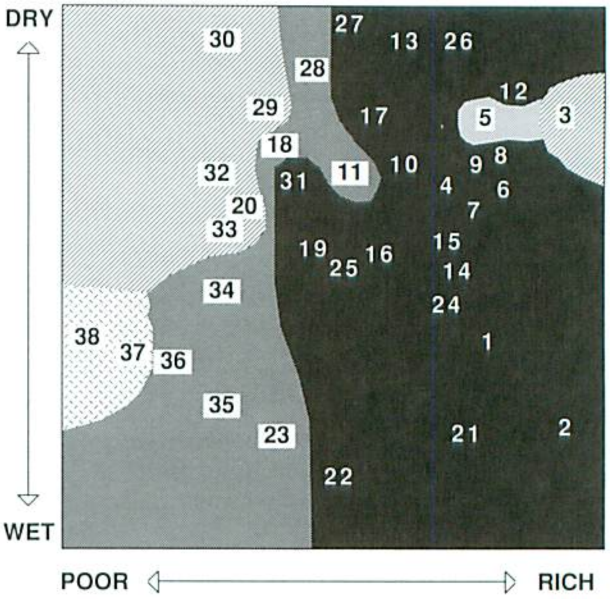
Frequency and Size of Seed Crops: Good seed crops occur at intervals of two to four years, with light crops during intervening years (Benzie *et al.* 1983). In good seed years, balsam fir stands may yield ≥ 6 kg/ha of seed (Bakuzis and Hansen 1965, Benzie et al. 1983). There are approximately 130,000 cleaned seeds/kg with ranges of 66,100 to 208,300 (Anon. 1974).

Pollen and Seed Dispersal: Pollination is by wind. Wind disperses seed to a maximum distance of 160 m; however, effective spread is much less, ranging from 25 to 62 m. Many seeds stick to the cone scales and fall near the base of parent trees (Johnston 1986). Seed is also spread by rodents.

Seed Viability and Germination Requirements: Seed viability averages 26% in natural stands (Benzie *et al.* 1983). Although not all balsam fir seed shows dormancy, best germination has been obtained by stratifying seed in a wet medium at 5.0 °C for 3 months or longer (Benzie *et al.* 1983). Natural seeding in fall allows seed to stratify over winter on the forest floor (Benzie *et al.* 1983). Almost any type of seedbed - mineral soil, rotten



Frequency of occurrence of **balsam fir** by soil texture class



Frequency of occurrence of **balsam fir** by NWO FEC Vegetation Type wood, or shallow duff is satisfactory for germination of balsam fir, provided there is sufficient moisture. Medium-textured mineral soil with some shade provides the best seedbed for balsam fir. Mineral soil may have disadvantages under certain conditions. Coarse sands in open areas will usually be too dry. Frost heaving can be serious on fine-textured mineral soils (Bakuzis and Hansen 1965). Low germination is observed on litter layers greater than 8 cm thick (Benzie *et al.* 1983). The closer seeds lie to mineral soil, the better the initial establishment but soil disturbance is required if prompt establishment is desired after harvesting. Few seeds remain viable in the forest floor for more than one year after dispersal (Johnston 1986).

Vegetative Reproduction: Balsam fir can reproduce by layering; however, it is not an important means of regeneration. Bonner (1941) estimated that one percent of balsam fir reproduction in the Clay Belt of NE Ontario results from layering.

Growth and Development

Fir stands typically have a reserve of established seedlings at all times after seed production begins, even where the crown cover is very dense (Roe 1953). Fir seedlings are reported to be inherently slow-growing for the first five or six years, even under full light (Zon 1914), reaching 31 cm in height in 5 years and 92 cm in 9 years. Balsam fir stands break up at fairly young ages even though individual trees may live for 200 years (Johnston 1986).

Balsam fir seedlings develop strong, slightly branched lateral roots in the surface humus. Frequently,seedlings develop a heavy central root, which initially appears to be a taproot but then splits at the bottom of the humus into a number of laterals which remain in the organic layer (Bakuzis and Hansen 1965). Root grafts are common amoung balsam fir (Johnston 1986).

Phenology

Root, Shoot and Foliage: Vegetative buds swell between early and mid-May, and flush between mid-May and early June. Rapid shoot elongation occurs between mid-June and mid-July. Shoot elongation generally ceases in late July or early August, but may continue until mid-August in some locations. Most height growth is completed in about 65 days (Bakuzis and Hansen 1965). Cambial activity at breast height begins between early April and mid-May and ceases between late July and September (Bakuzis and Hansen 1965). Abrupt changes in cambial activity correspond with sudden temperature changes. Rapid stem expansion of balsam fir occurs after periods of heavy precipitation (Bakuzis and Hansen 1965).

Needle expansion ceases near the end of July. Photosynthetic efficiency of new needles increases rapidly, but tends to be a sink rather than a source of photosynthate until mid-June. A decline in starch and total sugar content in both the current and one-year old needles during late summer and autumn may reflect an export of carbohydrates to the root system during these times (Clark 1956).

Reproductive Structures: Initiation of microsporophyll primordia in lateral buds starts in late July and continues until late August. Buds differentiating into male and female strobili become recognizable microscopically in the spring (Bakuzis and Hansen 1965). By this time the pollen is already fully formed. Male buds burst somewhat before female buds in early May. Female reproductive buds start to swell in early April and burst between late April and mid-May (Bakuzis and Hansen 1986). This corresponds to the period of vegetative bud swell or approximately ten days earlier than vegetative bud burst. Pollen is normally shed between mid-May and early June (Bakuzis and Hansen 1986). Pollen release and needle flush occur almost simultaneously (Bakuzis and Hansen 1986). Cones ripen in mid- to late August (Smith 1984) and begin to disintegrate in September. The majority of seed release is in October; however, seed release continues until early spring.

Competition

Response to Competition: Competing vegetation can delay balsam fir reproduction for 30-50 years (Bakuzis and Hansen 1965). During the first few years, balsam fir is susceptible to smothering by hardwood leaves. Once established, balsam fir early growth is determined largely by the amount and character of overhead competition. Balsam fir will grow well at low light levels during the first 6 to 8 years of life. Thereafter, it will live under dense cover for a long time, up to 50 years or more (Hatcher 1960), but needs nearly full light for best development. Vincent (1956) found that red raspberry spreading rapidly after cutting, suppressed small balsam fir advance growth and retarded regeneration, but affected only those balsam fir seedlings that it overtopped.

Bowman (1944) presented data from Michigan on the association of spruce-fir reproduction with varying species and densities of ground cover. The 73% stocking of spruce-fir reproduction at 0-50% ground cover density decreased gradually to 24% stocking at 90-100% ground-cover density. Species differences were also noted. Sedge and Labrador tea ground covers were found with 16% stocking. Comparable figures for other ground covers were *Sphagnum* spp., 66%; bunchberry (*Cornus canadensis* L), 72%; bracken fern, 83%; and speckled alder, 37%.

Quack grass is also considered to be a serious competitor of balsam fir in the Maritime provinces (Estabrooks 1988).

Bracken fern was found to impair reproduction of balsam fir on wet sites, although no differences were detected on fresh sites (Place 1952).

Competition from red raspberry affects growth and nutrient quality of foliage of balsam fir seedlings (Fox 1986). Seedlings overtopped by raspberries were smaller than open-grown seedlings. Root collar diameters averaged 5.5 and 8.2 mm in overtopped and open-grown seedlings, respectively. Foliar analysis revealed higher P (0.18% vs 0.16%) and lower K (0.59% vs 0.80%) concentrations in open-grown than in overtopped seedlings (Fox 1986).

Thompson and Mallik (1989) postulate that moose browsing of balsam fir reduces the extent to which balsam fir shades sheep laurel (*Kalmia angustifolia* L.), which can result in a higher density of the latter species, with consequent inhibitory effects on regenerating coniferous species.

Because of its tremendous regeneration potential, especially by means of sprouts from underground stems, beaked hazel presents a serious competitive problem to balsam fir within the area of overlapping ranges (Bakuzis and Hansen 1965). However, balsam fir seedlings are capable of becoming established even in a dense thicket of hazel brush (Hsiung 1951).

A study of natural speckled alder stands in Quebec indicated that balsam fir, when associated with alder, had higher absolute N, P, K, Ca, and Mg contents in the foliage than fir without alder (Fortin *et al.* 1983). The height growth of balsam fir reproduction growing under a canopy of speckled alder is significantly related to: 1) initial height of reproduction, 2) average canopy height of the alder, 3) number of alder per ha, 4) reproduction age, 5) maximum height of alder, and 6) light level received at the tip of the reproduction stem (Vincent 1965b).

Of all shrub species, mountain maple is the most serious competitor of balsam fir (Bakuzis and Hansen 1965). This is true not only because of similar site requirements but also because of the reproductive ability, and the somewhat greater shade tolerance, of mountain maple compared with balsam fir (Bakuzis and Hansen 1965).

Balsam fir will become established and grow more rapidly under a full aspen canopy than pines, partly because of its greater shade tolerance. A birch overstory can significantly reduce balsam fir mortality caused by spruce budworm (*Choristoneura fumiferana* Clemens) (Johnston 1986).

Response to Release: For best results balsam fir should be released while it is still young and vigorous (Johnston 1986). Indicators of such trees are a current annual height growth of 15 cm or more, a fairly pointed crown, and smooth bark with raised resin blisters. Older, severely suppressed trees (i.e., those with a current annual height growth of < 5.1 cm, flat-topped crowns, and rough bark) should not be released regardless of their size. These trees respond poorly to release and generally have a high incidence of rot (Johnston 1986). Total release is not considered desirable, because of the increased potential for spruce budworm damage (Johnston 1986).

When released, fir seedlings rapidly attain a growth rate comparable to that of non-suppressed seedlings (Hatcher 1960). In Quebec, Hatcher (1967) found that balsam fir and red spruce stem volume growth increased by a maximum of 273% over 20 years by girdling or felling hardwood competition.

On sandy, clay and silt loam sites, average heights of balsam fir were 47%, 19% and 51% greater, respectively, five years after herbicide spraying than they were in the unsprayed control areas, and volume production exceeded that in unsprayed areas by 152% to 165% (Lehela 1981). This benefit continued for up to 20 years after treatment with increases in volume ranging from 200% to 260% on silt loam. Similar, but less pronounced, responses were observed for height growth, with increased growth of 50% to 75% over a 20-year period (Carrow 1981).

Manually releasing balsam fir reproduction from mountain maple and associated shrubs has a marked influence on its rate of height growth (Vincent 1954). Baskerville (1961) concluded that balsam fir response to manual release from mountain maple was directly related to the initial height of the conifer seedlings. The taller the seedlings, the greater the response, with the exception of trees less than 30 cm high. These seedlings suffered from intense competition of invading red raspberry and did not gain sufficient height after release to compete successfully with raspberry regrowth. They were still suppressed ten years after release. The greatest and most rapid response occurred in trees between 0.3 and 1.2 m high at the time of release.

MacLean and Morgan (1983) followed up on Baskerville's (1961) study. They concluded that manually clearing a 1-m radius circle around each balsam fir seedling once can result in increases of 64% in total volume, 36% in mean dbh, and 22% in mean height, in comparison to controls 32 years after release from mountain maple. MacLean and Morgan (1983) also collected data from balsam fir natural regeneration areas which showed that the fir produced 265% greater stem volume 28 years after treatment with a mixture of 2,4-D and 2,4,5-T (Brushkill 96® at 17 l to 2730 l water using a truck mounted mist blower), than on similar untreated areas.

Natural balsam fir regeneration in New Brunswick, released from competition using a 2,4-D and 2,4,5-T mixture (Brushkill 76® at 9.3 l in 9.3 l water/ha (ester formulation)), responded with 257% greater stem volume growth after eight years than comparable untreated trees (Lanteigne 1984).

Although balsam fir achieves fair growth under stands of aspen and paper birch, it will reach pulpwood size considerably faster if released (Roe 1952).

Chemical Treatments: Balsam fir exhibits various degrees of tolerance to foliage herbicides. The response of balsam fir to 2,4-D, hexazinone and glyphosate are discussed separately.

***2,4-D*:** Balsam fir is generally rated as resistant to 2,4-D (Anon. 1986), but is susceptible during the early summer. After full leaf development (approximately July 30), concentrations of up to 2.2 kg/ha or less can be applied with a water carrier with only negligible damage to balsam fir. After August 13, balsam fir is resistant even at rates up to 3.4 kg/ha (Miller 1958).

Hexazinone: Balsam fir is rated as tolerant to Velpar-L (Corcoran 1989). However, tolerance is limited, and as rates increase the risk of injury also increases, especially on sandy soils (Estabrooks 1988). For this reason spot gun applications should not come within 1 m of balsam fir (Estabrooks 1988).

Glyphosate: Balsam fir is relatively resistant to glyphosate applied as a top spray in late August or September (Anon. 1989c). In a Nova Scotia study, naturally regenerated balsam fir was sprayed with two different rates of Vision® (3.2 and 4.7 l/ha of Vision) applied at 16 different dates between July 2 and October 22 (Anon. 1989c). The week prior to treatment, treatment areas were manually cleared of overtopping vegetation. Results collected one to two years after treatment indicated that foliar damage occurred on fir sprayed before the end of the first week in August. For trees sprayed in July, needle loss was extensive, sometimes defoliating shoots up to three years old.

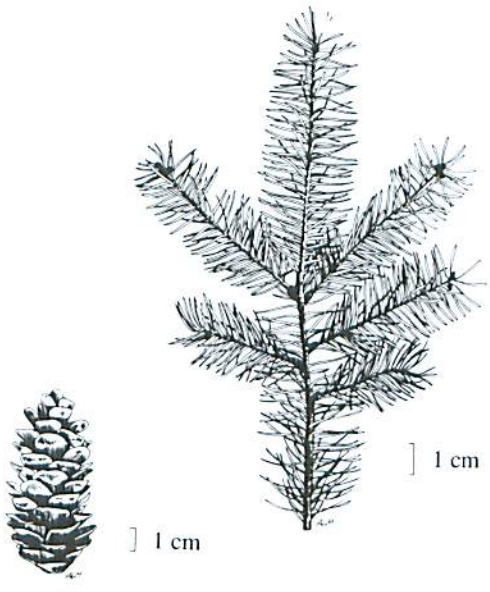
Uses by Wildlife

Large herbivores associated with balsam fir include beaver, white-tailed deer and moose. Balsam fir is an important browse species for moose in central and eastern North America (Peek 1974). Heavy reliance of moose on balsam fir may indicate reduced availability of more preferred browse species (Zach *et al.* 1982). Balsam fir is not frequently browsed during the summer or autumn months (Timmermann and McNicol 1988). During warm summer months balsam fir stands provide shade that helps cool deer, moose and bear after feeding in open areas (Johnston 1986). Balsam fir also provides late winter cover for moose (Timmermann and McNicol 1988) and deer (Johnston 1986). Compared to white spruce, balsam fir generally has few branches near the ground; thus, deer can bed down closer to a fir tree and be less exposed to heat loss (Johnston 1986). Snow is not as deep in balsam fir stands as in aspen and birch stands. Consequently, fir stands often are heavily used by deer and moose with calves during severe winter months (Johnston 1986). Small mammals that are common include the red-backed vole (*Clethrionomys gapperi* Vigors), meadow vole (*Microtos pennsylvanicus* Ord), deer mouse (*Peromyscus maniculatus* Wagner), chipmunk, red squirrel and snowshoe hare. Carnivores that frequent balsam fir stands include fisher (*Martes pennanti* Erxleben), marten (*Martes americana* Turton), Canada lynx (*Lynx canadensis* Kerr) and timber wolf (*Canis lupus* L.) (Benzie *et al.* 1983). Well-stocked balsam fir stands serve as protection from predators for several wildlife species, such as marten, hare, songbirds and deer (Johnston 1986).

Spruce and ruffed grouse are common inhabitants of balsam fir stands, as are a variety of songbirds. During summer various birds use fir stands for nesting; warblers such as the Cape May (*Dendroica tigrina* Gmelin), blackpoll (*Dendroica striata* Forster), and blackburnian (*Dendroica fusca* Müller) especially prefer the habitat provided by balsam fir stands (Johnston 1986). Balsam fir stands attacked by spruce budworm attract many insect-eating birds, especially warblers and woodpeckers (Johnston 1986).

Picea glauca (Moench) Voss
White Spruce

Description



General: medium to large-sized (averaging 17 m high, up to 28 m), evergreen conifer tree with a fairly uniform, conical crown and branches which spread or droop slightly; branchlets hairless with persistent, raised, woody leaf bases; trunk bark light greyish-brown, flaky or scaly, inner bark silvery-white to reddish.

Leaves: linear, needle-like, thick, stiff, sharp, about 2 cm long; four-sided in cross-section; green to bluish-green, often with a whitish powdery coating; strongly aromatic when crushed; individually attached in a spiral around the branchlet forming a cylindrical rather than a flattened spray.

Flowers: male and female flowers separate on the same tree; male flowers tiny, conelike, deciduous, short-lived, at the end of the previous year's growth; female flowers erect, red cones with numerous spirally-arranged scales, also at the end of the previous year's growth; appearing in May.

Fruit: winged seeds enclosed by the woody scales of the mature female cone; the cones are about 3.5-5.0 cm long, cylindrical, with smooth-margined scales which open in the autumn of the year of development to release seeds; mature cones pendant.

Habitat

Distribution in Ontario: The commercial range of white spruce extends thoughout most of the Boreal and Great Lakes-St. Lawrence Forest Regions of Ontario (Rowe 1972, Hosie 1979). The botanical range extends considerably beyond the commercial range (Arnup *et al.* 1988).

Climate: White spruce flushes earlier than black spruce and tends to be more susceptible to frost damage (Nienstaedt 1957).

Site and Soil Relations: White spruce dominated stands in NW Ontario occur primarily on morainal and lacustrine deposits, with minor occurrences on glaciofluvial outwash deposits. They occur on a variety of NWO FEC Soil Types, with the highest concentration of stands occurring on deep, fresh, coarse loamy soils (S3), deep, fresh, soils with a coarse, sandy or silty C texture (S1, S4) and deep, moist, fine loamy or clayey soils (S10). They also occur on shallow, coarse loamy soils (SS6). White spruce does not occur as the dominant species on wet or very shallow soils. It achieves its best growth on well-drained silty soils with adequate available moisture (Watson *et al.* 1980).

Distribution of **white spruce** in Ontario
(Adapted from: Hosie 1979)

Nutrient Requirements: White spruce is more nutrient demanding than black spruce and requires at least moderate fertility for optimum growth (Arnup *et al.* 1988). Wilde (1966) proffered the following minimum soil fertility factors, based on an examination of plantations on well-drained soils in Wisconsin: Total N, 0.120%; available P, 45 kg/ha; available K, 145 kg/ha; exchangeable Ca, 3.00 me/100 g; exchangeable Mg, 0.7 me/100 g.

White spruce tolerates a considerable range of pH, but optimum growth has been observed at soil pH values between 5.0 and 7.0 (Arnup *et al.* 1988). The lower pH limit for white spruce has been reported to be 4.5-5.0 (Watson *et al.* 1980).

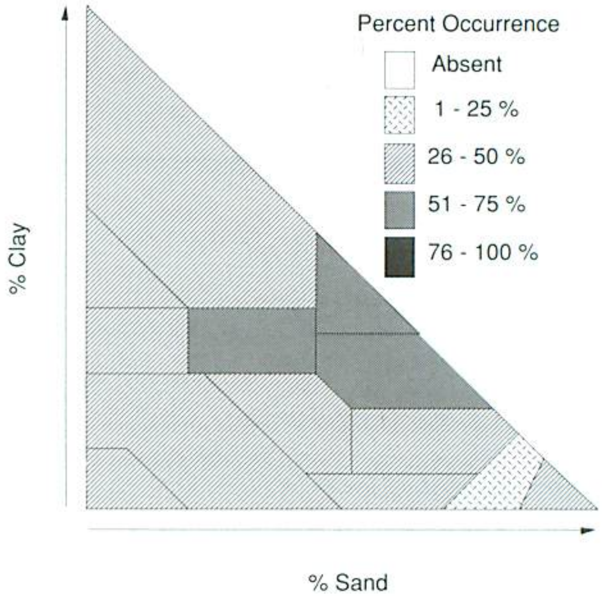
Moisture Requirements: White spruce will tolerate a wide range of moisture conditions, but generally performs best on well- or moderately well-drained soils (Arnup *et al.* 1988). Although white spruce is moderately drought tolerant (Watson *et al.* 1980), its growth will be stunted and scrubby on both wet and very dry soils (Nienstaedt 1957). For maximum development it requires a supply of well-aerated water (Nienstaedt 1957).

Light Requirements: The shade tolerance of white spruce is relatively low. On a scale of 1 to 10, Graham (1954) gave white spruce a score of 6.8, compared to 6.4 for black spruce and 9.8 for balsam fir. Results of studies by Shirley (1945) and Logan (1969) indicate that white spruce can be grown up to five years in light intensities as low as 45% of full sunlight without a significant reduction in height growth or increased mortality. At light intensities below 25%, severe reduction in height growth can be expected. The best height growth occurs between 45% and 100% of full sunlight. Diameter and biomass growth are reduced at light intensities lower than 100%. By nine years of age, however, full sunlight is required for optimum diameter and height growth.

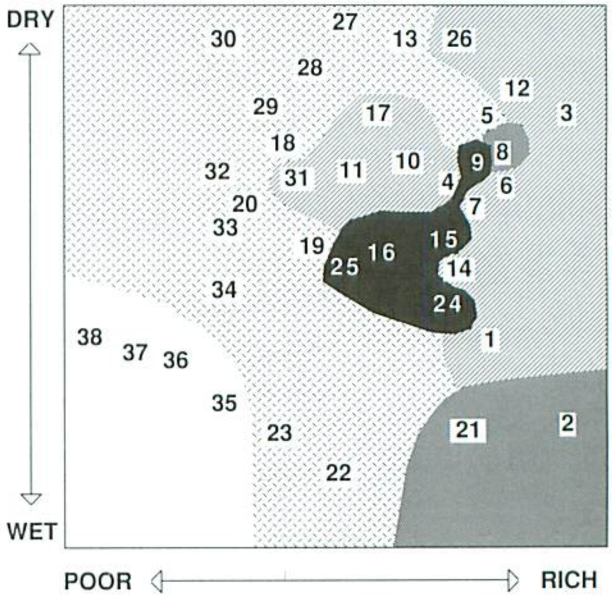
Reproduction

Sexual Reproduction: White spruce is monoecious, having separate male and female flowers on the same tree (Arnup *et al.* 1988). Male flowers occur most abundantly in the middle portion of the crown, and female flowers in the upper crown (Eis 1967).

Seed Bearing Age: Cones have been observed on trees as young as 10 years and excellent seed crops have been observed in 20-year-old forest plantations (Zasada 1971). In general, natural stands of white spruce do not produce seed in quantity until 40 years or older. Good cone crops have been observed on trees from 45-170 years old (Zasada 1971).



Frequency of occurrence of **white spruce** by soil texture class



Frequency of occurrence of **white spruce** by NWO FEC Vegetation Type

Frequency and Size of Seed Crops: Cones are produced every year, but in quantity only every two to six years or more (Nienstaedt 1957). The periodicity of good cone crops varies from one part of Ontario to another (Arnup *et al.* 1988). White spruce is capable of producing from 8,000 to 11,900 cones per tree or approximately 271,000 seeds per tree in a "heavy crop" year (Nienstaedt 1957). A "very heavy" crop from mixedwood stands in NW Ontario, containing less than 50 cone-bearing white spruce per ha, produced an estimated 77,800 cones per ha (Hughes 1967). In a "heavy crop" year, seedfall was estimated at 13.8 million seed/ha, but only 8.2 million were sound. In a year of "moderate" seed production it was estimated that 2.5 million sound seeds were shed (Waldron 1965). There are approximately 498,200 cleaned seeds/kg; with a range of 297,600-884,000 (Anon. 1974). Seed yields in Ontario average approximately 310,000 viable seeds/hl of cones (Arnup et al. 1988).

Pollen and Seed Dispersal: White spruce seed is primarily distributed by wind (Nienstaedt 1957). Patterns and distribution of seed dispersal are functions of tree height, seed weight and wind velocity at the time of dissemination. Maximum distance for the spread of adequate quantities of seed is about 46-62 m from the seed source.

Seed Viability and Germination Requirements: Seeds are generally viable for one year, or two if local climate conditions are extremely dry. The percentage of sound seed varies from 2-71% but averages 57%. Seed quality is usually better in years of heavy seed production than in years of light production (Jarvis *et al.* 1966). Low percentages of sound seed are generally associated with poor seed years.

The seed of white spruce possesses general dormancy and requires stratification or overwintering in the forest floor to induce germination (Arnup *et al.* 1988).

Since first-year white spruce seedlings are small and have shallow roots, survival and growth are dependent on availability of adequate moisture (Arnup *et al.* 1988). The most favourable seedbeds are mineral soil, mixed soil and humus, and decayed wood (Phelps 1955, Zasada 1971, Stiell 1976). Organic matter (litter, duff or humus) is a poor seedbed. Mosses are not a common seedbed in cutover areas because they are generally destroyed as a result of cutting and site preparation, or dried out from increased exposure. A charred surface may get too hot for good germination in dry years and may delay germination until fall, with subsequent overwinter mortality of unhardened seedlings (Stiell 1976). Of all the factors controlling the germination of white spruce seed, soil moisture conditions are most important (Nienstaedt 1957). Any seedbed which dries out to a depth of 5-8 cm or more will be detrimental to spruce seedlings during the first season (Nienstaedt 1957). Although some light improves germination of white spruce, under field conditions germination is best in the shade. Shade increases germination and early survival by reducing surface temperatures and evapotranspiration. Optimum temperatures for germination of white spruce occur from 18-24°C (Stiell 1976). Low temperatures will prevent germination regardless of soil moisture conditions. Very little germination will take place on any seedbed until the mean daily temperature has reached and remained at 5°C for several days.

Vegetative Reproduction: White spruce vegetative reproduction occurs only rarely (Nienstaedt 1957, Zasada 1971). With the right environmental conditions seedling cuttings can be rooted with good results in the greenhouse (Nienstaedt 1957). Cuttings from older trees are difficult to root, but can be easily grafted (Arnup *et al.* 1988).

Growth and Development

White spruce trees 34 m in height and more than 53 cm in diameter are not uncommon (Nienstaedt 1957). White spruce may reach ages of 250-350 years (Nienstaedt 1957).

In the juvenile stage of its life cycle white spruce experiences indeterminate growth (i.e., it is capable of growing and flushing continuously if favourable environmental conditions are maintained) (Arnup *et al.* 1988).

Seedlings often take several years after planting to assume a rapid or even reasonable rate of height growth (Arnup *et al.* 1988). If the period of minimal height growth is prolonged, the seedlings are said to be in "check" (Stiell 1976). Time to reach breast height was found to vary from 6-12 years in white spruce plantations at Chalk River, Ontario (Stiell 1976). Average heights for white spruce five years after planting in Ontario were reported as 61.0 cm for bareroot stock and 25.4 cm for tubed seedlings (MacKinnon 1974).

White spruce has a shallow root system with many wide-spreading lateral roots (Watson *et al.* 1980). Studies of white spruce plantations have shown that rooting is restricted to about the top 30 cm of soil. Root form and rooting depth is highly variable, in response to soil texture, moisture regime, and soil fertility. Restricted drainage near the surface tends to limit development of a tap root (Arnup et al. 1988).

Phenology

Root, Shoot and Foliage: The timing of bud break, flushing, leader development, bud set, and hardening of new growth varies greatly in different parts of the range (Arnup *et al.* 1988). White spruce flushes approximately 5-10 days in advance of black spruce in Ontario.

Root growth begins much earlier and stops much later than terminal or radial growth. At Riding Mountain, Manitoba, root growth usually begins about the end of April and continues well into October. Rate of growth appears to slow, when terminal development is at its peak. Root growth also slows and may even stop for a period, when the soil becomes dry (Jarvis *et al.* 1966).

Most terminal shoot growth occurs at night and the rate is influenced directly by night temperatures (Jarvis *et al.* 1966). Hot, dry weather is detrimental to height growth, whereas warm, moist weather is favourable (Jarvis *et al.* 1966). Vegetative bud swell and flowering frequently overlap. Measurable shoot elongation and bud scale initiation begin in late April with bud flush occurring in late May. The degree-day requirements for flushing average 91 days (O'Reilly and Parker 1982). Shoot elongation is very rapid with 90% completed by late June. Depending on the location and climatic conditions, shoot elongation may cease from early July to late August. Shoot growth is completed within a period of 36-48 days (Jarvis *et al.* 1966, O'Reilly and Parker 1982) and ends simultaneously with bud scale initiation.

Near Riding Mountain, Manitoba, radial growth of white spruce starts about the end of May, approximately the same time that height growth starts. Radial growth continues throughout summer and well into September, but is most rapid during June and July (Jarvis *et al.* 1966).

Initiation of needle primordia in lateral buds starts in late July (Owens and Molder 1977). The period of early, rapid needle initiation lasts for about six weeks, during which time about 75% of the final number of needles are initiated (Owens *et al.* 1977). Needle primordia continue to be initiated until the bud apices become dormant in mid-October (Owens and Molder 1977). Initial leafing occurs shortly after pollen shed in spring of the year after initiation. Multiple flushes may occur on juvenile plants.

The moisture content of newly flushed white spruce needles is over 300% in early June; drops rapidly to 150% by early August, then more slowly to 130% by early September (Van Wagner 1967). Chemical analysis and electron micrographs show that the cuticular wax deposition of white spruce is greater at 14 weeks after bud flush than at three weeks (Willis *et al.* 1989). Increased wax deposition with time after bud break may reduce herbicide uptake and may account partially for the increased tolerance to herbicides later in the growing season (Willis *et al.* 1989).

Reproductive Structures: Flower bud initiation commences in July of the year before flowering (Owens and Molder 1977). Male buds can be recognized as male flowers in mid-August in the year of formation. Development within buds continues throughout September and ends in early October. Male flowers overwinter, with development reoccuring in mid-April (Owens and Molder 1979). By late April, buds are visibly swollen (Owens and Molder 1979). Bud break occurs about one week before female flower buds, but pollen is generally not shed until the female flowers have emerged. Pollen dispersal occurs for about one week between late May and early June (Owens and Molder 1979). The earliest recorded date for the beginning of pollen shedding in western Manitoba was May 25 and the latest was June 13 (Jarvis *et al.* 1966).

Female flower bud initiation commences in late July of the year before flowering (Owens and Molder 1977). Female buds can be recognized as female flowers as early as mid-August in the year of formation. Female buds overwinter and flower for a period of three to five days in late May or early June (Arnup *et al.* 1988). Cones ripen from mid-August to late September of the year in which flowering occurs (Arnup *et al.* 1988). The exact time of cone ripening depends on locality and prevailing weather (Stiell 1976). Small amounts of seed may be ripe in late July (Zasada 1971). Seed matures before cones exhibit fully ripe characteristics. Hot, dry weather hastens seed dissemination while cool, moist weather retards it (Jarvis *et al.* 1966). The majority (75-90%) of the seed crop is released within a few weeks between early August and late November. Most cones fall in the year of formation after seed dispersal, although some may persist for 11 months or more (Zasada 1971).

Competition

Response to Competition: White spruce seedlings are unable to compete with dense growths of perennials, shrubs or an understory of hardwood trees, because of their slow initial height growth (Rowe 1955, Nienstaedt 1957, Arnup *et al.* 1988). White spruce often turns from deep green to pale yellow during the first growing season after outplanting when weed competition is intense, even when moisture is non-limiting (Sutton 1975). A sparse overstory that reduces light but increases humidity and soil moisture is beneficial to seedlings (Arnup *et al.* 1988). Light or moderate ground cover, such as herbs and graminoids, also help protect seedlings from exposure and frost in open plantations (Stiell 1976). In the Boreal Forest, young white spruce growing in the open are commonly damaged by spring frost; this obviously influences the degree and type of weed control that will most benefit the spruce (Sutton 1984). Posner (1984) showed that four to nine-year-old white spruce grew well in association with low or medium shrub heights and usually grew better with some shrubs present, rather than none. Increases in fireweed cover have been directly correlated to increases in growth and health of three-year outplanted 2+1 white spruce (Pitt et al. 1989). However, white spruce germinants are susceptible to smothering or crushing by hardwood leaves and dead grass (Waldron 1961). A closed-canopy overstory will seriously retard development of white spruce beneath it (Stiell 1976).

White spruce transplants and seedlings mulched with lichens (*Cladina rangiferina* (L) Harm. and *C. stellaris* (Opiz) Brodo) were stunted after 17 weeks growth (Fisher 1979).

Young spruce are often adversely affected by grass, particularly sod on compact soils (Stiell 1976). Spruce seeds that fall into a thick mat of grass in the fall become suspended and as the dead blades of grass dry out in the spring, most germinants dessicate before their roots penetrate into soil. Those germinants that do make contact with mineral soil are either shaded out in summer by rapidly growing grasses or smothered by dead grass compressed by snow during the next winter (Arlidge 1967). Crushing or smothering of young plantation trees by dense growths of grasses and deep snow can be a problem on rich clay soils (Arnup *et al.* 1988). White grubs are occasionally a problem on loams and silt loams, but mainly on coarse-textured soils, particularly where there is a grassy cover (Stiell 1976). Populations of grubs persist until crown closure shades out the ground vegetation (Stiell 1976). Fire can easily travel into a young plantation via grass or other suitable fuels between young trees, which are very vulnerable to scorch and dessication because of their thin bark and full-length green crowns (Stiell 1976).

Fisher (1980) reported that leachates from bog laurel (*Kalmia polifolia* Wang.) and large-leaf aster (*Aster macrophyllus* L.) contain allelopathic compounds that inhibit early growth of white spruce seedlings.

In white spruce stands in Alaska which we were close to high populations of Labrador tea, the incidence of needle rust (*Chrysomyxa leicola* Lagerh.) was over 90% during a cool, wet summer (McBeath 1986). Diseased needles turn brown, shrivel and drop from branches in the fall (McBeath 1986).

Increases in red raspberry cover have been directly correlated to decreases in growth and health of three-year outplanted 2+1 white spruce (Pitt *et al.* 1989).

Beaked hazel can have a detrimental effect on seedling height growth. For example, white spruce seedlings planted in the midst of dense hazel averaged only 28 cm in height four years after planting. Seedlings from the same stock planted on the same site, but where hazel had been cut, averaged 43 cm after four years (Waldron 1959).

Competition from speckled alder can stunt the growth of white spruce (Stiell 1955).

Waldron (1961) and Gregory (1966) found that only an occasional white spruce can become naturally established beneath trembling aspen and paper birch stands. After four growing seasons white spruce seedlings are generally large enough to avoid being smothered (Gregory 1966). Where white spruce grows with hardwoods established at the same time, it generally is overtopped and remains an understory species for long periods of time unless released (Nienstaedt 1957). White spruce is more shady-tolerant than hardwoods such as trembling aspen, balsam poplar and white birch and eventually replaces them, frequently at stand ages of 80-100 years (Zasada and Argyle 1983). In Alberta, white spruce grows through the aspen overstory between 55 and 75 years (Lees 1966). In addition to a reduced growth rate, white spruce leaders are often damaged or broken off when they reach the crowns of aspen, resulting in trees of poor quality (Jarvis *et al.* 1966, Lees 1966).

Examination of seeded plots indicated that seed loss due to mice and voles is much greater in stands with a dense understory of brush, herbs and graminoids than with a sparse understory (Jarvis *et al.* 1966).

Dense brush and aspen stands also offer the ideal habitat for snowshoe hare, which may severely damage young white spruce (Jameson 1956, Stiell 1976).

Overstory shade often limits the amount of weevil attack in natural stands, but open, unshaded plantations (whether pure or mixed) are vulnerable (Stiell 1976). Weevils tend to concentrate their damage on large diameter leaders growing in full light (Stiell 1976).

Response to Release: Control of dense grass competition prior to planting can significantly increase survival; height, diameter and volume growth; foliage colour; bud size and development; needle length; and the general vigour of outplanted white spruce (Sutton 1975). von Althen (1970) found that plowing and tilling of grasses prior to planting increased three-year height growth of white spruce by 37%. In a study of 2+2 white spruce transplants in southern Ontario, von Althen (1972) found that applying simazine to control grasses increased total height by 30% after eight growing seasons.

Waldron's (1959) study of the response of 3+2 white spruce to release from very dense hazel showed 28% better survival and 50% greater height for released trees.

Manually releasing white spruce reproduction from mountain maple and associated shrubs has a marked influence on white spruce's rate of height growth (Vincent 1954).

In northern Ontario, Willcocks (1979) found that weed control over a 28-year period in a white spruce plantation resulted in 310% greater merchantable volume than in an adjacent stand.

Results from studies to determine the effects of release cutting on the development of white spruce showed conclusively that all ages and sizes of white spruce respond to release from trembling aspen (Jarvis *et al.* 1966). For best results, white spruce should be released while young and vigorous. Greatest growth response occurs in the 20 to 40-year-old age class (Jarvis *et al.* 1966). White spruce over 75 years of age respond poorly to release from trembling aspen (Johnson 1986).

To avoid damage to leaders from whipping and abrasion, white spruce should be released before it comes into contact with hardwood crowns. White spruce understorys must be at least 2.5 m tall at time of release in order to stay ahead of new aspen sucker growth and shrub competition subsequent to a single manual release. If less than 2.5 m tall at the time of release they will likely require at least one additional release treatment (Johnson 1986).

Present information suggests at least a 35% increase in merchantable white spruce volume and a 30-40 year decrease in rotation age following appropriate release from trembling aspen (Johnson 1986). A study in an intermediate-aged mixedwood stand in Saskatchewan showed that diameter growth of spruce was increased by as much as 60% following aspen overstory removal (Jarvis *et al.* 1966). Rotation age of spruce in pure stands is 30-40 years less than in mixedwood stands due to aspen competition in the latter (Johnson 1986).

Total release is not considered desirable (Sutton 1969, 1984). Frost heaving can be a severe problem on bare mineral soils, particularly fine-textured soils with high moisture regimes (Place 1955). Ideally, a light or moderate ground cover should be maintained to protect white spruce from exposure to frost (Posner 1984, von Althen 1970). For example, sturdy white spruce, apparently well established after four and five growing seasons, were frost heaved when weed control was maintained to give bare mineral soil conditions around the trees (Sutton 1968). Heidmann (1976) recommended use of mulches, shade, or soil coatings to reduce heat loss from the soil and thereby maintain soil water above the freezing point in order to reduce frost heaving.

Chemical Treatments: The response of white spruce to 2,4-D, hexazinone and glyphosate will be discussed separately.

2,4-D: White spruce is highly resistant to 2,4-D (Schacht and Hansen 1963) except during the active growth period, when it can be seriously affected. Arend (1955), in a report on the tolerance of several conifers in lower Michigan to applications of 2,4-D and 2,4,5-T, found that there were no apparent effects of the phenoxy herbicides on white spruce if applied after July 15.

Hexazinone: Spruces are rated as intolerant/tolerant of Velpar-L (Corcoran 1989). White spruce may be planted on medium- and fine-textured soils, where the organic layer has not been removed, immediately after a 9.0 l/ha application (Dupont Canada 1987). If more than 9.0 l/ha are used, or the organic layer has been removed or severely disturbed, planting should be delayed until the season following treatment (Dupont Canada 1987). Blackmore and Corns (1978) studied residual activity of hexazinone (Velpar 10% pellets) applied at 2.2-5.6 kg/ha, on one-year-old white spruce seedlings planted a month after herbicide application. The soil was a sandy clay loam with 10-15 cm of peaty organic matter, supporting a dense stand of Canada bluejoint grass. When evaluated 11 months later, survival, leader length and dry weight of spruce were significantly lower than controls. Harvey and Day (1981) tested the survival and growth of white spruce seedlings planted one year after site preparation with hexazinone, which was applied in a grid pattern either as concentrated solution with a spot-gun or gridball pellets distributed by hand. Results indicated that hexazinone would be an effective herbicide for site preparation, and white spruce can be planted safely the following year. Concentrated Velpar-L spots may be lethal to white spruce; to avoid damage, spots should be kept at least 1 m away from crop trees (Presslee 1989).

Glyphosate: White spruce survival is relatively unaffected by glyphosate site preparation (Perala 1985). Sutton (1978) reported some damage to newly planted 3+0 white spruce. Corns (1978a) evaluated selectivity of glyphosate at 3.9 kg a.i./ha on white spruce seedlings planted at different times after spraying a sandy soil with a cover of mixed perennial grasses. Observations recorded 5, 8 and 11 weeks post-spray indicated that white spruce were injured if planted less than four days after herbicide applications. There was no visible response when spruce was planted six days after spray application. Glyphosate injury to white spruce may include top dieback, poor vigour, chlorosis, very slow, partial or retarded flushing, stunted needles on current year's growth, chlorotic buds and mortality (Gardner 1978). Foliar injury to white spruce is higher following field applications of glyphosate in July, during periods of active growth, than in September and October when the trees are not growing actively (Willis *et al.* 1989). Gardner (1978) stressed the need for newly flushed growth of conifers to be hardened-off before release with glyphosate. He suggested that mid-August would be the best time to apply glyphosate, rather than mid-Juiy or late August, because at this stage the current year's height increment would be completed and bud development would be well advanced. The seedlings would be more resistant to foliar application of glyphosate, but the herbaceous vegetation and shrubs would be more susceptible than later in the season.

Uses by Wildlife

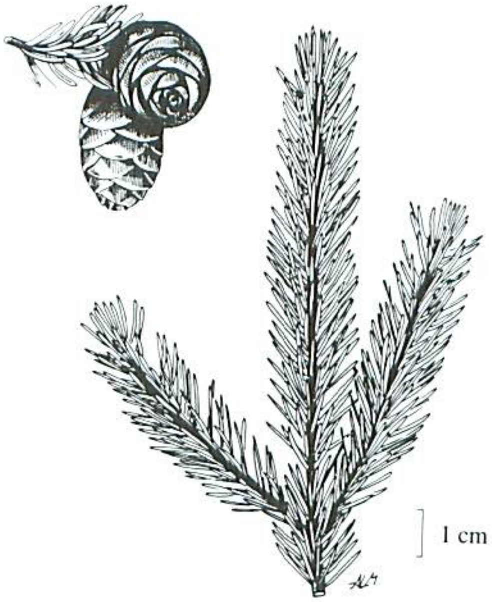
Deer and moose rarely feed on white spruce. Mature white spruce provide late winter cover to moose (Timmermann and McNicol 1988).

Damage from snowshoe hare can become a serious problem when populations reach their peak (Nienstaedt 1957). Where brush cover and small plantings give the hares protection, practically all trees may be damaged. Rowe (1955) mentioned cases in which repeated browsing by hares caused the death of white spruce up to 0.9 m tall.

White spruce seed is a preferred red squirrel food (Watson *et al.* 1980).

Picea mariana (Mill.) B.S.P.
Black Spruce

Description



General: small to medium-sized (averaging 15 m high), evergreen conifer tree with a narrow, often compact, conical crown; branches drooping with upturned ends; top of the crown often with dense clusters of branchlets forming a club-like shape; branchlets densely covered with velvety hair, with persistent, raised, woody leaf bases; trunk bark dark greyish-brown, flaky, inner bark dark and olive-green.

Leaves: linear, needle-like, thick, stiff, sharp, <2 cm long (usually about 1.5 cm); distinctly four-sided in cross-section; dark bluish-green, often with a whitish powdery coating; individually attached in a spiral around the branchlet forming a cylindrical rather than a flattened spray.

Flowers: male and female flowers separate on the same tree; male flowers tiny, conelike, deciduous, short-lived, at the end of previous year's growth; female flowers, red erect cones with numerous spirally-arranged scales, also at the end of previous year's growth; appearing in May.

Fruit: winged seeds enclosed by woody scales of the mature female cone; cones are about 1.5-3.0 cm long, egg-shaped to roundish, scales toothed or with frayed margins; persistent on the branches for years, after development opening periodically late in the winter to release seeds.

Habitat

Distribution of **black spruce** in Ontario
(Adapted from: Hosie 1979)

Distribution in Ontario: The commercial range of black spruce extends throughout most of the Boreal and Great Lakes-St. Lawrence Forest Regions of Ontario (Rowe 1972, Hosie 1979). The botanical range extends considerably beyond its commercial range (Arnup *et al.* 1988).

Climate: Within the natural range of black spruce, the frost-free season varies from 130-140 days in the southeast to less than 60 days in more northerly locations (Fowells 1965). Annual precipitation varies from a high of 114-140 cm in Quebec and the Maritimes to less than 25 cm in the tundra of northwest Canada (Fowells 1965).

Site and Soil Relations: Black spruce grows on an extremely wide range of sites, from dry sands and gravels to nutrient deficient organic soils rich in Sphagnum mosses (Heinselman 1957, Arnup *et al.* 1988). Black spruce dominated stands in NW Ontario are distributed among 3 major landform deposition types: 1/3 organic, 1/3 morainic tills and 1/3 glaciofluvial and lacustrine deposits (Sims *et al.* 1990). Maximum growth is attained on loams and clay loams with good drainage (Heinselman 1957).

Nutrient Requirements: Black spruce is considered to be less nutrient demanding than white spruce (Arnup *et al.* 1988). It is usually found on sites of low nutrient status (Carleton *et al.* 1985). Availability of nitogen is considered to be the nutrient factor most strongly related to growth of black spruce (Arnup *et al.* 1988). Black spruce is tolerant of high soil acidity levels.

Moisture Requirements: Black spruce is associated with a wide range of soil moisture regimes. Growth is best where slopes are gentle and moisture is plentiful, either from shallow water tables or seepage (Heinselman 1957). Growth and frequency of occurrence decline only on dry mineral soils, and on organic soils as the water table approaches the soil surface (Arnup *et al.* 1988).

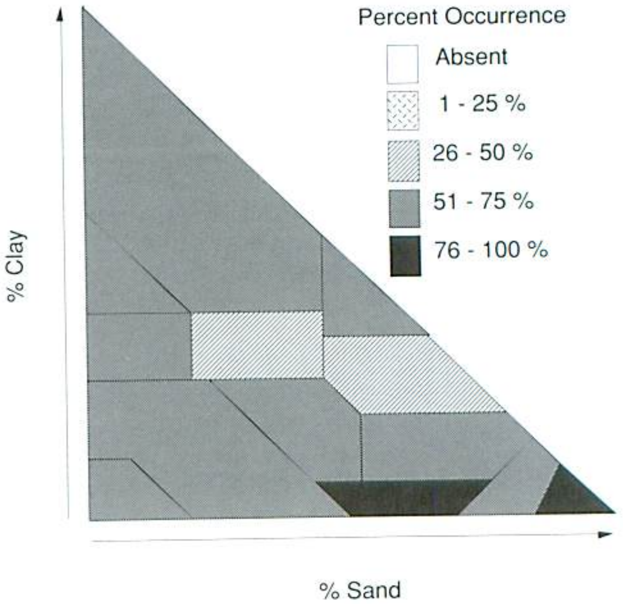
Light Requirements: Black spruce is shade-intolerant, and grows best in full sunlight (Arnup *et al.* 1988). On a relative scale from 0 to 10, black spruce scored 6.4 compared to 6.8 for white spruce and 9.8 for balsam fir (Graham 1954). Seedlings can survive and develop in as low as 10% full sunlight, but much faster growth is observed for seedlings grown in full sunlight (Heinselman 1957). Logan (1969) grew black spruce seedlings for nine years in 13%, 25%, 45% and 100% of full light. Height and diameter growth, as well as shoot and root weights, were greatest for black spruce grown in full light.

Reproduction

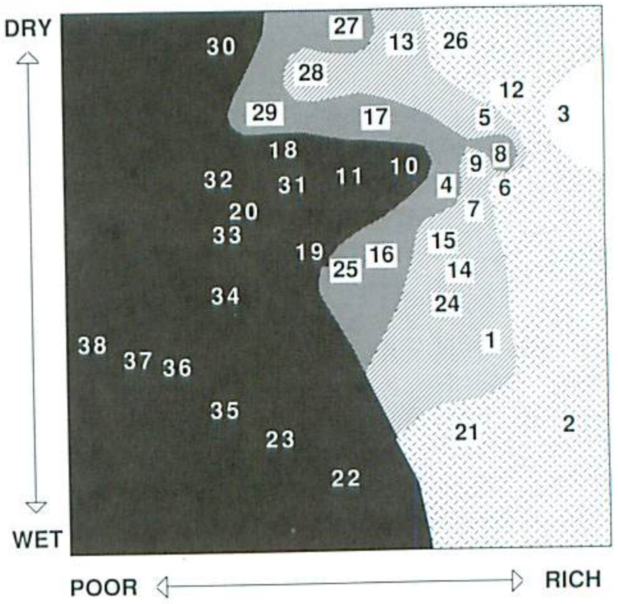
Sexual Reproduction: Black spruce is a monoecious species (Arnup *et al.* 1988). Male flowers are scattered over the crown from mid-height to the top, and may be terminal or axillary on branchlets of the previous year. Female flowers are found only near the tops of trees.

Seed Bearing Age: Small quantities of seed have been observed on 10 to 15-year-old trees in natural stands (Vincent 1965c). Most stands over 25 years of age bear seed regularly. Black spruce stands 40 or more years old have a nearly continuous seed supply because the persistent cones shed seed for at least four years after ripening (Johnston 1977). The optimum age for seed production is from 50 to over 150 years, but good crops are often observed on stands 200 years old or more (Heinselman 1957).

Frequency and Size of Seed Crops: Good cone crops occur at intervals of one to four years, averaging 1.9 years. Heavy crops occur at intervals of two to six years (Vincent 1965c). Black spruce is a dependable seeder and failures for as many as two or



Frequency of occurrence of **black spruce** by soil texture class



Frequency of occurrence of **black spruce** by Vegetation Type three successive seasons are rare (Heinselman 1957). Annual seed production per mature tree ranges from 20,000 to 32,000 cleaned seeds in a 'good' year. In poor years, the annual production may be more in the order of 4,000 to 5,000 viable seeds per tree. Average rates of seedfall range from 146,000 to 2,300,000 viable (filled) seeds/ha/yr. Annual seedfall in a given stand may vary up to twelve-fold from year to year. Upland sites tend to produce greater cone and seed crops and a larger proportion of viable seed than lowland stands.

Cleaned seed averages about 890,700 seeds/kg with a range of 738,500 to 1,124,000 (Anon. 1974). Seed yields in Ontario average approximately 350,000 viable seeds per hectolitre of cones (Arnup *et al.* 1988).

Pollen and Seed Dispersal: Cones are semi-serotinous and some seed is dispersed throughout the year (Hienselman 1957). Most viable seed is shed within four years of ripening, and viability of remaining filled seeds decreases rapidly after the fifth year (Arnup *et al.* 1988). Wind speed and direction are primary factors determining the distribution of black spruce seed. Natural seeding is most effective up to 80 m downwind from the edge of stands and up to 40 m upwind. However, black spruce seeds can travel farther, and good distribution may occur up to 200 m from a seed source (Fowells 1965).

Seed Viability and Germination Requirements: Most cleaned seed lots obtained from newly ripened cones have germination capacities in excess of 85%. Cones produced during years with large cone crops generally have a greater percentage of viable seeds than cones produced in poor years. The viability of black spruce seed deposited on or in the forest floor decreases with time and is completely lost within 10- 16 months (Arnup *et al.* 1988). Soil seedbanks under northern spruce forests contain no viable black spruce seeds.

Unstratified seeds from newly ripened cones require light for rapid and/or complete germination, particularly at low temperatures. When seeds are chilled under moist conditions (stratified), light is not required for germination (Arnup et al. 1988).

Under ideal outdoor conditions, black spruce germination starts 10 days after seed deposition and is complete within three weeks. Germination is slower when moisture is not continuously available or temperature is limiting. Seedling establishment requires a moist but unsaturated seedbed, free from competing vegetation (Johnston 1977). Natural establishment is generally successful if the surface layer is removed, compacted or composed of living Sphagnum moss (Johnston 1977). During the first season of growth the radicle of black spruce elongates 2 cm or less and seedlings are restricted to seedbeds of relatively constant moisture supply (Heinselman 1957). Mineral soils make a suitable seedbed (LeBarron 1948) but finer-textured soils are susceptible to frost heaving (Johnston and Smith 1983). Feathermosses usually die and dry out after timber harvest, and therefore make a very poor seedbed (Johnston and Smith 1983). Sphagnum mosses, particularly those species with a compact surface, make a good seedbed, but sometimes these mosses outgrow the seedlings (Arnup *et al.* 1988).

Vegetative Reproduction: Black spruce reproduces vegetatively by layering (Heinselman 1957). Layering takes place when portions of lower living branches droop to the ground and are subsequently buried by accumulated litter or are overgrown by moss (Heinselman 1957). Layering can take place at any age of the parent tree. It is an important method of regeneration in older, deteriorating forests and helps to maintain, and in some cases, increase the black spruce component (Vincent 1965c). Layering may often be the main method of natural regeneration in wet Sphagnum bogs and very dry, shallow soil upland sites where conditions are adverse for seedling establishment (Arnup *et al.* 1988). Layering is probably of little importance to reforestation of burned sites (Zasada 1971).

Cuttings taken from black spruce seedlings show good rooting ability. Vegetative propagation of clonal material can be used to quickly propagate genetically improved stock (Arnup *et al.* 1988).

Growth and Development

Black spruce is a small and slow growing but moderately long-lived tree. A height of 26 m is exceptionally tall for this species and diameters seldom exceed 43 cm at breast height. Most black spruce trees, even when not crowded by larger neighbours, succumb to various destructive agents long before they attain their maximum possible age of 250 years or more (LeBarron 1948).

Black spruce experiences free or indeterminate growth in juvenile stages of its life cycle. In other words, growth and flushing are more or less continuous as long as favourable environmental conditions are maintained. The free growth phase diminishes, and ceases between five to ten years of age. After this phase, annual growth originates solely from preformed, overwintered buds (Arnup *et al.* 1988).

In its first few years, natural origin black spruce only grows to about 2.5 cm in height on open sites and less under shaded conditions. Early height growth is often slower on mineral soil than on organic layers or burned duff. Height growth in nurseries and plantations often exceeds that of natural seedlings (Heinselman 1957). The height growth of upland black spruce while young is slower than that of its common competitors. Growth of unsuppressed trees at early ages in more fertile lowlands is only slightly slower than on typical upland sites (LeBarron 1948).

Primary rootlets penetrate to a depth of about 1.3 cm within a week of germination, but subsequent growth is slow (Heinselman 1957). Rooting characteristics of black spruce vary somewhat with soil features, but remain essentially shallow. Rooting depth can be restricted by fine-textured clayey soils, and tends to be somewhat greater on loamy or sandy soils. Although black spruce develops limited vertical root systems, it usually possesses an extensive fibrous, lateral root system. Many of the fine roots of black spruce on upland mineral soils tend to be located right along the organic humus/mineral soil interface, which supplies most nutrient needs, especially nitrogen (Arnup *et al.* 1988).

Phenology

Root, Shoot and Foliage: Overwintering vegetative buds of black spruce contain fully preformed shoots. Vegetative buds are set from early to mid-July (Arnup *et al.* 1988). Swelling of over-wintered buds begins between mid-April and mid-May, usually two weeks later than bud swelling of white spruce. Flushing occurs between late May and early June, approximately one week later than reproductive bud flush. Degree-day requirements for flushing average 150.5 (O'Reilly and Parker 1982). Elongation of the terminal shoot normally ceases in late July or early August (O'Reilly and Parker 1982).

Cambial activity is initiated between late April and mid-May and ceases between late July and mid-August. Increase in radial dimensions of the trunk coincides with, or slightly precedes, swelling of the leader's terminal bud. Spring cambial activity is first initiated behind the leader's bud or behind terminal buds of large branches and then progresses basipetally along the trunk.

The timing of bud break, flushing, leader development, bud set and hardening of new growth varies according to local climate conditions.

Reproductive Structures: Male reproductive buds of black spruce are initiated in the growing season previous to the one in which flowering takes place (Heinselman 1957). Reproductive buds can be distinguished from vegetative buds microscopically by the end of July. Bud primordia are set by September. Pollen is dispersed between mid-May and early June, approximately 9 days following the appearance of the first recognizable female flowers.

For a single seed crop, two years lapse between flower primordia initiation and the time that most seeds are dispersed. Female reproductive buds are initiated in the previous growing season (Heinselman 1957). Flower activity generally occurs between mid-May and early June, with floral flushing occurring between late May and mid-June (Heinselman 1957). Flowering dates vary as much as two or three weeks between seasons (Heinselman 1957). Cones reach their full size by early August and turn purple as they ripen between late August and mid-September (Smith 1984). Although cones may begin to open from late September to early November, the majority of the annual seedfall occurs from early spring to mid-summer of the following year. LeBarron (1948) reported that for a swamp black spruce stand in Minnesota, 9% of the annual seedfall occurred in August, 19% in September, 38% from October to April, 13% in May, 14% in June and 7% in July. Haavisto (1978) found that natural dispersal of a major proportion of viable seed of a lowland stand occurred during a six-week period between mid-April and late May. In a Newfoundland study, 28% of the seed in upland black spruce fell during the period of July 13 to August 12, 14% between August 13 and September 23, 8% between September 24 and October 24, and about 50% between late October and the end of the following May (Howard 1962).

Competition

Response to Competition: During the first few years of life, black spruce is susceptible to smothering or crushing by hardwood leaves and dead grass. Black spruce seedlings will develop under an overstory with as little as 10% of full sunlight intensity, but development is much better in the open. A light or moderate overstory of aspen is not usually harmful to black spruce and may be beneficial in some circumstanes. Slow growth and understocking result when black spruce is severely suppressed by competing shrubs or hardwoods (Johnston 1977).

Sphagnum spp., particularly those species with a compact surface, provide good seedbeds (Arnup *et al.* 1988). However, some types of *Sphagnum* spp. will outgrow black spruce germinants and smother them (Johnston 1977). In black spruce stands, Weetman (1968) showed that feathermosses, particularly *Pleurozium schreberi* (Brid.) Mitt., play a critical role in nitrogen cycling by accumulating and mineralizing nitrogen.

On sites with heavy grass competition, snow and ice can compress grass litter, crushing seedlings (Arnup *et al.* 1988). Bluejoint grass is especially problematic (Roe 1960), but sedges may also be a limiting factor to the stocking of natural-origin black spruce (Scott 1977).

A number of plants are allelopathic to black spruce. Fisher (1980) reports that leachates from common forest plants such as bog laurel (*Kalmia polifolia* Wang.) and large-leaved aster (*Aster macrophyllus* L.) inhibited germination and early growth of black spruce in the laboratory. Sheep laurel produces a water soluble substance that hinders primary root development of black spruce by destroying epidermal and cortical cells (Peterson 1965). Elongation of primary roots was progressively inhibited with increasing amounts of extract from dried sheep laurel leaves. The extract is believed to be active wherever sheep laurel predominates (Krause 1985). In the presence of sheep laurel, growth of black spruce seedlings is drastically reduced (Wall 1977).

Labrador tea is considered to be a serious competitor to black spruce regeneration on organic sites, particularly when poorly drained, and on some shallow soils. Labrador tea seriously retards both establishment and survival of black spruce..Once established, black spruce will eventually suppress Labrador tea (LeBarron 1948). Labrador tea competes with black spruce for nitrogen and phosphorus because of its higher uptake capacity per mass of roots compared to black spruce. As well, it has a shallower rooting depth and therefore earlier spring uptake compared to black spruce (Chapin 1983). Black spruce and Labrador tea are also similar to one another in magnitude and seasonal pattern of phosphate absorption, high in June and September and low in May and July (Chapin and Tryon 1983).

Other competitive species act as alternate hosts for needle rusts. While rusts are not known to seriously injure spruce, they may cause enough defoliation to interfere with its use for Christmas trees. Heinselman (1957) highlighted four needle rusts and associated alternate hosts:

Rust	***Alternate host***
Chrysomyxa cassandrae	*Chamaedaphne calyculata*
Chrysomyxa ledi	*Ledum spp.*
Chrysomyxa ledicola	*Ledum spp.*
Chrysomyxa chiogensis	*Gaultheria hispidula*

Layering is more frequent where black spruce is associated with dwarf shrubs such as *Kalmia* spp., *Ledum* spp. and *Vaccinium* spp. (Vincent 1965c).

Alder can be a serious competitor on better-drained organic sites and on some poorly drained mineral soils. Heavy leaf fall from speckled alder smothers black spruce seedlings (LeBarron 1948). Black spruce can survive for long periods under alder and eventually overtop it, but slow growth and understocking result when it is severely suppressed for several years (Johnston and Smith 1983). Shade from speckled alder competition reduces height growth of overtopped black spruce (Vincent 1964b). Height growth of seedlings under a speckled alder canopy is significantly related to: 1) initial height of reproduction, 2) canopy density of the alder, 3) age of the reproduction and 4) light level received at the tip of the spruce stem. Height growth of black spruce layers under a speckled alder canopy is less affected, than that of seedlings, by the alder's canopy density. Vincent (1964b) concluded that the overall effect of speckled alder on black spruce reproduction is beneficial, but that some manipulation of the alder canopy may be necessary if the full wood-producing potential of a site is to be realized.

On some sites, a light covering of aspen suckers and shrubs can help protect black spruce from late spring and early summer frosts. Trembling aspen will usually outgrow black spruce within a few years, unless site conditions are very unfavourable for the aspen (Heinselman 1957).

Response to Release: Black spruce should be released before it shows signs of suppression. If release is delayed, seedlings will take longer to respond and a second release may be needed. Severely suppressed black spruce do not respond quickly to release. Complete removal of an aspen or alder overstory will frequently result in an invasion by grasses or sedges, particularly on fine-textured mineral soils.

In general, seedlings and layers of the same initial size have a similar response to release from speckled alder (Vincent 1964b).

Sudden opening of a stand, either by cutting or severe windfall, may result in sun scald damage to suppressed advance growth (Miller 1936).

Chemical Treatments: The response of black spruce to 2,4-D, hexazinone and glyphosate will be discussed separately.

2,4-D: Black spruce is quite resistant to 2,4-D if it is applied after buds have formed.

Hexazinone: Spruces are rated as intermediate/tolerant of Velpar-L (Corcoran 1989). Black spruce may be planted immediately on medium- and fine-textured soils where the organic layer has not been removed, following an application of 9.0 l/ha (Dupont Canada 1987). If rates greater than 9.0 l/ha are used, or if the organic layer has been removed or severely disturbed, planting should be delayed until the next season following treatment (Dupont Canada 1987). Results from Wood *et al.* (1989) suggest that, for paperpots at least, chemical site preparation with 4.0 kg/ha is not advisable unless the site is left fallow for one full year following treatment. Differential tolerance of transplant and paperpot black spruce stock to hexazinone has been observed. Transplants appear to be more tolerant than paperpot stock (Wood *et al.* 1989). The safest chemical site preparation option on clay loam or finer-textured soils, for both stock types, is to apply hexazinone at 2.0 kg a.i./ha and to plant as soon as practical afterwards so that crop trees may take maximum advantage of the weed control.

Glyphosate: Black spruce is relatively resistant to glyphosate applied as a top spray in early August or September. In a Nova Scotia study, newly planted black spruce was sprayed with two different rates of Vision (3.2 and 4.7 l/ha) applied on 16 different dates between July 2 and October 22 (Anon. 1989c). During the week prior to treatment, the treatment areas were manually cleared of overtopping vegetation. Results collected one to two years after treatment indicated that some seedlings sprayed early in the season showed slight burning of the shoot tips in the year of treatment. This damage was evident in fewer seedlings towards the end of July and by August most seedlings exhibited no damage. One year later, damaged seedlings set normal buds.

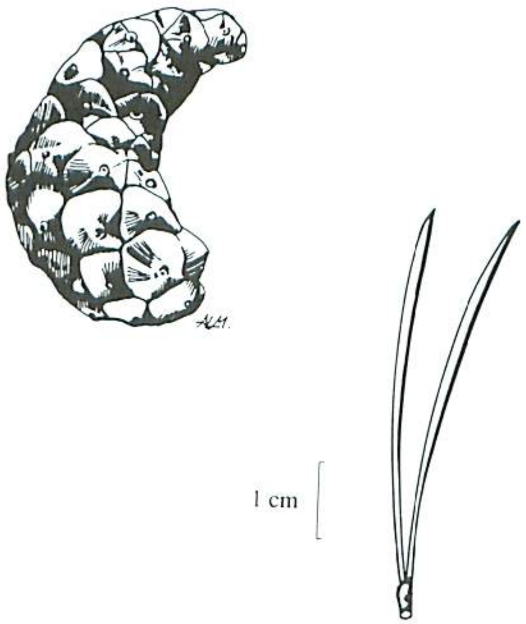
Uses by Wildlife

Moose occasionally browse leaders of black spruce, but black spruce is generally not a preferred browse species (Heinselman 1957). Mature black spruce provides late winter cover to moose (Timmermann and McNicol 1988). Black spruce is rarely eaten by white tailed deer, but under starvation conditions needles are sometimes taken in small quantities (Heinselman 1957). In late winter, caribou prefer black spruce bogs and lichen-rich, mature coniferous ridges associated with bog complexes. They occasionally frequent overmature black spruce upland sites in the 80 to 120-year age classes (Arnup *et al.* 1988). Snowshoe hares may extensively damage black spruce seedlings and saplings when hare populations are high (Heinselman 1957, Johnston and Smith 1983). Although black spruce is not a preferred food, hares will debark seedlings and saplings and nip off leaders and branches (Heinselman 1957). In dense black spruce reproduction some natural thinning is accomplished in this manner (Heinselman 1957).

Spruce grouse (*Canachites canadensis* L.) depend mainly on the black spruce cover type for food and cover (Johnston 1977, Rudolph 1983). It is also used by snowshoe hare and red squirrel. During summer, birds commonly found in black spruce stands include the ruby-crowned kinglet (*Regulus calendula* L.), magnolia warbler (*Dendroica magnolia* Wilson) and Cape May warbler (Rudolph 1983). Osprey (*Pandion haliaetus* L.) often nest in lowland black spruce cover types.

Pinus banksiana Lamb.
Jack Pine

Description



General: medium to large-sized (averaging 19 m high, up to 30 m), evergreen conifer tree with a sparse, variable crown; branches spreading or ascending; branchlets yellowish-green; trunk bark reddish-brown on young stems becoming dark brown, flaky or platey.

Leaves: needle-like, straight or slightly curved, somewhat twisted, stiff, sharp-pointed; in clusters of two, spread apart, short (2.0-3.5 cm long); light yellowish-green; with a persistent basal sheath.

Flowers: male and female flowers separate on the same tree; male flowers tiny, conelike, deciduous, short-lived, at the base of the current year's growth; female flowers erect cones with numerous spirally arranged scales; appearing in May.

Fruit: winged seeds enclosed by woody scales in mature female cones; cones are erect, egg-shaped to conical, straight or curved, 3-5 cm long, and usually remain closed and persistent on the tree for years.

Habitat

Distribution in Ontario: The commercial stands of jack pine occur primarily in the Boreal Forest Region; however, they also form a major part of the Boreal/Great Lakes-St. Lawrence Transition Forest in the Northeastern Region (Hosie 1979, Galloway 1986).

Climate: The natural range of jack pine is characterized by long frigid winters and short, warm to cool summers with low rainfall (Galloway 1986). Within the natural range of jack pine, average January temperatures vary from -29°C to -4°C; and average July temperatures range from 13°C to 22°C (Fowells 1965). Jack pine can tolerate summer droughts, or periods of 30 or more days without measurable precipitation. The number of frost free days across the range of jack pine varies from 50-180 days (Fowells 1965). The average date of the last killing spring frost ranges from April 30 to about July 1; that of the first killing frost in the fall, from about August 10 to October 20 (Fowells 1965). Since jack pine generally does not flush early, its resistance to frost is relatively high.

Site and Soil Relations: Through out its range, jack pine grows most commonly on level to gently rolling sand plains, usually of glacial outwash, fluvial, or lacustrine origin. It occurs

Distribution of **jack pine** in Ontario
(Adapted from: Hosie 1979)

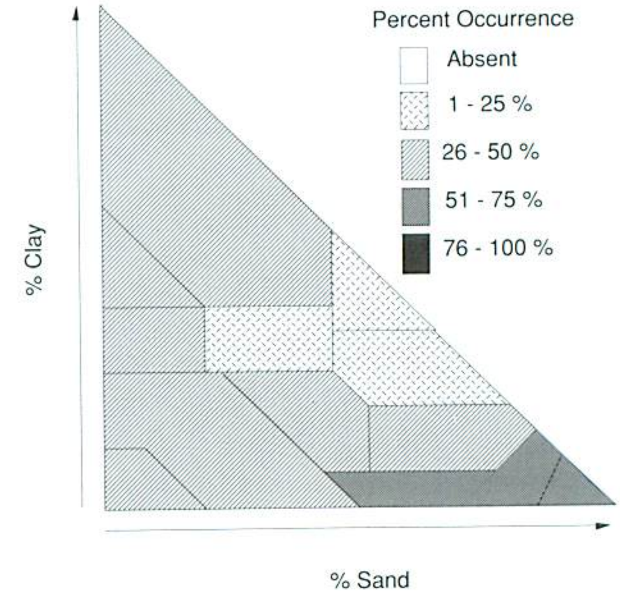
less commonly on eskers, sand dunes, rock outcrops and bald rock ridges (Fowells 1965). In NW Ontario, jack pine is primarily found on glaciofluvial deposits and morainal tills. Jack pine is less frequently associated with lacustrine soils and is not associated with organic terrain (Sims *et al.* 1990). Jack pine occurs most frequently as a tree species on deep, dry to fresh, coarse sandy soils (S1) and deep, fresh, fine sandy to coarse loamy soils (S2,S3). It occurs occasionally on shallow, coarse loamy soils (SS6). Jack pine is rarely found as the dominant tree species on fine-textured silt and clay soils or organic soils. Although jack pine may obtain its best growth on fine-textured soils (SiC, SC and C with a MR <4 or Si and SiL with a MR >4), other species usually outcompete jack pine on these sites. The highest site indices of jack pine in northern Ontario are associated with very fine sand in which the upper soil horizons are silty or loamy. As textures change from very fine sand to fine sand, and then to medium sand, the site indices gradually diminish (Chrosciewicz 1963).

Nutrient Requirements: Jack pine has a relatively low nutrient requirement and is usually found on sites of low nutrient status (Carleton *et al.* 1985). Jack pine achieves good growth on soils with a pH of 4.5-7.0. However, it will grow satisfactorily on calcareous soils (pH 8.2) if a normal mycorrhizal association is present (Fowells 1965).

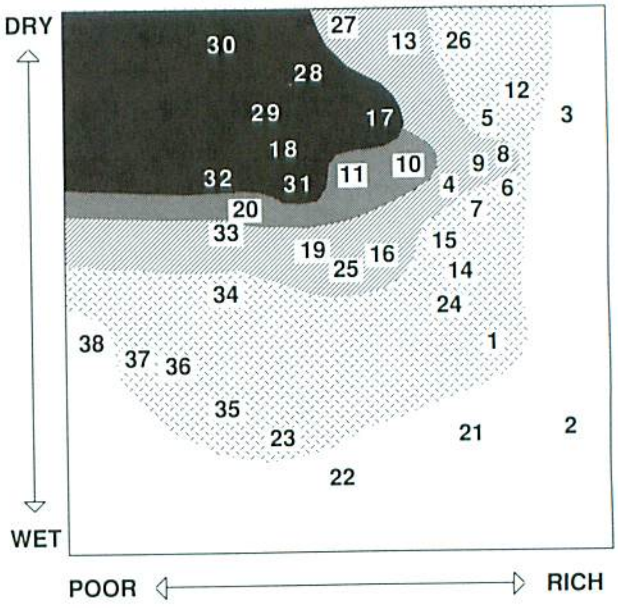
Moisture Requirements: Jack pine can maintain itself on very dry sandy or gravelly soils where other species can barely survive, but it grows best on well-drained loamy or very fine sands where the mid-summer water table is 1.2-1.8 m feet below the soil surface (Fowells 1965). Only rarely does it occur on poorly drained soils (Cayford *et al.* 1967).

In NW Ontario, jack pine dominated stands are mainly associated with moderately fresh, fresh, moderately dry, and dry soil moisture regimes. The highest site indices of jack pine are associated with soil MR 3 (fresh) (Chrosciewicz 1963).

Light Requirements: Jack pine is intolerant of shade and requires full sunlight to achieve optimum growth (Benzie 1977). In a study by Logan (1966), jack pine seedlings were grown for six years in 13%, 25%, 45% and 100% of full light. During the first four years, the tallest jack pine were growing in 45% light, but in the fifth and sixth years the tallest seedlings were those in full light. After six years, jack pine attained maximum height and maximum weight of foliage, wood and roots when grown in full light. In natural stands, jack pine seedlings are usually not found under crown covers greater than 60% (Rudolph 1983).



Frequency of occurrence of **jack pine** by NWO FEC soil texture type



Frequency of occurrence of **jack pine** by NWO FEC Vegetation Type

Reproduction

Sexual Reproduction: Natural origin jack pine are exclusively from seed.

Seed Bearing Age: Normally, seed production begins at 5-10 years in open-grown trees and 10-25 years in closed stands (Rudolph 1983). Seed production is best when trees are between 40 and 50 years old (Fowells 1965, Benzie 1977). Total crop failures are rare (Rudolph 1983).

Frequency and Size of Seed Crops: Good seed crops are produced at intervals of three to four years, with light crops in most intervening years (Fowells 1965, Benzie 1977). A well-developed, vigorous tree may produce from 1,000 to 1,200 cones per year, although 300-500 are more common. In Ontario, a mature stand was found to have from 741,300 to 988,000 cones per ha (Noakes 1946). In well-stocked stands in northern Minnesota the trees held an average of 5.1 kg, or about 4,942,000 cleaned seeds/ha in unopened cones (Eyre and LeBarron 1944). Jack pine has the smallest seed of any North American pine. Numbers of seeds/kg range from 156,500 to 390,000 and average 286,600 (Eyre and LeBarron 1944).

Pollen and Seed Dispersal: Jack pine has serotinous cones that usually do not open until subjected to temperatures of at least 50°C (Eyre and LeBarron 1944, Cayford et al. 1967, Dobbs and Oswald 1972). Jack pine cones open and disperse seed readily when placed within 30 cm of the ground (Cayford *et al.* 1967). Jack pine seeds are disseminated primarily by wind. The effective range of seed dissemination is about two tree heights, but effectiveness decreases beyond one tree height (Rudolph 1983). Squirrels store caches of cones and thereby facilitate dissemination. Other rodents and birds also aid in seed dispersal (Dobbs and Oswald 1972).

Seed Viability and Germination Requirements: Over a seven-year period in northern Lower Michigan, soundness of naturally dispersed seed varied from 24% to 72%, with the greatest soundness usually occurring during years of best seed production (Fowells 1965). Seed stored in cones on the tree remain viable in high proportions for 5 to 10 years (Eyre and LeBarron 1944). Germination of cleaned, filled seed commonly exceeds 95% at the Ontario Tree Seed Plant in Angus, Ontario (Galloway 1986).

Jack pine seed occasionally exhibits dormancy, but usually germinates within 15-60 days under favourable conditions. Some seeds have delayed germination, so substantial increases in stocking may be noted up to three years after seed dispersal (Rudolph 1983). Germination of jack pine varies greatly according to the character of soil surface. The best germination medium is exposed, moist mineral soil (Eyre and LeBarron 1944, Benzie 1977, Rudolph 1983). Seedbeds of mixed humus and mineral soil are generally not as good because roots and seeds in the humus provide increased competition (Benzie 1977). Germination and survival are poor where the surface is apt to dry out rapidly (Cayford *et al.* 1967, Rudolph 1983). In northeastern Minnesota, germination under clearcut and partially cut jack pine stands averaged 60% on mineral soil, 49% on burned duff, 47% on scarified and shaded duff, and 17% on undisturbed duff. Jack pine seeds germinate more rapidly in light than in dark (Fowells 1965, Cayford *et al.* 1967). Survival on the various soil surfaces showed the same trend as germination (Fowells 1965). Optimum conditions for survival are provided by mineral soil and burned seedbeds, particularly in areas where competition from other vegetation is not severe (Ahlgren 1979b). Losses resulting from heat and drought may be reduced in shaded conditions and on north and east slopes. Soil temperatures above 50°C, if they continue for a period of two hours, endanger young seedlings. Soil surface temperatures up to 79°C have been recorded on jack pine sites with temperatures for both burned and unburned duff higher than those on loamy mineral soil (Eyre and LeBarron 1944). Microsites that provide partial shading without allowing vegetative competition for light and moisture are the preferred sites for germinant survival (Galloway 1986).

Vegetative Reproduction: In nature, jack pine does not reproduce vegetatively (Fowells 1965).

Growth and Development

Jack pine achieves especially rapid growth in the juvenile stage (Cayford and Bickerstaff 1968). Under good growing conditions, seedlings reach breast height in four to six years, and a height of 6 m in about 18 years. In well-stocked stands, merchantable trees (trees at least 13 cm dbh.) are produced in 30 years. After trees pass 50 years of age, diameter and height growth progressively decline. On poor sites, height growth may slow at an earlier age (Eyre and LeBarron 1944). On better sites jack pine has been known to grow to a height of 32 m, and there are reports of trees as large as 71 cm dbh. However, heights greater than 24 m and diameters greater than 46 cm are uncommon. Jack pine may reach 175 years of age, but ordinarily matures in less than half that time (Eyre and LeBarron 1944). Although jack pine is a short-lived tree, a few individuals may live more than 200 years, and stands sometimes survive up to 100 years (Benzie 1977).

Sterrett (1920) reported that jack pine seedlings can develop a tap root of 15-30 cm in the first year.

Phenolgy

Root, Shoot and Foliage: In northern Minnesota, root growth begins when the temperature reaches 4°C in the upper 15 cm of soil. Root growth usually begins within a week of the onset of shoot growth and ceases in fall when soil temperatures drop to 7°C for 6 days or more. In some years, root growth may begin in April and continue to late October (Fowells 1965). If favourable moisture conditions prevail in late summer, jack pine may have a second period of shoot elongation and produce lammas shoots.

Moisture content of newly flushed jack pine needles is >260% in early June, drops rapidly to 150% by mid-August, then declines more slowly to 130% by mid-October (Van Wagner 1967). Chemical analysis and electron micrographs show cuticular wax deposition is greater 14 weeks after bud flush than three weeks (Willis *et al.* 1989). The increased wax may reduce herbicide uptake and partially account for an increased herbicide tolerance later in the growing season (Willis *et al.* 1989).

Reproductive Structures: Primordia for female flowers may be laid down well in advance (probably several weeks) before primordia for male flowers (Fowells 1965). Jack pine usually flowers in May to June (Anon. 1974). In the Lake States, the small conelets first become visible in late May and pollination occurs shortly thereafter. By late July or early August, conelets cease to grow for the season. Growth continues the following season with cones ripening between late August and mid-September of the second year (Smith 1984). Seedfall usually begins that fall and may occur intermittently for several years (Fowells 1965). However, peak seedfall periods for individual stands have occurred in autumn, spring, and occasionally, summer (Cayford *et al.* 1967).

Competition

Response to Competition: Jack pine is so shade-intolerant that it cannot survive long with overhead shade (Benzie 1977). Vegetative competition from shrubs and herbaceous vegetation, together with smothering by fallen leaves, were important causes of mortality following spot seeding on sandy soils in Ontario (Chrosciewicz 1960). Certain herbs and shrubs may provide a shady, cool microenvironment which is beneficial for germination and early survival of jack pine (Cayford *et al.* 1967, Benzie 1977, Cayford and McRae 1983). Jack pine seedlings grow rapidly in height after the first couple of years and can usually outgrow competition, except on better sites (Benzie 1977). As soon as seedlings are established they should be given full sunlight (Benzie 1977). The benefits of shade to the early survival of young jack pine are short-lived and shade soon becomes a detriment (Stoeckler and Limstrom 1942).

Adams (1928) found that intense root competition with a consequent decrease in available soil moisture reduced jack pine diameter growth prior to reduction of height growth.

Brown (1967) found that extracts of nine plants common in jack pine forests inhibited germination of jack pine seeds. Fisher (1980) reported that reindeer moss (*Cladina* spp.) restricted growth of jack pine seedlings by reducing root formation.

The large, resinous basal cankers commonly found on jack pine are symptoms of sweetfern blister rust disease (*Cronartium comptoniae* Arth.). The disease is characterized by two shrubby hosts, sweetfern and sweet gale (*Myrica gale* L.) (McGauley and Gross 1984). Cankers of sweetfern blister rust are associated with significantly reduced height, diameter and volume growth of jack pine (Gross *et al.* 1978). Jack pine older than one year appear to be resistant to the disease (Galloway 1986).

Both aster (*Aster* spp.) and goldenrod (*Solidago* spp.) serve as alternate hosts for needle rust (*Coleosporium asterum* (Diet.) Syd.) (Anderson and Anderson 1978).

Competition from grasses has resulted in severe mortality to young jack pine following scarification and slash scattering on clay soils in western Manitoba (Cayford *et al.* 1967). Competition from sedges can be severe enough to prevent natural establishment of jack pine on poor sandy sites (Rouse 1986a). Grasses may also provide favourable habitat for damaging insects. Among the more important insects affecting jack pine seedlings are white grubs, particularly in areas with a heavy sod (Cayford and Bickerstaff 1968).

Early height growth in jack pine plantations varies inversely with ground occupancy by ericaceous plants, predominantly sheep laurel (Krause 1985). Wilde (1970) estimated that growth of jack pine plantations may be retarded by as much as 35%, depending on the presence of heath vegetation. This was considered to be the result of competition for water between heath species and jack pine on coarse-textured soils. In a study of the effects of various depths of blueberry leaf litter, it was found that a light covering (0.3-0.6 cm) was beneficial to the survival of eight-week-old seedlings, while a covering of from 1.3 to 2.5 cm had a detrimental effect (Curtis 1964).

Hazel is often considered to be a major competitor of young jack pine in Minnesota (Stearns 1974, Cayford and McRae 1983). Competition from trembling aspen and hazel has been responsible for poor survival of jack pine planted on clay soils in Manitoba and Saskatchewan (Cayford *et al.* 1967). There is some evidence that the presence of hazel undergrowth in established jack pine stands alters the chemical composition of the litter layer and may significantly influence nutrient cycling. Where hazel was present, weights of macronutrients in litter fall were nearly double those in pure jack pine litter (Tappeiner and John 1973).

Jack pine develops poorly under a cover of aspen, paper birch, or other broadleaved trees (Stoeckeler and Limstrom 1950). Jack pine is most likely to require release from poplar, birch and cherry competition on loamy tills and graminoid, red raspberry and poplar competition on silty or clayey sites (Galloway 1986).

The most severe damage by snowshoe hare to jack pine reproduction has occurred in plantations planted under aspen canopies (Cayford *et al.* 1967) or close to weeds or brush tall enough to furnish cover for hares (Eyre and LeBarron 1944, Barteaux and Bailey 1984, Little 1984). In Saskatchewan, hare damage is a major factor contributing to mortality in pine stands. In some cases 100% of trees in plantations are affected (Little 1984).

Response to Release: Jack pine does best in full sunlight and should be released from practically all overhead competition within a year after planting. A light uniform cover of aspen or brush, transmitting about 80% of full sunlight, can be maintained for one or two years after planting and may reduce mortality in drought years (Stoeckeler and Limstrom 1950).

Elimination of competition for water could be a reason for the strong growth response observed by Weetman and Fournier (1984) in a jack pine stand following the smothering of heavy ericaceous growth by a layer of straw.

Three fall release treatments (manual and glyphosate at 2.0 and 4.0 kg a.i./ha) of natural origin jack pine significantly increased height increment for one year, but had no effect thereafter (Sutton 1984). The response of jack pine to 2,4-D, hexazinone and glyphosate will be discussed separately.

Chemical Treatments: The sensitivity of jack pine to most herbicide sprays contrasts strongly with the high resistance of white spruce in all stages of silviculture from nursery seedbed to plantation weed control. Jack pine has a thinner cuticle and less heavily plugged stomata than white spruce (Lehela *et al.* 1972). Chemical release treatments are best applied after the summer drought period when the current year's growth of jack pine has hardened off and terminal buds feel sharp to the touch. Jack pine is highly resistant to fall-applied herbicide (Sutton 1984).

2,4-D: When competing vegetation is to be controlled by phenoxy herbicides, timing and dosage must be carefully controlled to avoid injury to jack pine (Rudolph 1983). Under certain conditions mortality or minor damage can occur in released trees. Yellowing of the needles and spiralling of the current year's leader are considered light chemical damage from which jack pine is able to recover by the following year (Dennis 1984). Results reported by Walker (1967) indicate that even though active growth in jack pine seedlings was completed prior to August 5, the physiological changes making them resistant to phenoxy herbicides were not complete until well after August 5. Jack pine should be released with 2,4-D using low rates (1.1-1.6 kg a.e./ha) no sooner than August 15 (Arend 1955, Day 1971) and only if lammas growth is absent. Lammas growth of jack pine occurs commonly in NW Ontario and can be damaged by an application of 2,4-D (Carruthers and Towill 1988).

Hexazinone: Jack pine is rated as susceptible to Velpar-L (Dupont de nemours 1977; Corcoran 1989). Jack pine may be planted immediately on medium- and fine-textured soils where the organic layer has not been removed, following an application of 9.0 l/ha (Dupont Canada 1987). If rates greater than 9.0 l/ha are used, or if the organic layer has been removed or severely disturbed, planting should be delayed until the next season following treatment (Dupont Canada 1987). Mid-July foliar application of hexazinone at 1.0 kg a.i./ha had no effect on jack pine; but at 2.0 and 4.0 kg a.i./ha, some jack pine was partially defoliated (Sutton 1984). Early September foliar applications of hexazinone, even at 4.0 kg a.i./ha, had virtually no effect on jack pine (Sutton 1984).

Glyphosate: Application should be avoided during lammas or late season growth. Ingratta (1979) tested glyphosate on two sites for release of jack pine in early September, and a mixed stand of jack pine and black spruce in mid-July. No injury was observed on jack pine with the late summer application, but the July application severely injured both conifers. Glyphosate applied in early September at 1.0 or 2.0 kg a.i./ha had almost no effect on jack pine; even at 4.0 kg a.i./ha most of the jack pine was not damaged (Sutton 1984). Mid-July applications were much more damaging, as might be expected (Sutton 1984). Even 1.0 kg a.i./ha of glyphosate caused some damage. At 2.0 kg a.i./ha, damage to jack pine foliage was common, but there was little mortality. At 4.0 kg a.i./ha, damage to jack pine was heavy enough to depress mean total height growth below that of the previous year (Sutton 1984).

Uses by Wildlife

Many wildlife species, including major game species such as deer and snowshoe hare, find food or shelter in jack pine forests (Rudolph 1983). Jack pine is generally considered a moderately preferred deer food (Benzie 1977). Young jack pine may be heavily browsed where deer populations are high. Dense saplings and pole stands offer some wind protection and winter shelter, but generally jack pine stands do not provide as good winter shelter as most other conifers. Because older stands of jack pine are usually less dense than other conifers, the understory shrubs and herbaceous plants achieve better growth, providing a better food supply (Benzie 1977). Jack pine seedlings are highly preferred winter food for snowshoe hares, and high losses may be expected in areas supporting high densities of hares (Cayford *et al.* 1967, Bergeron and Tardif 1988). When pines are planted in thick stands they are most effective as cover for cottontail rabbits for about 10 years. After this, lower limbs die and stands become too open underneath to provide ground cover (Allen 1939). Jack pine is highly preferred by hares, relative to other conifers (Aldous and Aldous 1944). Jack pine is preferred over red pine, black spruce and white spruce (Bergeron and Tardif 1988). Field mice gnaw bark on boles and lower lateral branches (Cayford *et al.* 1967).

Clumpy stands of young jack pine with branches reaching the ground provide nesting sites for the endangered Kirtland's Warbler (*Dendrica Kirtlandi* Baird) in the Lower Peninsula of Michigan (Benzie 1977).

Pinus resinosa Ait.
Red Pine

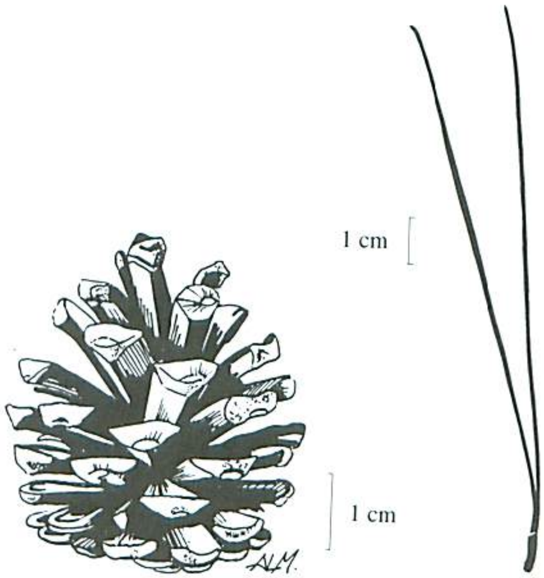
Description

General: large-sized (averaging 23 m high, up to 36 m), evergreen conifer tree with a sparse, oval crown and a straight, limbless trunk of little taper; branches usually spreading with the foliage tufted at the ends; branchlets stout, shiny, orangish; trunk bark reddish, flaky, becoming furrowed into thick plates.

Leaves: needle-like, straight, slender, flexible, sharp-pointed; in clusters of two, long (10-15 cm); shiny, dark green, with a persistent basal sheath.

Flowers: male and female flowers separate on the same tree; male flowers tiny, conelike, deciduous, short-lived, at the base of current year's growth; female flowers are cones with numerous spirally-arranged scales; appearing in May.

Fruit: winged seeds enclosed by woody scales of the mature female cone; cones are egg-shaped to somewhat conical, straight; tips of cone scales without spines; cones open to release seeds in the autumn of the year of development and fall from the tree in spring.



Habitat

Distribution in Ontario: The commercial range of red pine, in Ontario, is largely confined to the Great Lakes-St. Lawrence and Deciduous Forest Regions (Rowe 1972, Hosie 1979). The northern botanical range of red pine closely parallels the 2°C mean annual isotherm (Chapeskie *et al.* 1989).

Climate: Red pine is susceptible to frost damage on low-lying sites where cool air collects and on open, dry, sandy outwash plains where night radiation promotes rapid cooling (Chapeskie *et al.* 1989).

Site and Soil Relations: In NW Ontario, red pine occurs primarily on glaciofluvial and morainal landforms (Sims *et al.* 1990). It grows mainly on sandy, acidic soils that have good drainage and aeration, and infrequently on fine-textured soils. Best growth of red pine occurs on deep, well-drained, fine sands and loams (Chapeskie *et al.* 1989). Red pine is well adapted to coarse sandy soils with an unrestricted rooting depth and good soil aeration, but growth is poor on clay loam and clay soils that have weakly developed structures (Chapeskie *et al.* 1989).

Nutrient Requirements: Red pine grows on soils of moderate to low fertility (Chapeskie *et al.* 1989). Red pine grows better on

Distribution of **red pine** in Ontario
(Adapted from: Hosie 1979)

rich soils but often cannot outcompete hardwoods found on these soils (Stiell 1978). Red pine is characteristically associated with acidic soils (Stiell 1978). The optimum pH range for red pine is 5.2 to 6.5 (Chapeskie *et al.* 1989). Red pine height growth and vigour frequently decline where free carbonates are located within 60 cm of the soil surface (Chapeskie *et al.* 1989). Growth is not significantly affected when free carbonates occur at greater depths. Red pine dominated NWO FEC plots were associated with non calcareous soils (Sims *et al.* 1990). Red pine grows well on soils which have a base exchange capacity of 2 to 11 m.e.%, total N content of at least 0.03-0.04%, available P_2O_5 of 45-67 kg/ha and K_2O of 40-490 kg/ha (Fowells 1965).

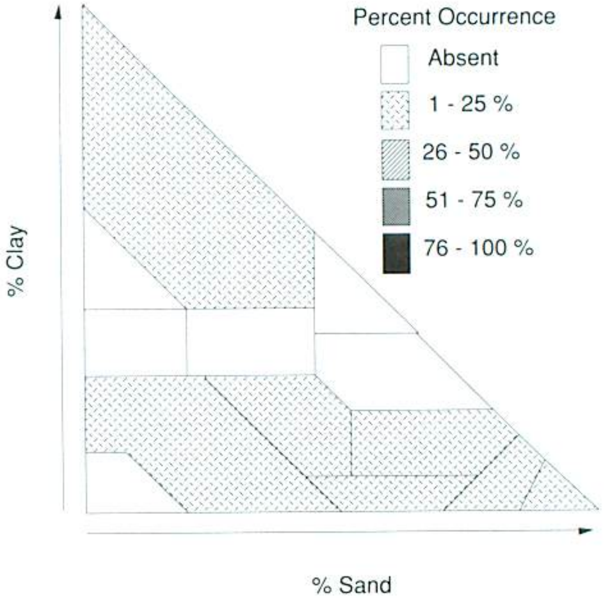
Moisture Requirements: Red pine achieves best growth on moderately well-drained, very fresh soils (Chapeskie *et al.* 1989). Over 80% of red pine dominated NWO FEC plots were associated with rapidly to very rapidly drained soils (Sims *et al.* 1990). Red pine is not suited to poorly drained soils (Stiell 1978).

Light Requirements: Red pine is intolerant of shade (Chapeskie *et al.* 1989). Approximately 35% full sunlight is required for satisfactory establishment of red pine seedlings (Grasovsky 1929, Shirley 1932). In a study by Logan (1966), red pine seedlings were grown for six years in 13%, 25%, 45% and 100% of full light. During the first four years the tallest red pine were growing in 45% light but in the fifth and sixth years the tallest seedlings were those in full light. After six years, red pine attained maximum height and maximum weight of foliage, wood and root when grown in full light. Growth was definitely inferior at 13% and 25% of full light. Red pine seedlings that have germinated under dense shade rarely persist to 10 years (Horton and Brown 1960).

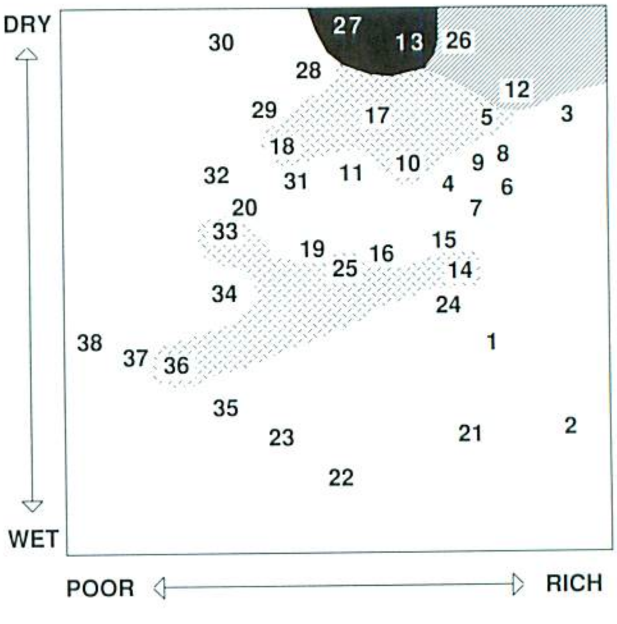
Reproduction

Sexual Reproduction: Red pine is monoecious, with male and female flowers borne on the same tree (Anon. 1974). Female flowers develop near the apices of vigorous twigs in the middle third of the crown, and male flowers are borne in groups around the bases of branches in the middle to lower crown (Stiell 1978, Chapeskie *et al.* 1989).

Seed Bearing Age: Seed production normally begins at about 20-25 years in open-grown stands and at 50 years in closed stands (Stiell 1978, Benzie and McCumber 1983). Optimum seed production occurs between 50 and 100 years (Benzie and McCumber 1983).



Frequency of occurrence of **red pine** by soil texture class



Frequency of occurrence of **red pine** by NWO FEC Vegetation Type

Frequency and Size of Seed Crops: Good crops of red pine seed are infrequent and irregular (Chapeskie *et al.* 1989). Medium to good seed crops are produced every three to seven years with light crops in most intervening years. Excellent red pine seed crops occur at intervals of 10-12 years or more (Benzie and McCumber 1983). The infrequency of good seed years is a major factor limiting regeneration of this species by natural seeding (Chapeskie *et al.* 1989).

The cone yields associated with good seed years are estimated to be 0.5 hl/tree or approximately 45,000 viable seeds/tree (Chapeskie *et al.* 1989). Examples of estimated high seed yields are 751,000 viable seeds/ha in southeastern Manitoba (Cayford 1964) and 2,263,000 viable seeds/ha in the Lake States (Roe 1964). The size of the cone crop is greatly affected by stand density, with open conditions permitting larger cone crops (Stiell 1978). Numbers of cones produced per tree in a mature, moderately stocked stand during a good seed year vary from 50 for unthrifty trees, 200 for average trees, 400 for very vigorous and partly open-grown trees, and 725 for open-grown trees. In overstocked stands, only a few trees may produce cones and seedfall may average less than 10 seeds per tree (Fowells 1965).

Pollen and Seed Dispersal: Seed dispersal is primarily by wind. Seeds usually land at a distance no greater than the height of the tree (Stiell 1978); however, seeds may be disseminated up to 274 m from seed trees (Benzie and McCumber 1983).

Seed Viability and Germination Requirements: Average germinative capacity is above 75% (Stiell 1978). Red pine seeds have no dormancy requirements and germination of naturally shed seeds usually occurs at temperatures above 16°C in late spring or early summer when moisture conditions are favourable. Little germination occurs at temperatures below 15.5°C, and is best at 21.1°C or higher (Fowells 1965). High temperatures that occur on fire-blackened soil surfaces for the first few years after fire are lethal to small red pine seedlings (Chapeskie *et al.* 1989). Soil must be moist during the germination period; this is most likely to occur with loam, silt and clay soils (Stiell 1978). Germination and survival are best on mineral surfaces, averaging five times as many seedlings as on undisturbed surfaces (Fowells 1965). Although red pine seeds can germinate on the organic floor, few seedlings survive because of the shade and rapid drying of litter (Benzie and McCumber 1983). A minimum of 10 cm of precipitation during early summer is required for germination and early growth of red pine seedlings (Chapeskie *et al.* 1989). If rainfall is deficient, germination may be delayed for up to three years (Benzie and McCumber 1983). Germination is satisfactory over a range of soil acidity, but is poorest at pH 8.5 or higher (Fowells 1965).

Vegetative Reproduction: In nature red pine does not reproduce vegetatively (Fowells 1965).

Growth and Development

Red pine usually produces one flush of height growth each year. Occasionally, a second flush produces lammas shoots in late summer. Red pine exhibits a preformed terminal shoot growth pattern in which the current year's height growth is determined by the previous year's growing conditions leading to bud development (i.e., elongation of the terminal shoot is determined by the number of needle internodes laid down in the previous year's bud) (Duff and Nolan 1958). However, moisture stress and effects of competing vegetation can limit elongation of internodes (Chapeskie *et al.* 1989).

Red pine seedling growth is described by Cayford and Bickerstaff (1968) and Chapeskie *et al.* (1989). In general, it exhibits very slow to moderately rapid growth during the first five years. After this period, an annual height increment of 30 cm or more is often achieved in the absence of competing vegetation.

Natural regeneration of red pine may reach a total height greater than one metre in five years where vegetative competition is not limiting growth. Red pine has a very high growth and yield potential on sites to which it is biologically well suited. On very productive sites in southern Ontario, growth rates of over 12 m^3/ha/yr have been recorded for red pine.

Red pine has an extensive, deep root system that can penetrate to a depth of three to four metres (Chapeskie *et al.* 1989). In early years it usually develops a taproot with numerous branched laterals. Lateral roots generally remain within 10-20 cm of the surface. The downward growth of red pine roots is restricted in moist soils because of inadequate soil aeration.

Red pine will develop natural grafts with root systems of neighboring trees of the same species (Chapeskie *et al.* 1989). The youngest plantations in which grafts between different trees were found was 15 years old. In all stands this age or older, grafting could be considered a common occurrence. The majority of grafts were found 10-36 cm below the soil surface (Armson and van den Driessche 1959).

Phenology

Root, Shoot and Foliage: On the basis of seedling studies, it appears that most root elongation takes place during two periods of activity: one in spring and early summer, the other in fall, with an intervening decline during mid-summer (Stiell 1978). Roots continue to grow even after cambial growth stops (Fowells 1965).

Cataphyll deposition, shoot elongation and needle elongation begin at the same time, during mid- to late April (Sucoff 1971). Ninety-eight percent of shoot elongation is completed by late July (Sucoff 1971). The period of cambial growth begins a little later than shoot elongation and is only about 2/3 complete when shoot growth ceases (Fowells 1965).

The apical meristem is capable of continuously producing cataphylls from mid-April until early September. Activity is slow between April and mid-June with less than one cataphyll deposited each day. The rate increases to a mid-summer high, one cataphyll every two and a half to three hours, between early July and early August. Rapid deposition continues for one to two months, ending in early September (Sucoff 1971). By the time the shoot is half elongated, 15-20% of the cataphylls are present in new buds; by late July when the stem is 95-98% elongated, about 50% of cataphylls are present (Sucoff 1971). Cessation of cataphyll deposition occurs once gradual autumn cooling has started (Sucoff 1971). Needle elongation continues for one month longer than shoot elongation, ending in mid- to late August (Sucoff 1971).

The moisture content of newly flushed red pine needles is over 260% in early June. This drops rapidly to 150% by late August, and decreases more slowly to 130% by late October (Van Wagner 1967).

Reproductive Structures: Flower initials of red pine are formed in the year preceding flowering. Cone primordia are differentiated in July of year one; become visible at the end of the growing shoot late the following spring (in late May or early June); and are pollinated in early to mid-June of year two. By the end of the second growing season, conelets are round and approximately 2 cm in diameter (Chapeskie *et al.* 1989). They complete their growth by mid-June of year three, after which fertilization takes place (mid-July). The cones ripen in mid-September to late October of year three (Lyons 1956). Most seed is dispersed within one month after cone maturity, in the fall of year three (Cayford 1964, Chapeskie *et al.* 1989). Some seed dispersal continues until the following spring, especially if weather conditions are wet and cool in autumn.

Competition

Response to Competition: Shade is favourable to germination and initial survival of red pine on dry sites, but it may seriously inhibit growth (Benzie and McCumber 1983, Chapeskie *et al.* 1989). A dense layer of grass, shrubs, herbs or tolerant hardwoods suppresses and greatly weakens red pine seedlings (Chapeskie *et al.* 1989).

Extracts of foliage from *Aster macrophyllus*, *Lonicera tatarica*, *Solanum dulcamara*, *Solidago gigantea*, *Prunus serotina*, and *Rubus idaeus* inhibited height growth, initiation of secondary needles, and dry weight increase of roots and shoots of red pine seedlings (Norby and Kozlowski 1980). Total dry weight increment of red pine seedlings was reduced by water extracts of *Lonicera*, *Solidago*, and *Rubus*. Red pine seedlings treated with *Lonicera* or *Solidago* extracts had significantly lower P concentrations in needles than those of control seedlings (Norby and Kozlowski 1980). Allelopathic influences on red pine in the field may be minor in comparison to effects of light, water and nutrient stresses, or may be present only under certain conditions of soil drainage (Norby and Kozlowski 1980).

Grasses, sedges and other herbs offer serious competition for young seedlings (Stiell 1978). Seedlings only survive where grass and litter are not thick (Chapeskie *et al.* 1989). Grass competition can cause loss of foliage on lower branches of young red pine (Stiell 1976) which may be an important factor if they are being grown for Christmas trees. Grasses also provide habitat for damaging insects such as white grubs (Cayford and Bickerstaff 1968).

A heavy cover of blueberries and sweetfern in a Wisconsin red pine plantation was estimated to reduce red pine wood yield by approximately 95 m^3/ha (approximately 40% of the total volume) in a 40-year rotation (Wilde 1970). The volume loss was attributed to water loss by evapotranspiration from a heavy cover of heath plants. The water loss occurred up until the time that crown closure shaded the heath plants out.

Raspberries are frequently found where both survival and growth of red pine are inferior (Stiell 1955).

Hazel is often considered to be a major competitor for young red pine (Stearns 1974). Natural red pine establishment is precluded beneath heavy hazel competition (Fowells 1965).

Height growth of red pine can be greatly reduced by competition from aspen suckers or a hardwood overstory (Chapeskie *et al.* 1989). Fine-textured soils can be the most productive for red pine, but usually hardwood competition associated with these soils limits natural pine regeneration. Once cleared of competition, these soils can support high-yielding red pine plantations (Stiell 1978).

A sparse tree canopy may provide valuable protection in the first season and aid survival, but any cover will later seriously suppress red pine (Horton and Bedell 1960).

Site ratings for red pine regeneration capacity have been set out by Horton and Brown (1960) as follows: *Easy*: in sparse heath, heath-grass and heath-herb types of lesser vegetation, usually on very dry and poor soil with a severe local climate. *Moderately easy:* in dense heath or weak shrub-herb and herb types, usually on somewhat dry and poor soil, with moderately severe local climate; *Difficult*: in moderate shrub-herb and herb types, usually with fresh, rich soil and standard local climate; *Very difficult*: in shrub-herb, shrub and herb types with strong development towards dense shrubs or hardwoods, with moist, rich soils and cool-moist local climates. (In terms of site productivity, this ranking might be reversed (Stiell 1978)).

Response to Release: Red pine plantations, severely suppressed by a dense oak and maple overstory for as long as 40 years, were still able to respond to release (Ralston 1953).

Diameter growth response of red pine growing on sandy soils and released from heavy grass competition can occur within two to three weeks after a May application of simazine (Lambert *et al.* 1972). Removal of grass competition resulted in 32% greater diameter growth, 6% greater terminal bud size and 18% greater needle length and a 4% decrease in height growth by August of the same season of herbicide application. Diameter growth rate was greater on sprayed than nonsprayed plots for at least two growing seasons and was most obvious during periods of drought. The growth increment was attributed to increased water resulting from grass removal. Height growth response was probably masked by a time lag due to the preformed elongation pattern of red pine.

Buckman and Lundgren (1962) studied a 19-year-old red pine stand. Eighteen years after release, this stand yielded 100% greater merchantable volume than a comparable unreleased stand.

Roe (1951) and Stone (1976) carried out manual release studies of red pine in the Lake States. In these two studies, hardwood competition was removed from plantations, resulting in merchantable volume increases of 46% and 160%, respectively, in comparison with controls. In Roe's study, pine were released from aspen once at 14-16 years of age, whereas in Stone's (1976) study the plantation was cleaned at least three times in its first 10 years. Roe (1951) concluded that in order to obtain the greatest dividends from over-topped plantations, release must be done at an early age.

Chemical Treatments: Red pine is relatively resistant to damage from herbicides commonly used to release it (Benzie and McCumber 1983). The response of red pine to 2,4-D, hexazinone and glyphosate will be discussed separately.

2,4-D: Good control of overtopping aspen has been obtained with both aerial and ground sprays of 2,4-D without serious damage to red pine, provided that the 2,4-D is applied after new growth has hardened off in late summer (Rudolf 1957, Benzie 1977). Arend (1955), in a report on the tolerance of several conifers in lower Michigan to applications of 2,4-D and 2,4,5-T, found that there were no apparent effects of the phenoxy herbicides to red pine if applied after August 1. 2,4-D will kill or suppress red pine during the period of active growth (Chapeskie *et al.* 1989).

Hexazinone: Red pine is very tolerant of Velpar-L (Corcoran 1989) and can be planted immediately following chemical site preparation (Carruthers and Towill 1988).

Spotgun applications, when applied in a grid pattern to release red pine crop trees, cause only minimal crop tree damage when applied up to 0.5 m from the stems (Carruthers and Towill 1988).

Glyphosate: Red pine is relatively resistant to glyphosate applied as a top spray in early August or September (Anon. 1989c). Glyphosate will kill or suppress red pine during the period of active growth (Chapeskie *et al.* 1989). In a Nova Scotia study, newly planted red pine was sprayed with two different rates of Vision (3.2 and 4.7 l/ha) applied at 16 different dates between July 2 and October 22 (Anon. 1989c). During the week prior to treatment, the treatment areas were manually cleared of overtopping vegetation. Results collected one to two years after treatment indicated that height and diameter growth were not related to timing of herbicide treatments. Leaders of some seedlings were damaged when sprayed before the end of July. However, one year later, these seedlings set normal buds. Sporadic mortality was noted within July-treated plots.

Uses by Wildlife

Red pine stands, in general, are not considered prime habitat for game birds and mammals, such as ruffed grouse and white-tailed deer (Benzie and McCumber 1983). However, even-aged seedling stands provide a relatively open area for about a decade with a large variety of pioneer plant species favourable for edge wildlife (Benzie and McCumber 1983). Dense sapling stands provide cover for many species of wildlife. Old-growth stands provide favourable habitats for species such as red squirrel, pine marten, and pileated woodpecker (*Dryocopus pileatus* L). Red pine may be more severely affected by snowshoe hare than any other conifer (Aldous and Aldous 1944). Porcupines eat bark of red pine and have seriously injured plantations (Stiell 1955).

Bald eagles (*Haliaeetus leucocephalus* L.) build nests in large old-growth trees (Benzie and McCumber 1983).

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Glossary

A

Abscission - separation of flowers, fruits, leaves or buds from a plant at a special separation layer.

Achene - a dry, one seeded, thin walled, indehiscent fruit.

Acid equivalent (a.e.) - the theoretical yield of parent acid from the active ingredient content of a formulation.

Active ingredient (a.i.) - the agent in a product primarily responsible for the intended herbicidal effects, and which is shown as the active ingredient on the herbicide label.

Adventitious buds - buds occurring sporadically or in other than the usual locations.

Aggregate fruit - formed from several separate or fused ovaries of a single flower, as in *Rubus*.

Allelopathic substances - secondary chemical compounds produced by plants that affect the subtle interactions between different plants, including microorganisms.

Allelopathy - the interference by one plant with the growth and development of another through chemicals produced by the plant and released into the soil.

Alternate - attached singly along a stem or axis; not opposite or whorled.

Amine - any compound derived from ammonia by replacement of hydrogen by hydrocarbon radicals, or containing one or more halogen atoms attached to nitrogen.

Annual - a plant which completes its life cycle in a year or less.

Anthesis - the period of opening of a flower.

Asexual reproduction - reproduction without fertilization, e.g. rooting of cuttings, rhizomes, layering, etc.

Astringent - a substance which contracts organic tissue, thus reducing secretions.

Autecology - study of the adaptations and behaviour of individual species, populations or organisms in relation to their environment.

Awn - a slender, terminal bristle.

B

Basal - pertaining to the base of a plant.

Basal buds - Adventitious buds found at the base of a plant.

Basal treatments - applied to encircle the stem of a plant above and at the ground such that foliage contact is minimal. A term used mostly to describe herbicidal treatment of woody plants.

Basipetal development (or differentiation) - produced or becoming differentiated in a succession toward the base of an organ.

Berry - a fleshy fruit with a pulpy interior, usually containing several seeds.

Biennial - a plant which completes its life cycle in 2 years. Flowers and fruits are normally produced in the 2nd year of a biennial life cycle.

Bipinnate - twice-divided in a pinnate arrangement; usually of ferns.

Blade - the flat, expanded part of a leaf.

Bract - a reduced or modified leaf, usually at the base of a flower or inflorescence.

Branchlet - a small branch, usually referring to the most recent year's growth.

Bristle - a stiff hair.

Browse - *n.* shoots, twigs, and leaves of trees and shrubs eaten by livestock and wild animals. *v.t.* to eat such material.

Bud break - the time in the spring when the overwintering bud begins visibly to expand into a shoot.

Bud set - the time when shoot elongation ceases and the shoot apex begins to take on the appearance of an overwintering bud.

C

Calcareous soil - soil containing sufficient calcium carbonate (often with magnesium carbonate) to effervesce visibly when tested with cold hydrochloric acid.

Capsule - a dry fruit, usually containing 2 or more seeds, that splits into sections at maturity.

Carcinogenic - cancer-causing.

Cataphylls - leaves inserted at low levels of plant of shoot, as bud scales, rhizome scales, and others.

Catkin - a dense spike of small male or female flowers without petals.

Chlorosis - loss of green colour in foliaige.

Ciliate - fringed with hairs.

Clasping - usually referring to leaves which partially surround a stem.

Clone - a group of plants propagated only by vegetative or asexual means, all members of which have been derived from a single individual.

Compound (leaf) - comprising 2 or more leaflets.

Concentration - the amount of active ingredient of herbicide equivalent in a quantity of diluent expressed as percent, kg/litre, ml/litre, etc.

Contact herbicide - a herbicide that causes localized injury to plant tissue where contact occurs.

Corm - the bulb-like, solid, fleshy base of a stem.

Culm - the aerial stem of a grass or sedge.

D

Decoction - an extract made by boiling plant material in a solvent.

Dichotomous - dividing into two parts.

Dioecious - plant species having male and female flowers on separate individuals.

Dormancy - continued suspension of seed growth or development in the presence of external conditions favourable for germination. A state of suspended development.

Double-toothed - with 2 sizes of teeth; fine teeth lining the margins of coarse teeth.

Drupe - a fleshy or pulpy berry with a single hard or bony seed.

Duff - forest litter and other organic debris in various stages of decomposition, on top of the mineral soil, typical of conifer forests in cool climates where rate of decomposition is slow, and where litter accumulation exceeds decay.

E

Egg-shaped (ovate) - broader at one end than the other, like the longitudinal section of an egg, and attached at the wide end.

Elliptic - broadest in the middle and tapering equally towards both ends.

Endocarp - the inner layer of the pericarp of a fruit, when it consists of two or more layers of different texture or consistency.

Entire - margins without teeth, lobes or divisions.

Ericaceous - belonging to the Heath family (*Ericaceae*). This family includes such genera as *Vaccinium* (huckleberries, blueberries, and cranberries), *Rhododendron*, and *Menziesia* (false azalea).

Ester - formed by the reaction of acid and alchohol, usually without water.

F

Floret - a small flower, usually one of a dense cluster.

Floricane - a flowering cane, e.g. in raspberries.

Foliar application - application of a herbicide to the leaves of plant foliage.

Forb - any broad-leaved herbaceous plant that is not grass-like.

G

Girdle - to cut away a ring of inner bark (cambium), completely encircling the stem of a plant, so as to interrupt the translocation of carbohydrates through the plant.

Glandular - hairy - having hair-shaped structures, each with a swollen tip which secretes oils, waxy material or other substances.

Glume - a bract at the base of a spikelet in the Grass Family.

Graminoids - grasses, wood rushes and sedges.

H

Head - a dense flower cluster with individual flowers stalkless or nearly so on a short axis or receptacle.

Herb - a plant, either annual, biennial, or perennial, with the stems dying back to the ground at the end of the growing season.

Herbicide - a chemical used to control, suppress, or kill plants or severely interrupt their normal growth processes.

Hip - (of a rose) a floral cup that usually becomes enlarged and fleshy at the fruiting time, the true fruits are the achenes inside.

I

Indehiscent - not opening spontâneously; refers to a certain fruit type.

Inflorescence - the flowering structure of a plant.

Infusion - an extract made by steeping plant material in hot solvent.

Internode - the section of a plant stem between 2 adjacent nodes.

Inversely egg-shaped (obovate) - egg-shaped, but attached at the narrow end.

Inversely lance-shaped (oblanceolate) - lance-shaped, but attached at the narrow end.

J

Julian day - a 24 hr period; following the Julian calendar which has 365 days per year with every fourth year having 366.

K

Key - popular terminology for the fruit of maples (technically a samara); a dry, winged fruit which does not open at maturity.

L

Lammas growth - to make an additional flush of growth, usually a result of vigourous growing conditions.

Lance-shaped (lanceolate) - shaped like a lance-head, much longer than wide, tapering towards the tip from below the middle and attached at the wide end.

Layer - a stem or branch that takes root while still attached to the parent plant, tending eventually to become a separate individual plant.

Lateral - on or from the side of an organ.

Leachate - soluble substances which are leached out by the percolating action of water.

Leaf scar - the mark on a stem after a leaf falls off.

Leaflet - one of the divisions of a compound leaf.

Legume - [Fr. a vegetable]: (1) a member of the Fabaceae, the pea or bean family; (2) a type of dry fruit developed from one carpel and opening along two sides.

Ligule - in grasses, the thin outgrowth from the inner surface of a leaf at the junction of the sheath and blade.

Lobe - a partial division of an organ such as a leaf.

M

Mesotrophic - of a habitat; moderately rich or productive.

Moder - forest humus intermediatein characteristics between a mor and a mull.

Monoecious - of a plant species having male and female flowers on the same individual but borne in different places.

Mor - forest humus that forms a layer of organic matter which is abruptly distinct from the mineral soil beneath it.

Mull - friable forest humus where the organic layer merges gradually into the mineral soil beneath it.

N

Necrosis - localized death of living tissue.

Node - the point on a stem at which a leaf, bud or branch arises; in grasses there is a noticeable swelling or "joint' at each node.

Nodule - a swelling on leguminous roots that contains symbiotic bacteria which often fix nitrogen.

Nonselective herbicide - a chemical that is generally toxic to plants without regard to species. Toxicity may be a function of dosage, method of application, etc.

Nut - a hard, dry, one seeded fruit which does not open at maturity.

Nutlet - a small nut.

O

Oblong - longer than broad with parallel sides.

Opposite - occurring in opposing pairs at the same node, esp. leaves or branches of a plant.

Oval - broadly elliptical.

P

Panicle - an elongated, branched inflorescene.

Perennial - a plant that normally lives more than 2 years.

Pericarp - fruit wall developed from the ovary wall.

Periderm - outer layer of tissue, especially the cortical protective layer on roots.

Perigynium - a special bract which encloses the seed of *Carex* spp.

Petal - a segment of the inner set of leaf-like flower parts (the corolla), often coloured.

Phenology - the study of relationships between plant development and seasonal climatic changes.

Phytotoxic - injurious or lethal to plants.

Pinnate - divided, as with a compound leaf, such that the segments are arranged on 2 sides of a central axis; featherlike.

Pinnatifid - cleft in a pinnate manner; almost pinnately divided; usually of ferns.

Pistil - the female reproductive organ of a flower, usually divided into 3 parts: the ovary, style and stigma.

Pistillate - unisexual (flower) with only female reproductive organs.

Pith - the central part of a stem.

Pod - a dry fruit, especially of the Pea family.

Post-emergence - applied after emergence of a specific weed or planted crop.

Pre-emergence - applied prior to emergence of a specific weed or planted crop.

Primocane - a vegetative cane, e.g. in raspberries.

Primordia - the rudimentary leaves formed in the buds of plants.

Purgative - laxative.

R

Rate - the amount of active ingredient or acid equivalent of a herbicide applied per unit area or other treatment unit.

Release - to free plants from competition by cutting, otherwise removing, or killing nearby vegetation.

Reticulate - forming a network, as the veins of a leaf.

Rhizome - a horizontal, underground stem bearing roots and leafy stems.

Rosette - a circular cluster of leaves, usually at the base of a plant.

Runner - a very slender, wiry stolon.

S

Samara - a dry, indehiscent, generally 1-seeded, winged fruit; see key.

Saprophyte - a plant, usually without green colour, which derives its food from dead, organic matter.

Scale - a thin, reduced leaf or bract; in the cones of conifer tree species the scales are woody and enclose the seeds.

Seral - relating to or constituting a stage of ecological succession.

Seed banker - a plant species whose reproductive strategy involves the production of long-lived seed that is stored in the forest floor until stimulated to germinate by a change in environmental conditions such as fire, increased light, or soil disturbance.

Selective herbicide - a chemical that is more toxic to some plant species than to others.

Senescence - plant growth phase from maturity to death associated with accumulation of metabolites, increasing respiration rate and decreasing dry matter.

Sepal - a segment of the outer set of leaf-like flower parts (the calyx), usually green.

Sheath - a tubular envelope surrounding another organ, such as the lower part of the leaves of grasses and sedges which surrounds the stem.

Shrubs - perennial woody plants, other than forest tree species.

Soil active herbicide - a herbicide applied primarily to the soil surface.

Spikelet - the smallest flower cluster in grasses and sedges.

Spine - a sharp, woody outgrowth from a stem; a thorn.

Spot treatment - a herbicide applied over small continuous restricted area(s) of a whole unit; i.e., treatment of spots or patches of weeds within a larger field.

Sprout - a shoot from dormant buds at the base of a tree or from an exposed root.

Stalk - the stem of a leaf or flower.

Staminate - unisexual (flower) with only male reproductive organs.

Stigma - the part of the pistil which receives the pollen grains and on which they germinate.

Stipule - a small, leaf-like growth at the base of a leafstalk.

Stolon - a creeping, horizontal branch or stem from the base of a plant which produces new shoots.

Stoloniferous - bearing stolons.

Stool - several stems arising from the same root, as with certain grasses.

Stratification - cold, moist storage of seed to overcome dormancy.

Strobile - a spike with persistent overlapping bracts that resembles a cone.

Style - the stalk of the pistil, connecting the ovary and the stigma.

Sub-tripinnate - almost tripinnate; not quite fully 3 times divided; usually of ferns.

Succulent - fleshy, juicy.

Sucker - a branch or shoot from an underground stem or root that ascends above ground and tends eventually to become a separate individual plant.

Susceptibility - magnitude of sensitivity to herbicide treatment.

Systemic herbicide - herbicide which moves within the plant following absorption.

T

Tendril - a slender, twining outgrowth from a stem or leaf; used for climbing or support.

Terminal - at the tip or end of an organ.

Thorn - a spine.

Tiller - sprout from the base of a plant or from the axils of the leaves.

Tolerance - usually, the capacity of a plant to develop and grow in shade of and in competition with other plants. Magnitude of capacity of a plant to withstand herbicide treatment without marked deviation from normal growth or function.

Translocated herbicide - a herbicide that is moved within the plant. Translocated herbicides may be either phloem mobile or xylem mobile, but the term is frequently used in a more restrictive sense to refer to herbicides that are moved in the phloem.

Trees - woody species which typically attain heights greater than 10 m and/or diameters at breast height (1.3 m) of more than 10 cm.

Trifoliolate (3-foliolate) - with 3 leaflets.

Tripinnate - fully 3 times divided in a pinnate manner; usually of ferns.

Tuber - a short, thickened underground stem.

Tussock - a compact tuft, especially of grasses or sedges.

V

Vegetative propagation - the reproduction of genetically identical plants in a non-sexual manner, e.g. rooting of cuttings.

Venation - the arrangement of veins on a leaf.

Viability - the potential of pollen or seed to germinate.

W

Weed - a plant growing where it is not desired. Plants are considered weeds when they interfere with activities of man or his welfare.

Whorl - a group of 3 or more similar organs radiating around a node.