WHITE AND RED PINE SYMPOSIUM

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September 20-22, 1977

D. A. CAMERON, COMPILER

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FOREWORD

The White and Red Pine Symposium held at the Petawawa Forest Experiment Station (PFES), Chalk River, Ontario, September 20-22, 1977, was cosponsored by the Ontario Ministry of Natural Resources and the Canadian Forestry Service. Its purpose was to review developments in white and red pine management, to disseminate information to provincial forest managers, and to attempt to stimulate interest in and improve the management of these two species. Over 110 delegates from government forestry services in Canada and the United States, forest industry, universities and colleges, and consulting firms attended the symposium.

The Proceedings consist of 14 papers and a summary. Abstracts in English and French are included with each paper.

For completeness, the essence of questions, answers and related discussion have been included after each paper.

The use of trade names in the papers presented does not constitute endorsement by the participants or by the organization with which they are affiliated.

The first day of the symposium was devoted to a field tour in and adjacent to Algonquin Park to improvement cuts in pine mixedwoods, shelterwood and strip cuts in pure pine and pine mixedwood stands, and weevil control strips in pine. A morning tour on the third day illustrating over 40 years of research on growth, development and management was conducted in the headquarters area of the PFES. The delegates were shown understory control by fire, red pine spacing trials, and regeneration obtained by shelterwood, strip cutting and seed tree methods.

The program committee is indebted to those people who presented papers, chaired and reported on the formal sessions, conducted the field tours and contributed in other ways to the success of this symposium.

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Cover photo: Symposium delegates in Permanent Sample Plot No. 1 established at the Petawawa Forest Experiment Station in 1918. Two special guests, A. Bickerstaff and G.H.D. Bedell, specialists in white and red pine silviculture who retired after long careers in the Canadian Forestry Service, are among those shown in the photograph.

KEYNOTE ADDRESS:

WHITHER NOW, O PINUS? (STROBUS, THAT IS!)

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It was exhilarating to learn, last spring, that plans had been laid to hold a symposium on white and red pine at the Petawawa Forest Experiment Station. It has been too many years since a good look has been taken at the state of the art as far as white and red pine are concerned. The appointed day has arrived. The delegates are assembled.

It is particularly fitting that this symposium should be held at the Petawawa Forest Experiment Station. The Station was established in 1918 just about in the centre of the pine forests of the Great Lakes-St. Lawrence Forest Region, probably for the primary purpose of conducting research on white and red pine. Sixty years is not long in the life of a pine. Much valuable work has been done here, particularly on white and red pine. It is to be hoped that before too long a break-through will occur and we can look forward to an economic rotation in pine of much less than a century.

In many parts of eastern Canada the mere mention of white and red pine causes older citizens to conjure up nostalgic visions of rivers full of logs, of shanties, cross-cut saws, salt pork, endless teams of horses, blacksmiths, steaming sawmills, buckbeavers, pigs' feet, jammers, chickadees, crazywheels, tanks, corner binds, woodpeckers and a host of other items whose meaning is fast disappearing from the lexicon of the logger. Who now can organize the effort known as "cutting main road"? I still chuckle when I remember hiring an old-time logger who had specialized in cutting main road all his working days, and said he used to like working for Booth because "Booth was always a pugger for road". As late as the second quarter of the 20th century, white and red pine remained a big economic factor in a way of life just starting to crumble.

To younger citizens and some professional do-gooders the words white and red pine conjure up visions of timber barons who raped the forest and flailed weak, groveling, sickly human flesh to produce timber and lumber for a world whose appetite for these products was insatiable. They are sure, too, that as each timber baron became wealthier than the Aga Khan, he caused to be wasted or to be destroyed much more timber than was used. Applied social science at its best or worst.

Nostalgia is really just as useful as hysteria as a gauge to measure what has happened and to project what might have been.

Let us try to review basic facts very briefly. There was in eastern North America an immense forest resource of white and red pine. It is impossible to estimate what the physical volume of this resource really was in the time of Champlain, Lord Durham or Sir John A. Macdonald. Even in the time of Pierre Elliot Trudeau, the estimate of the residual volume of this resource and its future potential is open to debate. Perhaps even vituperous debate. Debate that could hamper conclusions and decisions that might lead to the recognition of the best way of reinstating white and red pine in their particular niche in Canada's economy.

During the French regime in Canada the pine resource was barely used. Following the British conquest, very little happened for many years. Pine was used locally for construction; some ships were built, and from the Saguenay, the lower St. Lawrence and the Maritimes, some timber was exported.

This was all changed when Napoleon, by blockading the Baltic and denying Britain the main source of its wooden walls, unwittingly created the cornerstone of the economic forces that produced Canada. Canada became Britain's woodbox.

The square timber trade was born. Until the middle of the 19th century, square timber was the principal export. When one considers all the factors involved, the volumes were tremendous. Immigrants multiplied in the wake of economic growth, politicians appeared on the scene, and the Dominion of Canada was created in 1867.

Prior to the American Civil War the United States exported food to Britain and Canada exported timber to Britain. In the period of expansion following the Civil War, the roles changed. Canada began to export lumber to the United States and food to Britain whereas the United States needed everything to support her expansion.

The demand for lumber in the United States to construct homes for the large numbers of immigrants who arrived in the latter part of the 19th century was tremendous. Railways were built in the United States and in Canada to move lumber. The Erie and Oswego canals were built primarily to move lumber from Canada into the United States. Native Canadians, along with Americans immigrating from logged-out sections of the eastern states, were not slow in attacking the forest to produce marketable goods. Indeed, they were aided and abetted by government at all levels, for government, too, wanted its share of the golden income.

In fact, it is probably reasonable to say that pine, besides being the basic economic factor behind the political formation of Canada, also paid for the basic development of the country for many years. It has been stated that almost until the beginning of the 20th century tolls and dues levied on pine timber paid for the total cost of the government of Canada.

Some people were concerned because they knew that the pine forest was not endless. Among these was Sir John A. Macdonald. On 22 June, 1871 he wrote, apparently from his study at Earnscliffe, looking down on the rafts and booms of timber, to John Sandfield MacDonald, Premier of Ontario.

> "My dear Sandfield,
>
> The sight of the immense masses of timber passing my windows every morning constantly suggests to my mind the absolute necessity there is for looking at the future of this great trade. We are recklessly destroying the timber of Canada and there is scarcely the possibility of replacing it. The quantity of timber reaching Quebec is annually decreasing and the fires in the woods are periodically destroying millions of money. What is to become of the Ottawa region generally, after the timber is cut away, one cannot foresee. It occurs to me that the subject should be looked in the face and some efforts made for the preservation of our timber. The Dominion Government, having no lands, has no direct interest in the subject, but it seems to me that it would be a very good thing for the two Governments of Ontario and Quebec to issue a Joint Commission to examine the whole subject and to report:
>
> 1st. As to the best means of cutting the timber after some regulated plan, as in Norway and the Baltic: 2nd. As to replanting so as to keep up the supply as in Germany and Norway, and 3rd. As to the best way of protecting the woods from fires".

As time passed, more people--including many of the so-called timber barons--became very concerned about future supplies of timber and supported the unique idea of setting aside larger areas of land to form the basis of "reserves of timber for the future". One such area is Algonquin Park. These same people pioneered the concept of protecting forests from fire and aiding in regeneration.

The assault on the forest continued with more mills, more railways and more demand in spite of the repeal of reciprocity, export duties, import duties, stumpage, royalties, floods, hurricanes, forest fires and all. Sawmills were established and abandoned, and new mills sprang up in an as yet untouched forest. The spectacle prompted W. H. Withrow to write:

> "The ravenous sawmills in this pine wilderness are not unlike the huge dragons that used in popular legend to lay waste the country; and like dragons they die when their prey, the lordly pines, are all devoured". (quoted in A. R. M. Lower's "The North American Assault on the Canadian Forest")

How much pine was there? We will never know for sure. Franklin B. Hough in 1880 reports a Canadian source as saying "Crown lands returns are very untrustworthy". In the early days, no records were kept of what was cut, and it was not until the last 50 years or so that any effort was made to record more or less precisely the losses through fire, blowdown or insect attack. From 1900 to 1976 inclusive, Ontario reports that 15,887,000,000 cu. ft[1] of red and white pine timber were cut on Crown lands. At 5 fbm per cu. ft this would be 79,435,000,000 fbm or about 1 billion fbm per year on the average. For the past several years Crown land production in Ontario has been about 100,000,000 fbm per year. There is no record of private land production.

The high year was apparently 1907 with 197 million cu. ft and the low year was 1933 with 4,000,000 cu. ft cut.

The logging season 1934-1935 is known to old-time Gillies Brothers employees as the year of the bad pork. Two carloads of salt pork in barrels had been portaged to the Usborne Depot in the winter of 1932-1933 for use in the 1933-1934 cut. The depression markets were so bad in the spring of 1933 that it was decided not to cut in 1933-1934. What were they to do with the pork? The barrels were opened and rebrined, a monster hole was dug in the depot yard, and the barrels were buried. The barrels were dug up and the pork was eaten the following year. Frank Kelford has remarked that "that pork was as yellow as a duck's foot. You could smell it inside the bunkhouse all the way from the cookery".

James Elliot Defebough says that in 1874 Canada produced 1,434,000,000 fbm of lumber. He goes on to state that the estimate of 500,000,000,000 fbm of sawing stock of pine is not unreasonable. That was enough timber, he claims, to support all the then existing sawmills for a hundred years. Well, a lot of the dragons have eaten themselves out of existence since then. The wonder of it all is that there is as much white and red pine lumber production today as there is.

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[1] 1 cu. ft = .03 m^3 approx.

Whither now, O *Pinus*? You have assisted nobly in the conception, birthing and rearing of a country with one of the largest land masses in the world. What has been your reward?

White and red pine still provide the nation with an economic return that would be missed if it disappeared. Many million pine seedlings have been planted to encourage the maintenance of the species as a viable item of forest commerce. There has probably been more written on the silviculture, silvics, regeneration, growth characteristics, lumber quality, logging methods, etc. of pine than of any other of our commercial species. But we still lack a great many answers.

This was pointed out very clearly in Bulletin 124, released in 1960 by the then Department of Northern Affairs and National Resources, Forestry Branch, entitled "White and Red Pine - Ecology, Silviculture and Management". The section on Research Requirements begins as follows:

> "There is a wealth of information on white and red pine. Probably in combination these trees have been the object of more research than any other forest type in North America. Still there is much to be learned - and much to be learned about applying the available knowledge. A silvicultural treatment satisfactory in one set of circumstances may be inapplicable ecologically or economically in another. Therefore, sweeping recommendations for particular methods are inadvisable; rather, flexible silviculture, designed to adapt to a diversity of needs in pine forest management, is advocated. This necessitates a complex research program".

Those words are just as true today as they were when they were written 17 years ago. Why have we made so little progress in our search for answers to the problems of management of white and red pine?

For many years it has been emphasized that our forests should primarily be producing fibre for the manufacture of pulp and paper, almost to the exclusion of timber. Right now our pulp and paper are difficult to sell. They are just too expensive. Lumber, however, is in a very buoyant position. Let us continue to be concerned about the management of our pines for lumber production. Our pines grow just as well as any other species on some sites. All trees produce fibre but only some species produce salable lumber.

Canada has covenanted to spend 1% of its G.N.P. to help emerging countries. In comparison, how much do we spend on basic forest research? In terms of 1960 dollars, probably much less than we did 17 years ago. Almost one quarter of Canada's foreign exchange is generated from our forest. White and red pine account for a significant portion of our merchantable timber. Without research how long can we compete in international trade? Until now we apparently could afford to give away a billion dollars a year. Can we keep it up?

Two simple chaps drove up to a lumber yard. One got out and asked the clerk for two pieces of 4 x 2. The clerk suggested the customer meant 2 x 4. After consulting with his friend, the customer agreed that it was 2 x 4 that was required. The clerk then demanded to know how long the customer wanted the 2 x 4. After further consultation with his companion, the customer said to the clerk: "We are building a house. We want it for a long time!"

We are still building a nation--a nation that pine started and nurtured for many years. White and red pine do not occupy nearly as large a part of our economic spectrum as they once did; but they still constitute an important part.

That is why this symposium is so important. I hope that it will prove to be a turning point, a bench mark, a foundation, a force, pointing the way towards the required basic research and the application of the results of that research to solving practical problems in the management and harvesting of these wonderful, ubiquitous white and red pine that are an essential part of our landscape and our economic life.

CHARACTERISTICS OF EASTERN WHITE PINE AND RED PINE

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*This review deals with general characteristics and requirements, and associated forest management implications, of eastern white pine (*Pinus strobus *L.) and red pine (*P. resinosa *Ait.), with particular reference to Canadian conditions. Topics included are distribution, taxonomy and genetics, environmental factors, seed production, morphology, growth and yield and damage.*

*Cette revue traite des caractéristiques et exigences générales, et les implications de l'aménagement forestier associées, du Pin blanc (*Pinus strobus *L.) et du Pin rouge (*P. resinosa *Ait.), avec référence particulière aux conditions canadiennes. Les sujets inclus sont la distribution, la taxonomie et la génétique, les facteurs d'environnement, la production des graines, la morphologie, la croissance et le rendement et les dommages.*

INTRODUCTION

Justification for considering these two unrelated pine species together lies in their common association in natural stands and sufficient similarity in their environmental needs, growth rates and economic importance to allow management of the two as a cover type. Nevertheless, eastern white pine (*Pinus strobus* L.) and red pine (*P. resinosa* Ait.) differ radically in many respects and unless their particular requirements and growth characteristics are understood, efficient management of the species together, or separately, will not be possible.

The ecology and life histories of these pines are well worked fields of interest. Of particular value are the compendium of silvical characteristics of white pine (Wilson and McQuilkin 1963) and of red pine (Rudolf 1957); the bibliography of white pine (Wilson and Hough 1966) and red pine (Shoup and Waldron 1968); and the comprehensive treatise on the two species by Horton and Bedell (1960). The following review, which relies heavily on these sources as well as the others cited, attempts to update the general subject with special reference to Canadian sources and conditions. Much of the new material in the field deals with plantations, which are becoming increasingly important in white and red pine management.

RANGE

General

The natural ranges of white pine and red pine in Canada are fairly similar, extending from southeastern Manitoba to Newfoundland. Both species occur widely in the Great Lakes—St. Lawrence Forest Region[1], the northern boundary of which corresponds "reasonably closely" with their northern *commercial* range (Horton and Brown 1960). Both occur widely in the Acadian Forest Region, and have limited distribution in the southern Boreal Forest Region. Red pine is found in the northern portion of the Deciduous Region, white pine throughout it (Horton and Bedell 1960).

In the United States, white pine ranges through the Lake States south to Iowa and Illinois, throughout much of the northeast, and south in the Appalachians to Georgia; 1900 kilometres separate the main continuous range from the occurrence of a putative variety growing in southern Mexico and Guatemala. Red pine distribution is much more restricted in the United States, ranging through the Lake States and the northeast, with outliers in Illinois and West Virgina (Critchfield and Little 1966).

The original distribution of these pines has been much modified by logging, fire and settlement. Both species thrive when planted in many situations outside their natural range, depending on local soil—climate combinations as elucidated later.

Canadian Distribution

Figure 1 attempts to reconcile various published representations of the species' range limits in Canada.

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1 "Forest Regions" and "Forest Sections" refer throughout to Rowe (1972).

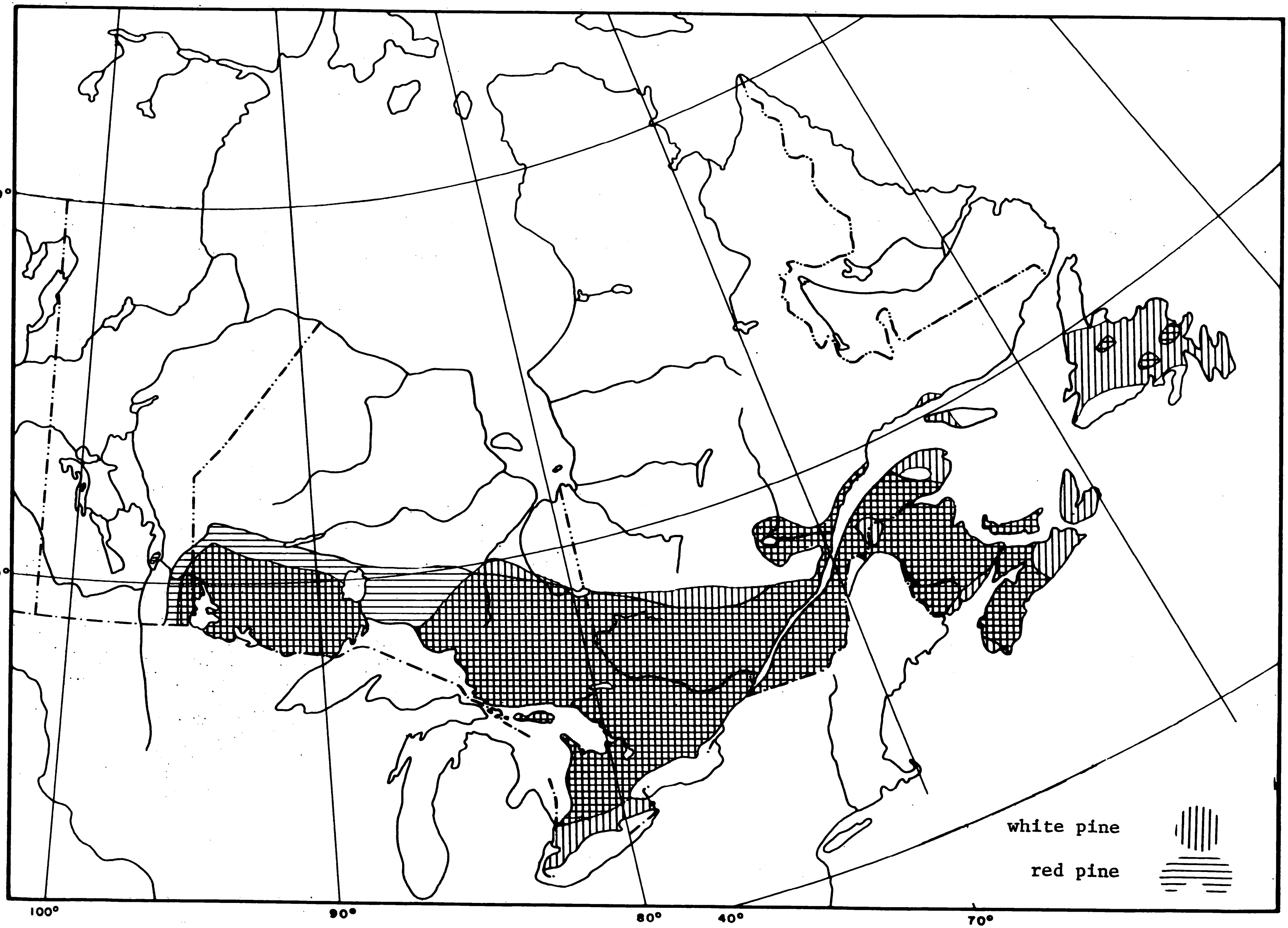

Figure 1. Range of eastern white pine and red pine in Canada.

<u>White pine</u>: White pine is found throughout *Newfoundland* except for Labrador, the northern peninsula and the south coast; it is fairly common in the central and western parts of the island, usually scattered through stands of other species; occasionally it is found on wet sites but usually on fresh, sandy loam soils where it grows best (Bearns 1969, Page et al. 1974). Only scattered patches of white pine remain on *Prince Edward Island*, where it is confined to the southeast portion, and reaches its greatest size in mixtures with eastern hemlock (*Tsuga canadensis* [L.] Carr.), yellow birch (*Betula alleghaniensis* Britt.), and sugar maple (*Acer saccharum* Marsh.) on rich loams (Gaudet and Profitt 1958). White pine is found throughout most of *Nova Scotia*, but is most common in the western half and is scarce or absent in parts of Cape Breton and along the south and east coasts; it occurs in pure stands, or mixed with red spruce (*Picea rubens* Sarg.), hemlock, yellow birch and sugar maple, where it attains its greatest size, but is also found in bogs with black spruce (*Picea mariana* [Mill.] B.S.P.) and tamarack (*Larix laricina* [Du Roi] K. Koch), and on dry, sandy ridges with jack pine (*Pinus banksiana* Lamb.) and red pine (Fowler and MacGillivray 1967, Saunders 1970). White pine is scattered throughout *New Brunswick*, although it is scarce or absent in the northwestern parts of the province and along the south coast (Fowler and MacGillivray 1967).

In western *Quebec*, the northern limit of the range of white pine extends eastward from Lake Abitibi, approximating the boundary of Forest Section B.7, thence into B.1a almost to the St. Lawrence, and northwards in a narrow zone parallel to that river to about 49° latitude. It also occurs in the Saguenay River and Lac St-Jean valleys, and outliers are found in western Anticosti and the adjacent mainland. It is distributed throughout the province south of the line described, except at high elevations in the Gaspé (Hosie 1969, Rowe 1972).

White pine has no southern limit in *Ontario*. In the eastern part of the province it extends north to Lake Abitibi and, with outliers, follows reasonably closely the northern limit of Forest Section B.7. There is a discontinuity in a zone north of Lake Superior from about Marathon to Nipigon, whence the line moves west and north through Sections B.11 and B.8, reaching about latitude 51° before running southwest to the Manitoba boundary north of Lake of the Woods (Haddow 1948, Horton and Bedell 1960, Rowe 1972). White pine occurs in extreme southeastern *Manitoba* in dry habitats, extending about 29 km west of the Ontario boundary from the Winnipeg River south to the international line (Stevenson 1938, Oswald and Nokes 1970).

<u>Red pine</u>: In *Newfoundland* red pine is found in only a few scattered localities in the central part of the island, at Terra Nova, Hawley and Alexander Bay, on dry sandy or gravelly soils (Bearns 1969, Page et al. 1974). Red pine in *Prince Edward Island* occurs mainly in three separate areas, around Murray, Fort Augustus and New

London districts; it grows in pure stands and also mixed with spruce and balsam fir (*Abies balsamea* [L.] Mill.) and reaches its best development on deep loamy sand or gravel (Gaudet and Profitt 1958). In *Nova Scotia* red pine is found mainly on sandy and rocky soils on the lowlands of Colchester and Cumberland counties, and in northern Queen and southern Annapolis counties; it occurs in pure stands and in mixtures with white or jack pine (Saunders 1970).

According to Rowe (1972), red pine is found in most forest sections of *New Brunswick*, except for the south coast (Section A.9), the central portion of the St. John River valley (Section A.4) and the northwestern corner of the province (Section B.2); sites include sandy soils, river terrace materials and rocky knolls. In *Quebec*, red pine has a range somewhat similar to that of white pine but, except near the Ontario border, does not extend so far north, and is absent from much of the Gaspé (Horton and Bedell 1960, Hosie 1969).

In western *Ontario*, the range limit of red pine runs parallel to that of white pine, but about 40 to 80 km further north (Horton and Bedell 1960). In the region north of central Lake Superior where white pine is absent, red pine does occur but is exceedingly rare; in the western zone of its northern range limit red pine is commoner than white pine, while east towards the Quebec border and in the Nipigon area it is less common. The relative abundance of red pine increases towards the north, occurring typically in small stands on coarser glacial deposits (Haddow 1948). In the Clay Belt, red pine occurs a little more frequently than white pine (Baldwin 1958). Red pine is absent from the Niagara Peninsula south of a line between the southern tip of Lake Huron and the western end of Lake Ontario (Horton and Bedell 1960, Hosie 1969).

Red pine occurs in dry habitats in southeast *Manitoba* where it extends somewhat further north and west than white pine; its western range is in the Sandilands, with an outlier on Black Island, Lake Winnipeg (Stevenson 1938, Oswald and Nokes 1970).

TAXONOMY AND GENETICS

White pine: In the complicated taxonomy of the genus *Pinus*, eastern white pine is a member of the *Haploxylon* subgenus, or those pines having needles with a single vascular bundle. It can be further classified as belonging to the section *Strobus*, the five-needled pines, and subsection *Strobi*, those with adherent seedwings (Shaw 1914, 1924; Critchfield and Little 1966). Other Canadian representatives of this subsection are limber pine (*P. flexilis* James) and western white pine (*P. monticola* Dougl.), both western species. Despite considerable variation in appearance (e.g., in needle length and color and bark color) in difference parts of its range (Heimburger and Holst 1955), which suggests that as yet unidentified ecological or geographic races may exist, eastern white pine has had only one variety named: *P. strobus* L. var. *chiapensis* Mart. in Mexico, which may in fact be an independent species (Mirov 1967).

Variation in certain characteristics of eastern white pine, e.g., stratification requirements of seed, height and diameter growth, response to day length and night temperature, have been related to geographic origin of the seed (provenance), indicating the possibility of improvement by selection of seed source (Wright 1970). On the basis of height growth at age 7 years in two test plantations established with numerous seed sources, a Pennsylvania provenance was recommended provisionally for use in southern Ontario pending future observations on weevil damage (Fowler and Heimburger 1969). By age 12, the Pennsylvania, Nova Scotia and New York sources in these plantations all showed better height and diameter growth than the local Ontario source (Zsuffa 1975). Pending specific information on performance of other provenances in a particular area, stock planted there should be derived from the seed collection zone in which that area is located.

The occurrence of individual trees showing immunity to white pine blister rust (*Cronartium ribicola* J.C. Fisch.) and the white pine weevil (*Pissodes strobi* Peck) has suggested the feasibility of selection and propagation by grafting, controlled crossing, etc., of such types to develop resistant populations (Wright 1970). Progress in screening for weevil-resistant clones was reported by Heimburger and Sullivan (1972). The ability of eastern white pine to hybridize with some other species in the *Strobi* subsection provides scope for introducing various desirable traits, including resistance to specific pests, but two or three generations (about 75 years) would be needed to provide resistant material for propagation (Heimburger 1972). In Ontario a number of hybrids between white pine and Himalayan pine (*P. griffithii* McClelland) have been produced which show vigorous growth and a "practical level" of resistance to blister rust, with advanced generations seeming to maintain these characteristics (Zsuffa 1976).

Vegetative propagation allows development of clones, providing genetically identical material for testing and saving many years in research programs; efficient means of rooting white pine cuttings and needle fascicles have been developed for these purposes (Zsuffa 1972).

Red pine: Red pine belongs to the subgenus *Diploxylon*, in which the needles have two vascular bundles. It can be placed additionally in the section *Pinus* (needle fascicle-sheaths persistent and seed-wings articulate) and subsection *Sylvestres* (seed-wing membranous, cone opening at maturity and pits of ray-cells large) (Shaw 1924, Duffield 1952, Critchfield and Little 1966). There is no other Canadian pine in this subsection, and probably the most closely related species is Austrian pine (*P. nigra* Arnold) (Shaw 1914). No varieties of red pine have been described, and the species is morphologically very uniform (Mirov 1967).

While natural variation for many traits, including growth rates, survival, photoperiod and wood quality, for example, has been found between provenances, the pattern is often obscure and difficult to relate to climatic data (Fowler and Lester 1970). The 10-year results of comprehensive provenance trials with red pine throughout eastern and central Canada showed differences in height growth at individual test sites, for which promising seed sources were thereby indicated, and while they did not identify any consistently good performers, some consistently poor ones did emerge, i.e., pine from Stanley, N.S., Grand Lake, N.B. and Kenogami, Que. (Holst 1975a). Application of the seed collection zone principle still seems appropriate for red pine also.

The possibility of inducing genetic variation by hybridization is minimal since attempts to cross red pine with other species have failed, with the possible exception of two attempts with Austrian pine and one with Japanese red pine (*P. densiflora* Sieb. and Zucc.) (Duffield and Snyder 1958, Fowler and Lester, 1970, Zsuffa 1976). The best expectations from tree improvement programs seem to lie in making small genetic gains, probably respecting growth rate, in large numbers of seedlings, e.g., where red pine is a major part of large-scale reforestation (Fowler and Lester 1970, Holst 1975b). Selection of plus trees and their propagation in seed orchards is proceeding to this end.

ENVIRONMENTAL FACTORS

Climate

The large geographic range of white and red pine embraces considerable climatic diversity. The general climate over the range of white pine has been described as cool and humid (Wilson and McQuilkin 1963), and habitats where red pine grow are characterized by cool-to-warm summers, cold winters, and rather low-to-moderate rainfall (Rudolf 1957). In Canada, representative conditions within the range of these pines include cold-dry for the southern Boreal in Manitoba, cold-wet in Newfoundland, warm-moist in the Maritimes and warm-dry in southern Ontario; for the central part of their range in Ontario and southwestern Quebec, temperatures are moderate (annual average daily mean 4.4°C) and precipitation is somewhat low (77 cm), with warm and somewhat droughty summers (Horton and Bedell 1960).

The northern limit of distribution is related to the length of the frost-free period, according to Haddow (1948). Likewise, Horton and Brown (1960) suggest that it is cold climate which restricts the development of these pines to the north. That red pine is better adapted to colder and drier continental conditions may be indicated by its further extension north and west in the western part of the range, while white pine has the more northerly limit in the east. Also, red pine is at the natural limit of its range in Newfoundland, where its occurrence is very restricted and the maximum height attained only about 12 m, whereas white pine seems well adapted to this maritime climate and capable of twice the height growth (Page et al. 1974).

Local climate can both extend and restrict the area of species survival in particular situations, and should be taken into account in planting programs. Thus warmer and drier sites permit intrusion of both pines north into the Boreal, and west into the Prairies (Horton and Brown 1960) and allow the survival of red pine in Newfoundland (Page et al. 1974). Frost-prone areas experience unseasonable freezing temperatures which cause serious damage or mortality to newly flushed growth. These areas include depressions or breaks in natural slopes where free air drainage is impeded, or even dry sand flats where radiation allows rapid cooling, particularly if there is a lack of tree cover to reflect back heat losses (Duffy and Fraser 1963). Such areas should be avoided for planting. Fail spots in red pine plantations that are due to frost-pocket conditions are said to be characterized by a particular vegetation type composed of sweet-fern (*Comptonia peregrina* [L.] Coult.), stunted blueberries (*Vaccinium* spp.), sedges and grasses (Horton and Brown 1960). Bracken fern (*Pteridium aquilinum* [L.] Kuhn) is frost-sensitive and unseasonal browning of its foliage can help identify frosty sites (Fraser 1965).

Specifically, minimum air temperatures in frost pockets can be between 8°C and 11°C lower than those prevailing on normal sites (Duffy and Fraser 1963). Exposed, young unhardened red pine were injured in a frost pocket in September when the temperature dropped to -5°C, and were killed at -9.4°C (Fraser 1953). In that area phenology lagged by up to 3 weeks, but planted red pine eventually became established while white pine did not.

Extremely high temperatures can develop at the ground surface (insolation) on exposed sites and are damaging to young reproduction; fire-blackened surfaces are particularly hazardous in this regard. A temperature of 49°C is lethal to small seedlings within an hour (Shirley 1937). Four-year transplants of both white and red pine can be killed by exposure to 58°C for 2 hours under dry conditions (Shirley 1936).

Generally, red pine seems to withstand extremes of local climate better than white pine, as shown by its predominance on dry sandy plains which are exceptionally hot by day and cold by night (Horton and Brown 1960).

Fire

Naturally occurring fires are a feature of the drier conditions where these pines normally occur. Maissurow (1935) concluded that forest fires were necessary to the perpetuation of white pine, as one of the main agents exposing mineral soil and removing vegetation which would compete with pine reproduction. Van Wagner (1970) considered that fire was even more important to red pine with its more stringent seedbed and seedling-environment requirements; only fire could provide these in the natural state. The normal balance that ensured pine regeneration after a fire in a good seed year was upset by logging and clearing and the fires associated with them which recurred at such short intervals that young stands could not reach seed-bearing age. Thus pine types were eliminated on a large scale.

The following is taken from Methven (1973) and Van Wagner (1970). While white and red pine stands maintain maximum flammability up to heights of ca 18 m, thereafter the possibility of crown fires lessens with increasing length of clear bole and is rare in mature stands. Mature pine have thick, insulating bark (possibly more resistant in red than in white pine) which will prevent cambial damage from "fairly intense surface fires". However, foliage can be killed by hot gas rising above the flames, and if more than 75% of the crown is killed the tree will die. In this respect fires with an energy output rate per unit length of front greater than ca 1700 kW/m would be dangerous to large pines. On the other hand, a prescribed surface fire would be feasible in mature pine stands, say 21 m or taller, for the removal of litter or unwanted vegetation to encourage the establishment of regeneration, provided the intensity did not exceed ca 700 kW/m.

Light

White pine is acknowledged to be more tolerant of shade than is red pine (e.g., Shirley 1943). In studies with seedlings, Logan (1966) found that red pine could achieve maximum height growth in as little as 45% of full light up to age 5 years, after which full light was required for maximum growth. White pine, however, continued to make maximum height growth at the 45% level. For both species, leader diameter and weight of roots, wood and foliage all increase markedly up to full light. Decreasing light levels diminish root weight more than top weight.

The difference in light requirements is sufficient to give white pine a decided competitive advantage in becoming established and growing, if at a reduced rate, under overhead shade in the range 25-45% of full light. This facility can be exploited in growing white pine, e.g., by underplanting, since shade conditions and associated slender leaders both limit attacks by a major pest, the white pine weevil (Sullivan 1961). By contrast after the first few years red pine may survive, but cannot grow satisfactorily, under even moderate overhead cover. Red pine seedlings that have germinated under dense shade rarely persist to 10 years (Horton and Brown 1960). Underplanting with this species should be avoided unless early release is planned.

Other Vegetation

Other than merely shade effects are proffered by associated plant species. The success of conifer reproduction depends chiefly on adverse effects of subordinate vegetation, particularly by root competition (Shirley 1945). Penetration by roots of first-year seedlings, presumably advantageous in escaping surface layers depleted of moisture by competitors, is much superior for white pine (Shirley 1943). The drain on soil moisture by a heavy cover of heath plants such as blueberries and sweet-fern in Wisconsin red pine plantations was estimated to divert ca 85 kg of water per kg of oven-dry weed biomass, reducing the wood yield by ca 40% in a 40-year rotation (Wilde 1970).

In some red pine plantations at the Petawawa Forest Experiment Station, trees growing in dense sweet-fern have been observed to have stunted height growth, yellowish foliage, crooked stems and dead shoots; while excessive drain on soil moisture by sweet-fern, as compared to other ground cover, i.e., grasses and blackberry (*Rubus allegheniensis* Porter), was demonstrated in these situations, experimental work excluded the likelihood of toxic secretions by the sweet-fern (Clements et al. 1968). Sweet-fern, in addition, is an alternate host to sweet-fern blister rust (*Cronartium comptoniae* Arth.) and the Saratoga spittlebug (*Aphrophora saratogensis* Fitch), two damaging agents which attack red pine. Similarly, currants and gooseberries (*Ribes* spp.) are indirectly hazardous to white pine, as alternate hosts to white pine blister rust.

Black walnut (*Juglans nigra* L.) is known to secrete a substance from its roots toxic to some plant species, and von Althen (1968) reported mortality, needle loss and discoloration of red pine interplanted with walnut in southern Ontario, presumably from this cause. White pine planted in a black walnut stand in West Virginia exhibited depressed height growth independent of any possible shade effect (Wiant and Ramirez 1974).

Soil

In broad terms, the soil groups on which white and red pine occur are predominantly podzols and podzolics. Common materials are glaciofluvial and aeolian in origin, while lacustrine deposits and loamy and finer till soils are less frequently occupied (Rudolf 1957, Horton and Bedell 1960). Preferences might be explained in terms of individual soil properties, considered next.

Texture: A relatively high proportion of sand characterizes the soils most often occupied by both species, with red pine generally more abundant on the coarser sandy materials, white pine on the finer sands or loams (Horton and Brown 1960, Wilde et al. 1965). Heavier soils can be the most highly productive for both white and red pine, but usually the hardwood competition associated with them limits the natural establishment of pine regeneration. Once cleared, these soils can support high-yielding plantations; however the extra yield may not justify the cost of weed control (Wilde et al. 1965).

The effect of soil texture is influenced by soil depth, structure and prevailing moisture. Thus, sandy soils with thin strata of finer material, and loose, sandy dune soils not excessively drained, are very favorable to root development, but dry, coarse compacted materials restrict root growth (Brown and Lacate 1961).

Moisture: Both species achieve superior growth on fresh to moist well-drained soils, but occur over a much wider range of moisture conditions; of the two, white pine has the wider range, being found from wet swamps to dry sand plains and rocky ridge tops (Horton and Brown 1960). White pine is the less drought resistant (Shirley 1943) and is the poorer performer when planted on dry sites, but is tolerant of much wetter soil conditions.

Red pine is not suited to poorly drained soils, which cause stunting and mortality of roots, and severely inhibit growth; best plantation development is made on soils which range from moderately drained to very fresh (Brown and Lacate 1961, DeMent and Stone 1968, Love and Williams 1968). Despite these preferences, red pine is an efficient producer on much drier soils, and a good choice for planting under such conditions.

Nutrients: Few specifics have been offered, but white pine is usually considered the more demanding of the two species in terms of soil fertility (e.g., Wilde et al. 1965). In the Lake States, Shirley (1943) rated seedlings of red pine as more "vigorous" than those of white pine in both nitrogen- and phosphorus-deficient soils. In red pine plantations in New York, superior growth was found over the range of surface soil chemical properties common to acid sandy soils and silt loams except for the lowest content of soluble phosphorus--1 pp2m (DeMent and Stone 1968). The presence of a calcareous gravel layer close to the surface was considered to have reduced survival and growth of red pine in certain plantations in southeastern Manitoba (Haig and Cayford 1960). Excessive mortality and symptoms of nutrient imbalance (possibly a lime-induced deficiency of manganese and/or iron), including diminished leader length and chlorotic aborted needles, were reported in two 30- to 35-year-old red pine plantations in southern Ontario growing on well-drained calcareous till soils (Ellis and Whitney 1975). According to Horton and Brown (1960) white pine growth was not appreciably retarded by lime concentrations near the surface, while red pine was, though not by lime in the subsoil; a strong concentration of iron and humus in the upper B horizon seemed to have an adverse effect on both species. In Wisconsin, Wilde (1966) recommended minimum soil-fertility standards for planting well drained soils as follows:

	Red pine	White pine
Organic matter (%)	1.3	2.5
Exchange capacity me/100 g	3.5	5.7
Total N (%)	0.05	0.10
Available P (kg/ha)	28	34
Available K (kg/ha)	78	112
Exchangeable Ca (me/100 g)	0.80	1.50
Exchangeable Mg (me/100 g)	0.20	0.50

Horton and Brown (1960) maintain that "both pines ordinarily occur and grow satisfactorily on soils of moderate to low fertility", and while they can do better on richer soils they cannot normally compete with hardwoods thereon.

Reaction: Red and white pine are characteristically associated with acid soils. For natural stands in Canada, Horton and Brown (1960) reported satisfactory growth in both species on soils with a surface pH as low as 4.0, but on somewhat basic soils with a surface pH of 7.0 to 7.5 white pine could thrive but red pine might be inhibited. Wilde (1966) considered the optimum pH range for planting in Wisconsin to be 4.7 to 7.3 for white pine, and 5.2 to 6.5 for red pine. The majority of red pine plantations of "superior growth" examined in New York were on soils with pH from 4.6 to 5.0 (DeMent and Stone 1968). It appears that basic soils (for forest sites, effectively those derived from calcareous materials) should be avoided for planting red pine.

Integrated Site

It is the combined action of individual environmental factors that determines the characteristics of a site for a particular species, necessitating some composite designation. The "total site" approach of Hills (1952 et seq.), widely applied in Ontario, divides the province into temperature-based regions, within which sites are described according to local climate, surface relief, soil materials and moisture conditions. This approach was used by Horton and Brown (1960) in classifying sites in Forest Section L.4c (Middle Ottawa) in terms of pine productivity and ease of regeneration; in this Section "pines predominate on the shallow upper slopes and ridges and on the water-worked and windblown materials, and as the physiographic site becomes more mesic, pine distribution generally wanes". The application of Hills' system in classifying sites for planting red pine has been well described by Williams[2].

Similarly, but on a broader scale, white pine distribution, succession and silviculture in central Ontario have been discussed for outwash sands, shallow tills and deep tills by Scott (1957), and the major site conditions for the White Pine Working Group as recognized by the Ontario Ministry of Natural Resources are shallow sandy soils on low granitic ridges, sandy outwash plains and terraces, and glacial tills; deep loam and clay soils in the southern part of the province are excluded as the costs for retaining the pine are considered excessively high (Anon. 1973).

The following are examples of site descriptions for superior performance by red pine plantations, offered in various regions: deep, moderately rich, fresh, sandy loams, not closer than 1 km from salt water coast lines, in the Maritimes[3]; deep (1.5+ m), well drained sandy soil, on the plain between the St. Lawrence River and Laurentian foothills in Quebec (MacArthur 1959); well drained and moderately well drained sandy and loamy soils over tills and fluvial deposits, gleyed at depths of 0.6 to 0.8 m in the Eastern Townships of Quebec (Truong dinh Phu 1972); fresh lacustrine silt loams, molded tills, and windblown loamy and sandy soils near Chalk River, Ontario (Stiell 1955); very fresh, deep, sandy soils in southern Ontario (Love and Williams 1968); naturally subirrigated soils with well aerated surface layers and water table at a depth of from 1.2 to 2.7 m in Wisconsin (Wilde et al. 1965); a variety of well drained and moderately drained acid soils in New York (DeMent and Stone 1968).

SEEDS AND SEEDLINGS

Flowering

In all pines, both the male and female flowers are monoecious (borne on the same tree). In white and red pine they appear in May and June (Anon. 1961).

Female flowers of red pine are borne mostly in the middle third of the crown, next to the shoot apices, and the male flowers around the bases of developing shoots in the lower crown (Hard 1964, Fowler and

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[2] Williams, J.R.M. 1968. Land classification for plantations. Pap. presented at Annu. Meet., Can. Inst. For., St. John's, Nfld., Sept. 25, 1968. 9 p.

[3] Hughes, E.L. and L.G. Yarn. 1963. Survey of planted red pine in the Maritime provinces. Can. Dep. For., For. Res. Br., 63-M-2. 21 p. (unpubl. report).

Lester 1970). The cone primordia are differentiated in July (Year 1), become visible at the end of the growing shoot late the following spring, and are pollinated in early June (Year 2); they complete their growth by mid-July of the next year, after which fertilization takes place and the cones mature in early fall (Year 3) (Lyons 1956). Usually, most seed-fall takes place that fall and the remainder the following spring, but the bulk of it can be deferred by cool, wet weather (Cayford 1964). On young trees, female flowers are produced for a few years before male flowers (Fowler and Lester 1970).

In white pine, female flowers are usually confined to the upper third of the live crown, and the male flowers are borne on lower branches (Wright 1970). The sequence of cone development is similar to that in red pine, although pollination occurs about 2 weeks later (Horton and Bedell 1960). Virtually all seed is shed in the same fall that the cones ripen (Graber 1970). When flowering begins in young white pine only female flowers are produced--for up to 20 years before the male flowers appear (Wright 1970).

Cone Crop

While cones with viable seeds may be borne by very young trees, e.g., age 12 in red pine (Roe 1945), the appearance of appreciable seed crops is deferred for many years, and even in the mature cone-bearing phase good crops are produced only every few years (Table 1).

Less than half the ovules in a red pine cone are capable of developing into seeds; these ovules are confined to the central part of the cone, and numbers vary from ca 30 to 110+ depending on cone length and number of scales, as well as position in the crown (i.e., higher numbers occur in the upper crown and on main branch terminals). Abortion of ovules reduces actual seed production by 50 to 60% (Lyons 1956), so that a red pine cone might contain ca 15 to 50 seeds. Wright (1970) gives much more variable figures for white pine, but cites a series of collections made in 1955 over the entire range of the species in which yields varied from 20 to 70 filled seeds per cone.

The size of the cone crop is much affected by stand density, more open conditions permitting larger crowns and higher cone yields per tree. Dense stands with short-crowned trees are poor cone producers, as reported for red pine by Fraser (1951) and for white pine by Graber (1970). Observations made at the time of the first heavy cone crop in an 18-year-old red pine plantation, established as a spacing trial with the spacing interval ranging from 1.2 x 1.2 m to 6.4 x 6.4 m, showed maximum yields per tree (average 340 cones) and per hectare (79,823 cones) at the widest spacing, which had full-crowned trees and appeared to give close to maximum production for that age (Stiell 1971). Thinning has been shown greatly to increase cone production in red pine (Godman 1962, Roe 1964, Sims and Campbell 1970).

Table 1. Conspectus of representative flower, cone and seed data for white and red pine.

	White pine	Red pine	Source
Seed bearing age (yr) - minimum	5–10	20–25	Cited by Krugman and Jenkinson 1974
	15	25	Anon. 1966
- optimum	50–150	50–150	" "
Frequency of good cone crops (yr)	3–10	3–7	Cited by Krugman and Jenkinson 1974
	4	5	Anon. 1966
Flowering	June	May–June	" "
Cone ripening	Aug.–Sept.	Sept.–Oct.	" "
Attributes of ripe cones: color	yellowish-green brown scale tips	Deep purple with reddish-brown scale tips	Anon. 1966
specific gravity	0.92–0.97	0.80–0.94	Cited by Krugman and Jenkinson 1974
will float in	raw linseed oil	kerosene	Anon. 1966
Recorded collection dates: earliest	25 Aug.	10 Sept.	" "
latest	12 Oct.	16 Oct.	" "
Seed dispersal	Sept.–Oct.	fall–spring	" "
Approximate cone yields per tree (hL)	1.8	0.5	" "
Approximate closed cones per hL	1375–1925	3575–4950	" "
Clean seeds per hL of cones (kg)	1.01	0.75	" "
	0.57-1.42	0.92-1.14	Wang 1973
Clean seeds per kg: low	46,300	103,620	Anon. 1966
avg	61,730	121,250	" "
high	70,550	143,300	" "
Approximate viable seeds per kg	47,530	103,060	" "
Germinative energy (% of seeds germinated when germination trend reaches peak)	33% in 8 days	69% in 10 days	Cited by Krugman and Jenkinson 1974
Safe storage conditions (dry, sealed)			
- moisture content (% of dry weight)	5–7	5–8	Cited by Wang 1974
- temperature (°C)	-7–2	1–3	" " " "
- possible duration (yr)	10+	30	" " " "

For seed production areas on medium sites, Rudolf (1959) recommended maintaining an average spacing equivalent to one-half the average height of dominant and codominant trees by periodic thinning, for both species. Cooley (1970) considered that thinning for seed production should be limited to young stands on good sites, owing to the much better response.

Within the stand, crown position or relative diameter class is important to cone production: size of crop tends to increase with tree size although variability within diameter classes is large (Godman 1962, Stiell 1971). Some red pine are said to be consistently good or consistently poor cone producers (Conzet 1913, cited in Rudolf 1957), and observation should indicate unproductive trees which ought to be removed from seed orchards or seed production areas.

Nutrition plays a part in flower production which can sometimes be stimulated by chemical fertilizers, although the matter does not seem to be sufficiently well understood to allow consistent results. An increase of 41% in numbers of cones in the third growing season was obtained in 45- to 75-year-old red pine in southeast Manitoba by the application in May of ammonium nitrate at the rate of 335 kg/ha (Cayford and Jarvis 1967). A composite fertilizer (urea--45% N and ureaform--35% N, plus potassium sulphate--40% K and superphosphate--13% P) was applied at rates of 622 and 1244 kg/ha in 20-, 53-, and 55-year-old stands of red pine in lower Michigan; while there was no effect on cone production in the young trees, an increase was observed in the older stands but only where thinning had reduced them to ca 100 trees/ha (Cooley 1970). Female flower production in 22-year-old white pine was significantly increased in trees fertilized with ammonium nitrate at levels up to 177 kg/ha, with 59 kg/ha seeming to give best results; numbers of trees bearing cones were not increased, and flowering was not induced in younger stands, aged 7 and 14 years (Stephens 1964). Complications in which increased female flowering was followed by a sharp decrease, and reduction in male flowering, with results affected by season of application, have been reported following treatment with nitrates and ammonium sulphate (Holst 1971).

Seed Yield

Potential seed production can be diminished by a number of non-physiological factors. Among the most serious are various cone insects which can reduce the seed crop by 40% to 100% in open-grown red pine (Lyons 1960). Unfavorable weather during flowering and pollen shed and depredations by squirrels are the other main hazards.

Examples of estimated high seed yields are 751,200 "sound" red pine seeds/ha in southeast Manitoba (Cayford 1964), 2,263,400 viable red pine seeds/ha in the Lake States (Roe 1964), and 4,431,000 viable white pine seeds/ha in Maine (Graber 1970). "Average" yields would of course be much lower, but it is difficult to set a figure for them. Rudolf (1959) estimated that 600 red pine on 12 ha, and 240 white pine on 6.5 ha would be required to yield one million plantable seedlings per year, respectively, on seed production areas.

Average germinative capacity is above 75% for both species (Krugman and Jenkinson 1974), and if properly stored under dry, sealed conditions red pine can maintain high viability for 30 years, white pine for 10 years (Table 1).

Seedling Establishment

Cones open best on warmer autumn days, and seeds usually land at a distance no greater than the height of the tree, although they are capable of much further flights if windborne (Horton and Bedell 1960). Prior to germination, shed seeds may be eaten by birds, insects, squirrels, chipmunks, voles and mice.

In general, factors of particular importance to seedbeds are soil condition and vegetative cover. Soil must be moist near the surface during the germination period, and this is more likely with loam, silt and clay soils, and with northern exposures; while shade is favorable to germination and initial survival, grass, sedges, other herbs and shrubs offer serious competition to young seedlings (Shirley 1937).

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 and seedbed conditions are favorable. The seedlings become established only in partly shaded places where grass and litter are not thick or where mineral soil is exposed (Rudolf 1957).

White pine seeds exhibit embryo dormancy, but for the majority this is broken by natural stratification on the forest floor in autumn and early spring, giving germination later in the spring (Horton and Bedell 1960). Under full exposure to sunlight, favorable seedbeds are moist mineral soil, polytrichum moss or short grass of light to medium density (Wilson and McQuilkin 1963).

Site ratings for regeneration capacity for white and red pine have been set forth 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 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: moderate shrub—herb and herb types, usually with fresh, rich soil and standard local climate very difficult: shrub—herb, shrub and herb types with strong development towards dense shrubs or hardwoods, usually with moist, rich soils and cool—moist local climates. (In terms of site productivity, the ranking might be reversed for the foregoing situations.)

Following germination, young seedlings are highly vulnerable to climatic and biotic hazards. Prominent are drought, insolation, freezing temperatures, flooding, rodents, root competition, shade and smothering by tall grasses or hardwood leaves (Shirley 1936, 1945, Smith 1951, Fraser 1953, Fraser and Farrar 1955).

Two of the main implications for management in promoting seedling establishment are the need for (a) site preparation to expose mineral soil and remove competition from low vegetation, and (b) control of the overstory to provide sufficient light for established seedlings to develop (Logan 1950, 1951).

MORPHOLOGY

Bark

The bark of both species changes considerably with age in color, surface texture and thickness (Harlow and Harrar 1941, Anon. 1948, Hosie 1969).

On young stems and branches of white pine the bark is thin, smooth, and grey-green to dark green. As it ages, the bark turns grey or greyish-brown, and becomes deeply furrowed longitudinally into rectangular ridges. Thickness in mature trees may be 2.5 to 3.2 cm. The thin bark of young trees is easily damaged, and vulnerable to sun scorch and fire. Mature bark is very fire-resistant.

The bark on young red pine is scaly, thin and orange-red. With age the bark turns reddish-brown, and becomes furrowed into large, flat plates, superficially flaky, up to 4.6 cm thick, and highly resistant to fire.

Crowns

Leaf development: White pine seedlings have seven to ten toothed, needlelike cotyledons (seed leaves); much longer primary leaves are soon formed; normal (secondary) leaves, borne in bundles of five, without basal sheaths, and 6.3 to 12.7 cm long, appear in the second year, persisting usually for two growing seasons but sometimes until late in the following spring (Sargent 1905, Brayshaw 1959, Hosie 1969).

Red pine seedlings have six to nine cotyledons, without teeth; normal leaves, produced after the first year, are borne in bundles of two, with a persistent sheath at the base, and are 10.2 to 16.5 cm long (Brayshaw 1959, Hosie 1969). New leaves begin their development in the spring, complete it by late summer and make no further growth in subsequent years. While the majority probably persist for 3 years, some may be retained for 6 years. A study of one crown showed that ca 33% of the foliage by weight was formed in the growing season just ended, while 25% was formed in each of the previous two growing seasons. Mortality usually occurs in early fall when the older needles turn brown and drop within a few weeks (Kienholz 1934, Stiell 1962, 1966).

Crown structure: Both species produce one annual whorl of branches from lateral buds formed at the end of the leading shoot, and occasionally a second flush produces lammas shoots in late summer, perhaps as a result of rain followed by a dry spell (Harlow and Harrar 1941, Horton and Bedell 1960). White pine crowns are somewhat irregular and tend to have long, nearly horizontal isolated branches; red pine crowns are dense and more symmetrical, generally ovoid in shape with upcurved branches (Ardenne 1950, Horton and Bedell 1960, Stiell 1962). Within red pine crowns, foliage weight increases from the top downwards for the first few whorls, remains constant for several more, and then diminishes towards the crown base, with the mean weight at or slightly below the midpoint (Stiell 1962, Stephens 1969).

Branch growth and foliage production: Crowns are enlarged by the annual extension of the main stem and branches. In relatively open-grown red and white pine, Smithers (1954) found that the rate of branch extension, like height growth, diminishes with age, with the effect most marked at 45 years and up. For stand-grown trees, crowns expand until the canopy closes, and the lower branches die from mutual shading; crown width is also limited by whipping abrasion (Richards et al. 1962). On medium sites, in medium- to well-stocked stands in Algonquin Park and vicinity, crown width of dominants and codominants increased with DBH, averaging 6.8 m in white pine and 6.4 m in red pine for 40.6 cm trees (Ardenne 1950).

Stand density is critical in controlling the length and thickness that branches will attain, as well as the amount of foliage they bear, before being shaded out. Plantation spacing trials have shown that red pine branch diameters increase with spacing for a given height (Stiell 1965, 1966). Likewise, quantity of foliage per tree is a function of spacing, and in one red pine trial the average oven-dry weight of foliage in stands 10 m tall was 4.5 times as heavy (22 kg) where spacing was 4.3 x 4.3 m as where it was 1.2 x 1.2 m (Stiell and Berry 1977). In 28-yr-old white pine plantations, average foliage weight at 1.2 x 1.2 m was 1.5 times that at 0.6 x 0.6 m (Burns and Irwin 1942). Following closure, crown size of individual trees tends to stabilize. Brown (1963) found that, on the average, foliage made up 43% of the total crown weight in red pine.

Foliage weights per unit area are higher at closer spacings, at least until canopy closure, after which they may fluctuate without much further change; for a stand height of 10 m, oven-dry weights of ca 24,700 kg/ha were observed at a spacing of 1.2 x 1.2 m, compared to 15,300 kg/ha at 3.0 x 3.0 m; however, weight was also 24,700 kg/ha at 3.0 x 3.0 m in stands 18 m tall (Stiell 1966, Stiell and Berry 1977). Similarly, in 28-yr-old white pine plantations, foliage weight was 14,900 kg/ha at a spacing of 0.6 x 0.6 m, and 5,710 kg/ha at 1.2 x 1.2 m (Burns and Irwin 1942).

As a rule, stemwood increment increases with descent from the apex, and reaches a maximum near the live crown base or point of greatest branch development (Larson 1963). The relationship between red pine foliage distribution and stemwood increment is rather obscure (Hall 1965), but there is evidence that, within the live crown, growth of a stem internode is influenced mainly by foliage in the whorl immediately above it (Stiell 1969). One-year-old leaves seem to be the most productive (e.g., Linzon 1958, Kozlowski and Winget 1964). In a closed stand, the lowest living branches are little if at all productive, owing to sparse foliage and low light levels. Pruning about the lower 45% of the live crown in dominant trees should cause little reduction in stem diameter growth, and growth rates should soon be recovered.

Roots

Growing periods: On the basis of seedling studies with white pine (Stevens 1931) and red pine (Merritt 1959, 1968, Wilcox 1968) it appears that in both species most root elongation takes place during two periods of activity, one in spring and early summer, the other in early fall, with an intervening decline during summer. The pattern is apparently inherent, but prevailing soil moisture and temperature conditions can influence the timing and intensity of growth activity.

General structure: Both red and white pine tend to have widespreading, moderately deep root systems, subject to modification by soil conditions. In early years, both species develop a taproot and numerous branched laterals; later the taproot is more often retained in red than in white pine, which, however, tends to have wider lateral spread (Brown and Lacate 1961).

Lateral roots: The lateral roots radiate from the tree at irregular intervals but generally in spokelike fashion, remaining close to the surface (usually within 10 to 45 cm), and may attain a length in excess of tree height in stands up to ca 9.5 m tall (Day 1941, Brown and Lacate 1961, Stiell 1970, Fayle 1975). In red pine planted on dry to very fresh sandy and loamy soils, Fayle (1975) recorded about a dozen main laterals per tree; they reached their greatest length in 15 to 20 years, and he considered 11 m to approach the maximum for those conditions. The greatest lengths encountered by Brown and Lacate (1961) in natural stands up to age 100 yr were 18.3 m for white pine and 12.2 m for red pine.

Lateral roots tend to be cordlike with little taper except near the point of origin (Day 1941). They follow a somewhat sinuous course without changing main direction, and the entire lateral system is oval rather than circular; fine roots, usually concentrated near the surface, develop along the main laterals, and vertical "sinkers" descend from them (Day 1941, Brown and Lacate 1961, Fayle 1975).

The considerable length of lateral roots means that very large areas are shared by the root systems of a number of trees, and not just those of immediate neighbors. Stiell (1970) described a red pine 8.2 m tall whose roots extended into the local areas occupied by 23 other trees in the plantation, and its own local area was invaded by roots of 11 other trees.

<u>Vertical roots</u>: In natural stands, Brown and Lacate (1961) observed both central and lateral sinkers in each species, but more abundant and better developed in white pine, which often did not have a taproot; maximum depth of penetration observed was 4.6 m for both species. In red pine, taproots and sinkers tended, when meeting an obstacle, to follow its surface and turn downwards at the first opportunity, whereas white pine tended to react by spreading laterally.

In young red pine, Day (1941) found taproots usually present, but not highly developed, and soon branching into subsidiary roots; sinkers were longer than taproots and reached a maximum depth of 1.9 m. Risers were thin roots ascending from the laterals to within 1.3 cm of the surface and then growing parallel to it. In red pine plantations Fayle (1975) described two types of vertical roots, most originating within 1.75 m of the stem base; deep verticals, averaging seven in number and extending to the full rooting depth of 2.8 m in 8-11 years; and shallow verticals, averaging three per tree, fan-shaped and only reaching a depth of 1 to 1.5 m in 20 years, with slow growth attributed to high bulk density (above 1.40) of the soil.

<u>Soil conditions</u>: The nature of the material in which they grow distinctly influences the extent and character of tree roots. Day (1941) found longer laterals in "dry" soils, Fayle (1975) in "very fresh" soils, probably indicating different descriptive standards for two widely separated study areas. Loose,

well-drained soils permit deep penetration of vertical roots (Brown and Lacate 1961). Underlying fractured sandstone and siltstone may even be penetrated by red pine roots where soil drainage is good (DeMent and Stone 1968). Fine roots may proliferate just above and below thin layers of finer textured material in otherwise coarse soils. With high water tables, white pine develops shallow, flattened root systems. Impeded drainage restricts downward growth of red pine roots, which experience dieback in soils seasonally saturated for more than three months (Stone et al. 1954, Fayle 1975). Hardpan, gley near the surface, and coarse compacted soils stunt root systems, particularly those of red pine.

Root grafts: Natural grafting between root systems of individual trees is common. Aboveground evidence is the continuing survival of stumps and stem-girdled trees in thinned stands. These are sustained by manufactured food (no longer available from their own crowns) passed to their roots via grafts with living trees.

Bormann (1966) considered that root grafting between white pines is a normal phenomenon which delays mortality of trees threatened by competition. He concluded that the dominant member of a grafted pair does not benefit from the connection: if the two trees are equally dominant, a balanced exchange of food occurs; if crown class is unequal, food moves to the lesser tree; if one member of a grafted pair is cut, the stump may be kept alive, passing water to the living tree, and receiving food in exchange.

In red pine plantations studied by Armson and van den Driessche (1959), grafting was common in those 15 years old or older. Most grafts were found 10 to 36 cm below ground, and the number of grafts appeared to increase after a thinning; at a graft, the root of smaller diameter, or further from its origin, received a net increase in food supply. In a 40-year-old row-thinned red pine plantation the great majority of trees were connected directly or indirectly with one or several other stems; very variable diameter growth was made by codominants and intermediates, perhaps because of haphazard occurrence of grafts (Horton 1969). Stone (1974) examined red pine surviving 18 years after complete girdling in a precommercial thinning, and found each to be grafted to an average of three intact trees. Diameter growth of girdled trees had stabilized at a reduced rate after a few years, but growth of the intact trees was not affected by the additional drain on them. It seemed that only a limited amount of food could be supplied by the relatively few root connections involved, and no fully communal root system existed.

Adverse effects of grafting could include transmission of disease; e.g., infection by *Fomes annosus* (Fr.) Karst. can be spread in this manner, though not exclusively (Gross 1970). Non-target trees can be killed by silvicides passed through root grafts from stem-treated individuals of the stand, as experienced by white pine treated with ammate (Bormann and Graham 1960) and red pine treated with sodium arsenite (Cook and Welch 1957).

Summary of management implications: Root systems may be modified by soil conditions, and poor drainage is inimical to red pine roots. The wide and irregular dispersal of roots makes it impossible to judge the origin of root competition with respect to a given tree, or to give that tree full underground release simply by removing its immediate neighbors. Local application to the soil of fertilizer or silvicide will find multiple targets, diluting the effectiveness for the tree it is supposed to treat. Root grafting may further confound results. Stem-applied silvicides can kill other trees, not directly treated, via root grafts. Disease can be spread by grafts, and infection rate may accelerate after a thinning which itself leads to increased grafting.

GROWTH AND YIELD

Age

Maximum age for white pine probably exceeds 450 years (Harlow and Harrar 1941). The greatest age recorded for red pine was 307 years (Rudolf 1957), and 350 years is probably the potential maximum (Harlow and Harrar 1941).

Anticipated rotation ages are very much lower as they are based largely on product size. Smithers (1954), assuming a minimum crop tree DBH of 30.5 cm, considered 100 years for stands treated to periodic thinning, or 120 years for unmanaged stands, to be rotation ages indicated for medium sites. McCormack (1956), using a dominant height of 15.2 m for starting high-grade pole production, concluded that minimum rotations in his Site Groups I, II, III, and IV would be 30, 35, 45, and 65 years, respectively; or, taking maximum board foot production as the criterion, rotations of 80, 110, 120, and 130 years would be appropriate for those site groups. On the basis of maximum growth rate in total cubic volume for mixed pine stands in Algonquin Park, rotations of 100 to 110 years were indicated for red pine, and 130 to 150 years for white pine, depending on density of stocking and site quality, according to Ardenne (1950).

Height

Potential: Old growth trees in natural stands attained much greater sizes than will be encountered today.

A specific height of 80.5 m for a white pine in New Hampshire was reported on hearsay near the beginning of the last century (Dwight 1821). Nearly 100 years later Sargent (1905) described heights of mature white pine as occasionally reaching 76 m. Harlow and Harrar (1941) gave 67 m as the maximum height for white pine, and according to Hosie (1969) 53 m might be attained on favorable soils. These reductions with time reflect the removal of old growth stands and the shorter rotations now practised for second growth. A Canadian Forestry Service crew measured a white pine 51.8 m tall on the Mississagi River in 1947[4]. A tree 45.1 m tall in Macaulay Township, Muskoka was recently said to be the tallest tree in Ontario (Beagan 1975), and a 48.2 m tree was reported from Ontonagon County, Michigan (Pardo 1973). Not many white pine taller than 46 m can be in existence, although heights of 30.5 m are commonly encountered.

For red pine, Sargent (1905) gave 46 m as a height occasionally attained; Harlow and Harrar (1941) considered 37 m the maximum; and Hosie (1969) reported 38 m as possible under favorable conditions. Exceptional heights recently recorded for red pine include 35.4 m for a tree measured in 1975 near Watersmeet, Michigan (Pardo 1976), and 32.9 m for a tree measured in 1972 on a sample plot at the Petawawa Forest Experiment Station (Butwick 1975). Heights of 24.5 m are not unusual for mature red pine.

Growth rates: It is apparent that white pine has much the greater potential for height growth, although this takes some time to manifest itself. McCormack (1956) found that in natural stands, pure or mixtures of the two species, red pine grows faster at first but is overtaken at a breast-height age of about 40 years on better sites, 85 years on the poorest. Ardenne (1950) concluded that white pine overtakes red pine at between 60 and 70 years. In mixed plantations of the two species, this seldom occurs. The white pine characteristically lags behind and is suppressed by the red pine, an effect intensified where the white pine loses height growth through attacks by the white pine weevil; in these situations, failure of most of the white pine in the plantation may occur.

Overhead cover will restrict height growth, particularly of red pine which will usually be shaded out unless released. The more tolerant white pine may eventually come through and if released is capable of overtaking free-growing members of the stand (McCormack 1956). Where there is no overstory, stand density has little if any effect on height growth. Nor was thinning in natural stands found to affect

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[4] Can. For. Serv., For. Manage. Inst., Ottawa (unpubl. data).

height growth of either species, in any crown class (Smithers 1954).

Early growth may be slow, particularly if there is much ground cover, and McCormack (1956) used an average value of 10 years to reach breast height. Early plantation growth is more rapid, and red pine usually takes 4 to 6 years to reach breast height in plantations at Petawawa; for red pine planted in New York State, 2- or 3-year-old seedlings took an average of 7 years (Richards et al. 1962). Height variability within a red pine plantation is greater at earlier ages; e.g., at Petawawa the coefficient of variation fell from 30% when average stand height was 1.5 m to less than 8% when average height was 12.2 m (Stiell 1955).

The pattern of height growth by each species in natural stands was shown by McCormack (1956) for four site groups as dominant height over age curves for the breast-height age range of 20 to 220 years. Plonski (1974) presented curves of mean height of dominants and co-dominants over age for three site classes for each species: for white pine over the range 20 to 190 years, and for red pine 20 to 160 years. Anamorphic site index curves of dominant height over age from planting for 15-, 18-, 21-, 24-, and 27-m SI classes at age 50 were constructed for planted red pine at Petawawa by Berry (1977). Other site index curves prepared for red pine plantations in specific areas or on specific sites include polymorphic curves for New York State (Richards et al. 1962) and for Quebec (Truong dinh Phu 1974, Bolghari 1976), and anamorphic curves for Wisconsin (Wilde et al. 1965).

The frequent occurrence of weevil damage seems to have prevented the establishment of height/age relationships for white pine plantations.

Diameter

Maximum DBH of about 183 cm for white pine and 152 cm for red pine have been proffered (Sargent 1905, Harlow and Harrar 1941), but again these are values for old growth trees accompanying the exceptional heights cited above. Today, DBH for mature white pine is commonly up to 91 cm, and 31 to 61 cm for red pine (Hosie 1969).

On a given site, diameter growth is directly controlled by crown size, and therefore indirectly by stand density. The relation of greater DBH to wider spacing is clearly shown in red pine plantation trials, e.g., Stiell and Berry (1977). Similarly, diameter growth shows a positive response to thinning as seen in natural stands (Smithers 1954) and plantations (von Althen and Stiell 1965, Stiell 1968).

In red pine plantations, the range in diameters may be as little as 10 cm where mean DBH is 5 cm or as much as 25 cm where the mean is 30 cm (Stiell and Berry 1973). Coefficients of variation of from 31% where mean DBH was 10.7 cm to 19% where the mean was 17.3 cm were reported by Love and Williams (1968); and of 20% and 21% where mean DBH was 12.4 cm and 15.5 cm, respectively, by Richards et al. (1962).

Form Class

Form class (FC) is the ratio of diameter at half height above breast height to DBH expressed as a percentage, and is a means of describing the shape of the stem for volume determination. FC is a reflection of the development and location of the crown, stems with full crowns tending toward the conical, stems with short crowns tending toward the cylindrical. FC is therefore lower in more open stands.

When closure occurs, there is a tendency to rapid increase in FC, then little change for long periods unless the stand is disturbed. In a 10-year-old red pine spacing trial, FC varied from only 53.2 to 56.7, but by age 20 years FC of the plantation at the closest spacing, 1.2 x 1.2 m, had risen to 67.9 while at the widest spacing, 4.3 x 4.3 m, FC was 53.6 (Stiell and Berry 1977). In an older study, a heavily thinned red pine plot at first lagged behind the control plot in FC increase, but later increased more rapidly and 30 years after treatment was only 4% lower in FC (Berry 1971). In red pine plantations representing a wide range of stocking, Richards et al. (1962) found average FC to vary from ca 57 to 77, and to be closely correlated with height and stem numbers.

The variation of FC with age, DBH and height in white pine aged 25 to 200 years is shown by Bedell (1948) to range from 45 to 79. Much variation is found within stands. The compilers of form-class volume tables (Anon. 1948) gave values for white pine under 120 years in natural stands in FC 65, 70 and 75, and those over 120 years in FC 65 and 70; values presented for red pine under and over 120 years were in FC 70 and 75.

Volume

<u>Tree</u>: Stem volume varies inversely with stand density, i.e., the volume of the average tree increases with wider plantation spacing (Stiell and Berry 1977).

Tables based on height, DBH and form class (Anon. 1948) show total and merchantable volumes for red pine and white pine in two age groups: under and over 120 years. Standard volume tables, based on regressions using height and DBH, and excluding form as an independent variable, were produced by Honer (1967), and present total volumes by species, and a variety of conversion factors for different utilization standards.

Total and merchantable volume tables and taper curves for red pine plantations were prepared by Stiell and von Althen (1964).

Stand: Of these two pines, red pine makes the fastest volume growth per unit area in early years on good sites, and in fact is the highest yielding species in Ontarip up to about age 70 when white pine overtakes it (Plonski 1974). Thereafter red pine may attain about 470 merchantable m^3/ha by 160 years when growth is almost at a standstill, whereas white pine continues to increase in volume until ca 190 years when the yield may be 594 m^3/ha. On these sites, mean annual increment of gross total volume culminates at 40 years for red pine, at 55 years for white pine. On poor sites, however, yields for red pine exceed those for white pine at all ages.

Various yield tables for natural stands have been prepared for white pine and red pine. Those cited above (Plonski 1974) are normal yield tables for total and merchantable volumes for three site classes for each species, with an age range of 20 to 190 years for white pine, 20 to 160 years for red pine. McCormack (1956) presented yield tables by four physiographic site groups, applicable to both species or mixtures of the two, and representing stands of "average density", for ages 20 to 200 years; also included are unit volumes per unit of basal area, allowing calculation of volume from stand basal area and height. Smithers (1954) prepared yield tables by five site index classes for the two species combined, both for "fully stocked" stands aged 10 to 100 years and for stands under a regular thinning regime for ages 30 to 100 years.

Their more rapid early growth, and more uniform age, composition and spacing justify separate yield tables for plantations. Berry (1977) prepared tables of total and merchantable volume for unthinned red pine plantations at Petawawa, based on five site index classes--dominant heights of 17 to 24 m at age 50 years, and eight planted spacings--1.25 x 1.25 m to 4.00 x 4.00 m, for ages 20 to 50 years from planting. These tables clearly show the influence of stand density: the closer the spacing, the higher the stand volume at all ages. Plonski's (1974) yield table is for planted and moderately thinned red pine on one site class, and shows total and merchantable volumes for ages 5 to 65 years. Love and Williams (1968) prepared yield tables of total volume by three potential production classes for thinned red pine in southern Ontario, aged 20 to 70 years. Bolghari (1976) derived regression equations for predicting yields of red pine planted in Quebec at spacings of up to 3 x 3 m.

DAMAGE

Both pines are subject to damage from numerous biological and climatic agents, but no extensive discussion of them is attempted here. The following are brief descriptions of the most common causes of severe damage. The main reference sources used are Anon. (various dates), Davidson and Prentice (1967), Gross (1970), Hiratsuka and Powell (1976), Horton and Bedell (1960), Peterson and Smith (1975), Rose and Lindquist (1973) and Rudolf (1950).

Insects

The white pine weevil (*Pissodes strobi* Peck) is the most serious insect pest of white pine. Larval feeding kills the leading shoot, resulting in crooked or multiple stems and associated losses in lumber volume and value. Attacks are most damaging in young trees where the valuable first log length is affected. Plantations established in the open are severely damaged, but seedlings grown in partial shade are less subject to attack (Berry and Stiell 1976). Red pine is occasionally attacked. Other, comparatively minor, weevil pests are the northern pine weevil (*P. approximatus* Hopk.) and pales weevil (*Hylobius pales* Hbst.), populations of which may build up in fresh slash and stumps and damage or kill pine regeneration in the vicinity by adult feeding on young bark; and the pine root collar weevil (*H. radicis* Buch.) which sometimes kills red pine planted on dry, sandy soils, by larval stem girdling at the root collar; incidence of this pest appears to be increasing.

The European pine shoot moth (*Rhyacionia buoliana* Schiff.) is now found throughout southern and eastern Ontario and in scattered localities elsewhere in eastern Canada. It causes serious injury to red pine plantations by larval mining of the current needles and terminal buds and shoots over two growing seasons, resulting in severe stem deformities. The eastern pine shoot borer (*Eucosma gloriola* Heinr.) occurs in Canada throughout the range of white pine except in the Atlantic provinces. It is often abundant in understocked white pine plantations. The larvae bore into the pith of the leading shoot which wilts and breaks off, and a lateral assumes dominance, causing a crook in the stem.

The larvae of sawflies feed on foliage, and heavy infestations may be fatal, especially to young pine. The redheaded pine sawfly (*Neodiprion lecontei* Fitch) is the most serious pest of red pine plantations in southern and central Ontario and south-central Quebec. Feeding is on the previous year's needles, and trees up to 13 to 15 cm DBH are the most heavily defoliated; complete defoliation kills smaller trees, and lesser attacks kill individual branches and reduce diameter growth. The European pine sawfly (*N. sertifer* Geoff.) and red pine sawfly (*N. nanulus nanulus* Schedl) cause sporadic damage to red pine.

The white pine sawfly (*N. pinetum* Nort.) and introduced sawfly (*Diprion similis* Htg.) occasionally attack white pine.

Spittlebugs, so called from the frothy liquid secreted about themselves in the immature stages, feed on pines by puncturing the bark and sucking the sap; twig, branch or even tree mortality occurs the year following heavy infestations. The pine spittlebug (*Aphrophora parallela* Say) is often abundant on white pine, the immature and adult forms both feeding on the tree's sap. The Saratoga spittlebug (*A. saratogensis* Fitch) adults feed on red pine, the young only on ground cover, especially sweet-fern and *Rubus* spp.

Bark beetles normally feed on slash and dead and dying trees, including both red and white pine. After cutting operations or fire, populations may build up and attack healthy trees in the vicinity. The pine engraver (*Ips pini* Say) sometimes attacks red pine plantations in these situations, as well as those suffering from drought, the adults and larvae tunnelling in the inner bark and surface of the sapwood. Young trees are easily killed, and the sapwood badly stained. Ambrosia beetles attack mainly dead and dying trees and bore into the wood, causing degrade from wormholes as well as from staining.

Various cone and flower insects threaten seed crops, and red pine seems particularly vulnerable. Examination of cones in the second year of their development will indicate the extent of damage and whether cone collection will be worthwhile. The red pine cone beetle (*Conophthorus resinosae* Hopk.) is the most destructive pest of red pine cones, the larvae feeding inside the cones in the second year; injured cones wither and shrivel. Similar damage to white pine cones is caused by the white pine cone beetle (*C. coniperda* Schw.). Larvae of the rusty pine cone moth (*Dioryctria disclusa* Heinr.) feed on the male flowers of red pine and excavate the second-year cones which then seldom produce sound seeds.

White grubs, the larvae of June beetles (genus *Phyllophaga* is the most important), feed on the roots of seedlings in nurseries and young plantations, causing extensive mortality and loss of growth; taprooted species are most vulnerable; most damage is caused by second-year larvae, and light soils with a sod cover such as old fields are the most susceptible sites; heavy infestations are cyclical (Sutton and Stone 1974).

Diseases

Pine seedlings are susceptible to a number of fungi. Damping-off (the fungi are commonly of genera *Rhizoctonia, Fusarium, Pythium* and *Phytophthora*) causes wilting and death, and most often occurs in forest nurseries. Soil and atmospheric conditions may be critical for infection, e.g., high pH, excessively wet soils, and high air humidity and temperatures (27° to 35°C) are said to favor incidence. A needle-cast fungus (*Lophodermium pinastri* [Schrad. ex Fr.] Chev.) attacks both species, red pine most severely, especially seedlings and low-vigor plantations exposed to wind. Snow blight, which is due to a number of fungi (snow molds), may be severe on both species in nurseries, injury appearing first under the snow in spring as a covering of white mycelium on the browning foliage, and spreading to other seedlings the next winter.

White pine blister rust (*Cronartium ribicola* J.C. Fisch.) infects the needles of white pine, the fungus spreading to the twig, branch and finally the stem which it eventually girdles. Seedlings and saplings are killed rapidly, larger trees more slowly. The disease is transmitted to the pine by spores from infected gooseberry and currant bushes which are the alternate hosts necessary for completion of the pathogen's life cycle. Symptoms are dead branches, cankers, and chlorotic foliage. This introduced disease, now distributed throughout the range of white pine, has caused heavy losses, especially to regeneration, wherever gooseberries and currants occur, e.g., particularly in hardwood stands. Canopy closure in plantations eventually suppresses the gooseberries and currants and infection rates decrease with stand age.

Red pine is infected by a similar pathogen, sweet-fern blister rust (*C. comptoniae* Arth.), which completes its life cycle on either sweet-fern or sweet gale (*Myrica gale* L.). The damage is like that caused by white pine blister rust, but the disease is not so destructive and trees past the seedling stage often survive. Swollen lower stems may degrade log quality.

Red pine is highly susceptible to Scleroderris canker (*Gremmeniella abietina* [Lagerb.] Morelet), probably an introduced fungus now present in eastern Canada across northwest and central Ontario, in many areas of Quebec, and in the Maritimes. The disease is lethal to seedlings and small trees, but those taller than 2.5 m are usually safe from fatal attacks. Infection occurs in the current year's branches and needles, spreads to the stem cambium, and develops a canker. Symptoms include dead leaders and lateral branches of small trees, or lower branches of trees over 1 m tall, the cankers, and yellowish-green discoloration of dead stem cambium. Infected nursery stock has dead buds with yellow-orange needles immediately below them, and a grey-green cast to the rest of the foliage. Low-lying frost-prone sites may favor the pathogen, growth of which is not inhibited by near-freezing temperatures. Plantations established with infected nursery stock will fail, and the disease is now established on many planting sites in older, surviving red pine and jack pine (Dorworth 1970a,b, Dorworth and Buchan 1972).

A non-parasitic disease, semimature-tissue needle blight, afflicts white pine of all ages throughout its range. It is characterized by orange-red bands which spread to tips of current-year needles, and sometimes by small needles and twigs, premature defoliation, and reduced height, diameter and root growth. Trees may die after being affected for several years. The cause is believed to be the occurrence of particular weather patterns rather than a toxic substance; atmospheric ozone does not appear to be a factor (Linzon 1965, 1967). Fume injury, from toxic gases released by industrial plants, notably sulphur dioxide in concentrations greater than 0.4 ppm, occurs to pine needles and repeated defoliation is lethal. White pine are more susceptible than red pine and have been killed at considerable distances from the source. Salt spray injury occurs along highways as a result of salt spread in winter, and up to 30 km from the seacoast as a result of onshore gales, usually causing partial defoliation and some mortality. White pine is particularly vulnerable.

Armillaria root rot (*Armillaria mellea* [Vahl ex. Fr.] Kumm.) is ubiquitous, and often kills young conifers, singly or in groups, and commonly in plantations. Invasion of tree roots is by the fungus rhizomorphs which grow freely through the soil and can penetrate unwounded bark. Reduced terminal and diameter growth, chlorotic foliage or thin crowns and dieback are characteristic of infected trees; mycelial fans occur between the bark and wood, and honey-colored fruiting bodies occur at the base of dead or dying trees in the fall. The fungus can invade dead or moribund root systems as well as apparently healthy ones, and can survive in dead wood. Hardwood stumps are therefore common sources of infection on planting sites.

Fomes root rot (*Fomes annosus* [Fr.] Karst.) affects both pines, but extensive killing is confined mostly to younger stands, particularly plantations of red pine. The fungus usually becomes established through infection of freshly cut stump surfaces, or wounds, and spreads to adjacent root systems through root grafts and contacts. In older trees, heart rot develops. Infected trees may have chlorotic and sometimes dwarfed foliage, and stem growth may be reduced, but aboveground symptoms are not always apparent despite severely rotted roots. Fruiting bodies may be found beneath the duff on the base of infected trees. Trees die in groups, and the disease increases (and often is first recognized) after the first thinning in a plantation.

A trunk-rotting fungus, *F. pini* (Fr.) Karst., invades the heartwood, gaining entry through branch stubs or wounds that penetrate the sapwood. It results in pockets of white fibres surrounded by firmer, reddish wood. This pathogen causes most of the decay losses in white pine. It occurs sporadically in red pine.

Animals

Damage by mammals tends to be localized, and erratic, and to fluctuate with population cycles.

White pine regeneration, once above the snow line, may be heavily browsed in winter in yarding areas by white-tailed deer

(*Odocoileus virginianus* Zimm.); red pine is not a preferred deer forage. Porcupines (*Erethizon dorsatum* L.) feed on pine bark in winter, usually girdling the tree. The tree then dies, or at best the top dies and a severe crook develops where a lateral becomes the new leader. Red pine plantations may have many trees girdled at almost identical heights. Snowshoe hares (*Lepus americanus* Erxleb.) and cottontail rabbits (*Sylvilagus transitionalis* Bangs) girdle young pines above the snow line, and clip off seedling tops. Red squirrels (*Tamiasciurus hudsonicus* Erxleb.) seriously deplete the red pine cone crop, and in removing the cones damage the bark and cause some branch-end mortality. However, caches of cones can be robbed by human cone collectors. Mice and voles (*Microtus* spp.) are responsible for killing young pines by feeding on the bark beneath the snow.

Weather

The effects of heat and frost on pine seedlings were discussed earlier. Once trees are past the seedling stage, damage from climatic causes is infrequent, although it can be severe and can seldom be avoided. Drought can kill plantation trees up to at least 3 m tall, and probably is more of a risk on the drier sites. Sunscald can damage the thin bark of young white pine, which would be more subject to injury after a release or heavy thinning. Ice storms and sleet sometimes cause top breakage and permanent bending of trees in dense plantations; thinning seems to reduce susceptibility, although the newly thinned stand will still by vulnerable. White and red pine exhibit natural deep-rooting on unstratified soils, and except for older trees or those with root rot are not particularly subject to windthrow. Browning of foliage caused by winter drying occurs after a mild spell when transpiration-depleted needle moisture cannot be replaced by the dormant roots in still frozen ground; partial defoliation may occur over large areas, and recently planted seedlings may succumb.

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DISCUSSION

Question: What is the significance for Ontario of the virulent New York strain of Scleroderris?

Answer: C. Dorworth was asked to answer this question. He stated that so far this strain of Scleroderris had not been reported in Canada and that it would be difficult to predict how much damage would be caused to forests in Ontario. This would be known only after the disease had been reported and studied in our forests.

SILVICULTURAL REQUIREMENTS OF WHITE AND RED PINE MANAGEMENT

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*With adequate seed, seedbed suitability and competing vegetation determine regeneration success in white pine (*Pinus strobus *L.) and red pine (*P. resinosa *Ait.). Clear-cutting, strip cutting and uniform shelterwood are the only alternative treatments used in the even-aged management of these species on the three basic pine sites in Ontario.*

*Avec des graines de qualité adéquate, les lits de germination convenables et la végétation concurrente déterminent le succès de la régénération de peuplements de Pin blanc (*Pinus strobus *L.) et de Pin rouge (*P. resinosa *Ait.). Les seuls traitements de rechange utilisés dans l'aménagement des peuplements équiennes de ces espèces en trois stations ontariennes consistent en la coupe à blanc, la coupe par bandes et la coupe progressive (uniforme) de régénération.*

INTRODUCTION

The organization of this symposium with the field trip yesterday and this morning's papers giving the keynote address and silvics of the species have made it possible for me to deal directly with the topic of silviculture. For simplicity I will use the term white pine (*Pinus strobus* L.) to denote the white pine working group including red pine (*P. resinosa* Ait.) and other associated species.

The first priority in the management of any species is to secure regeneration at the time of harvest and white pine is no exception. The silvicultural characteristics of the species require that they be managed according to an even-aged system and it is the various even-aged alternatives that I will discuss today. Even-aged management requires that regeneration of acceptable species be established in less than 20 years to produce an even-aged forest. An uneven-aged system of management is not acceptable and hence the selection system should not be used in white and red pine management.

Pilot or demonstration areas using a variety of cutting systems have shown excellent results in various parts of the province over the last 25 years. Clearcutting in strips, in small blocks and with seed trees as well as uniform and strip shelterwood are all represented. Unfortunately, there are numerous examples of the same cutting systems which have not regenerated successfully. This difference between success and failure--if we assume an adequate seed source--can be related very simply to seedbed suitability and competing vegetation.

The successful use of any silvicultural cutting system is dependent upon the recognition of basic site differences and the application of the proper combination of cutting system and cultural treatment to the various site conditions. These basic pine sites can be described on a province-wide basis.

BASIC PINE SITES IN ONTARIO

Deep, Sandy, Outwash Plains

These are the easiest sites to manage and any recognized even-aged silvicultural cutting system will be successful in securing regeneration, in most cases without additional site preparation. The white pine weevil (*Pissodes strobi* Peck.) is an ever present problem and some competition may develop after logging even on these dry sites, especially if there is a long regeneration period because of seed crop periodicity.

On these sites uniform shelterwood, strip shelterwood, clear-cutting in strips or groups with seed trees or large seed tree cuts will be successful. Site preparation in a seed year will improve pine stocking and shorten the establishment period. Site preparation and planting, particularly with improved stock, can be used, but will greatly increase the cost per hectare for regeneration.

Shallow, Sandy Sites on Low, Granitic Ridges

These areas are common over much of the normal range of white and red pine. They are characterized by moderately broken topography, rock outcrops and sufficient range of soil depth and moisture to produce a variety of forest conditions for pine and hardwoods. The most efficient method of silvicultural cutting is by strip or uniform shelterwood.

Strips less than 40 m in width can be used where topography permits them to be laid out at right angles to prevailing autumn winds and still have skidding and logging disturbance confined to the strip. Strips perpendicular to rough and broken topography are not recommended. Scarification will not be required on the drier sites and may actually be detrimental to the site and to advance growth that is present. Moist pockets or brushy areas are difficult and expensive to restock with pine and will regenerate naturally to aspen (*Populus* sp.) and other hardwoods. Hardwood management on these microsites on the strip should be considered.

Regeneration of the last strip may require some cutting to induce regeneration more or less under uniform shelterwood conditions prior to the final harvest cut. This will save planting or seeding after the cut. Winter logging is recommended where regeneration is established prior to the final cut.

Uniform shelterwood is ideal for regeneration and site protection. Logging presents difficulties, in preventing damage to the residual stand and in removing the final cut without damaging the regeneration. The standing trees also inhibit mechanical site preparation.

Glacial Tills

These are the most productive, and the most difficult, sites to manage in the white pine group. The shelterwood and clearcutting systems mentioned previously will be successful on this site only if they are followed by site preparation and later cleaning or release. Clearcutting in strips or groups without seed trees permits better slash disposal and mechanical scarification than do the uniform shelterwood or seed tree systems. Where site protection and aesthetics are not a problem, clearcutting followed by site preparation, planting with nursery stock and subsequent release will give good results. Pockets of deep, rich soils will regenerate to hardwood and should not be managed for pine. Slash disposal and site preparation by burning are suggested wherever site and ecological conditions permit.

I have described soil and site characteristics and the effect on pine regeneration secured by various cutting methods. I would now like to describe the salient features of the most appropriate silvicultural systems.

SILVICULTURAL SYSTEMS

Clearcutting

Clearcutting has been defined as "the removal of the entire growth in one operation, with or without leaving seed trees, from an area wider than 40 m".

Clearcutting without seed trees is a recognized system of even-aged management which can be used in white and red pine management only with great difficulty and cost. It maximizes harvest volume per hectare and minimizes logging costs, but it also maximizes silvicultural costs and environmental damage. It provides an opportunity for efficient mechanical site preparation and herbicide spray release from competing vegetation but provides optimum conditions for the white pine weevil and damage from blister rust (*Cronartium ribicola* J.C. Fisch.).

Logging and silvicultural costs can be quantified and perhaps economic tradeoffs can be worked out but there are no solutions or reliable cost figures for insect, disease or environmental damage.

The high silvicultural costs, environmental damage and susceptibility to insect and disease losses make clearcutting an unsuitable silvicultural system for management of white and red pine.

Clearcutting with seed trees is the lowest level of silvicultural cutting which should be considered and it can be recommended only for those dry, sandy, pine sites or ridges where pine regenerates easily without mechanical site preparation and with little competition from woody shrubs. Experience has shown that on sites suitable for clearcutting with seed trees, 25 good seed-producing trees per hectare are sufficient. Best results are obtained following summer logging in a seed year to provide very light scarification and adequate seed. This practice is suitable where site protection is afforded by scattered woody plants, off-site aspen, birch (*Betula* sp.) or other hardwoods. No harvest or salvage of the seed trees is planned. Seed trees left on these sites may be subject to windthrow and stem breakage on exposed edges or in large areas of disturbance. Seed trees are selected before cutting and marked with a 5 cm blue band around the circumference 2 m or more above ground with a 7.5 cm blue dot on the root at ground level for control. This system has some significant advantages over clearcutting without seed trees:

1. Silvicultural costs are greatly reduced.
2. A pine seed source remains on the area and will provide adequate seed for regeneration.
3. Seed trees remain after regeneration is established and provide good insurance against wildfire.
4. The seed trees, together with pioneer species such as cherry (*Prunus* sp.), aspen, and soft maple (*Acer* sp.) will provide some shade, thereby reducing weevil damage.

Strip Cutting

Two basic strip cutting systems have been used in white pine. Strips wider than 40 m which are considered clearcut strips require the addition of seed trees or seed and additional shade to be effective.

Strips less than 40 m in width are by definition strip shelterwood and can, if properly applied, be a successful method for pine regeneration. Strip shelterwood has probably the greatest potential for pine management of any silvicultural system. The only pine areas not suitable are overmature stands that do not provide a seed source and rugged terrain which precludes skidding the material down the strip without damaging adjacent strips. For best results, areas in the pine working group to be harvested by strip shelterwood should be accessible by all-weather roads and organized into compartments which consider skidding and hauling requirements.

Strips should be perpendicular to the topography and can be broken or zigzag to reduce visual impact and wind damage. Strip width should not be more than the height of the adjacent stand to reduce weevil damage and may be narrower with good results: 15 to 23 m is the recommended width of the first strip. On fresher sites, site preparation is essential to reduce competition and ensure a suitable pine seedbed. Careful cleaning on these sites will ensure release of pine from overtopping vegetation while retaining partial shade to reduce weevil damage. Some microsites will regenerate to dense clumps of aspen, red maple (*Acer rubrum* L.), balsam (*Abies balsamea* [L.] Mill.) and possibly other species. These clumps should be accepted and no attempt made to remove them and put pine on every hectare.

The arrangement of the cut in strips makes mechanical treatments for site preparation and application of herbicide more feasible. Cutting of the second and subsequent strips can be done only after regeneration is secured and some protection from weevils assured. If required, the seed and shade on subsequent strips can be supplemented by leaving seed trees on the strip.

Uniform Shelterwood

Uniform shelterwood is currently being used under a variety of conditions and on a variety of sites for pine regeneration. It has all of the features required for successful white pine regeneration: seed, shade, shelter and favorable visual impression after logging. Uniform shelterwood is a more complex silvicultural system than either seed tree or strip shelterwood cutting and should be used only where trained staff are available, and where logging is done carefully and efficiently.

Marking procedures for true uniform shelterwood require that the trees removed in the preparatory cut represent the full range of species and diameters in the stand and that the amount removed provides the necessary light adjustment to encourage pine seedling establishment and growth. For white pine 40% to 50% shade is the recommended light adjustment and marking and logging must be carried out to provide this; hence, the size and volume of timber removed will vary throughout the stand, reflecting variations in the precut stand. A good market for the species and products to be removed is essential to a successful uniform shelterwood cut. Marking for uniform shelterwood should be done with yellow paint in the customary manner: a 7.5 cm dot on the trunk 2 m or more above ground and a corresponding dot on the stump at ground level for control.

ASSESSMENT OF WHITE AND RED PINE REGENERATION

I have made a comprehensive review of Ministry records to assess silvicultural cutting systems and regeneration projects, including tree planting, to see how successful we have been in regenerating the pine stands. These assessments represent only a small portion of the area cut and include planting on open land and in other working groups. The figures presented should be regarded as examples and are not a statistically sound sample of regeneration for the districts mentioned.

Tree Planting

Sudbury and North Bay have reported thirteen 1970 planting projects assessed in 1975 with white pine stocking ranging from 8% to 60% for an average pine stocking of 37% and an average total conifer stocking of 63%.

Seed Tree Cutting

North Bay has reported 10 areas cut by the seed tree system and assessed in 1973, 1974, 1975, and 1976. These areas have an average white pine stocking of 43% and an average total conifer stocking of 77%.

Strip Cutting

Algonquin Park District has reported on 240 plots taken on strips cut in Barron, Bronson, Fitzgerald and Stratton townships in the mid-1960s and sampled in the fall of 1976. These strips had a weighted average total conifer stocking of 52.1%. No figure is available for pine stocking.

Uniform Shelterwood

Parry Sound District reported on 11 projects in Mowatt and Blair townships cut between 1959 and 1969 and assessed in 1976. These areas have 23% stocking to white pine and 37.5% stocking of all conifer species. All of these areas are being managed intentionally for white pine and in all cases the stocking to white pine is disappointingly low.

These are not good indications of our success in managing for white and red pine.

The preparation of a paper such as this provides an excellent opportunity for self examination and it is becoming increasingly apparent to me that we have a lot more knowledge than we are using at present. Literature from the northern states in the 1920s, 1930s, and 1940s contains most of the principles and suggested systems for white pine management. Canadian and Ontario publications in the 1950s and early 1960s further identify species and site characteristics and describe the same silvicultural cutting systems I have been talking about today. It is painfully apparent that detailed knowledge of the management of white and red pine has been available for years and we are not using this information to the best advantage. I hope that this meeting will help to emphasize pine management and increase the area of treatment while good stands remain.

DISCUSSION

Question: In the last paragraph of your paper you state that "we have a lot more knowledge than we are using". Could you speculate on the reasons we are not using this knowledge?

Answer: I would say that the following reasons, either alone or in combination, account for our failure to use all available knowledge in the management of white and red pine:

1. Limitations of staff and budget which make it impossible to use and implement the available knowledge.

2. Political restraints.

3. Economic restraints. It may not be profitable to do certain operations.

Question: What assurance have we that we will obtain better results in the future than we have in the past?

Answer: More emphasis is being placed on applying the right system on the right site than was done before. Consequently, the results will be better than they were in the past where silvicultural systems were applied without too much thought to site conditions, etc.

Question: Have we overemphasized the use of artificial regeneration?

Answer: I would say that we have not overemphasized it, but we are stressing that artificial regeneration is necessary where nature has not been successful in restocking an area to desired species.

WHITE AND RED PINE MANAGEMENT PRACTICES: LOGGING

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Portage du Fort, Quebec

Logging operates within a framework of economic, political and biological constraints: the mills require year-round supplies and profitable products, various Acts and regulations with respect to labor and resources govern the operations, and the species under discussion have to be considered in relation to other species in the stand.

L'exploitation s'effectue dans un cadre de contraintes économiques, politiques et biologiques: les usines exigent des approvisionnements, durant toute l'année, des produits peu coûteux. Plusieurs lois et règlements régissent les opérations quant à la main-d'oeuvre et aux ressources, enfin, les essences concernées doivent être considérées par rapport aux autres essences du peuplement.

My task is to present the management of white pine (*Pinus strobus* L.) and red pine (*P. resinosa* Ait.) from the logger's point of view. Constraints on the cutting of white and red pine on Consolidated-Bathurst's limits are applied both by the company and by the provincial ministries. Furthermore, the two species cannot be considered in isolation when we are formulating our plans for cutting.

Our timber limits and volume cutting agreement areas are situated in the Ottawa Valley in the Great Lakes-St. Lawrence Forest Region. In these mixedwood conditions we encounter about 23 species, including white and red pine. We deal with two provinces, each with its own laws pertaining to Crown timber, health and safety, workmen's compensation, vehicle licensing, language, etc.

To survive and prosper under such constraints, we must be flexible and ready to accept change and confusion as part of our working conditions. As an illustration, we must be aware of three sets of regulations applying in certain cases: one for Ontario, one for Quebec, and one for the federal government, because the Ottawa River is under federal jurisdiction. This would be true regarding union matters and the Industrial Relations Act or its equivalent. (There are considerably more constraints, but I think I have made my point.) These are important considerations when there is a choice of where to cut.

Fulfillment of the requirements of mills and other customers is dictated wholly or in part by *choice, economics,* or *decree*. In these fully integrated cuts, species and products not required by the company mills (e.g., hardwood sawlogs) will be produced. This is an example of *choice* dictating the fulfillment of customer requirements in that the company has no hardwood sawlog mills of its own, sells the sawlogs at cost, or thereabouts, and may make a profit on the veneer. A good example of *economics* in operation is the poplar splintwood sold to Eddy Match Company. The return from splintwood is slightly higher than that from pulpwood. Although the difference is not great, it may be that, if we sell splint to Eddy for little better than pulpwood prices, Eddy will give us a good deal on white or red pine sawlogs from their operations. It is a matter of mutual aid to meet volume requirements.

At times the company is compelled by the provincial ministries to turn red pine or jack pine (*Pinus banksiana* Lamb.) into poles. In other words, requirements for this material, which could well be made into sawlogs with the tops going into pulp, have been set by *decree*. We could use the material but are forced to make some other product from it.

Tables 1, 2 and 3 show the original volumes required for 1976-1977. As a result of a multimillion dollar fire at the Braeside sawmill, the requirement is almost nil this year for red pine, white pine and spruce sawlogs.

Once we have the requirements for our mills, our planning continues with a meeting of the Division Manager, Operations Manager, Manager of Division Services, District Superintendents (three), Foresters (one in Quebec and one in Ontario), and the Wood Procurement Supervisor. When total requirements, less the inventories, have been determined, the apportioning of volumes to the various segments begins. The Wood Procurement Supervisor may claim to be locked into taking X number of cunits of chips from our company sawmill. This amount is then deducted from the total. Next, other volumes are pegged. The Wood Procurement Supervisor again may say that, in order to meet an objective for other pulpwood species, he must be allowed to purchase a set quantity of softwood sawlogs. This too is deducted. Then a distribution is made among the various limits with such factors as allowable annual cut and price being kept in mind (Table 4). However, from time to time certain volumes must be cut in areas in which a liquidation cut is being carried out. Other areas may be cut for political reasons (e.g., to avoid loss of limits).

Table 1. CONSOLIDATED-BATHURST LIMITED

Ottawa Division

1976 Wood Program

Product softwood sawlogs

Wood requirements	(in '000 cunits or '000,000 fbm)				
Consumption - January 1-December 31, 1976				51.0	
- January 1-May 31, 1977			22.0		
(Less wood deliveries, planned for same period)			(5.0)		
			17.0		
Add: safety margins required on block piles - May 31, 1977				nil	
Required on block piles - December 31, 1976				17.0	
Total mill requirements - calendar year - 1976					68.0
Less: opening inventory - January 1, 1976					(15.1)
Required deliveries - calendar year - 1976					52.9
To come from:					
1. streams - fall of 1975					41.2
2. unhauled from previous season					
3. limit production 1975/1976 cut	29.7				
Less: deliveries to streams 1975	(26.6)				
Add : 1976/1977 predeliveries direct to mills	4.2				
to water	21.0				
		252			
Total:			28.3		
Less : expected streams inventory 1976			(36.3)		
Net limit deliveries					(8.0)
4. purchases - roundwood - 1976					20.5
5. purchases - chips					nil
6. less: 2% shrinkage on (39.5) (1)					(.8)
Total expected deliveries - year 1976					52.9

Prepared by: A. Vietinghoff

Date: October 1/76

NOTE: Direct deliveries to mill
from purchases - 5.1
from limits - 4.2
Total - 9.3

Table 2. CONSOLIDATED-BATHURST LIMITED

Ottawa Division

1976 Wood Program

Product hardwood pulpwood

Wood requirements (in '000 cunits or '000,000 fbm)

	Birch	Maple	Poplar	Total
Consumption - January 1-December 31, 1976	35.4	43.8	43.5	122.7
- January 1-May 31, 1977	16.0	25.5	26.8	68.3
(Less wood deliveries, planned for same period)(1)	(10.4)	(18.4)	(13.2)	(42.0)
Add: safety margins required on block piles - May 31, 1977	12.0	14.0	14.0	40.0
Required on block piles - December 31, 1976	17.6	21.1	27.6	66.3
Total mill requirements - calendar year - 1976	53.0	64.9	71.1	189.0
Less: opening inventory - January 1, 1976	35.6	31.7	26.6	93.9
Required deliveries - calendar year - 1976	17.4	33.2	44.5	95.1
To come from:				
1. streams - fall of 1975	--	--	--	--
2. unhauled from previous season	.9	2.7	.4	4.0
3. limit production 1975/1976 cut	6.0	10.8	9.2	26.0
Less: deliveries in 1975	(2.2)	(3.8)	(4.5)	(10.5)
Add : 1975/1977 predeliveries	3.8	7.0	4.7	15.5
direct to mills	2.4	3.0	2.4	7.8
Less: estim. bush inventory, Dec. 31/76	(2.0)	(4.2)	(2.0)	(8.2)
	4.2	5.8	5.1	15.1
4. purchases - roundwood	5.3	8.7	32.0	46.0
5. purchases - chips	7.0	16.0	7.0	30.0
6. less: __ shrinkage on ( )	--	--	--	--
Total expected deliveries - year 1976	17.4	33.2	44.5	95.1

Prepared by: A. Vietinghoff

Date: October 1/76

(1) Wood Deliveries, Jan. 1/77 - May 31/77

	Birch	Maple	Poplar	Total
chips	3.0	6.0	4.0	13.0
purchased roundwood	4.4	7.0	6.3	17.7
limit roundwood	3.0	5.4	2.9	11.3 - Total hardwood left in bush as of Dec. 31/76
Total	10.4	18.4	13.2	42.0

Table 3. CONSOLIDATED-BATHURST LIMITED

Ottawa Division

1976 Wood Program

Product softwood pulpwood

(in '000 cunits or '000,000 fbm)

Wood requirements				
Consumption - January 1-December 31, 1976			103.2	
- January 1-May 31, 1977	51.4			
(Less wood deliveries, planned for same period)(1)	46.3			
		5.1		
Add: safety margins required on block piles - May 31, 1977(2)		34.1		
Required on block piles - December 31, 1976			39.2	
Total mill requirements - calendar year - 1976				142.4
Less: opening inventory - January 1 - 1976				(57.0)
Required deliveries - calendar year - 1976				85.4
To come from:				
1. streams - fall of 1975				11.1
2. unhauled from previous season				.3
3. limit production				
1975/1976 cut	8.6			
Less: deliveries to streams 1975	(6.8)			
Add : 1976/77 predeliveries		1.8		
direct to mills	10.0			
to water	4.1			
	14.1			
Total:			15.9	
Less : expected streams inventory 1976			(19.6)	
Net limit deliveries				(3.7)
4. purchases - roundwood - 1976				34.9
5. purchases - chips - 1976				42.9
6. less: 2% shrinkage on (6.8)				(.1)
Total expected deliveries - year 1976				85.4

Prepared by: A. Vietinghoff

Date: October 1/76

1) Deliveries Jan. 1/77 - May 31/77

River haul-up May 77	20.0
Chip deliveries	26.3
Total	46.3

(2)

Safety margin required April 30/77	12.0
Add: chip deliveries in May 1977	5.7
Add: river haul-up in May 1977	20.0
Less: consumption May 1977	(3.6)
Safety margin: May 31/77	34.1

Table 4.

OTTAWA DIVISION
1976/77 LIMIT CUTTING PLAN
AND 1976 PURCHASES

Source	Softwood pulpwood ('000 cunits)	Hardwood Pulpwood birch	maple ('000 cunits)	poplar	total ('000 cunits)	Softwood Sawlogs ('000,000 fbm)	Softwood Sawlogs ('000 cunits)	Re-sale ('000,000 fbm)	Re-sale ('000 cunits)	Total ('000 cunits)
Limitwood										
Schyan	3.6	.7	3.2	.1	4.0	3.0	5.5	.2	.4	13.5
Coulonge	5.0	.4	1.0	.1	1.5	3.0	5.4	.6(1)	1.2	13.1
Madawaska	-	-	-	-	-	-	-	-	-	-
Algonquin Park	4.3	1.5	.6	3.2	5.3	4.2	8.2	.5	1.0	18.8
Maganicippi	.7	-	-	-	-	4.0	7.7	-	-	8.4
Upper Ottawa	-	-	-	-	-	2.5	4.4	-	-	4.4
Temagami	1.6	-	-	-	-	9.0	15.7	.1	.2	17.5
Mattawa	-	-	-	-	-	-	-	-	-	-
Total limits:	15.2	2.6	4.8	3.4	10.8	25.7	46.9	1.4	2.8	75.7
Purchases										
roundwood	27.0(2)	5.3	8.7	32.0	46.0	18.0	31.9	-	-	104.9
chips	60.0	7.0	16.0	7.0	30.0	-	-	-	-	90.0
Total purchases:	87.0	12.3	24.7	39.0	76.0	18.0	31.9	-	-	194.9
Grand total:	102.2	14.9	29.5	42.4	86.8	43.7	78.8	1.4	2.8	270.6
Purchases: Jan. 1/77 - May 31/77										
roundwood	3.0	2.3	4.1	15.0	21.4	immaterial		-	-	24.4
chips	17.7	3.0	6.0	4.0	13.0	-	-	-	-	30.7

Notes: (1) re-sale wood Coulonge: poles: .5 M.fbm = 1.0 cunits
sawlogs: .1 " = .2 "
Total: .6 M.fbm = 1.2 cunits

(2) additional 10.0 cunits of softwood pulp will come from A.F.A.

It often happens that there is no demand for softwood sawlogs from a particular area because they may be obtained more cheaply elsewhere, but the company is forced to take them to get a proper species balance in the pulpwood requirements of the pulpmill. For example, the company may take softwood logs from a high cost area because it requires the birch pulp material that may be harvested in an integrated operation in that cutting district.

One must bear in mind the diameter range that is dealt with in the Ottawa Valley. For example, the logs from Algonquin Park are small (55-60 fbm each) and those from the company's Temagami and Coulonge limits are large (about 140 fbm each). A balance must be maintained so that the mill can give each area approximately the same "run" of logs each year, that is, an average of about 90-100 fbm.

Another big item is to keep a balance of log grades. A good percentage of long lengths is required (i.e., 4.88 m) and a good percentage of high-quality logs yielding considerable No. 1 lumber; otherwise there will be no profit, which, of course, is the name of the game.

Once the planning is completed, the actual cutting, hauling and driving operations are fairly straightforward. It is then a matter of maintaining a continuous flow of the right amounts of products in the right direction. It sometimes happens that, to maintain this flow without interruption, some softwood sawlogs are trucked directly to the sawmill. Normally they would be river driven to the mill. The lumber mill needs enough material before freezeup to enable it to debark and land-store approximately 20 million fbm of debarked logs to carry it through the winter months when the river is frozen. Just to complicate things, some wood cut this season is not delivered until next season.

Since Ross Silversides will be talking about logging equipment later today, I will restrict myself to giving the following background information. We use four Tanguay slasher sorters, each of which can handle about 35 thousand cunits per season. These slasher sorters are fed tree lengths, from which the 152.4 cm diameter circular saw cuts the appropriate product and sorts the pulp from sawlogs. The real advantage here is that one man (a specialist) is making the decision about which is log and which is pulp material. Formerly this decision was made by the 10 or 15 cutters of the two-man cutting and skidding gangs that it takes to feed wood to the slasher sorter site.

We take advantage of long distance skidding by using large skidders to skid 1.8-2.4 thousand m to the yard. In theory, yards are spaced 3.6-4.8 thousand m apart and are usually 120 m x 180 m in size. A typical yard layout is shown in Figure 1.

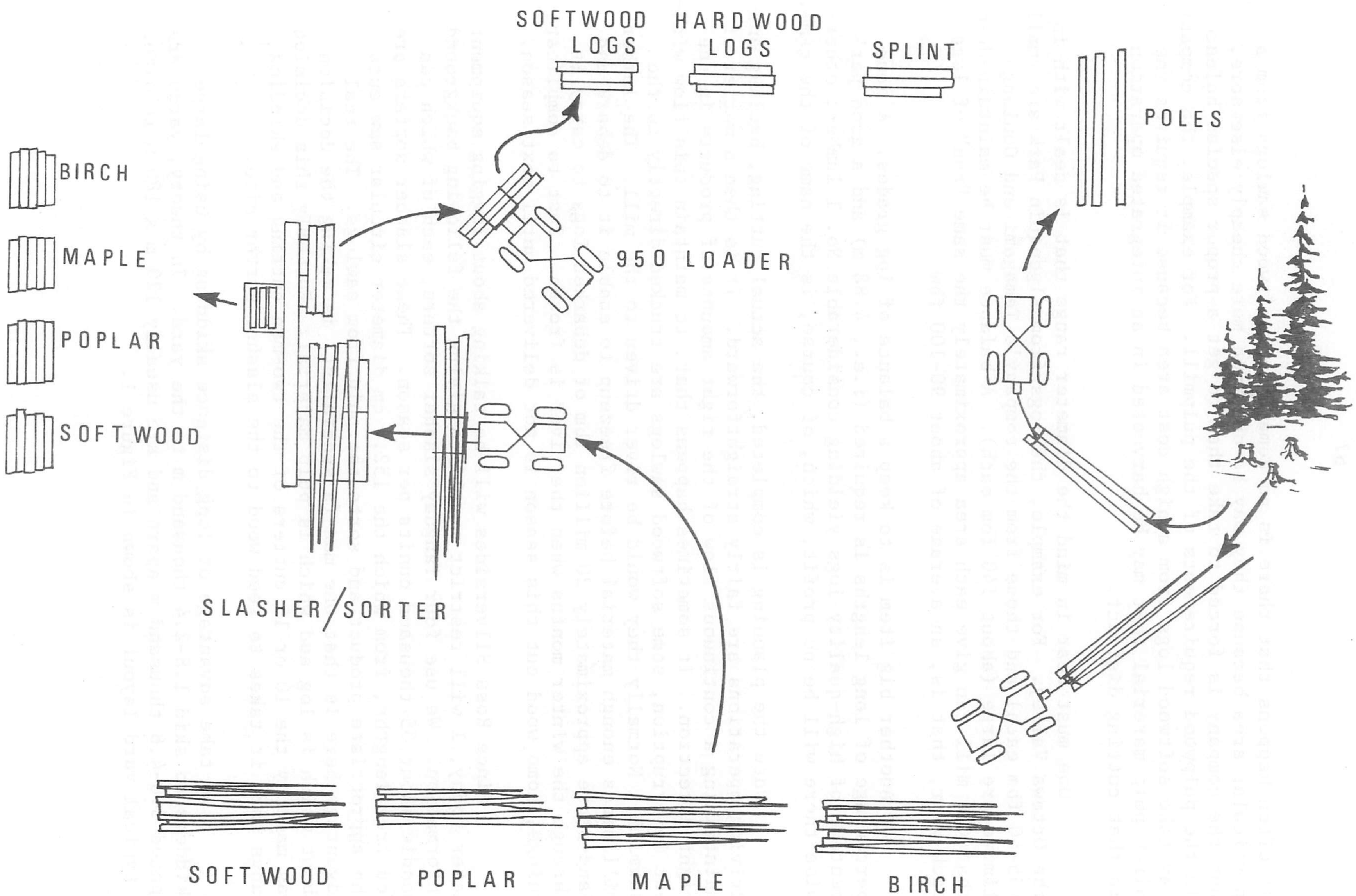

Figure 1. Layout slasher/sorter system

Not much equipment of the tree snipper-harvester-forwarder type has been designed for this mixedwood forest, partly because hardwoods are difficult to debranch and the wide variety of species and diameters is hard to match to any of the equipment designed so far.

SUMMARY

Basically, we submit to all ecological restraints as decreed by law, and to our own silvicultural restraints. Our mills and others must be supplied with particular species and products at particular times, and must maintain a predetermined inventory balance with a forecasted cost. Other wood users deliver specified volumes to us on contract at specified times and at negotiated prices. We, too, deliver specified volumes, at specified times at negotiated prices to other wood users. All of this is accomplished within the limits imposed on industry by many different government agencies. Logging restrictions mean additional costs, such as those incurred in obtaining material from Algonquin Park.

DISCUSSION

Question: Are there any plans by Consolidated-Bathurst Ltd. or other companies to change the approach to logging in the shelterwood system from that of clearcutting or strip cutting systems, or will that come about only by decree?

Answer: The logging system in use on Crown land in Ontario is established by decree. The company is told to use certain systems and it must abide by the rules laid down. But under any system, education of the cutting crews is necessary to keep logging damage within acceptable limits.

Question: Do you see any future in driving the Ottawa River?

Answer: Before a definite answer can be given to this question many aspects of the situation that have to be considered. Some of the major considerations are the volumes and species to be moved, economics, political pressure, and environmental concerns, etc.

Paul Aird made the comment that environmental concerns are a compromise between each of the different aspects.

SPLENDOR UNDIMINISHED: A MANAGEMENT OBJECTIVE FOR RED PINE AND EASTERN WHITE PINE ECOSYSTEMS

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Some of the environmental implications of more intensive forest management are identified. It is suggested that an environmental assessment of pine management in Ontario cannot be conducted until the objectives of the undertaking have been defined more clearly. An annual biological audit of change in numbers, distribution and genetic diversity of important indicator species in man's ecosystem is recommended as a means of providing better biological information to political decision makers.

L'auteur identifie quelques influences sur le milieu dues à un aménagement forestier très prononcé. Il suggère qu'une évaluation du milieu pour l'aménagement de Pins en Ontario est impossible avant que les buts d'une telle entreprise n'aient été plus clairement définis. Il recommande une vérification biologique annuelle des changements en nombre, distribution et diversité génétique chez les espèces que l'on sait être de précieux indices dans l'écosystème de l'homme, comme moyen de fournir une meilleure information biologique aux responsables de décisions politiques.

"Splendid", "magnificent", "strikingly impressive" are words used to describe the large red pine *(Pinus resinosa* Ait.) and eastern white pine (*P. strobus* L.) trees of the past and present. But what of the future?

Times change. Yesterday large-diameter pine trees were numerous. Today they are few. Yesterday pine seeded naturally in abandoned Indian corn fields and after wildfire. Today few Indians grow corn, forest fires are less extensive, and man now relies on artificial regeneration through seeding and planting.

Logging practices change, too. During the last two centuries man has tried harvesting squared timber on 200-year rotations, logs on 150-year rotations, poles and logs on 100-year rotations, pulpwood and poles on 50-year rotations, pulpwood on 25-year rotations, and chips on rotations of 10 years or fewer. The trend is toward the production of more merchantable wood on shorter rotations.

As man tries to increase production with shorter rotations and monoculture he can lose the stability of natural ecosystems. His problem is to achieve short-term gains without jeopardizing long-term productivity. Can the short-term increases in production be sustained? My task at this symposium is to identify some of the environmental implications of more intensive forest management.

At one end of the forest management spectrum is the wilderness. Many people consider 200-year-old forests decadent. The modern phrase is "overmature slums". The urge is to convert these slums into healthier forests producing more wood on shorter rotations.

On the other hand, in the struggle for survival, only the fittest survive. The fittest are those that survive under wilderness conditions. All the biological raw materials that man depends upon for food, fibre, physical, chemical and biomedical products have been selected from the wilderness. There is splendor in wilderness.

At the other end of the forest management spectrum is the forest tree nursery. Seed collected in the wilderness is germinated in the nursery. The act of re-creation is splendid. There is splendor in the nursery, too.

The word "decadent" can apply to nurseries as well. In the past, shipments of nursery stock have introduced, spread, or contributed to the spread of, diseases and insects throughout Ontario. White pine blister rust disease is an example. The tragedy is that such practices continue today, and that there are few restrictions on inter-regional or inter-provincial shipments of infested nursery stock.

In 1976, 5,000 red pine seedlings from the New York State Tree Nursery at Saratoga were introduced to the Brockville District of Ontario as part of an experiment in out-planting performance (Coons 1977). Perhaps nothing will happen, but the prospects are frightening. A new strain of Scleroderris canker, causing heavy losses in both young and mature red pine plantations in New York State (Setliff et al. 1975) is a serious threat to pine management in Ontario. To my mind, the risk of damage is so great that no reason can justify importing red pine nursery stock from anywhere outside Ontario.

Some insects and diseases become much more harmful to trees planted off-site. Knowing this, why do we continue to plant trees off-site?

What management objective is satisfied when red pine trees are planted on jack pine sites in Algonquin Park? What management objective is satisfied when seed collected outside the Algonquin region is planted within? What are the implications of such practices for maintaining the natural diversity of flora and fauna?

Logging and silvicultural practices can significantly reduce the diversity of species. For example, if short-rotation forestry becomes widespread it will discourage hole-nesting species of birds such as woodpeckers, nuthatches and chicadees that prefer older stands containing large, dead snags.

I am concerned not only with preserving diversity of species but also with preserving diversity within species. Native Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco), a species which exhibits great genetic diversity, is being domesticated by the widespread planting of genetically superior trees and by the introduction of strains of outside origin that cross with the native strain (Anon. 1973). Will we domesticate red pine and eastern white pine, too? Will the diversity of these wild species have to be preserved in places outside their present range? This is a valid question in light of current plans to introduce white pine from Pennsylvania into Ontario (Coons 1977) because its growth potential is assumed to be superior to that of pine obtained from local sources (Zsuffa 1975).

What is the energy budget for pine management? Will energy conservation measures increase the emphasis on natural regeneration and decrease the emphasis on artificial regeneration? increase the use of wildfire for site preparation prior to seeding or planting? reduce the use of nitrogen in favor of phosphorus and potassium fertilizers? increase the size of clearcuts? reduce the number of thinnings? increase the rotation length? increase the river drive? reduce the consumption of newsprint manufactured from groundwood?

Foresters predict a triple to quadruple increase in wood production through use of genetically superior trees, complete tree utilization, better control of insects, disease, and fire, applications of fertilizer, land drainage, irrigation, better regeneration, etc. But predictable economic, political, social and environmental constraints may limit the potential increase to 25-50% over present harvest (Spurr 1976). Let us not set our hopes too high and expand the forest-based industry beyond the capacity of the forest and foresters to produce merchantable forest products.

CONCLUSIONS

A thorough environmental assessment of pine management in Ontario cannot be conducted at this time. To conform with the

Environmental Assessment Act (Anon. 1975) would require, among other things, a description and statement of the rationale for the undertaking, for the alternative methods of carrying out the undertaking, and for the alternatives to the undertaking.

But what is the undertaking? We cannot conduct an environmental assessment before we define the undertaking! Should Ontario try to produce as much pine as possible to meet world needs? What quantities and qualities of pine should be produced under different management practices? What tradeoffs are acceptable between increasing pine production and environmental degradation?

The focus of this symposium is on activities rather than objectives. I contend that we know how to do the tasks. What we lack, more than anything else, is political direction. To my knowledge, general and specific objectives for pine management have not been clearly defined.

A general objective based on the concept of *splendor undiminished* would be to maximize the yield of flora and fauna from the forest to meet the essential needs of man on a long-term continuing basis, consistent with maintaining the genetic diversity of all species in the system.

This broad objective has been defined to express concern for posterity. The problem is how to express this management objective in operational terms to guide daily job performance. The success of environmental policy-making depends on how each participant performs his daily tasks.

How do we evaluate the success of environmental policy-making? One approach would be to initiate an annual biological audit. I maintain that we need an annual focus on man's changing biological base. In its simplest form, this would involve an annual examination of change in numbers, distribution and genetic diversity of the important indicator species in man's ecosystem.

For example, an annual biological audit of red pine and eastern white pine ecosystems would show changes in numbers, distribution and genetic diversity of red and white pine, Scleroderris canker, white pine weevil, pileated woodpeckers, marten, and other species. As results accumulate, management practices would be maintained or modified to conform with the desired objective of maintaining the genetic diversity of all species in the system.

Canadians still have the opportunity to maintain the splendor of many forest ecosystems. Let us inject better biological information into the political decision-making process. Let us begin by maintaining the splendor of red pine and eastern white pine ecosystems for posterity.

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DISCUSSION

Question: What is the objection to using seed from Pennsylvania?

Answer: There is no objection to using seed from any source for testing, but there is an objection to the indiscriminate use of seed without knowing how it is going to behave. Also there is a need to preserve the diversity of the species.

M. Rauter commented that it is necessary to keep complete documentation on source of seed and how it developed in different locations. We also need stricter regulations and inspection of any material that we import.

TRENDS IN LOGGING EQUIPMENT DEVELOPMENT

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Lumbering preceded pulpwood cutting in Canada by at least half a century. Because of the size of the trees and the logs produced from them the use of power hand tools gained early acceptance, but sawtimber harvesting, unlike pulpwood harvesting, did not lend itself to a high degree of mechanization.

Au Canada, l'exploitation forestière (pour le bois d'oeuvre) a précédé d'au moins cinquante ans les coupes destinées au bois à pâte. Vu les dimensions réduites des arbres et des billes à pâte, on utilisa tôt des outils mécaniques. Cependant la récolte du bois d'oeuvre n'a pu être beaucoup mécanisée.

The purpose of this paper is to describe and discuss suitable logging equipment in the light of present silvicultural systems for managing white pine (*Pinus strobus* L.) and red pine (*Pinus resinosa* Ait.).

In Canada most of the highly developed logging systems and component machines have been developed by the pulp and paper industry to be used with spruce (*Picea* spp.), balsam fir (*Abies balsamea* [L.] Mill.) and jack pine (*Pinus banksiana* Lamb.). The pulpwood logging industry is concerned with relatively small trees which can be readily manipulated and maneuvered by machine, felled by hydraulic shears, limbed by knives or chain flails, cut to length by shears or saws, and readily handled with hydraulically operated loaders. These operations are sometimes carried out by single-function machines, but more commonly several distinct operations are combined in one multi-function machine.

Small trees lend themselves more readily to mechanical processing and handling than do large trees. This is very evident if one compares the changes in logging machinery and systems in eastern Canadian pulpwood operations with the relatively static developments in coastal British Columbia.

Historically, lumbering preceded pulpwood cutting in Canada by half a century or more. The traditional methods used in white and red pine sawlogging in eastern Canada have been a) the felling and crosscutting of trees initially with axe and crosscut saw and later with chainsaw, and b) the skidding of log lengths--in some instances multiples of log lengths or even tree lengths--initially by animal power, later with crawler tractors and currently with wheeled skidders.

Because of the size of trees and tree products, there has not been the same opportunity for the development of a variety of equipment and methods in sawlog production. Sawtimber operations in general have shown less initiative in devising and using mechanized forms of production than have pulpwood operations. The situation cannot be blamed entirely on tree and product size, however. The sawmilling industry in eastern Canada has neither the size nor the financial resources of the pulp and paper industry. It tends to be fragmented into relatively small units which cannot support costly equipment developments.

The mechanization of pulpwood harvesting systems has been predicated to a large degree on the output of a relatively short bolt of uniform length which permits automation or semi-automation of the crosscutting or bucking operations. Another important factor has been the characteristic shape of spruce and fir--conical crown and gradually tapering bole with relatively small limbs. These characteristics have favored the development of tree harvesters for these species rather than for intolerant hardwoods, for example. The boles of the latter are much more subject to crook, sweep and bow, and because of their nonconformity are therefore difficult to manipulate and operate upon with an automated system.

Perhaps the potential for developing a relatively high level of mechanization in tree harvesting for a given species can be assessed by looking at a mature specimen in silhouette. Trees with large crowns, heavy branches and short stout boles are poor candidates for mechanization. They tend to vary substantially in size and even more in the proportions of their components.

White and red pine fall between the coniferous pulpwood species and hardwoods when it comes to mechanizing their harvesting. These two species have characteristics that present real problems to the equipment designer. Other problems are posed by the sizes of sawlogs demanded by industry.

In mature pine trees the limbs tend to be much larger than those of spruce and fir by an order of two or three. Even though in dense stands trees may be free of branches for one half to two thirds of their length, their crowns tend to be relatively broad and their limbs large. Pine limbs grow in whorls, with branchless or almost branchless internodes. The occurrence of large-diameter limbs in whorls around the bole at relatively short intervals of 30-60 cm would subject any delimbing device to great strains.

The species that are not considered candidates for a high level of mechanization in harvesting do lend themselves to the use of powered hand tools such as chainsaws and to machines for dragging and lifting. A great deal of energy is required to carry out the different harvesting operations such as felling with axe and saw, limbing with axe, rolling with canthook, etc. Although formerly lumberjacks were extremely skilful in the use of nonpowered hand tools, these skills disappeared with the advent of mechanical power.

The development of logging equipment for the white and red pine sawlogging industry has followed a different path than that for the pulplogging industry because of the physical characteristics of the species involved and the length of the logs as dictated by the lumber industry.

In the mechanization of harvesting white and red pine material of sawtimber size, major changes from the pulpwood harvesting systems are needed. Hydraulically operated shears (tractor mounted) have been a common means of felling trees of eastern sawtimber size, particularly in the interior of British Columbia. However, such shears produce some damage in the form of splits and cracking to the butt of the tree stem and this degrades the butt log. This damage is much more pronounced in winter than in summer as the wood is frozen, is more resistant to localized crushing and is more likely to split extensively. A number of modifications have been made to felling-shear blades in an attempt to reduce the potential for damage, with only limited success.

Tractor-shear felling of white and red pine really does not have a place in eastern Canada for a number of reasons. Many of the trees cut are in mixedwood stands, or else the pine is cut selectively or in a manner to promote regeneration. Unless felling is in substantial clearcuts in pure stands the tractor shear cannot compete with a well trained chainsaw operator.

When a tree has been felled, it may be found to be free of limbs for 50-75% of its total length. For this reason the mechanization of the delimbing function shows little potential for cost reduction. Depending upon the upper top diameter desired the tree may be topped before the crown has really begun. If the stand has been open and the crowns are heavier and penetrate over a greater portion of tree, the operation will still be difficult to mechanize because of the size of the limbs. Limbing in large trees may account for 32% of the total cutting time. In small-diameter timber it may account for up to 60% of the total cutting time (Hamilton 1964). Any delimbing device would have to be a component of a harvester as it is not feasible to undertake the whole-tree skidding of pine any distance through the forest to a roadside, where the limbs could be removed mechanically by a processor. A trained operator with a chainsaw and axe would be difficult to beat in eastern Canada.

There is a European development in sawlogging that could be of interest to Canadian operators (Haeberle 1974). It is the SERIAS "Tree Monkey", a development of the Institute of Forest Work Study and Forest Engineering at the University of Goettingen and a private company named Rabeneick (Fig. 1). The Tree Monkey is based on an earlier development, the KS31 climbing saw. This unit will not work on trees below 12-14 cm in diameter. One model is used on trees 20-35 cm in diameter and a larger heavy-duty model is designed to work on trees 20-65 cm in diameter. The machine, which is self powered with a light-air-cooled engine, is attached to a tree at its base. It will climb the tree, removing bark and limbs at the rate of 1 minute per running metre of tree height (including all running and servicing times). When the unit reaches a predetermined diameter it reverses itself and descends to the ground. Developments have overcome many original problems. If the saw jams in a branch, the engine will not stall and after a given time the device will pull backwards and downwards out of the cut. If for any reason the engine stalls, automatically a fine strong rope is released from a case and with this rope the operator can reverse the unit and guide it down the tree. These units are fairly heavy and the method of application that has been developed involves the use of a small all-terrain vehicle, two operators and five machines. In Germany it is expected that by 1985 some 40-50% of conifers in the larger diameter classes will be barked and branched with this equipment. Studies to date indicate savings of 25% over conventional methods. This unit should be worth a substantial Canadian trial, particularly if the barking element is detached and only the limbing operation is considered. The productivity should be considerably increased over that indicated.

Skidding of logs has been carried out mechanically for many years. Initially all skidding was done with crawler tractors, either direct ground skidding on the tractor drawbar, or later with an integral arch and sometimes with a wheeled or track-equipped arch. The wheeled skidder is a versatile vehicle but does not replace the crawler tractor completely. If a company requires a machine that builds roads, clears landings, removes stumps and skids logs it will choose a crawler tractor (Conway 1976). Direct ground skidding with little or no lift on the front end of the log often caused hangups which led to the use of skidding pans. These skidding attachments in turn led to the integral arch and winch. The concept was good, as there was no restraint on the tractor in maneuvering backward or forward in the forest. However, the arch and winch with a load of logs upset the balance of the tractor unit by making the rear heavier than the front, thereby overloading track

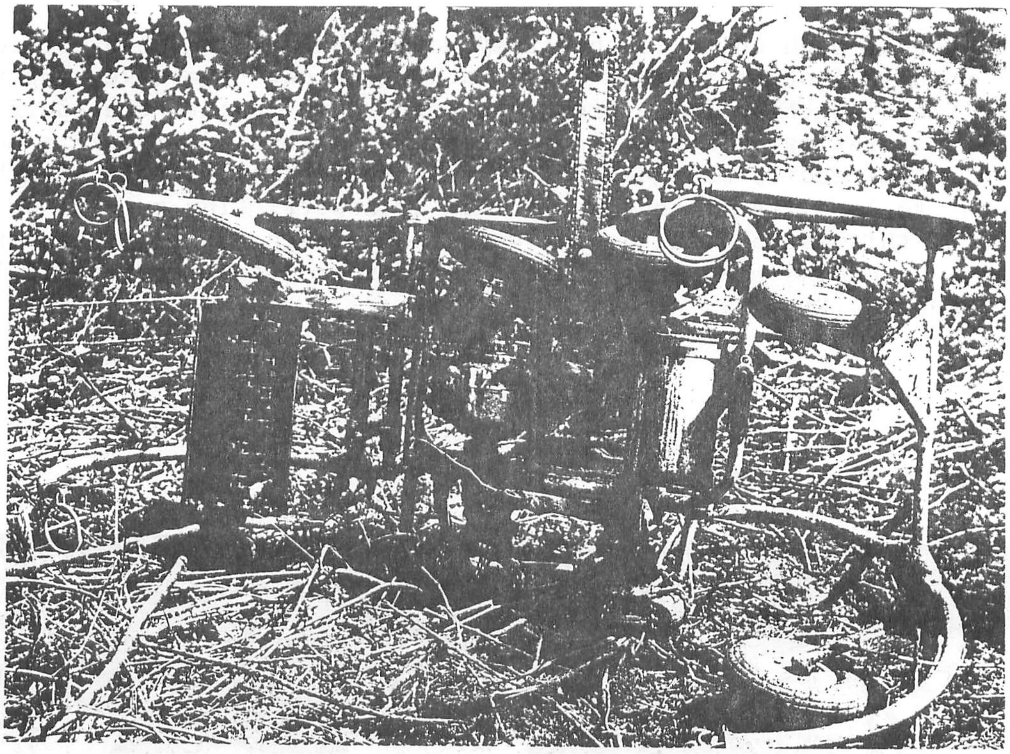


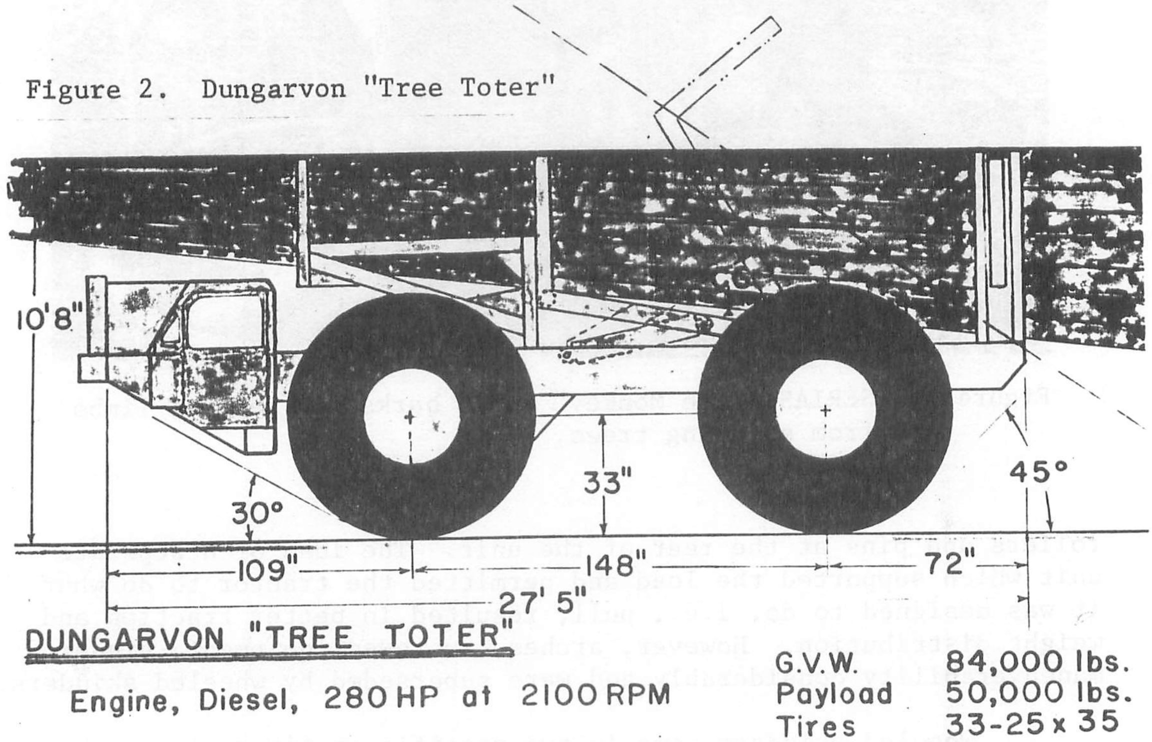
Figure 1. SERIAS "Tree Monkey" which barks and removes limbs from standing trees.

rollers and pins at the rear of the unit. The idea of a separate unit which supported the load and permitted the tractor to do what it was designed to do, i.e., pull, resulted in better traction and weight distribution. However, arches, as towed equipment, hindered maneuverability considerably and were superseded by wheeled skidders.

Wheeled skidders come in two specific configurations, choker skidders and grapple skidders. Both have their own place in the harvesting operation. The load a choker skidder handles is governed by the number of chokers carried by the unit and by the average tree size. A grapple skidder is generally used when an optimum payload can be made up regularly, usually by a feller-buncher harvester. It can also be used with large diameter logs. It has the operational advantage that the operator doesn't have to dismount from the cab of the machine to act as chokerman. One disadvantage of the grapple skidder is that if the machine becomes stuck it cannot move ahead like the choker skidder, leaving the load behind for winching. It must drop the whole load to be recovered at a later date.

There is a move in pulpwood sawlogging towards very large long-distance wheeled forwarders. These units normally carry full trees or tree lengths with payloads up to 110,000 kg. One argument for the use of such units is that they would obviate the need for costly branch roads. Another is that there is a trend now toward keeping the logs or tree lengths off the ground throughout the entire transport phase of harvesting. In some ways a load of sawlogs would make a more compact, more readily manageable load than full trees or tree lengths and ought to lend itself to this form of transport. The success or failure of this method will depend upon the terrain and stand density, for these determine to a great extent whether or not a substantial load can be made up (Fig. 2).

Figure 2. Dungarvon "Tree Toter"



Helicopter transport of sawlogs has been attempted in different areas around the world, including northern Ontario (Silversides and Richenhaller 1975). William Milne and Sons Ltd. of Temagami were attracted "by its potential role in yarding timbers in areas of different or impossible access as well as in areas where environmental, aesthetic and silvicultural considerations are of prime importance. The latter especially in regard to patches of over-mature timber which for some reason or another remained unharvested, but in the meantime have become surrounded by vigorous regeneration. The dispersed pattern and the volume involved of such stands, of course would not allow, economically, construction of road systems" (Buck 1974). In this particular trial three areas were chosen, all difficult or inaccessible by wheeled or tracked vehicles. The organization of the operation was critical. Because of the high cost of helicopter charter and operation it had to be used at its maximum efficiency. The major factor in helicopter logging, made compelling by the cost of the helicopter, is the absolute need for a very efficiently run operation with little or no allowance for human or mechanical error or for lost time, no matter what the reason. This was very obvious and is in striking contrast to conventional operations. The whole tempo of the operation imposed by the helicopter is peculiar to the machine used (Fig. 3). This is a historic pattern, as animal power first controlled productivity through its tempo. Later the tireless machine introduced its tempo and radically changed the whole environment of forest harvesting operations. The change from a slow agrarian type of operation to one representative of industrialization is very obvious. The change to the use of helicopters is just as striking in its effect. The method of transportation dominates all other operations. For example, trees are bucked into lengths, not to produce the highest quality but to produce pieces of suitable weight. Weight becomes the controlling factor as the cost of transport outweighs the differential between log values. It would appear that in the harvesting of timber of high value under conditions which prohibit conventional logging methods, helicopter logging has a place.

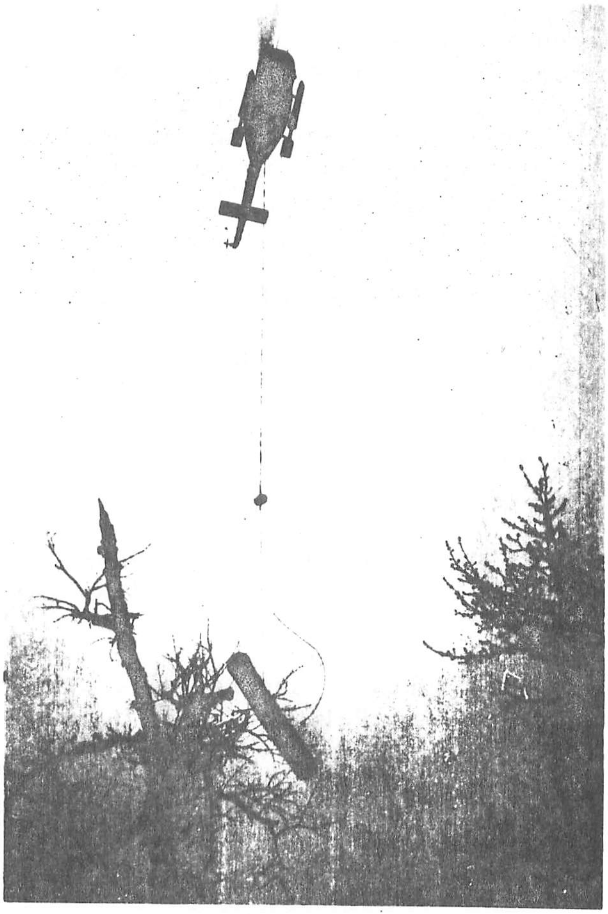


Figure 3. Helicopter transport at William Milne & Sons Ltd., Temagami, Ontario.

Log handling, loading, and unloading have changed drastically since the early labor-intensive days of logging white and red pine. Like all material handling problems, log handling and loading have received considerable attention from equipment manufacturers. There is an almost infinite variety of log handling equipment on the market today: what is needed is to assess the needs of an operation accurately and to obtain the most efficient loader in the circumstances. Loading is the link between logging and transportation. For this reason loading has a great impact on productivity and cost. Loading may take place at the stump, the roadside landing or some distant transfer point. Loaders may be stationary or mobile. If mobile they may be either tracked or rubber tired, front end loaders, grapple loaders, heel boom loaders, etc.

In a recent assessment of harvesting equipment currently utilized in logging in eastern Canada it was found that loaders which serve also as unloaders were the most common type of equipment. It is important to obtain a loader that fits the operation, one that is sufficiently powerful to handle the maximum anticipated load but still operate economically below this level.

From this discussion it will be seen that logging equipment development in the harvesting of white and red pine sawtimber is following an entirely different route than that for pulpwood species. Almost all efforts are directed to improving manual methods through the development of power tools and to applying new technologies to the transport of sawlogs in the early stages.

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DISCUSSION

Question: We tend to be going to bigger and bigger machines. Is there any work being done on the development of small machines?

Answer: There are one or two machines in production primarily for plantation thinnings. The development of small machines appears to be a question of economics. At present there is no big demand for small machines; consequently, the machine companies have not undertaken a development program.

MECHANICAL SITE PREPARATION METHODS AS PART OF A SILVICULTURAL SYSTEM TO REGENERATE WHITE AND RED PINE

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*Site preparation is an important phase in a silvicultural system whose aim is to establish white pine (*Pinus strobus *L.) and red pine (*P. resinosa *Ait.). Various types of equipment have been developed to operate within specific terrain and stand conditions to produce a predetermined seedbed or planting area.*

*La préparation de la station constitue une étape importante dans un régime sylvicole qui vise à l'établissement du Pin blanc (*Pinus strobus *L.) et du Pin rouge (*P. resinosa *Ait.). Divers types d'équipement ont été mis au point pour fonctionner dans des conditions précises de terrain et de peuplement, afin de produire un lit de germination ou une aire à planter prédéterminés.*

INTRODUCTION

The use of site preparation tools and methods to assist in regenerating white pine (*Pinus strobus* L.) and red pine (*P. resinosa* Ait.) should be compatible with the silvicultural system employed. It should also be effective in producing site conditions that favor the establishment and subsequent growth of these species. The silvicultural system, or the combinations thereof, used in Ontario to manage particular stands of white and red pine are as follows:

1. clearcut with subsequent planting or seeding
2. seed tree
3. uniform shelterwood
4. strip shelterwood

The equipment used for site preparation is not species specific, but more appropriately has been developed to operate within specific terrain and stand conditions to produce a predetermined seedbed or planting area. The success of site preparation prescriptions is dependent on more than equipment design and function. Correct choices with respect to the most suitable silvicultural system to use, the most appropriate species to regenerate, the best time to schedule site preparation and subsequent follow-up treatments must be made. Steps within a silvicultural system must be compatible. For example, if site preparation is scheduled after the seeding cut in a uniform shelterwood system, sufficient volume must be removed to permit access to the stand without causing damage to the remaining standing trees.

To outline the range of equipment used and the site conditions for which they are suitable, a review was made of the site preparation projects for the 1976 season in the Northeastern and Algonquin regions of the Ontario Ministry of Natural Resources. Details of these projects are summarized in the Appendix.

Although equipment type and use may vary from area to area, three major groups can be distinguished. The equipment described in this paper is as follows:[1]

1. blading - after the seeding cut in a uniform shelterwood silvicultural system
   - to site prepare backlog areas
   - after the harvest cut in a seed tree silvicultural system
2. site preparation tool mounted on prime mover
   (a) V blade mounted on skidder
   (b) V blade mounted on bulldozer
   (c) scarifying (Young's) teeth mounted on bulldozer
3. Site preparation tool drawn by prime mover
   (a) flanged barrels and anchor chains drawn by a skidder
   (b) shark-finned barrels drawn by a bulldozer
   (c) Bräckekultivatorn drawn by a skidder

1. Blading

Straight-blading has proven to be a versatile site preparation method used in a variety of silvicultural systems.

Parry Sound District is using John Deere 350 (42 hp) and 450 (65 hp) bulldozers to prepare a seedbed after the seeding cut in a white pine uniform shelterwood system. Basal areas in the stands are reduced to between 9 and 16 m^2 per ha. Machines working around the

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[1] The comments and observations made in this paper are from Ontario Ministry of Natural Resources field staff and are based on projects carried out in the 1976 season. All costs in the following descriptions are based on 1976 figures. The Appendix summarizes the site preparation projects carried out in the Northeastern and Algonquin regions in 1976 to regenerate white and red pine.

remaining trees and patches of advance regeneration pushed the ground vegetation, the logging debris and the organic layer of the soil into piles. This site preparation is concentrated on deeper sites within the stands, while the delicate, shallow-soiled sites are avoided. To supplement natural regeneration the area is hand seeded at a rate of 12,350 seeds per ha. The cost incurred when bulldozers with 42-65 hp were used was approximately $35.00 per ha.

In the North Bay District, areas of fresh, glacial till and rock outcrops, which were harvested of their overmature white and red pine 10 to 20 years ago, are now supporting a dense growth of shrubby species. These areas are being straight-bladed to remove the unwanted vegetation. Where possible, brush piles are located in areas which could not be planted, thereby preserving the potentially available production forest. Production rates using a D7F (180 hp) range from a low of 0.1 ha per hour to approximately 0.4 ha per hour. The cost for this type of site preparation averages $128.00 per ha. Drawbacks to this system are its high initial cost, the need to train operators not to bulldoze mineral soil, and the inevitable loss of some production forest because of brush piles. These are usually offset by the establishment of a pine forest that would not be possible without this type of severe treatment.

In North Bay District, straight-blading is used on sandy outwash plains that have been harvested using a seed tree system. Blading can be successful in that it will provide large areas of exposure for possible germination and allow 2 to 3 years before vegetation limits pine establishment. Unfortunately, areas bladed are prone to rapid drying during the spring, with resultant seedling mortality. Furthermore, in areas with shallow soil profiles, an inexperienced tractor operator may remove the upper layers of the developing soil. The cost incurred with a D7F is approximately $97.00 per ha.

2. *Site Preparation Tool Mounted on Prime Mover*

(a) <u>V blade mounted on skidder</u>: Sudbury District made use of a V blade with a replaceable foot to site prepare for white pine planting on a deep, fresh-to-wet, silty loam soil. The humus layer was thin and the area was interspersed with bedrock outcrops. A ripping nose 7.6 cm wide and 0.4 m long was inserted into the foot position of the V blade. The V blade did an acceptable job of removing slash from the planting corridor and mixing mineral soil with organic soil. It was hoped that the ripping nose, by disturbing poplar (*Populus tremuloides* Michx.) root systems, would stimulate suckering. To reduce this competition after the initial rapid growth, the area was sprayed with a 2,4D 2,4,5T mixture in preparation for planting the following year. Where it was not necessary to stimulate poplar suckers artificially, a planting shoe 35 cm wide and 20 cm deep was attached to the V blade. The V blade was mounted on a C5 Tree Farmer wheeled skidder (97 hp). In a situation such as this where the terrain was broken, the equipment performed well because of its maneuverability. Where the silty loam was particularly wet the skidder wheels left ruts which slowed production and disturbed the site excessively. Production rates averaged 0.8 ha per machine hour at a cost of $59.28 per ha.

(b) V blade mounted on bulldozer: In areas of heavy brush competition or large logging debris, V blades have been used to prepare areas for planting or seeding. V blading is generally confined to sandy soils and, depending on site conditions, the V blade has been mounted on D5 bulldozers (97 hp) to D8 bulldozers (270 hp).

Experience in Pembroke District suggests that V blading with a D5 bulldozer is effective because of the machine's maneuverability in small clearings and partial cutovers. As is the case with straight-blading, however, V blading creates windrows of logging debris and soil. However, if well maintained, V blades exhibit a better shearing action than do straight blades, and at a lower cost. The production cost on the Pembroke project was approximately $71.00 per ha. The treated area was subsequently planted to red pine within the 3 m wide V blade swath.

Temagami District has found that V blading with a D8 bulldozer can be effective in preparing a seedbed for hand seeding of white and red pine using shakers and rakes. The area site-prepared was a sandy loam soil, 30 to 90 cm deep, containing many stones interspersed with rock outcrops. Production costs were approximately $86.00 per ha.

(c) Scarifying (Young's) teeth: Scarifying teeth mounted on bulldozer blades have been used with mixed success. The use of these teeth permits variability in the degree of site preparation ranging from a full blade effect to a light mixing of organic and mineral soil. Depending on the desired spacing and subsequent treatments, either two or three teeth are mounted on the bulldozer blade. Scarifying teeth produce brush piles, but to a lesser degree than either straight-blading or V blading if the teeth are being used properly.

Chapleau District cleared an area for white pine research planting using three Young's teeth mounted on a D7E (180 hp) bulldozer at a cost of $265.00 per ha. Using this same equipment, the field staff were particularly satisfied with the seedbed preparation results of a 1974 project after the area had been cut and a white pine seed tree system employed.

Work in Temagami District using Young's teeth indicated that these are ineffective in very stony areas and areas with heavy logging debris.

North Bay District mounts two Young's teeth on a John Deere bulldozer (65 hp) to prepare field areas for the planting of red pine at a cost of $47.96 per ha.

3. *Site Preparation Tool Drawn by Prime Mover*

(a) Flanged barrels and spiked anchor chains drawn by a skidder: Sudbury District is using such a drag combination for seed tree and uniform shelterwood systems, as well as in areas scheduled for planting. The unit is made up of three flanged barrels attached in parallel to a 3 m, single hookup angled drawbar. Each barrel is followed by 4.5 m of 14.5 kg per link spiked anchor chains. The barrels with 13 cm wide flanges are 0.8 m long by 0.4 m in diameter and weigh approximately 90 kg empty. The unit with unloaded barrels was drawn by a power shift Case 600 Skid King skidder (103 hp). A V blade was mounted on the skidder to remove slash from the path of the drag. The drag was used on shallow, sandy soils and on sandy loam boulder till with numerous rock outcrops. Both supported stands of white pine prior to cutting. The single hookup angled drawbar was effective in deflecting stationary objects. The flanged barrels by virtue of their configuration did not furrow as deeply as shark-finned barrels. The flanged barrels and anchor chains mixed the organic and mineral soil well, but where slash conditions were severe the drag tended to ride up over the debris. In areas where the organic layer was deep the unloaded barrels were insufficient to expose mineral soil. If barrel loading was necessary, a skidder larger than 100 hp would be required to pull the drag. The production rates using this unit were 0.6 ha per hour around seed trees at a cost of $49.40 per ha and 0.5 ha per hour in uniform shelterwood areas at a cost of $61.47 per ha.

(b) Shark-finned barrels drawn by a bulldozer: Pembroke District made use of two units of three shark-finned barrels, each hooked to a 2.4 m drawbar and pulled by a D7E bulldozer. Each unit of three was made up of one 0.7 m water-filled barrel and two 0.4 m concrete-filled barrels. Depending on site and slash conditions, costs ranged from $58.21 to $119.81 per ha. The area was planted to red pine the year following treatment.

Algonquin Park District used a D7F bulldozer to pull two units of four medium-sized barrels at a cost of approximately $78.00 per ha. The area was subsequently planted to red pine. Experience in the district indicates that in most instances shark-finned barrels provide adequate preparation for planting. In areas of light, sandy soil, barrels may furrow too deeply and expose the site to wind erosion along the furrows. On richer sites it has been found that the exposed soil in the furrows is quickly invaded by herbaceous and woody vegetation.

(c) Bräckekultivatorn drawn by a skidder: When used in areas of moderate slash on sandy to loamy sites, the Bräckekultivatorn (Bräcke), by producing scalps, makes suitable planting or seeding spots at regular intervals. Espanola District used the Bräcke to site-prepare areas for red pine planting. The Bräcke, pulled by a Clarke 668 skidder (180 hp), obtained production rates of 1.0 to 1.4 ha per hour at a cost of $27.00 to $37.00 per ha. This type of skidder was overpowered for the drag unit. A machine of approximately 90 to 100 hp equipped with chains on the front wheels would have been sufficient to complete the work. A V blade mounted on the skidder blade assisted progress by removing slash from the path of the Bräcke. As part of this site preparation system, the area was sprayed with a 2,4D 2,4,5T mixture to eliminate unwanted competition after the Bräcke had passed. The total cost for site preparation plus herbicide treatment was $96.00 per ha.

The Bräcke was found to be less than effective on fine soils because the mineral soil that was exposed after scalping tended to dry out and bake during the summer months.

CONCLUSION

The intent of this paper was to provide an overview of some site preparation tools and methods used in regenerating white and red pine. Descriptions of the entire silvicultural systems employed are not complete but it is hoped that an appreciation was gained of what equipment is being used and where it is being used. Perhaps the most important purpose of the paper is to introduce forest managers to new ideas on site preparation for establishing white and red pine that might be applicable to their areas.

APPENDIX

Site preparation projects to regenerate white and red pine in the Northeastern and Algonquin regions, Ontario Ministry of Natural Resources (1976 season)

District	Description of site preparation equipment used	Total area and cost per ha	Subsequent treatment
Algonquin Park	D7F bulldozer pulling two units of four medium-sized shark-finned barrels	167 ha $78.37/ha	plant to red pine
Bancroft	prescribed burn to remove dead grass, herbaceous and woody growth; subsequent furrowing with single disc plow on a small farm tractor	45 ha	plant to red pine
Blind River	straight blade with D7 bulldozer	51 ha $185.00/ha	plant to red pine
Bracebridge	Hitachi T12 bulldozer equipped with scarifying teeth	11 ha $45.70/ha	plant to red pine
Chapleau	D7E bulldozer equipped with three scarifying teeth	3 ha $265.00/ha	research planting of white pine
Espanola	Bräckekultivatorn drawn by skidder with subsequent herbicide treatment; costs combined	132 ha $96.08/ha	plant to red pine
	V blade mounted on skidder with herbicide treatment; costs combined	21 ha $237.49/ha	plant to white pine
North Bay	John Deere 450 bulldozer equipped with two scarifying teeth	16 ha $47.96/ha	plant to red pine
	straight blade with D7E bulldozer in seed tree system	265 ha $97.17/ha	natural seeding to white pine
	straight blade with D7E bulldozer	464 ha $128.27/ha	plant to white and red pine
Parry Sound	straight blade with HD16D bulldozer; windrows burned	33 ha $155.51/ha	plant to red pine
	straight blade with John Deere 350 and 450 bulldozers after seeding cut in uniform shelterwood system	352 ha $33.47/ha	natural seeding to white pine plus hand seeding
Pembroke	D7E bulldozer pulling two units of three shark-finned barrels	115 ha $70.59/ha	plant to red pine
	rubber-tired farm tractor pulling a double-disc scalping plow	4 ha $14.82/ha	plant white pine between rows of hybrid poplar
Sudbury	Case Skid King (103 hp) wheeled skidder pulling three units of one-flanged barrel plus 4.5 m of 14.5 kg/link spiked anchor chain	126 ha $51.87/ha	seed tree or uniform shelterwood system. Plant or seed to white pine
	V blade mounted on G5 skidder with subsequent herbicide treatment	89 ha $59.28/ha	plant to white pine
Temagami	D7E and D8 bulldozer using (a) V blade (b) straight blade (c) scarifying teeth	561 ha $86.50/ha	hand seeding to white and red pine

DISCUSSION

Question: Have you experienced any trouble with the hitch as shown on the T.T.S. disc trencher, and, if so, are you aware of the hitch that KBM Forestry Consultants have designed which allows the trencher to pivot in all directions?

Answer: We have had no problems with this hitch up to the present time. The only problem is that it is beginning to wear out.

Question: What percentage of the area should be treated and how much mineral soil should be exposed?

Answer: The greater the area scarified the better the results will be, but at least 60% of the area should be treated.

PRESCRIBED FIRE FOR SITE PREPARATION IN WHITE AND RED PINE

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*Prescribed fire is a promising technique for the preparation of seedbed of the quality needed for the regeneration of white pine (*Pinus strobus *L.) and red pine (*P. resinosa *Ait.). Its twin effects are the removal of duff and the control of competing vegetation. A scheme for pine management based on prescribed fire and partial cutting has been worked out at Petawawa.*

*Le brûlage dirigé constitue une technique prometteuse pour la préparation de lits de germination conformes aux normes de qualité requises pour la régénération du Pin blanc (*Pinus strobus *L.) et du Pin rouge (*P. resinosa *Ait.). Il a pour double effet d'enlever la litière et de contrôler la végétation concurrente. On a mis au point à Petawawa une méthode d'aménagement des pineraies fondée sur le brûlage dirigé et à la coupe partielle.*

INTRODUCTION

It is generally admitted by forest managers that modern logging methods do not favor the subsequent regeneration of white pine (*Pinus strobus* L.) and red pine (*P. resinosa* Ait.). The Ottawa River Valley has received two free crops of pine, the first a gift of nature to the early loggers, and the second an incidental result of early logging methods and the inevitable fire. Achieving a third crop will not be so easy. Apparently the ecologies of white and red pine are not well suited to the conditions resulting from modern logging methods and the exclusion of fire, and special silvicultural treatments become necessary. Any untried technique that is potentially effective and economical deserves an honest, serious appraisal.

Such a prospective technique is prescribed fire. (In this concept we include both site preparation and natural regeneration.)

There is plenty of evidence that white and red pine in the natural state benefit from fire of a certain periodicity and intensity--red pine more so than white pine--and the reason for this lies in the regeneration requirements of these species. The optimum conditions are fairly well known:

1) a seedbed either bared to mineral soil or with its duff cover substantially reduced
2) relative freedom from competition by shrubs and understory trees of undesired species
3) a live overhead seed source
4) considerable opening in the overhead canopy

Site preparation is required to achieve the first two conditions. On an area so prepared, if the last two conditions are met, good regeneration of both pine species will usually result; without such preparation, however, pine regeneration will usually fail.

Research into the use of prescribed fire as a technique for regenerating white and red pine began at the Petawawa Forest Experiment Station in 1959, and has been pursued more or less continuously since then. Two questions were posed at the outset: 1) Can regeneration of these pines be accomplished through the use of fire? 2) Is the process practical? We can now answer both questions with a definite yes. Altogether some 30 areas have been treated with fire, many of them more than once, under various stand conditions and combinations of stand conditions and fire weather. These trials have demonstrated the conditions essential for a safe, effective fire that can lead to adequate white and red pine regeneration. The remainder of this paper deals with some specific aspects of the technique, and includes a proposed method for the use of fire in red and white pine management.

SEEDBED

White pine will germinate and survive on a litter surface over several centimetres of duff, but it prefers mineral soil. Red pine, on the other hand, requires a seedbed bared to mineral soil, or nearly so. The proportion of the duff layer consumed by fire depends mainly on its moisture content. The desired effect is a moderate degree of duff removal, enough to create adequate seedbed for both pines, but not enough to open the way to erosion or to cause unnecessary loss of nitrogen and phosphorus through volatilization. The degree of duff removal varies from place to place, and a patchy effect is quite satisfactory.

BRUSH AND UNDERSTORY COMPETITION

A good seedbed is not enough; on good pine sites especially, the competition from shrub and understory tree species must be sharply reduced to permit the pine seedlings to survive and grow well in the first few years. In this region, the main competing species are hazel (*Corylus cornuta* [L.] Mill.), red maple (*Acer rubrum* Marsh.), and balsam fir (*Abies balsamea* [L.] Mill.). Balsam fir can be eliminated by one fire, but the hardwood competition sprouts or suckers and generally requires two fires for adequate control. The aim is not to eliminate hardwood tree and shrub species completely--that would be ecologically undesirable--but merely to reduce their quantity and vigor temporarily to favor the establishment of a new pine crop.

In our experience, prescribed fire normally kills all brush-sized stems as well as tree stems up to about 10 cm DBH by girdling the cambium. White birch (*Betula papyrifera* Marsh.) of larger size may be killed if its bark burns intensely all the way to the top. Sapling conifers may be killed by cambium girdling, by crown scorch, or by torching out.

FIRE INTENSITY AND OVERSTORY DAMAGE

Natural regeneration implies a live overhead seed source, and the question of damage to the standing trees then arises. Our experience is that the main mortality mechanism in pines is scorching of the crown foliage rather than overheating of the basal cambium. (The term "scorching" as used here means killing by hot convection gases, not actually flaming combustion.) We have found that large pines will stand the loss by scorching of up to half their crowns with less than 10% mortality. The height to which crowns are killed depends directly on fire intensity and flame height. A reasonable fire intensity is about 400-600 kW/m, corresponding to a flame height of up to a metre or so. Occasional surges of higher intensity may damage or even kill a mature pine or group of pines, but these can be salvaged in the partial cut that follows the fire treatment. We have observed little or no fire scarring on crop-sized pines following fire. Generally, if a fire is intense enough to cause fire scarring on mature pines, it will kill the tree by crown scorching first. In brief, a prescribed fire that is carried out properly will result in very little damage in mature pine stands, with no measurable effect on the subsequent growth rate.

EFFECTS OF PRESCRIBED FIRE ON SOIL AND SITE QUALITY

The purpose of prescribed burning in red and white pine is to convert the soil surface temporarily into a medium that favors the establishment and early growth of pine seedlings. The effect of direct heat on the soil is slight, since only patches of mineral surface are created, and these result from gentle smoldering rather than prolonged intense heat. During burning some heavy mineral nutrients are ashed into a more readily available state; some nitrogen and phosphorus are also volatilized and lost in the smoke. However, according to both the literature and our own data, the nutrient losses are a small part of the total capital, and are in any case soon replenished to the normal equilibrium level by income through rainfall and other sources.

There is also the question of the minor vegetation. We have found that almost all the minor plant species growing in the red and white pine forest have regeneration mechanisms that have apparently evolved in the presence of periodic fire. Thus, within a few years after prescribed burning, essentially the whole species spectrum is present and flourishing. This includes the woody understory species, which are reduced but never eliminated.

Since fire is a treatment to be contemplated only once or twice per rotation, the effects should be viewed in that perspective. There is also the argument that all pine sites have been exposed to fire of varying intensity probably a hundred times or more since the original soil was laid down, and that permanent changes of any sort as a result of further fire are unlikely. In our opinion, the effects of prescribed fire on long-term site quality are transient and insignificant.

FITTING FIRE INTO A MANAGEMENT SYSTEM

Except for white pine on the drier sites, all good stands of red and white pine are of fire origin. Nature, of course, did not worry about the loss of a fair proportion of the mature pines, as long as enough remained alive to provide an adequate overhead seed source. The ecology of the red and white pines thus favors even-aged management, with a pronounced overlap at the end of each rotation to provide seed and a nursing function for the new stand in its first several decades. This suggests some sort of partial cutting system in which fire is used to induce the new crop, the final cut in each rotation taking place some years after regeneration has been initiated. The question is, exactly how should the fire be fitted into the schedule?

In our experience, prescribed fire after a partial cut is very difficult. The intermittent slash results in too much high-intensity fire, and pine mortality may be unacceptably high. A better solution, therefore, is prescribed fire in the untouched stand before the first partial cut.

The best time to burn for effective hardwood kill is after the leaves have flushed, when root reserves are at a minimum. However, when hardwood brush is plentiful, summer flammability is very low, and the first fire must be in spring before flushing. The second fire can, if desired, be run after the leaves are out for the greatest possible effect.

The two fires should be run in consecutive years for best results. The first cut should then be taken within 5 years or so. The occurrence of a good pine seed year just after the second fire would of course be highly welcome. However, strict attention to seed years would complicate the management scheduling severely; besides, the two pines do not necessarily seed well in the same year. In any event, a well-prepared site is receptive for several years at least.

Obviously, the larger the pines, the easier it will be to burn under them without damage. On average-to-good sites, trees of 80 years or more will sustain little or no damage in a properly conducted prescribed fire. Such trees will also continue to grow well for several decades as a residual stand. Stands as young as 60 years can be burned with great care and moderate damage, but operation at such an age in red and white pine could be justified only as a measure to balance a badly regulated age-class distribution in a larger forest.

Some demonstration stands at Petawawa have been both burned and partially cut. There are examples of satisfactory regeneration from 2 to 17 years of age. However, complete removal of the original stand has not yet been accomplished on any one area.

PRACTICAL APPLICATION

It has been said that prescribed burning is an art as well as a science. This may be true, but it should not be a deterrent to honest trial, since the same could be said of many other silvicultural treatments as well.

The Canadian Fire Danger Rating System provides reasonably good quantitative guides to choice of burning day. The limits in use at Petawawa for burning in red and white pine are:

Fine Fuel Moisture Code (FFMC)	-- 90 - 95
Initial Spread Index (ISI)	-- 8 - 16
Buildup Index (BUI)	-- up to 52
Fire Weather Index (FWI)	-- 12 - 24

The months of May and June are the most suitable from both the fire and silvicultural points of view. In this region most years provide at least 10 good days plus a number of marginal burning chances. Late April and July are also satisfactory for certain situations.

The nature and density of the understory in red and white pine forests vary tremendously with history and site quality. The pre-burning preparations and firing pattern must of course be based on an appreciation of both the understory and the topography of the block to be treated. Here are a few general points to keep in mind.

1) If the hardwood brush and understory are heavy, the fire must be run before leaves flush in spring.

2) If the understory is pure hardwood, fire behavior is uniform and predictable, and control is relatively easy.

3) Balsam fir understory complicates fire behavior, and is most difficult when present as distinct clumps that tend to crown and damage the pines above.

4) White birch complicates fire control because of its tendency to produce down-wind spot fires.

5) Headfire is preferred because it spreads faster and interior lines can be lit within a block.

5) Backfire is used when dictated by fuel, weather, and topography.

COST OF PRESCRIBED FIRE

The largest area treated in one afternoon at Petawawa was 12 ha. It was what might be called a pilot-scale operation, and was carried out by five experienced men and a tank truck. A couple of hours of preliminary bulldozer work to secure parts of the area not bounded by roads, followed by several man-hours to patrol them, were necessary. The estimated total cost, including man and machine time, was about $450, or $37.05 per ha. Since fire control is essentially a perimeter operation, the economy of working on larger areas is obvious. There is no doubt that, with good planning, the crew in question could have burned an area several times larger with little more effort.

The fire described above was the first of two conducted on an area with a fairly difficult fuel complex. The second fire a year later, in simple litter fuel, cost about half as much.

CONCLUSION

We believe that prescribed fire is a potentially useful tool in the management of white and red pine, whether the objective be timber management, wildlife habitat, or the maintenance of pine in wilderness areas and parks. Of all site preparation techniques leading to natural regeneration, it is surely the one closest to the natural ecological process, and may be the least expensive as well.

DISCUSSION

Question: Was there any difference between the two species (red and white pine) in their resistance to fire?

Answer: The stems of both species are very resistant to fire; 50% of the crown can be destroyed by crown scorch and the trees will not be killed.

Question: If there are only about 10 days suitable for prescribed burning in a year would this be too restrictive for management foresters?

Answer: The number of days suitable for prescribed burning varies from area to area. The system would have to be tried out in operational trials before any definitive answers could be given.

RED AND WHITE PINE PLANTING

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*In the Eastern Region, red pine (*Pinus resinosa *Ait.) and white pine (*P. strobus *L.) are planted mostly in abandoned submarginal agricultural fields. Formerly, the presence of white pine weevil and blister rust discouraged white pine planting, but owing to better understanding of white pine management, its comparatively high value and yield, and the existence of large acreages of suitable sites, planting will be significantly increased over the next 5 years.*

*Dans la Région de l'Est, le Pin rouge (*Pinus resinosa *Ait.) et le Pin blanc (*P. strobus *L.) sont plantés surtout sur des terres agricoles submarginales abandonnées. Autrefois, le Charançon du Pin blanc et la Rouille véseculeuse du Pin blanc entravaient le plantage du Pin blanc, mais grâce à une meilleure connaissance de l'aménagement des pineraies, de leur valeur et de leur rendement comparativement élevés, et grâce à l'existence de grandes superficies convenant à l'établissement de stations, on augmentera significativement le plantage au cours des 5 prochaines années.*

INTRODUCTION

This paper deals primarily with old field planting of red pine (*Pinus resinosa* Ait.) and white pine (*P. strobus* L.) in eastern Ontario.

In the Eastern Region the majority of red and white pine planting occurs on abandoned submarginal agricultural fields. During the fall of 1976 and the spring of 1977, a total of 1,197,900 red pine and 228,000 white pine seedlings were planted in Crown, W.I.A., and Agreement forests.

Red pine now represents 30% of the bare root standard reforestation stock planted, while white pine represents only 5.6%. Changes are planned with respect to species distribution for future reforestation efforts.

By 1981-1982 white pine will constitute about 17% of the Eastern Region's reforestation program, while red pine will be reduced to approximately 13%. The shift to a larger component of white pine is due in part to a better understanding of white pine management. In the past, planting of white pine was largely discouraged because of insect and disease problems. Ideal white pine sites were most often planted to white spruce (*Picea glauca* [Moench] Voss) or red pine, which sometimes did poorly as the sites were often marginal.

Matching species with sites to obtain good survival and growth is the basis of a high yield forest management program. In the past, too little emphasis was placed on economic criteria.

SPECIES

Reforestation in eastern Ontario was first documented in 1889, when white pine was planted in the shelterbelts of the newly formed Dominion Experimental Farm at Ottawa (Macoun 1909). In 1914 a private plantation was established by the late Senator W. C. Edwards at Rockland. The planting consisted of 20,000 white pine and 16,000 red pine 3-year-old seedlings.

The high value of, and demand for, white pine as a lumber species made it a very early choice for planting. This demand resulted in early importation of white pine nursery stock from the United States and Europe.

From 1904 to 1909 eastern white pine of German origin were imported into Ontario. During that period over a million imported white pine trees had passed through the nurseries at Guelph and St. Williams for distribution in Ontario. The importation of this stock also introduced white pine blister rust (*Cronartium ribicola* J. C. Fischer) to Ontario. The first recorded collection of blister rust in Ontario was made by the late J. E. Howitt of the Ontario Agricultural College at Guelph, in 1914 (Haddow 1969).

Foresters and owners of white pine plantations soon became discouraged with the species as a result of serious white pine weevil (*Pissodes strobi* Peck) and blister rust attacks. Consequently, between the years 1905 and 1953 the Division of Reforestation of the Ontario Department of Lands and Forests distributed 81.3 million red pine seedlings, and only 30.1 million white pine seedlings, for planting in the province (Stiell 1959).

During the planting year 1976-1977, 8.7 million red pine and 3.4 million white pine were distributed by provincial nurseries. The ratio of red pine to white pine has changed only slightly on a provincial basis.

In 1939 a report (Sisam 1939) was compiled on the Rockland plantations by J. W. B. Sisam, at that time an employee of the Dominion Forest Service. Sisam's remarks, with respect to white pine, were as follows:

"The actual experiment deals only with red pine. However in November 1938 when the work was started, the white pine was examined and it was found to be so badly weevilled that there was not a tree in the stand with possibilities of ever producing even fair quality lumber. Every tree has been attacked to some extent, and most of them appear to have been attacked every year, and such trees are, of course, deformed so that they are of no value except for fuelwood. Besides the white pine weevil damage, many of the trees have been infected with blister rust and the white pine aphid, so that altogether this stand is in very poor condition and may act as a warning against the planting of white pine in pure stands in Eastern Ontario."

Sisam's prediction with respect to the future value of this stand has proven to be most inaccurate. Although the Rockland white pine stand has never been managed, i.e., it has been neither thinned nor pruned, it does contain substantial volumes of white pine timber suitable for lumber production. It has also served as a nurse crop for excellent sugar maple regeneration.

SEED SOURCE

Seed is always identified by site region. It may also be identified as coming from special sources such as seed collection reserves, seed production areas and seed orchards. A major problem with respect to white pine seed collection is that large quantities of seed have been picked by contractors from branchy, low-quality, scattered trees. Every attempt should be made to discourage this practice.

There is much more variability in the growth and development of white pine than of red pine; therefore, much more attention must be paid to seed collection and tree improvement in the former.

On the basis of results of a 7-year experiment at Ganaraska and Turkey Point (Fowler and Heimburger 1968) white pine seed from Pennsylvania has been recommended for planting in Ontario. We are therefore planning to acquire white pine seed of known origin from Pennsylvania and from the northern Appalachians for seeding at Kemptville this fall.

NURSERY STOCK

Healthy green seedling nursery stock with a well balanced top-to-root ratio is preferred over transplant stock. White and red pine

3-0 stock have proven excellent for old field planting. White pine 3-0 stock must have a stem caliper just above the root collar of at least 3.6 mm and a minimum top height of 15 cm. Red pine 3-0 stock must have a stem caliper of at least 4 mm and a minimum top height of 15 cm. In both cases, the stock meets the Ontario standards for the medium size class.

The present average cost of producing 3-0 seedling stock in provincial nurseries in Ontario is $43 per thousand. The foresters of the Eastern Region do not feel that the additional cost of $27 per thousand for pine transplant stock is warranted on the basis of the high seedling survival achieved to date. When necessary, site preparation is carried out to ensure high survival. Most pine planting in the Eastern Region is carried out in the spring.

At the present time the Kemptville Nursery is growing 300,000 red pine 2-0 on a trial basis for planting in the spring of 1978. The development of high quality seedling stock is a major objective of the nursery.

SITE PREPARATION

Site preparation may or may not be required. If it is undertaken it should facilitate good survival and initial growth of the stock. Dense herbaceous or shrub growth should be reduced, since such growth, together with high water tables, often causes significantly high mortality in plantations.

On the driest sandy sites where red pine is often planted, site preparation is not normally needed. On sites covered with willow (*Salix* spp.) and alder (*Alnus* spp.) it is necessary to remove this competition by the use of brush cutters. Subsequently, the site must be furrowed and white pine or other suitable species planted in the furrows.

On poorly drained rubicon sandy soils, a deep furrowing plow with a 61 cm bottom is used to prepare the site. Two of these plows were manufactured at the Larose Forest shops near Bourget. Recently white pine has been planted on these deep furrowed sites and the results to date are promising.

Simazine is the principal chemical used in site preparation. Results have been good on sandy loam and loam sites treated with 6.72 kg/ha of active simazine. This is normally applied at the time of planting, either by spot treatment in the case of hand planting, or by power sprayer when machine planting is carried out. The spray is placed on the ground in a 61 cm band ahead of the colter. When the grass exceeds 10 cm in height, amitrole-T is added to the simazine and applied at a rate of 0.94 L/ha.

Pure stands of red pine are planted with an allowance of 3.78-4.41 m^2 per tree, i.e., 2.1 x 1.8 m or 2.1 x 2.1 m, with 2.1 m between the rows in both instances.

Pure stands of white pine are planted at 2.70-3.24 m^2 per tree, i.e., 1.65 x 1.65 m or 1.8 x 1.8 m. It is desirable to maintain a survival of 85% through to approximately 20-25 years at the spacings recommended for each species.

High density planting of white pine is the most promising solution to the white pine weevil problem. The closest spacing is used when the potential for weevil damage is greatest. Close spacing helps prevent development of broad irregular crowns. It also ensures that adequate numbers of good quality stems are available for selection of crop trees.

SPECIAL PROBLEMS WITH RED PINE

In November 1975 an ad hoc committee was formed to consider the problem of poor performance of freshly outplanted red pine in the province. The committee is made up of representatives from the Forest Management Branch, the Forest Research Branch and the Central Region.

The problem involves reduced survival of red pine seedlings and abnormal development of terminal leaders on surviving trees. Various factors that may contribute to the problem are being investigated. These include nursery herbicidal practices, nursery stock quality, and stock handling and planting.

The problems experienced with red pine in other regions did not appear in the Eastern Region with the same intensity, although some red pine overwinter cold storage stock has performed poorly, and this has often resulted in high mortality and subsequent refilling.

To examine the situation in the region more closely, a comprehensive experiment was set up in the Brockville District. Red pine 3-0 stock was obtained from the following: New York State Tree Nursery, Saratoga (fresh lifted); Orono (overwinter cold storage); Kemptville (overwinter cold storage); and Kemptville (fresh lifted). In each case 5,000 trees were obtained. The trees were planted by three different methods in three different silvicultural situations:

1. by machine with simazine and amitrole-T
2. by hand on prepared furrows
3. by hand in sod.

Planting was done on an alternate systematic row basis.

At the end of the first growing season, randomly located sample plots were located for a 10% sample. Cumulative height, survival

Furrowing to remove grass and weed competition has not been practised to any extent in recent years.

FIELD STORAGE

Field storage is undertaken to keep storage on the site to an absolute minimum. Trees are not normally stored more than 2 days at the planting site. In each district cold storage facilities are provided: normally empty apple storage coolers are leased for this purpose. Nursery stock is stored at $1^{o}C$.

Stock is transferred directly from the nursery to the storage facilities, and is then distributed daily to the planting sites. Since lengthy storage in the field is discouraged, no healing-in of stock is necessary. Watering the overwinter cold storage stock is essential when the kraft bags are opened at the planting site. All stock is kept moist at the planting site.

PLANTING METHODS

(a) Machine

Both red and white pine are machine planted whenever conditions are suitable. Production averages about 8,000 trees per 8-hour day. In recent years scalpers have not been used on machines; instead, chemical site preparation is used when necessary.

(b) Hand

On steep slopes, stoney or shallow soils, machines are seldom used. Hand planting is done on a piece-work basis. Last spring a rate of 3.75¢ per tree was paid. In an average 8-hour day a planter will plant 1,000 pine seedlings.

The hand planting methods preferred are the "wedge" and the "L". Planting holes must be deep enough to accommodate the roots adequately and the seedlings must be packed tightly. Excellent results have been achieved by the use of both methods.

The "T" slit method is sometimes used where the sod cover is thick. Slit planting is discouraged.

SPACING

The initial spacing is very important since it must reflect future requirements for high yield and favorable development.

and percentage of healthy stock were examined.

As a result of the analysis, it is apparent that Orono overwinter cold storage stock was the best on silvicultural prescriptions for all criteria, Kemptville fresh-lifted stock was second best on all silvicultural prescriptions for all criteria, Saratoga fresh-lifted stock was third best on all silvicultural prescriptions for all criteria, and Kemptville overwinter cold storage stock was poorest on all silvicultural prescriptions for all criteria. A refill is required.

In this experiment all stock was handled similarly from the time it was received by the District until planting. The Saratoga nursery stock was the control factor in the experiment in that it was not subject to conventional Ontario nursery practice procedures.

Although it is still very early in the experiment to draw conclusive results, the superiority of the Orono overwinter cold storage stock is quite evident. The results of our regional experiment indicate that the differences in survival, cumulative height, and percentage of healthy stock relate to nursery origin and handling of stock previous to its acquisition by the District.

The first report of the Ministry's Red Pine Committee, however, indicates that the typical handling and planting process reduces performance very significantly, and stock quality may have some effect on performance as well.

The answer to the red pine problem may lie in a consideration of both factors in combination, i.e., stock quality and handling at the nursery as indicated by the Eastern Region experiment, and handling and planting activities in the districts as indicated by the Ministry's Red Pine Committee Study.

Results obtained from planting overwinter cold storage red pine nursery stock have been inconsistent from year to year and from nursery to nursery. A careful analysis of the procedures for the lifting and storing of overwinter cold storage stock must be carried out so that the problems can be identified.

The Brockville District experiment provides ample evidence that overwinter cold storage stock, when properly handled and stored, can in fact be equal or superior to fresh-lifted stock.

SUMMARY

In the past, much greater success has been achieved in planting red pine than in planting white pine in the Eastern Region. A much larger red pine planting program has been carried out in the province since the turn of the century: nearly three red pine have been planted for every white pine. Over the next few years a major effort will be made in the Eastern Region to increase white pine planting because of its superior productivity, demand, and site availability.

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DISCUSSION

Question: Have you tried using poplar instead of tamarack to provide shade in your white pine plantations? Would it not be satisfactory?

Answer: We have not used poplar yet for this purpose but we intend to try this species in the coming year.

Question: You mentioned two white pine plantations which exhibited good growth and very low incidence of weeviling. To what would you attribute the absence of weevils in unprotected plantations?

Answer: The reason for the low incidence of weeviling in these two plantations is probably the absence of natural white pine in the general area and as a result there is no resident white pine weevil population to cause any trouble.

Question: What technical means do you use to determine which species to plant on a given piece of land?

Answer: In deciding which species to plant we take a look at the soil, water and drainage, existing stands on similar soils, and soil maps of the area.

Question: Is the production of seedlings tied into available land?

Answer: Seedling production is tentatively tied into the land to be planted. Five years before the planting stock is required we must determine the quantity of each species that will be required but we must remain flexible in case we have to change our plans.

INTERPRETING PERFORMANCE OF RECENTLY OUTPLANTED PINE SEEDLINGS

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Maple, Ontario

*Shoot and root development of red pine (*Pinus resinosa *Ait.) are discussed to provide a foundation for understanding problems of performance after outplanting.*

*Le développement des pousses et des racines de Pin rouge (*Pinus resinosa *Ait.) est expliqué pour éclairer le lecteur sur les problèmes de rendement après plantage et lui fournir une base de connaissances visant à résoudre ces problèmes.*

The audit-type assessment of recently established plantations stresses early survival, with relatively little consideration being given to the early performance of the surviving trees. For example, *Green is beautiful* seems sometimes to be the only criterion applied, rather than characteristics of bud, needle and stem development. Ideally, root growth should also be assessed, but sampling tends to reduce survival!

Of course, some forest managers do pay attention to the developing leaders of young trees, and this has led to the recognition of the so-called "red pine problem". Here, abnormalities in the terminal leaders of freshly planted red pine (*Pinus resinosa* Ait.) seedlings range from a nonelongated or barely elongated "silver bud" to an elongated leader with deficient leaf development (Glerum et al. 1977). We believe that unsatisfactory development occurs also in outplanted white pine (*P. strobus* L.), although the symptoms of its poor performance may be more subtle.

Do we have available the biological information necessary for interpreting performance, for diagnosing the reasons for both good and poor performance, and for avoiding problems in the future? Our answer is "Yes, to a certain degree". We suggest that an understanding of the development patterns of the shoot and root systems is a good foundation, for, as the Arabs say, *Understanding is the wealth of wealth.* We will limit our discussion here to red pine[1].

The potential length of the shoot that will elongate in the spring is already determined the previous summer, i.e., when the new bud was being formed. Environmental conditions in midsummer affect the number of stem units that are laid down in the bud. (A stem unit is a portion of the shoot bearing a primary scale and its axillary structure, if any. The number of units can be found by counting the fascicles, lateral buds and sterile scales.) The number of units may be increased by extending the period of initiation through irrigation or possibly fertilization later in the summer.

Each stem unit has the potential to elongate to a certain length, but whether or not each one realizes this potential depends on moisture stress in the tree during the spring when elongation is most active. Thus, a bud with 20 stem units has a greater potential for total length than one with 15 units. But if a spring drought or inadequate root development severely limits moisture uptake, the total elongation of the 20-unit leader may be no more than that of the 15-unit leader with no moisture restriction. Shoot elongation typically occurs within an 8-week period after buds enlarge in the spring. Carbohydrates produced the previous year, stored over winter in various tissues, and translocated upwards through the phloem in the spring are the main source of food material for shoot extension, along with current photosynthate from older needles.

Initiation of the needle primordia in red pine is believed to occur in early spring, although primordia have been reported in winter buds. Subsequent elongation of the needles is most rapid after stem elongation is largely completed. The ultimate length of the needles is particularly affected by moisture availability in midsummer (which is also the general period in which the new stem units are being laid down in the bud). Thus, moisture restrictions in midsummer will result in shortened needles (as well as fewer stem units for next year's leader). However, if relatively few needles were produced because of unfavorable conditions in the previous year during bud formation, competition for nutrients, etc., is lessened and needles tend to be longer, i.e., there is some compensation with respect to the photosynthetic area produced. Growth of the needles takes place at their base. Thus, tissue in this

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[1] Our discussion of shoot development is based primarily on material on red pine in the review papers by M.G.R. Cannell et al. and R.M. Lanner, and in the included references (Cannell and Last 1976). The discussion of root growth leans heavily on the published studies of H.E. Wilcox (e.g., Wilcox 1968).

region is always the most succulent and easily damaged part of the needle until growth is over and cell wall thickening, lignification, cutinization, etc., are completed at the base. Occurrence of rapid, severe internal moisture deficits before completion of these processes can produce what is called needle droop (Patton and Riker 1954), especially on trees in which needle elongation was most vigorous. Needle elongation is largely complete by late August.

The current year's needles do not contribute any significant quantities of carbohydrates to shoot elongation as they are net users of carbohydrates during their own extension period. It is not until late summer, therefore, that these new needles contribute carbohydrates to growth elsewhere in the plant.

Increase in foliage mass is accomplished principally through the production of branches, whose numbers can often double or quadruple in the first 2-5 years from seed. Factors influencing the formation of lateral buds that will produce the branches appear to be linked with the size of the parent structure on which they form. The number of lateral buds tends to increase with the number of needles on the shoot.

After outplanting, height increment typically is 10-20 cm annually for a few years, increases fairly rapidly to a maximum of about 60-80 cm by about the 15th year, and then gradually declines.

Radial growth in the stem starts in the spring and ends about the time the needles cease elongating. Unlike current terminal growth, cambial growth is influenced significantly by moisture conditions late in the growing season.

In summary, leader length is the result of environmental conditions in two years: midsummer of the previous year and spring of the current year. The number of needles is determined in the year (midsummer) previous to their elongation, but their actual length is determined by conditions in the current year (midsummer), modified by the number of needles produced. Needle growth occurs at their base. The density of needles on the stem is determined by conditions in the spring of the current year. Few carbohydrates for shoot elongation are provided by the current year's needles. Leaders with large terminal buds generally have more lateral buds than have leaders with small terminal buds. Ring width is influenced strongly by moisture conditions in late summer. To conclude, we suggest you keep in mind those early Greek and Chinese sayings: *A sensible man judges of present by past events* and *Study the past if you would divine the future.*

Let us now turn to the remainder of the plant: the roots. From our preliminary observations it appears that the primary root of red pine is probably triarch or tetrarch in its upper region, i.e., first-order side roots emerge in three or four directions, respectively, from the root. However, examination of a few 3+0 seedlings showed us that roots in only two of these directions (and on opposite sides) grew in diameter; the others remained small. The majority of first-order and higher-order roots are diarch, i.e., side roots emerge from opposite sides of the parent root, but triarch and tetrarch conditions can occur.

Two main types of root have been recognized: long roots, which include pioneer and mother roots, and short roots. Pioneer roots have large-diameter tips and few side roots, are never abundant but rapidly extend the root system. Mother roots have smaller-diameter tips and bear many side roots. Vigorous mother roots commonly produce a higher proportion of long root branches than do less vigorous mother roots. Short roots have the smallest-diameter tips, are more or less ephemeral --many surviving only one or two seasons--and are commonly converted to mycorrhizae.

Short roots make up a major percentage of the root area and a high proportion of water and nutrients used by the plant enters through them. They must be renewed continually to ensure good growth. Furthermore, there must be an increasing number of vigorously growing mother roots to provide the framework for long and short roots, and pioneer roots must develop to enlarge the volume of soil exploited by the tree.

Lateral root primordia are produced within the body of the parent root behind the apex. Many of these primordia die before or soon after emerging, particularly on pioneer roots and those initiated in midseason on mother roots. New root apices can be destroyed in various ways, e.g., by nematodes. The most successful laterals seem to be those initiated when the mother root is entering or emerging from dormancy. At the former time, lateral roots may become dormant before or immediately after emerging from the mother root, and then resume growth the following spring.

When a root first emerges, its attachment to the mother root is through primary vascular tissue. If this is very reduced in size and little or no secondary tissue develops, a new root is easily broken off by physical stresses within the soil. This contributes to the attrition of small roots.

For a root to gain dominance it must increase the size of its apex and attract the substances required for its growth. The physiological processes involved are not known, but it has been inferred that if the tree cannot produce or maintain such apices, the overall system will become inadequate. Thus, an insufficient number of mother roots will develop and, as a result, there will be fewer short roots; consequently, the absorption area will not keep up with transpiration requirements, internal moisture deficits will occur and growth of the tree will be affected.

Initiation of root activity in nursery beds of red pine in the spring is reported from New York State to occur about a week prior to separation of the bud scales on the terminal shoot. Root growth of spruce (*Picea* spp.), fir (*Abies* spp.) and larch (*Larix* spp.) in the same nursery started 4-6 weeks ahead of shoot growth. Initiation of activity throughout the root system may take place over several weeks, and, within the overall environmental conditions, is affected by root branching order, root vigor and depth of the apices. For example, roots in the upper soil layers start elongating earlier than those in deeper layers; second-order laterals frequently start elongating before their parent first-order lateral.

Activity increases to a peak in June for all categories of roots, both in the nursery and in plantations. There is then a mid-summer lull with a subsequent renewed surge of activity, particularly of mycorrhizae and pioneer roots. Elongation of roots can continue well past cessation of needle elongation and of cambial activity in the stem.

The above pattern applies to the root system as a whole, but growth cycles for individual roots must also be recognized. For example, after an initial period of activity, first-order roots on seedlings may (a) enter a brief or longer dormant period and then continue growth at a reduced rate, or (b) enter an extended dormant period. Signs of marked intra-seasonal cycles of activity are often evident on roots in the surface soil layers of plantations in the form of light- and dark-colored bands. Here, periodic lack of moisture directly curtails activity. Activity can also be curtailed by waterlogging. If this occurs in the surface soil in the spring, initiation of root activity can be delayed.

The presence of white root tips is not a sure sign of active root growth because these can be present on dormant roots of red pine.

In the early life of a plantation, extension of the main horizontal roots is much more rapid initially than that of the stem. The annual extension of roots reaches its maximum rate 5-10 years after planting whereas annual height increment is not at a maximum for another decade. The main horizontal roots reach their maximum length (approx. 10 m) at about 20 years. Many of the main vertical roots are probably initiated in the first 5 years and may reach maximum depth within the first decade of planting.

We have a general picture of the development of the red pine root system, but know little of root growth immediately following outplanting in the field. There is no information available on where new root growth originates after damage to the root system such as that which occurs on lifting and replanting. Red pine probably does not have the ability to develop much in the way of adventitious roots, i.e., those formed in older tissue and distinct from the normal sequence of development behind the root apex. If new root development is a problem, the application of growth substances may help. No controlled studies similar to those of Stone (e.g., Stone and Jenkinson 1971) of the root regenerating potential, later termed the root growth capacity, of red pine have apparently been conducted. However, a limited study (The influence of prelifting cold treatment on the root regeneration [sic] potential of overwinter stored red pine seedlings, by P. J. Fraser, Degree IV Thesis, Lakehead Univ., Sch. For., 1976) showed that 3+0 red pine required a minimum of 325 degree hardening days (cumulative daily temperature differences below 50°F (10°C) recorded in the rooting zone) before fall lifting and storage if acceptable post-planting root growth was to be obtained in the spring.

It has been suggested that the relationship between initiation of shoot and root activity in the spring may be closer in red pine than, for example, spruce, in view of the short time lag between these two activities. The lack of a clear understanding of root-shoot interrelations is not unique to this species, but we are confident in stating that, for any species, good initial root growth after planting is absolutely essential for good stem development. Hence, although we recognize that we must be concerned with the care of the stem, we might (to make a point) paraphrase a sterling proverb: *Look after the roots and the stems will take care of themselves.*

In the north central United States where there is also a "red pine problem", some emphasis is being placed on the role of mycorrhizae (D. D. Skilling to D. C. F. Fayle, 28 February, 1977, personal communication); but we should not overlook the development of long roots since these are the sites of lateral root initiation and mycorrhizal infection. The root system must exploit as large a volume of soil as possible, and as rapidly as possible, to reduce moisture stress.

Let us keep this biological information in mind and consider now an outplanting experiment conducted last year to elucidate the "red pine problem". The first year results (Pierpoint et al. 1977) showed a slightly reduced survival and a very highly significant reduction in leader length and quality that were due to typical handling and planting techniques. This is perhaps not surprising when we remember that, in our manipulation of seedling stock in the nursery and in the field, we wrench, we root prune, we use tiny containers, we expose, we distort, we stuff roots in restricted slits. In other words, *Much is done for mechanical convenience, little for biological necessity.*

Typical needle and shoot growth conditions found at the end of the first season after outplanting are indicated in the bottom row of Figure 1. They range (left to right) from good shoot elongation, "normal" needle lengths and good bud formation, through partial needle flush, short leader growth, small needles and small buds, to a dead seedling whose terminal bud may or may not have flushed. We will assume

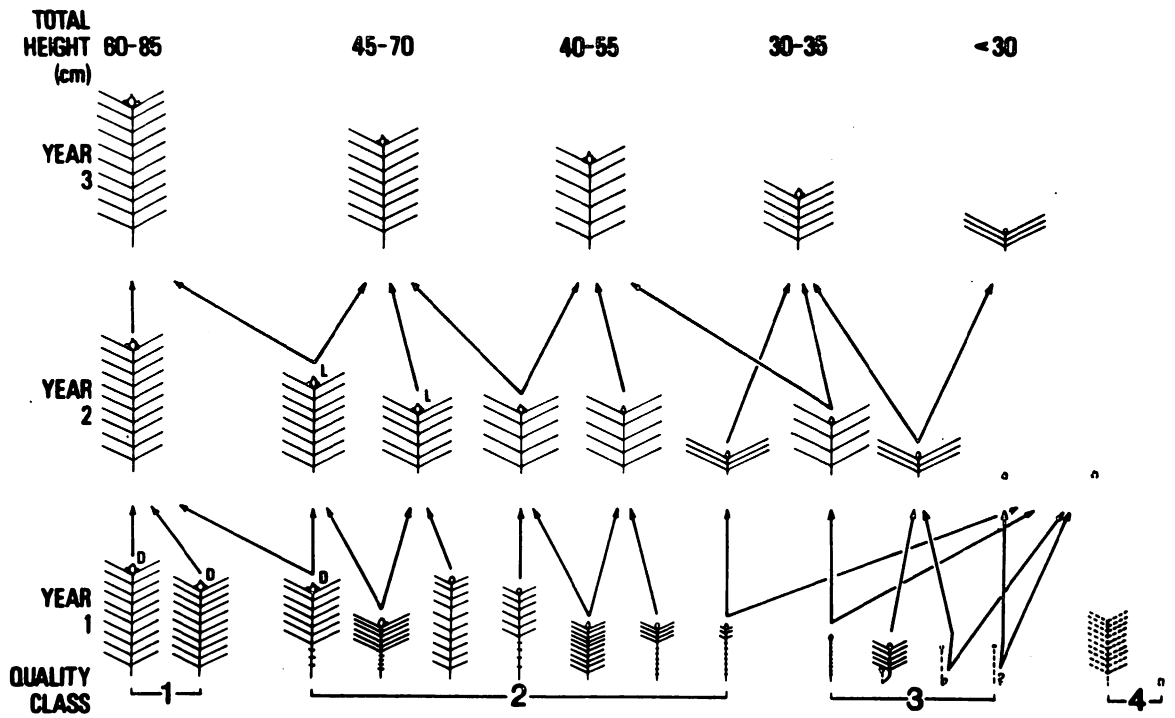

Fig. 1. Schematic presentation of leader, needle and bud development after outplanting of 3+0 red pine, assuming generally favorable overall environmental conditions. Bottom row shows development by end of first year, by quality classes (from 1, "normal" development, to 4, dead) used by Pierpoint et al. (1977). Second and third rows show possible developments from these classes in the second and third growing seasons, respectively. Total heights include an initial height of 25 cm. Needle droop (D) and lammas growth (L) were observed in certain conditions.

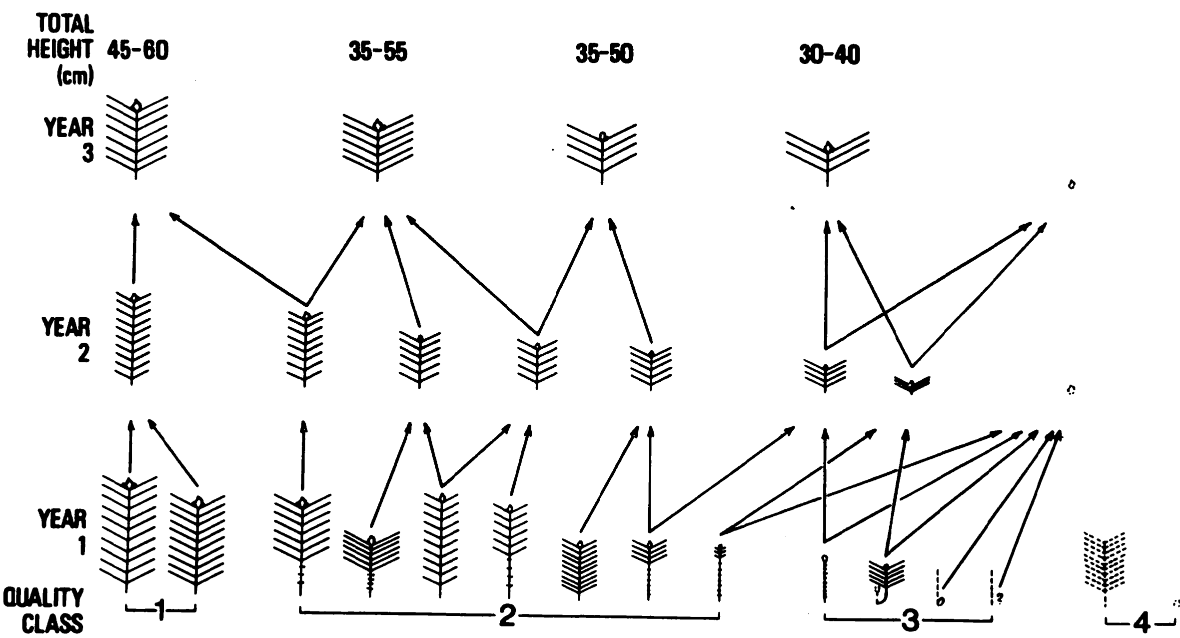

Fig. 2. Schematic presentation of leader, needle and bud development after outplanting of 3+0 red pine, assuming generally favorable overall environmental conditions in the first and third years, but unfavorable conditions in the second year.

that all these conditions arose from seedlings whose shoot morphology (as opposed to physiology) was the same. Furthermore, the overall environmental conditions were assumed satisfactory. Thus, any departure from the "ideal", shown on the left, was due to physiological differences and/or the inability of the plant to obtain sufficient moisture because of deficiencies in root development. The upper two rows of Figure 1, which are based on field observation of older plantings and incorporate the biological information presented earlier, illustrate how these trees might develop in favorable growing conditions in the second year (middle row) and third year (top row) after planting. The cumulative total height of an individual tree, depending on its pattern of development, could range from 30 to 85 cm in 3 years, if we assume an initial height of about 25 cm.

Figure 2 shows the likely development through the same three years if conditions in the second year were unfavorable throughout the growing season, but returned to more favorable conditions in the third year. In this case maximum heights are only 60 cm and many of the seedlings at the "weak end" (right) will have succumbed.

It remains to be seen how many of the trees of poorer quality surviving in the outplanting experiment after one year will still be alive several years hence, but the development of these plantations is being monitored. Meanwhile, we suggest that, *Once an underprivileged tree, always an underprivileged tree* is a useful adage to remember, especially in even-aged pine management. We have evidence that suppressed trees in a stand can be inferior from a very early age.

Nearly 40 years ago, Rudolf (1939) in his appraisal of pine plantations in the Lake States wrote: "With reforestation so much in the public eye, foresters are upon their mettle as never before to conduct their enterprise successfully. Obviously one of the best insurances for success is the ability to avoid failures, and to do so it is necessary to know the many causes of failure and their relative importance."

Almost 50 years ago, Stevens (1931) in his study on root growth of white pine wrote: "From the point of view of the forester, the roots of trees are of particular significance. Almost every silvicultural operation achieves its purpose, at least partially, by its effect upon the roots, and the results are influenced more or less by the entire system of roots present in the soil."

And last year, Art Herridge, in addressing the Plantation Management Symposium at Kirkland Lake, said: "How many times do we have to reinvent the wheel because foresters don't write, read or listen? It seems that I have read many of the 'complaints' before." Which reminds us of the remark made by a German philosopher: *What is true is seldom new.*

We suggest that a careful look at, and an enlightened interpretation of, seedling performance can diminish the problems of red and white pine management.

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TENDING OF WHITE PINE AND RED PINE

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*White pine (*Pinus strobus *L.) and red pine (*P. resinosa *Ait.) tending practices and problems are analyzed. The importance of appraising stand dynamics correctly before harvesting and of using the understanding gained to prevent serious tending problems is stressed. Timing of release treatments, and the influence of original stand composition and site productivity on tending treatments are discussed, and specific tending recommendations are made.*

*L'auteur analyse les pratiques et problèmes relatifs au Pin blanc (*Pinus strobus *L.) et au Pin rouge (*P. resinosa *Ait.). Il met l'accent sur l'importance d'évaluer correctement la dynamique des peuplements avant l'exploitation et d'utiliser l'expérience acquise afin de prévenir de sérieux problèmes de soins culturaux. Il présente un abrégé des méthodes et des pratiques appropriées aux soins culturaux. Il disserte sur le moment propice aux traitements et sur l'influence de la composition du peuplement d'origine et sur la productivité de la station, face aux traitments culturaux. Il fait des recommandations précises touchant les soins culturaux.*

INTRODUCTION

White pine (*Pinus strobus* L.) is one of the most difficult and therefore one of the most challenging species to establish and tend successfully. Red pine (*P. resinosa* Ait.) management, by contrast, is usually much less demanding.

White pine is usually managed most successfully by means of a carefully prescribed tending and harvesting program that emphasizes fairly selective silvicultural practices. The essence of white pine management is a continuous manipulation of competing vegetative cover types. Red pine, on the other hand, may have to be tended only once or twice following the very simple prescription of providing almost total release.

The failure to recognize the varied and sometimes complex growth demands of white pine and the importance of appropriate tending practices has been responsible for numerous plantation failures of this species. Difficulties encountered and the stigma of poor performance have turned management efforts away from white pine, especially where planting or seeding was required to establish it.

Red pine tending is not often accompanied by serious problems, for the species' intolerance to competition is well recognized. The most critical problem is its tardiness in release. In addition, there is a widely held belief that red pine is completely intolerant of shade and should be exposed immediately to full sunlight. This conviction may have occasioned a few failures on some sites; it certainly has made some hand release projects more costly than was necessary.

An analysis of conversations with field staff, literature reviews and some personal experiences suggests very strongly that the principal error in our tending practices with both species, but particularly white pine, lies in our failure to use a "total silvicultural system" approach. There is insufficient integration of all the management components necessary to ensure that tending procedures are effective. The plan for tending must be determined *before* the area is harvested, as is the plan for regeneration of the area. The forest manager must have a visual concept of the type of stand that will best satisfy the major criteria of silviculture and forest economics. For example, one successful white pine management technique consists in leaving a residual overstory to be manipulated in accordance with the requirements of the new seedling stock for light and protection; therefore, reserving a constituent of the original stand becomes an important part of the tending scheme for the new regeneration and stand.

A poor assessment of the potential impact of stand or site conversion from a predominantly hardwood association to pine has provided a few lamentable management experiences. Often the endurance of the hardwoods was underestimated, and consequently, tending practices were inadequate. Some hardwood sites are, however, ideally converted to pine.

TENDING PRACTICES AND PROCEDURES

Tending practices for white pine are usually quite different from those for red pine. The fact that the two species are normally associated would suggest certain similarities in silvicultural treatments. Although they share a number of common site requirements, however, particularly in terms of soil type and soil surface characteristics essential for germination and establishment, markedly different treatments are needed for the continued survival and proper growth of each species.

Natural regeneration or a plantation with a mix of the two species is common. For practical reasons, only one tending procedure, possibly an aerial release treatment, may be uniformly applied over the entire area. Quite often, however, the use of a single treatment for both white pine and red pine will necessitate additional tending expenditures either to counteract an adverse condition that may have been created or to make up for the inadequacy of the treatment for one of the two species.

The practicability and success of vegetative control measures depend directly on the original stand composition, logging practices, site conditions and regeneration objectives. The prescription for tending is largely inherent in the first planned disturbance, the harvesting plan. The harvest prescription provides the primary opportunity to influence the type and intensity of control measures to be applied for optimum survival and growth of the new stand.

Pre-planting Release

Insufficient thought is sometimes given to the desirability of applying a pre-planting control on indigenous vegetation. Such a control, in effect, would be classified as a site preparation technique; nevertheless, the advantages of implementing vegetative control measures before regeneration is established should not be overlooked. A more common pre-planting release is a herbicide treatment. White pine is intolerant of herbicides except at the very low concentrations of 2,4-D and 2,4,5-T at 1.12 kg/ha to 1.68 kg/ha acid equivalent (A.E.), and then only after physiological hardening. Red pine is only slightly more tolerant within the range of 1.68 kg/ha to 2.24 kg/ha A.E. Effective control of a few broadleaf species begins at an A.E. concentration of 1.68 kg/ha. The most difficult but also most necessary release usually requires a concentration of a minimum of 2.24 kg/ha. Obviously, it would be better to obtain effective broadleaf control at the higher concentrations needed--concentrations which are harmful to white pine or red pine--before these species are planted.

Post-planting herbicide release may be too risky or may prove ineffective where there is a serious competition problem immediately after planting.

Post-planting Release

Stand development must be appraised carefully to establish the need for a release treatment. White pine and red pine must be able to utilize effectively the additional growing space made available by the removal or retardation of competing vegetation. An effective assessment for release must anticipate both the response of the stock to be released and the future position of any competing vegetation. For example, the object of white pine release is nearly always to create only a partial opening; therefore, full growth response does not occur until the trees are past the weevil stage. Some suppression of white pine is therefore evident for a considerable period; it is only when the pine leader shows a gradual reduction in growth that additional release is undertaken. One must also be aware of competition shifts when, say, a broadleaf overstory is eliminated. This may encourage the establishment of lower competition, particularly brush. The period of competition with brush is the most serious phase for white pine and red pine. Thus, the timing of release becomes very important.

Release Methods

Each release job requires an individual prescription. However, there are common methods employed for a wide range of prescriptions.

<u>Mechanical release</u>: Usually this is referred to as hand release since it normally requires the use of some hand tool, a sandvik, ax or machete and, lately, powered hand tools such as a chainsaw or brush cutter. Hand release is ideally suited to white pine because it enables selective release. It achieves almost perfect control over the type and amount of competition which is eliminated. Its most serious drawback is cost as it is very labor intensive.

<u>Chemical release</u>: The economics of tending large and sometimes inaccessible areas has taken forest management in the direction of chemical controls which may be applied by aircraft or on the ground by a number of methods. Herbicides have been used with good success but have not been applied extensively, mainly because their use is not entirely trusted or accepted as a good management technique. Since both white pine and red pine are very sensitive to herbicides the forest manager should exercise caution until he has learned, from his own experience, the capabilities and limitations of the various herbicides. Chemical release does not provide the selectivity of control of individual stems as does mechanical release; rather, it provides selectivity of control through the different susceptibilities of tree or brush species to a particular herbicide.

Spraying for white pine and red pine release should be done at a time when the seedlings are overtopped by a fairly prevalent broadleaf cover. Premature spraying may cause great injury to exposed seedlings. Satisfactory stocking of these species is essential; otherwise spraying becomes a wasteful and unjustifiably destructive technique.

The rate and formulation of a herbicide must be defined. Aerial spraying normally uses the low-volatility ester of 2,4,5-T in an oil-water emulsion. A low-volatility ester of 2,4-D is recommended to control hazel (*Corylus* spp.) alder (*Alnus* spp.), birch (*Betula* spp.), cherry (*Prunus* spp.) and poplar (*Populus* spp.). It is much cheaper than

2,4,5-T, which is more effective on maple (*Acer* spp.), oak (*Quercus* spp.) and raspberry (*Rubus* spp.). Mixtures of the two herbicides are not generally recommended. The recommended application rate is 1.12-2.24 kg/ha in 9-22.5 L of mixture. High-volume aerial spraying at a rate of 1.68 kg/ha in a spray mixture of 18 L/ha has provided the best results (herbicide diluted in fuel oil and emulsified in water; oil is 1/8 of spray mixture by volume). The amine salts of 2,4-D and 2,4,5-T have produced good results for ground spraying applications. The carrier used with the amines is water; application rates are from 1.68 kg/ha to 3.36 kg/ha A.E. The rate used is governed by the species to be controlled and the density of the overstory. Spraying should not be done until after the hardwoods have leafed out fully and the conifers have started to harden off. For white pine and red pine, this occurs about the first two weeks in August, or later.

Basal release treatments provide a certain selectivity depending on the mode of application. Bark spraying using 2,4,5-T ester in oil is an effective basal spray. Stem infection treatments by either cutting the bark or using a hypohatchet are good for eliminating overstory hardwoods. The stem injection method is most effective in late summer or fall; silvisar (cacodylic acid), picloram (tordon) and the amine salts of 2,4-D and 2,4,5-T are employed. Ammate crystals (ammonium sulphamate) may also be used as a stump treatment to prevent suckering and resprouting. They are also effective on standing trees.

Either simazine or Gramoxone® (paraquat and a wetter) may be used to control grass. Simazine is effective for 2 years. It is applied in the fall or early spring and must be absorbed by the roots to be effective. It is confined to the upper 5 cm of the soil profile. Gramoxone kills all green growth to which it is applied. The best results are obtained by applications to short grass. Gramoxone may be used on bracken as well but recovery is likely. The arbogard is a piece of equipment recommended for hand treatments of grass competition.

THE INFLUENCE OF ORIGINAL STAND COMPOSITION AND SITE PRODUCTIVITY ON THE DEGREE AND COMPLEXITY OF TENDING TREATMENTS

Very often, discussions of red and white pine management are based on a concept of a fairly pure and homogeneous stand composition of the two species. If this were always the case, management and tending practices would be very much simplified.

The original stand composition should be a major factor in determining the most appropriate silvicultural system for the sustained management of red and white pine on a particular area. The harvest method and site treatments that may follow will largely determine the type, degree and frequency of tending treatments needed. The tending ramifications of each and every prior disturbance or treatment must be carefully appraised.

The hardwood constituent in either the main story or the understory usually poses unexpected and very serious tending problems for the forest manager. He must have an appreciation of the growth, regeneration and longevity potentials of all the hardwood tree species present in the stand. The silvical attributes of each species should be taken into account to provide the best possible environment for regeneration of white pine or red pine without the exorbitant tending costs or disease problems that are sometimes intensified by a poor choice of tending technique or practices. Unfortunately, some people believe that tending denotes only a removal of competing vegetation; they do not see the value of preserving and protecting a given stand component to minimize or complement tending procedures and disease protection.

Site productivity must also be assesssed correctly, for it, too, has a very direct effect on the difficulty of tending red and white pine. Coarse-textured soils do not usually present a serious tending problem, but fine-textured soils, the silts and clays, are a prolific source of brush, shrub and broadleaf tree species. It is no coincidence that the latter soil types most often support mixedwood stands in which hardwoods are the established majority. Even with the best silvicultural design for re-establishing a component of pine, some difficult and costly tending procedures are inevitable on these sites. The competing hardwoods generally grow at a much faster rate than white pine or red pine. The regrowth of shrubs is much more serious on the deeper and moist sites. Vegetation shifts or succession of plant species can occur if too much ground exposure to sunlight results from release treatments to control broadleaf competition. The area may then be invaded by subordinate vegetation of grasses, bracken and aster and even revert slowly to shrubs. Tending treatments may have to be repeated several times to obtain a slow and controlled release of red and white pine without triggering the introduction of new but equally serious competition problems.

A SUMMARY OF TENDING RECOMMENDATIONS COMMON TO THE MANAGEMENT OF WHITE PINE AND RED PINE

White Pine

This species must always be established with a nurse crop. An overstory of hardwoods, softwoods or a mix of species is a prerequisite to good tending practices. A mixed stand reduces sprouting, weevil damage and the incidence of *Ribes* spp. The regulation of shade, cover, density and rate of growth of the white pine seedlings is an integrated stand development concept. A maximum of 50% sunlight is the most practical compromise for seedling growth and weevil control. The silvicultural control of stand density and light intensity must be maintained for the first 20 years of the plantation's life. This control is best attained through gradual or periodic (every 5 years) release treatments which are selective for the individual stems that should be removed. Mechanical or hand release is more certain to obtain the desired release results than are silvicide applications by aerial or ground spraying of foliage. The timing of release is very important; the pine leader should show a gradual reduction in growth as a result of suppression but should be vigorous enough to respond and compete with brush or other tree species. White pine should never be completely exposed after release; side shade and competition, as well as higher, but light, overhead shade should be maintained for early natural pruning as well as weevil control. Chemical release should not take place until the overtopping of brush is prevalent. Finally, the species should not be managed on very fertile soils since tending practices become very costly as well as unproductive owing to continuing competition problems.

Red Pine

Some shade, especially during the establishment phase, is beneficial. An open crown canopy that permits a minimum of 50% full sunlight to reach the seedlings can be tolerated for the first 10 years of the plantation. Extensive side shade and competition should be eliminated within 2 to 5 years after planting. Several releases may be necessary during the first 20 years of the plantation. Red pine lends itself fairly well to chemical release although large areas have traditionally been hand released. No special site conditions for tending seem to be necessary except adequate exposure to direct sunlight once the species is established. Red pine, like white pine, should not as a rule be planted on the very fertile soil types as these sites may prove unmanageable.

AN INTERMEDIATE CUTTING IN PINE MIXEDWOODS

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An average net sawlog yield gain of about 8000 fbm/ha after 20 years is indicated as a result of improvement cutting in two-storied pine mixedwoods. Logging damage resulted in a gross volume loss of 0.25% after 5 years; this loss is expected to increase with time. The establishment of uniform shelterwood management by improvement cutting resulted in minimal effects on stand aesthetics as assessed by numerical index.

Un gain moyen net d'environ 8000 pieds-planches/ha dans le rendement des grumes de sciage après 20 ans résulte de coupes d'amélioration dans des peuplements mixtes à deux étages. Les dommages dus à l'exploitation causèrent une perte brute de 0.25% du volume après cinq ans; on s'attend à une augmentation de cette perte avec le temps. L'établissement d'un aménagement uniforme par coupes progressives via les coupes d'amélioration eut des effets minimes sur l'esthétique des peuplements tel qu'évaluée par indice numérique.

BACKGROUND

In 1971 an improvement cutting was applied to 121.4 ha of pine mixedwood forest at the Petawawa Forest Experiment Station near Chalk River, Ontario. The cutting was carried out as a commercial tree-length logging operation using wheeled skidders.

This report deals only with the two-storied component of the mixedwood complex--about two-thirds of the entire area treated--which is characterized by an understory of eastern white pine (*Pinus strobus* L.) with small amounts of red pine (*P. resinosa* Ait.), white spruce (*Picea glauca* [Moench] Voss), and balsam fir (*Abies balsamea* [L.] Mill.), and an overstory of aspen (*Populus tremuloides* Michx. and *P. grandidentata* Michx.) with scattered dominant and codominant white and red pine. The understory averaged 55 and the overstory 80 years of age in 1971. Understory pine ranged up to 30.48 cm DBH and 18.3 m in height, with 25% to 50% live crown.

Total volume averaged 211.32 m^3/ha, of which 63% was removed. About 16% of the cut was sawlog material and the rest was pulpwood.

Details of the project plan are outlined in an unpublished report by Brace[1]; establishment results covering stand descriptions, the silviculture and logging systems, crew supervision and training, initial logging damage, projected sawlog yield increase, and costs and returns from the operation are presented by Brace and Stewart (1974).

The main objective of treatment was to increase the growth and yield of understory white pine from existing middle-aged pine mixedwood stands for use as sawlogs in the ensuing 20-30 years, and to prepare the stands for shelterwood management. Amenity values were given special consideration in all aspects of the work, in view of their importance in the pine-mixedwood region.

This paper presents 5-year results of treatment in terms of sawlog yield, logging damage, and amenity effects.

RESULTS AND DISCUSSION

Growth

A series of sample plots was established on the area according to a randomized block split-plot design. The experimental design[2] provided a test of treatment effect in terms of basal area growth for residual softwood growing stock levels of 6.9, 11.5, and 16.1 m^2/ha of basal area. There were five replications of each treatment level. Analysis of variance indicated a very highly significant treatment effect after 5 years, and multiple comparisons (Tukey 1953) indicated significantly less growth in the lowest density class. Growth data are given in Table 1.

The growth potential of released understory white pine is clearly demonstrated for the initial 5-year period of the study.

Sawlog Yield

Diameter growth regressions and mortality percentages were derived from the plot remeasurements for use in stand table projections

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[1] Brace, L. G. 1972. Assessing silvicultural stand improvement alternatives in pine mixedwoods. 1. Costs and effects of treatment. Project plan and progress report. Can. For. Serv., Chalk River, Ont. Intern. Rep. RS-27. 31 p.

[2] Provided and analyzed by Dr. A. Douglas, Computing and Applied Statistics Directorate, Department of the Environment, Ottawa, Ontario.

Table 1 Mean volume, basal area and growth[a] - softwood residual - 2.54 cm + DBH

Treatment	1971 density class (m^2/ha)	Volume 1971 (m^3/ha)	Volume 1976 (m^3/ha)	5-year volume growth (m^3/ha)	Basal area 1971 (m^2/ha)	Basal area 1976 (m^2/ha)	5-year basal area growth (m^2/ha)
Treated	6.9	48.98	65.49	16.51	7.389	9.296	1.907
Control	6.9	56.40	67.73	11.33	7.796	8.864	1.068
Treated	11.5	87.39	111.32	23.93	12.111	14.707	2.596
Control	11.5	83.48	99.22	15.74	11.821	12.973	1.152
Treated	16.1	121.96	143.09	21.13	15.813	18.269	2.456
Control	16.1	126.72	147.57	20.85	16.977	18.416	1.439

[a] Data compiled using standard Permanent Sample Plot techniques for the Petawawa Forest Experiment Station, based on plot measurements in 1971 and 1976. Volumes from Anon. (1948).

(Husch 1963) to estimate sawlog yield increases over a period of 20 years.

Table 2 shows sawlog yield projections for released understory white pine for 10 and 20 years following treatment. Data indicate a considerable gain in sawlog yield, averaging 7985.0 fbm/ha in 20 years, with a maximum gain of 9495.0 fbm/ha for the mid-density class. These results compare closely with those projected by Brace and Stewart (1974) who used other sources of growth and mortality data.

Logging Damage

Logging damage was assessed after treatment in 1971 (Brace and Stewart 1974) to determine the relative amounts of damage sustained from felling and skidding operations and to provide a basis for later pathology studies of such damage. Results in 1971 indicated about 6% fatal damage to understory residual pine, 14% nonfatal, and 80% undamaged. Fatal damage was concentrated in trees 12.70 cm DBH and smaller. Damage was considered acceptable in terms of the practicalities of skidder logging.

During the fall of 1976 the wounds on living, damaged, residual white pine were examined to determine the kind and extent of stain and decay development over 5 years[3]. The following seven wound types were photographed, sectioned, and examined in the field.

Felling:

1. damage on butt log--bark removed

2. removal of 50% + green crown

3. broken top--2 yr +

4. root spring--10° +

Skidding:

1. bark removed within 0.3 m of root collar

2. damage on butt log--gouged into wood

3. damage on butt log--bark removed.

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[3] Whitney, R. D. and L. G. Brace. 1977. Internal defect resulting from logging wounds on residual white pine trees. (Unpubl. ms)

Table 2. Projected sawlog volume, growth and yield[a] - softwood residual

1971 density class (m^2/ha)	Treated							Control							Yield difference		
	Volume (fbm/acre)[b]				Growth (fbm/acre)[b]			Volume (fbm/acre)[b]				Growth (fbm/acre)[b]					
	1971	1976	1981	1991	1971-76	1971-81	1971-91	1971	1976	1981	1991	1971-76	1971-81	1971-91	5 yr	10 yr	20 yr
6.9	1751	2728	4071	8090	977	2320	6339	1819	2729	3519	5186	910	1700	3367	67	620	2972
11.5	2959	4347	6106	10912	1388	3147	7953	2695	3477	4439	6850	782	1744	4155	606	1403	3798
16.1	4094	5683	7661	12752	1589	3567	8658	4507	5645	6975	10352	1138	2468	5845	451	1099	2813
											Mean yield difference (fbm/acre)[b]				375	1041	3194

[a] Sawlog data obtained from taper curves in Table 93 of Anon. (1948) - Form Class 65 - applying average 1971 heights and Ontario Log Rule Volumes.

[b] 1 fbm/acre = 2.5 fbm/ha

Decay and stain associated with each wound were described, and stem and decay dimensions were recorded. Samples were taken to the laboratory for culturing and identification. Sample numbers varied from 6 to 10 for each wound type.

Gross tree volume loss due to wound-related decay averaged 0.25% after 5 years. Milling losses might bring the total to 2-3%. This is not considered serious at present.

On the average, 30% of all wound types had some decay associated with them after 5 years; 70% of all gouge wounds had advanced decay. About 19% of the trees contained decay not related to logging wounds.

The size of wound did not affect the incidence of infection except for felling scrapes on the butt log, where infection incidence increased with wound size.

Wood stain was associated with 63% of all wounds. The largest proportion of decay and stain was associated with felling scrapes, skidding gouges, and broken tops--1.19, 0.87, and 0.80% of gross tree volume, respectively. Gouges were the most serious source of decay.

The implication for total decay loss in residual white pine in 20 to 30 years is a matter of speculation and will depend on the rate of development of such potentially fast-growing fungi as *Stereum sanguinolentum* (Alb. and Schw. ex Fr.) Fr. and *Coniophora puteana* (Schum. ex Fr.) Karst., which, though not commonly reported in the past in white pine, were the most frequently isolated pathogens in the samples.

Both sunscald and compression wood occurred as a result of treatment, but they appeared to be of minor importance.

Results indicate that efforts to control the incidence of felling scrapes, broken tops, skidding gouges and skidding scrapes during logging will tend to reduce future wood decay resulting from logging damage.

Amenity Effects

The amenity effects of the improvement cut were assessed in 1976 (Smyth and Methven 1978) using a numerical index designed to measure aesthetic impact at the stand or plant community level. The index employs the following measures of visual attractiveness:

1. species diversity and variety

2. structural complexity--vertical and age

3. view--within the stand

4. slash visibility

5. pattern--uniformity and regularity of spacing

6. boundary form--straight or naturalistic

The numerical assessment showed a marginal reduction in the aesthetic appeal of two-storied mixedwoods as a result of treatment--2% of maximum theoretical reduction. This compares with a 10% reduction for strip shelterwood and a 60% reduction for block clearcutting. The greatest decrease in aesthetic appeal resulted from an ingrowth of aspen suckers following treatment, which reduced the view within the stand. There was also a negative effect caused by a structural change from a two-storied to a single-storied stand.

In general, the impact of the treatment on the aesthetic appeal of two-storied stands was relatively small, and amenity loss resulting from aspen suckers should be reduced in the near future as suckers are shaded out by the developing pine canopy.

SUMMARY AND CONCLUSIONS

Improvement cutting in two-storied pine mixedwood stands resulted in a projected average sawlog yield gain of 7985.0 fbm/ha in 20 years, reflecting the growth potential of 55-year-old healthy white pine when released from overstory competition. Stands such as these are a potential source of increased white pine sawlog volume within the next two to three decades.

Decay related to logging damage was 0.25% of gross tree volume after 5 years, and could amount to a 2% to 3% net volume loss after milling. Such losses are relatively minor after 5 years but could be considerably greater in 20 to 30 years when the trees are ready for harvest. Efforts should be made to reduce the incidence of felling scrapes, broken tops, skidding gouges, and skidding scrapes during logging, because these appear to be the main source of decay.

The reduction of amenity values as a result of improvement cutting in two-storied pine mixedwoods to establish uniform shelterwood management was only about 2% of the maximum theoretical reduction, in comparison with 10% reduction for strip shelterwood and 60% for block clearcutting. This indicates the value of uniform shelterwood silviculture in minimizing conflicts between a variety of forest-land users in the pine mixedwood region.

ACKNOWLEDGMENT

I wish to acknowledge the assistance of Mr. W. M. Stiell of the Petawawa Forest Experiment Station, Chalk River, Ontario, and of Dr. W. D. Johnstone of the Northern Forest Research Centre, Edmonton, Alberta, in expediting the preparation of growth and yield data used in this report.

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DISCUSSION

Question: Is there any thought being given to developing a wound classification by size classes?

Answer: Developing guidelines would be useful but there has been no move in that direction. More sampling would have to be done to derive such guidelines. In general, the larger and deeper the wound the more serious it is. But any wound that breaks the fibres is serious.

Question: How do you guarantee that the cutters will do the careful job that is required?

Answer: In any cutting operation there must be goodwill and cooperation among the cutter, the skidder operator and the forest manager. A system of penalty clauses does not seem to work.

In discussing the decay associated with logging damage to white pine, R.D. Whitney of the Great Lakes Forest Research Centre gave the following outline of the results obtained.

Before going into details of what we found the following preliminary remarks may be needed to clarify the situation.

1. Fungi were found to result in two types of damage to wood:

   a) Decay - where the wood is weakened and eventually destroyed.

   b) Stain - where the wood is discolored but not weakened and the stain may be the incipient stages of decay.

Both types of damage develop slowly and require many years before decay is well advanced.

2. Three general types of logging wounds were examined:

   a) Gouges - where the wood fibres are broken and are usually caused by the skidder blade or cable.

   b) Scrape - where the bark is removed but the fibres are not broken. This is usually caused by trees falling, logs rubbing against standing trees, or skidder tires rubbing against standing trees.

   c) Broken tops, branches or roots. This is usually caused by trees falling and by root spring.

The incidence of decay found on the area five years after the logging operation will be shown for the three types of logging wounds mentioned.

a) Gouges
Ten gouges were examined and decay fungi were isolated from seven of the ten. In all seven, species of wood-rotting fungi were found.

The general conclusion with respect to gouges is that the larger and deeper the gouge the more liable it is to be infected.

b) Scrapes
Twenty-six scrape wounds were examined. Decay fungi were isolated from eight of the wounds (about 30%). Again, seven species of fungi were found. Some wounds had two fungi developing.

The larger scrapes and those in contact with the ground are most likely to be attacked by fungi.

c) Broken Tops, Branches and Roots

1. Broken Tops: Six tops were examined and four were infected. Four different fungi were isolated. The larger the broken top the more susceptible it is to infection.

2. Branches: Thirty specimens were examined. Cultures were taken from ten of them but no decay fungi were isolated. Many of the branches were stained.

3. Roots: Six sprung roots were examined and two of these were found to be infected with three fungi. One of these fungi is capable of rapid growth in other tree species, so it is logical to assume that it can develop rapidly in white pine.

In discussing fungi it should be noted that the wound fungi were somewhat different from those obtained from white pine heartwood of living trees in decay studies. Several species that occur only in dead trees were isolated. It is presumed that these fungi will not develop extensively from the wound area.

To sum up: the more extensive the logging wound the more extensive the decay.

GUIDES TO GROWTH IN RED PINE PLANTATIONS

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Permanent sample plot information has been used in two ways. Marking guides were established for intermediate thinnings using plot growth records as examples of past management. Response of younger stands, thinned to variable stocking levels, can be estimated from growth tables made from the plot data.

On a utilisé de deux façons l'information provenant de placettes d'échantillonnage permanentes. Des lignes directrices concernant le marquage des arbres furent établies pour les éclaircies intermédiaires en se servant d'archives sur la croissance des placettes comme exemples d'aménagements antérieurs. On peut évaluer la réponse des jeunes peuplements, éclaircis à divers niveaux, à partir de tables construites avec les données sur la croissance provenant des placettes.

INTRODUCTION

Red pine (*Pinus resinosa* Ait.) has been planted in southern Ontario for the last half century. Many of the earlier plantations were established on submarginal farmlands, abandoned because the sites were too dry. Later plantations have been established on similar or better sites ranging up to 4 on Hills' (1950) moisture regime scale. Site class usually ranges from 19.8 m to 24.3 m at 50 years with a few stands in the 25.9 m class.

Red pine is generally thought to be a very uniform species; it is often assumed to be an easy species to deal with silviculturally. Consequently, many treatments have been prescribed or recorded for mixed pine plantations throughout which red pine has been expected to perform uniformly. At least three treatments that influence growth have commonly been varied during the years since planting of red pine became widespread in Ontario: these are spacing, species mixture and thinning method. When these treatments are combined with normal variations in site and the density of the residual stand is changed at each successive thinning, the resulting stands can acquire some distinctly non-uniform characteristics.

We have used data collected from stands of this variety in attempting a) to prescribe stand treatments at the local management level, and b) to analyze growth and yield for forest regulation purposes. The aim, of course, is to grow stands that allow a greater number of trees per hectare to be used for the more valuable products (e.g., construction posts, utility poles, sawtimber) rather than for pulpwood.

USE OF DATA

Control of the older permanent sample plots (P.S.P.s) in Ontario's county forests was transferred in 1962 (at the time of their fourth thinning) from the then Reforestation Division to the Forest Research Branch. The plots were located in pure red pine stands or red and white pine (*Pinus strobus* L.) mixtures, either in alternate rows of each species or in 64-tree blocks of each arranged in checkerboard fashion. The planting space was nominally 1.68 m x 1.68 m with some trees or rows as close as 1.52 m x 1.52 m. Thinning was begun in these stands in 1947, at 23 or 24 years from planting, and has continued at 5-year intervals since then. Trees are chosen for cutting by either of two methods: individual tree selection from below or the removal of poorer quality stems. Residual stand density is intentionally varied but the thinnings on most of the plots tended to be much lighter in the early days than they are at present in plantations managed by the Ministry. The stands sampled by these plots are now over 50 years of age and have had six thinnings.

A later series of permanent plots, established since 1965, is located in younger pure red pine on county forest properties. The planting distance in these stands was usually 1.83 m x 1.83 m although mortality had increased this spacing in some cases before thinning was begun. Several of the stands were 28 to 36 years old by the time they were given their first thinning. In all cases, the first thinning removed regularly spaced rows of trees, reflecting present practices, while the second was a row thinning, a cross-row thinning, or a selection cutting. Neither of these conditions covers the complete range of variability encountered in the field. Nor were there sufficient data in each series upon which to base growth or yield tables independently. To overcome these difficulties, the data from both series of plots have been pooled to cover as wide a range of sites and thinning levels as are available in southern Ontario. The plot data collected at each 5-year remeasurement and thinning basically provided estimates of gross total stemwood volume. Form-class volume tables (Anon. 1948) were used for volume determination throughout. Volumes removed in thinning and by mortality were recorded systematically. Thus periodic growth, the independent variable analyzed in the production of growth tables, was obtained.

The other immediate use for the data was to determine prescriptions for silvicultural treatment of younger stands. Here, the older permanent plots served as demonstrations of the particular form of management used in the stands over a period of several thinnings. The levels of basic stand and stocking figures realized on the individual plots before and after thinnings were significant for this purpose. They have been used in setting out a guide to thinning levels in younger stands. In addition, at the last two times of thinning, each tree in the older plots was assessed for its pole potential. Factors such as branch size and stem crooks were observed as well as ground-line diameter and length to a minimum top diameter. Pole material was considered important since it gives the best return per unit volume of stemwood.

A few direct comparisons of different management methods, based on the number of potential pole trees in each plot, were possible. One such comparison, presented earlier by the Forest Research Branch (Anon. 1974), showed the following result. At 50 years of age the return from poles in a stand originally planted to red and white pine in alternate rows was more than twice as great as that from a pure red pine stand given the same level of management. The difference stemmed directly from the more rapid growth in diameter of red pine in the mixed plot. While the number of plots useful for such comparisons is very limited, this particular result has been corroborated in the practical marking of similar stands for commercial pole cutting operations. This type of information from the permanent sample plots has been combined with District experience on pole operations in the latter part of this paper.

YIELD AND GROWTH TABLES

Most of the wood cut from the plots to date has been in the form of pulp, posts or short construction poles. Gross total volume has, therefore, been the main criterion used in the preparation of growth and yield tables until more pole data are available. This is normal. However, the objective in this case was to develop tables for estimating volume growth in stands of different stocking. The variable density approach is a feature not found in normal yield tables. It has the key advantage that "normal" stocking need not be established nor the subsequent estimate of "deviation from normal" made when relating to actual stand conditions. On the contrary, the tables should be useful for estimating either long-term or short-term growth responses in stands for which a series of thinnings, perhaps to different levels of stocking, have been proposed.

Consequently, in 1976, Professor V. G. Smith of the Faculty of Forestry and Landscape Architecture at the University of Toronto was engaged to produce such tables.[1] Stand information from a total of 231 growth periods from 63 plots was available for analysis. Each set of measurements included thinning, post-thinning, mortality and end-of-period records in terms of number of stems, basal area and gross volume on an area basis, as well as stand age, average diameter, dominant height and an estimate of site index.

Stepwise regression was used to develop equations which estimate present stand yield and volume growth during the subsequent 5-year period. The background of these equations and the tables based on them are available from the Forest Research Branch, Ontario Ministry of Natural Resources, Maple, Ontario. Samples of these tables are included as Appendices A to D of this paper.

Entry into all the tables is basically by dominant height and basal area. Appendix A gives the present stand volume directly with no additional consideration of site except as accounted for by stand height. The amount of volume growth expected over the ensuing 5-year period is given in Appendix B. It varies with two factors, site index and the anticipated thinning percent. When the desired levels of these two parameters have been determined[2], entry to the body of the table is by dominant height and basal area recorded before thinning.

It is at the point of establishing which thinning percentage table to use that the management prescription comes into play. If a guide that employs basal area and makes use of past experience with older plots is available, as outlined in the next section, it may be used directly. Alternatively, where the effects of apparently desirable sequences of thinning levels are unknown, estimates of the simulated resulting growth may be ascertained. The sequence of thinning giving the best total volume production may then be selected for use.

In either case, it is usually desirable that growth be estimated over a period of more than 5 years. Therefore, Appendices C and D are required so that Appendix B can be re-entered at increased levels of height and basal area. Appendix C gives the estimated 5-year growth in basal area which, as will be noted, is independent of site class. Appendix D shows the increase in dominant height expected in the corresponding 5-year period. Both these figures must be added to the figures used to enter Appendix B tables at the start of the previous growth period. The basal area prescription for the second 5-year period is consulted and the thinning percentage determined. Appendix B is re-entered at the appropriate

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[1] Smith, V. G. 1976. Red pine plantation yield tables for southern Ontario. Ont. Min. Nat. Resour., For. Res. Br., Unpubl. Rep. 11 p. + appendices.

[2] Site index may be estimated from Appendix E. Thinning percentage is obtained in terms of basal area.

thinning percentage table to obtain volume growth over the second 5-year period. The whole process is then repeated to cover as many successive growth periods as desired. The Appendix tables have been set up to provide a versatile tool for the management forester to use in assessing his own thinning prescriptions. However, they should be used only for the purpose intended. The sole purpose of Appendices C and D is to provide estimates for re-entering the volume growth tables. For differing reasons, the values for basal area growth underestimate actual recorded amounts, while the height growth values tend to be overestimates.

As a check on the use of growth tables, two plots not used in preparing the tables have been reviewed. The plots were in different portions of the same 47-year-old plantation in Mono Township, one estimated to be on site index 18.6 m and the other on site index 25.0 m. The stand had received one thinning at 32 years of age, 15 years before the plots were established. Stand data at time of thinning were reconstructed from district thinning information, stump counts and stem analysis for diameter and height growth.

Three estimates of total volume were made for each plot as shown in Table 1. The first was a direct estimate using local volume-diameter curves from stem analysis. The second was the more typical estimate arrived at by the application of a volume table to the measured height-diameter relationships on each plot. The third estimate was obtained by the use of the yield and growth tables as outlined above. Differences between the first and third estimates are indicated in Table 2. Percentage differences of the order shown should be expected from the use of these tables.

THINNING GUIDELINE

The second and more direct use of the permanent sample plot information has been in the establishment of a practical marking guide to be used in thinning prescriptions. The red pine in many of the earlier plantations have reached the size at which they can be used as poles. Prescription thinning for poles in these stands must be based on a guide that considers future stand development as well as rapid diameter growth. The merits of management for pole production are apparent in the generation of greater net revenue from higher stumpage values and in satisfaction of the demand for the larger classes of pole. At the same time, the hazards of management for pulpwood on short rotations may be avoided.

The objective in establishing a guide for thinning levels has been to produce stands from which an optimum number of large poles may be cut. At the same time, the residual stand should provide for a full range of management options.

Table 1. Total volume of two red pine plots in Mono Township, Ontario at 0, 5, 10 and 15 years after thinning.[a]

Plot	Site index (m)	Method of volume estimate		Stand age (yr) 32	37	42	47
				Volume (m^3/ha)			
1	18.6	Stem analysis	(1)	178.1	231.5	291.1	346.8
		Ht-Diam and V.T.	(2)	169.6	226.4	278.0	342.0
		Growth tables	(3)	161.4	214.6	279.3	340.5
		Difference (1-2)		8.5	5.1	13.1	4.6
		Difference (1-3)		16.8	16.9	11.8	6.3
		% Difference (1-3) as % of (1)		9.4	7.3	4.1	1.8
2	25.0	Stem analysis	(1)	252.0	338.7	429.5	508.6
		Ht-Diam and V.T.	(2)	232.9	323.5	413.0	496.4
		Growth tables	(3)	233.3	302.8	386.3	465.8
		Difference (1-2)		19.1	15.2	16.5	12.2
		Difference (1-3)		18.7	35.9	36.2	42.8
		% Difference (1-3) as % of (1)		7.4	10.6	8.4	8.4

[a] Plot 1 thinned by 34% at age 32; plot 2 thinned by 30% at age 32.

With these objectives in mind, C. J. Heeney, provincial silviculturist, has outlined a set of general rules for management of red pine plantations. In 1976, after reference to the older permanent sample plot information, the outline for pure red pine management was reviewed with staff of the Central Region and revised (Anon. 1976).

Recently, an inventory of the pole potential in southern Ontario plantations was conducted by Central Region staff in cooperation with industry[3]. The critical features of "pole trees" were identified by reference to CSA specifications for jack and red pine poles. Basically, these were estimates of standing tree sizes (DBHOB and merchantable height) and quality necessary to produce poles of various grades.

Several considerations emerged from these activities and from the experience of marking for pole cuts in the Central Region. Initially, the *planting spacing* between rows (2.13 m) and between trees in rows (1.33 m) must be specified. Between-row spacing must be sufficient to provide good access for the self-loading skidders used in pulp thinnings.

[3] Irwin, W. G. 1976. A survey of the long-term pole production potential of the Agreement Forests in southern Ontario, 1976-2005. Ont. Min. Nat. Resour., For. Manage. Sect., Central Region. Unpubl. Rep. 6 p. + appendices.

Table 2. Model of thinning sequence in pure red pine plantation

(Yr)		Time of measure-ment[a]	Avg diam (cm)	Trees/ha	Basal area (m^2/ha)	SDI	Thinning
25-28		B.T.	13.7	2152	31.9	803	
	(1)	T.	13.7	719	10.6	264	remove 1/3 of rows
		A.T.	13.7	1433	21.3	539	pulpwood
33-35		B.T.	17.8	1433	35.6	811	
	(2)	T.	15.0	622	10.8	267	select 43% stems
		A.T.	19.8	811	24.8	544	pulpwood
42-45		B.T.	24.1	811	37.0	746	
	(3)	T.	21.3	267	9.4	202	select 33% stems
		A.T.	25.4	544	27.6	544	pulp and poles
50-55		B.T.	29.2	544	36.5	680	
	(4)	T.	27.2	121	7.1	136	poles
		A.T.	29.7	423	29.4	544	
58-65		B.T.	32.3	423	34.6	620	
	(5)	T.	27.7	67	4.1	076	poles
		A.T.	33.0	356	30.5	544	
66-75		B.T.	35.8	356	35.8	618	
	(6)	T.	31.0	52	3.9	074	poles
		A.T.	36.6	304	31.9	544	
76-87		B.T.	39.6	304	37.4	618	
	(7)	T.	37.6	40	4.3	074	poles
		A.T.	39.9	264	33.1	544	
88-100		B.T.	42.9	264	38.6	618	last pure pole cut
	(8)	T.	42.9	29	4.6	074	piling beyond this point
		A.T.	42.9	235	34.0	544	

[a] B.T. - before thinning   T. - thinning   A.T. - after thinning

Total tree numbers must be large enough to allow for mortality (15% considered reasonable) and still provide adequate stocking for later stand manipulation.

Next, emphasis is placed on continued rapid *diameter growth*. This is because the diameter at ground level of a pole (1.52-1.83 m from the stump) is far more critical as a determinant of pole quality than is pole length. The upper diameters of pole trees found in most plantations indicated the potential for a higher class of pole than was supported by the minimum "ground-line" diameter.

However, the stand must not be opened up excessively at the first or second thinning in order to get fast diameter growth. Since the first and possibly the second thinnings may be mechanical, the number of trees left for later selection of pole trees could be reduced too greatly. Heavy thinning might also induce branch retention so that *knot restrictions* are surpassed in pole grading.

Intermediate thinnings should be selective, though not necessarily from below. A cardinal rule followed at these thinnings is that the volume of pulp and number of poles removed per unit area should be sufficient for a *commercial operation*. Absolute numbers of poles per unit area, average stand diameter, and the percentage of total stems (or their basal area) to be removed, have all been used to describe the limit of commercial viability. Generally, an average diameter of 23 cm should allow an integrated pulp-pole operation, while an average diameter of 25 cm would be needed to support a pole cut alone.

A corollary limitation, especially for intermediate thinnings, is that the residual stand retain a specified level of stocking and spacing. This has led directly to the development of prescription marking for pole management. The intent is to maximize diameter growth on the largest number of trees balanced against an adequate stocking for a future sawlog stand.

The Marking Guide

Most of the practical requirements for commercial thinnings outlined above may be determined for a particular plantation by inspection or sample measurement. The limiting aspect, which requires experience when marking for thinning, is biological as opposed to commercial. It relates to the expected growth rate of the stand after the thinning has taken place. The residual stocking level and the spacing of the remaining trees have appeared, therefore, as the main conditions to be defined in a thinning guide.

The examples afforded by the permanent sample plots have been valuable for determining the levels of both these factors. During the pole survey each plot was reassessed and a judgment made as to its suitability for pole production. The two plots which appeared best for pole management were located in York County Forest at Vivian. The most heavily thinned of the pure red pine plots was P.S.P. 2, and the next most heavily thinned in that series was P.S.P. 37, which was planted to red and white pine in alternate rows. The most heavily thinned red and white pine plot, P.S.P. 38, was not considered further since the trees in it had developed excessive branch diameters. The records of basal area, total stems, average diameter and stand density index (SDI)[4] (Reineke 1933) for the two selected plots have been related in different ways to form the proposed guide.

Residual basal area was used as a guide at the first three thinnings on these plots. An initial attempt was made to relate residual basal area and numbers of trees to stand age. It was immediately apparent that this would not be a practical approach because of the differential effect of site on the development rate of the other two factors.

The relationship of basal area to average diameter (Fig. 1) is proposed as the most useful for field application. It has the added advantage that classes of SDI, a function of average diameter, can be indicated in the same figure. The measurements taken at 5-year intervals from 1947 through 1977 on P.S.P. 2 and P.S.P. 37 are plotted in Figure 1 for both before and after thinning. Residual SDI was used as the marking guide at the last three thinnings. The residual values for both plots fell within the range of SDI 507 to 581. Basal areas within this range of SDI are proposed for future intermediate thinnings.

Basal areas prior to thinning are more variable. They would usually lie below the heavy jagged line in Figure 1. Ideally, stands would be thinned before their basal areas exceeded this upper limit. It has been the experience in the Southern Region that most of the stands now due for their first pole thinning are far more heavily stocked (because of denser planting) than is desirable. They will require two consecutive thinnings to reduce them to approximately SDI 544.

Approximate pole production from one of several plausible model stands is estimated in Table 2. The initial number of trees conforms to the current OMNR minimum stocking level at age 25 which was mentioned earlier. Thinnings are proposed as follows: from SDI 803 up to an average diameter of 17.8 cm; from SDI 741 up to 25.4 cm; from SDI 680 up to 30.5 cm, and below SDI 618. The total number of poles produced is about 383 in all classes. Some of the trees cut in the last thinning could be used for piling.

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[4] SDI is based on the relationship between number of trees per hectare and their average diameter, and is read at the intersection of the regression line and the 25.4 cm diameter as the number of trees per hectare at that intersection when plotted on logarithmic graph paper.

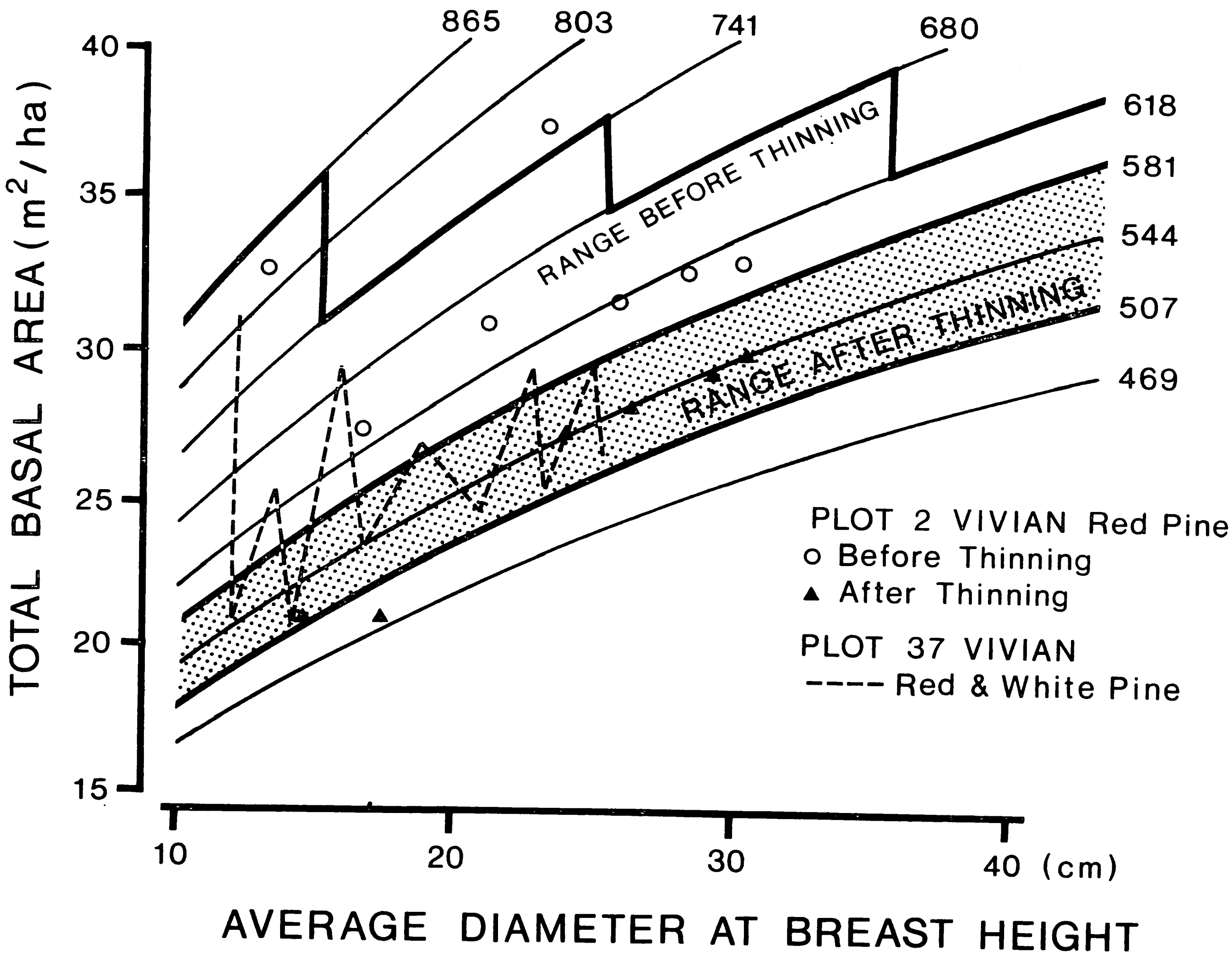

Figure 1. Thinning guide to stand density for pole management.

A thinning may be described in terms of the percentage to be removed of the number of stems, as for thinnings (2) and (3) in Table 2. Or, it may be desirable to express the cut as a percentage of the basal area removed. A combination of the two will indicate the type of selection, whether from below or a high-grading. The relationship between these two percentages, termed the thinning factor, is shown in Figure 2 where:

$$\text{Thinning factor} = \frac{\text{original stems as \% of residual}}{\text{original basal area as \% of residual}}$$

The immediate effect of a proposed thinning upon the average stand diameter is often used as a rule of thumb to estimate the intensity of thinning (or release). The thinning factor obtained from Figure 2 may be used to estimate this change in stand diameter. For instance, where the proportion of stems cut is the same as the proportion of basal area removed (as in a row thinning), the thinning factor is 1.00 and there is no increase in average diameter. However, for most intermediate thinnings, selection is mainly from below and the factor is usually larger than unity. Figure 3 provides data to assist the manager in deciding upon the type of thinning to prescribe for a given stand, and to show its effect in terms of stand diameter.

Marking to Prescription

Some of the experience in marking pine plantations for poles has been recorded recently in Huronia District. Five field trials of pre-marking cruising, prescription preparation and marking to prescription were carried out in 1977. At the time of these trials, residual basal areas and numbers of trees recorded for P.S.P. 2 were followed as guides. The plantations involved had previously received one or more thinnings, so that access to the stand was provided and a selection prescription was applicable.

Sample measurements were taken for each stand to be marked on a strip plot 80.5 m long by 10.06 m wide. Trees were calipered and their diameters were tallied by grade. Each red pine was graded A or B respectively, to indicate whether or not a pole might be cut from it either now or in the future. The white pine in mixed stands was classed on its potential as a long-term seed source. The number of stems and basal areas were compiled in the field for each diameter class on a unit area basis, and the average diameter of the stand was calculated.

A marking prescription was then written on the field tally sheet. Residual basal area was given priority following the guide (Fig. 1).

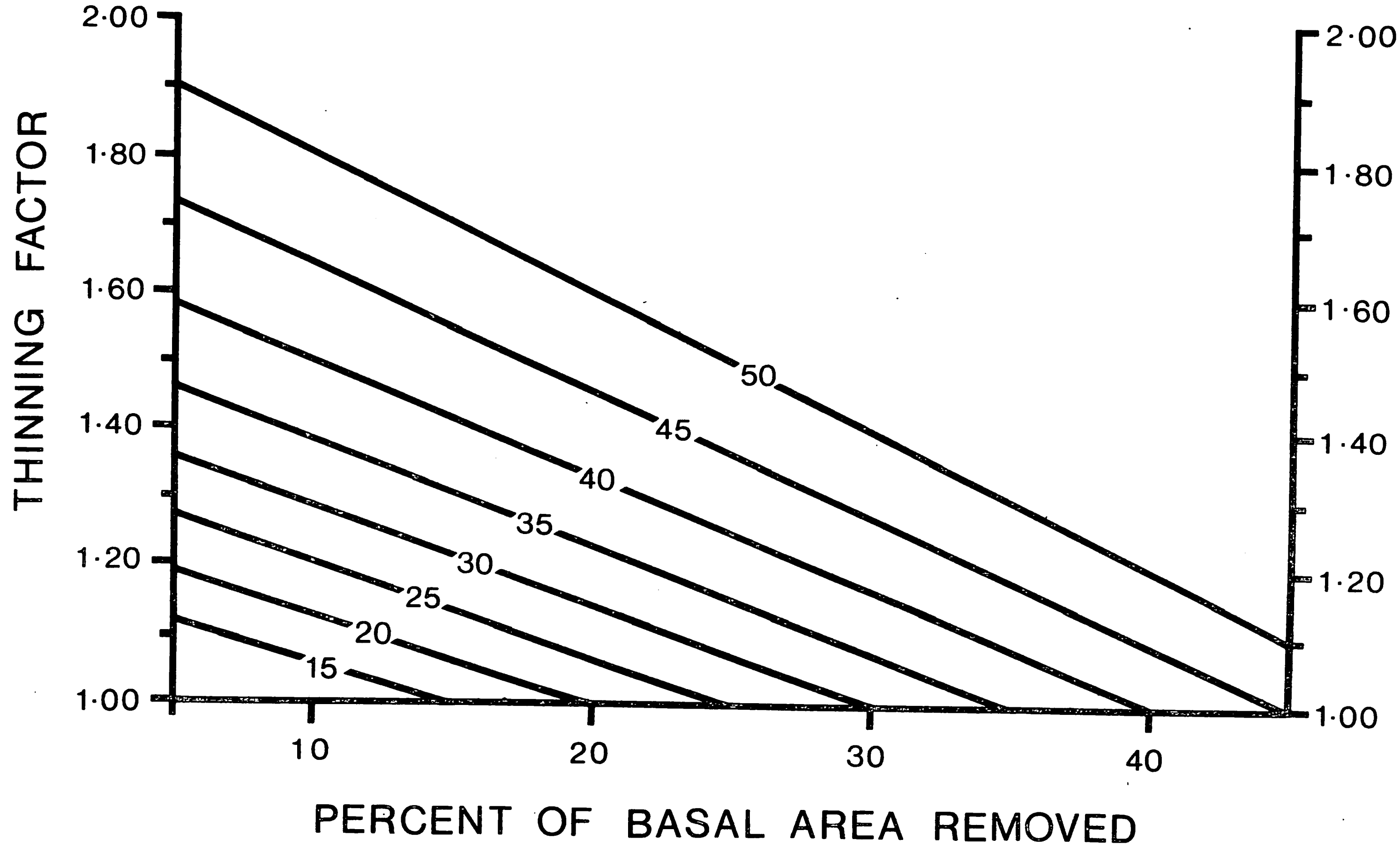

Figure 2. Thinning factors for varying percentages of stem and basal area removals.

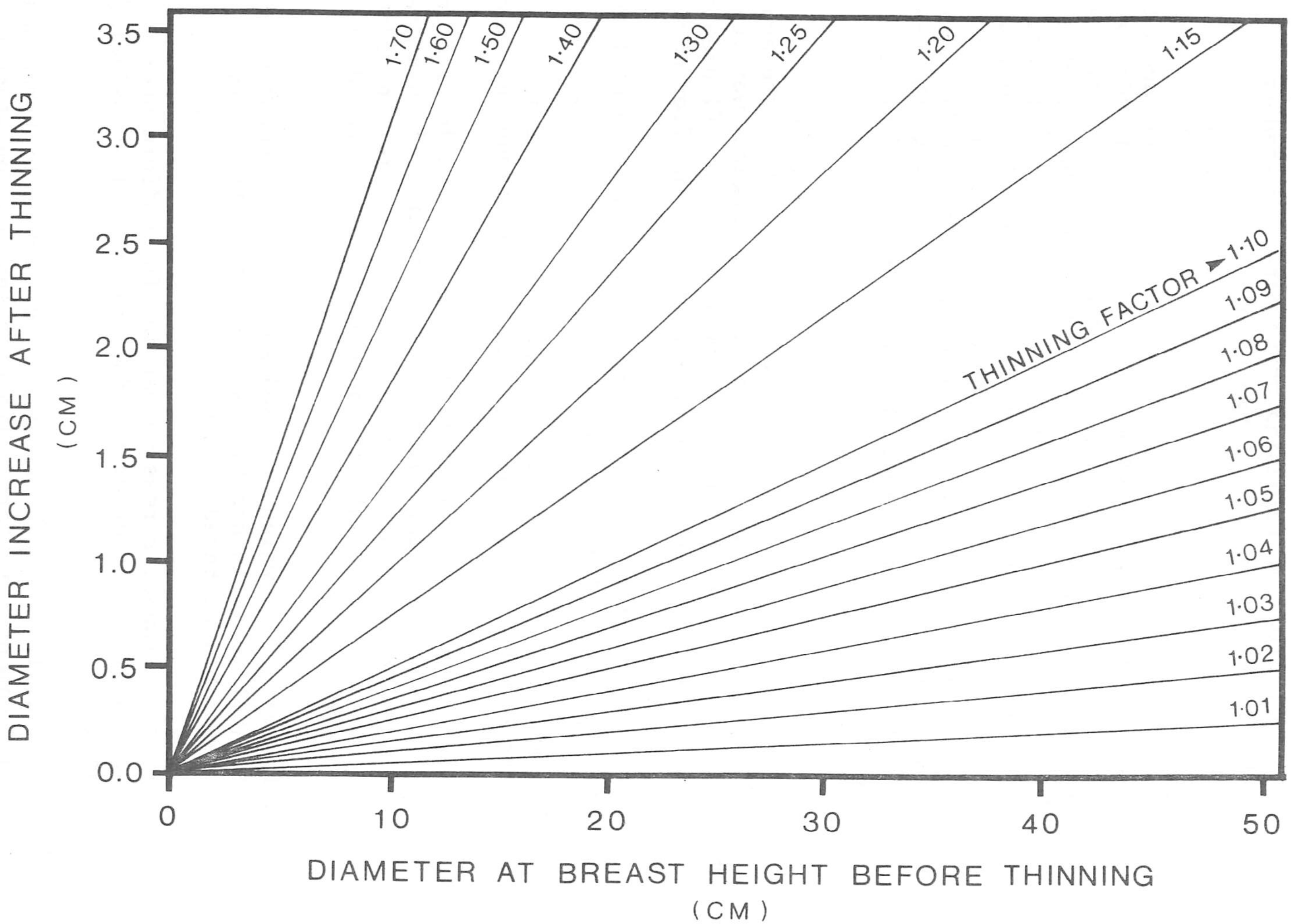

Figure 3. Diameter increase after thinning by thinning factor.

Diameter classes to be completely removed were specified. The corresponding total number of stems to be left was shown and the desired spacing was indicated. Any other considerations such as cutting larger diameter, grade B trees or releasing white pine for seed trees were also specified by diameter class. Two examples of prescriptions used are given in Appendix F: stand T-3A in a red and white pine planting, and stand T-4 in a pure red pine plantation. Then the whole section was marked by experienced men according to the prescriptions set out for each stand. Following the marking, a 0.40 ha square plot was laid out to straddle the original sample plot and to represent the "actual" stand condition. All trees within this area, both those marked to be cut and those to be left, were remeasured and regraded. Several comparisons were then available to check the expected results against the actual results of marking. Individual prescriptions to be used may be decided upon from the initial rectangular plot tally as in stand T-4. Alternatively, as in the case of stand T-3A, the prescription may be changed somewhat since the tally from the "actual" square plot was taken as the basis.

In either case, figures for the residual stand could be predicted (subtracted) from the cruise plot figures or from the square "actual" plot figures. Differences between such figures were the result of stand variation, not marking difficulty. The figures in Appendix F were obtained from the square plots put in after marking.

Appendix G provides a summary of the various sets of figures from each of the five stands marked.

From the results in Appendix G and from the experience gained in marking these field trials the following observations were made.

1. The considerable variability which occurred in plantations with smaller average diameter was primarily in diameter distribution rather than in basal area. Field procedures to test stand variability need to be incorporated in future trials.

2. Prescriptions which stressed spacing improvement were less subject to influence by sampling errors than were prescriptions based on diameter class alone.

3. In pole stands, stress on marking for uniform stem distribution produced better stands subject to less skidding damage.

4. Reliability of tree grading is influenced by human and environmental factors. Training sessions on stand tree grading are desirable to standardize preparation of guidelines and determination of stumpage prices.

5. Prescriptions for tree markers must be clear, must be listed in order of priority, and must provide practicable alternatives.

6. Marking results should fall consistently within ± 2.3 m^2/ha of the prescribed basal area. Therefore, in setting guidelines, a range of basal area and number of stems is desirable rather than a single specified level.

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APPENDIX A

Red pine plantation yield table (m^3/ha)

Dom ht (m)	Basal area per hectare (m^2) 7.4	8.4	9.3	10.2	11.1	12.1	13.0	13.9	14.9	15.8	16.7	17.7	18.6	19.5	20.4	21.4	22.3	23.2
7.6	64.6	74.5	84.2	93.7	102.9	112.0	121.1	129.9	138.6	147.3								
9.1	76.3	87.7	98.8	109.7	120.4	131.0	141.4	151.8	162.0	172.1	182.1	192.1						
10.7	88.0	100.8	113.4	125.7	137.9	150.0	161.8	173.6	185.3	196.9	208.4	219.9						
12.2			128.0	141.8	155.5	168.9	182.3	195.5	208.7	221.7	234.6	247.6	260.4	273.1	285.8			
13.7			142.5	157.9	173.0	187.9	202.7	217.4	232.0	246.4	260.9	275.3	289.5	303.8	318.0	332.1	346.2	
15.2				173.9	190.5	206.8	223.1	239.2	255.3	271.3	287.2	303.0	318.7	334.4	350.0	365.6	381.1	396.7
16.8				189.9	208.0	225.8	243.5	261.1	278.6	296.1	313.4	330.7	347.8	365.0	382.1	399.1	416.1	433.1
18.3				206.0	225.5	244.8	263.9	283.0	302.0	320.8	339.6	358.4	377.0	395.6	414.2	432.7	451.2	469.6
19.8					242.9	263.7	284.4	304.9	325.3	345.7	365.9	386.1	406.2	426.3	446.3	466.2	486.2	506.0
21.3					260.4	287.7	304.8	326.8	348.7	370.4	392.1	413.8	435.4	456.9	478.3	499.8	521.2	542.5
22.9							325.2	348.6	372.0	395.2	418.4	441.5	464.5	487.5	510.4	533.3	556.1	579.0
24.4							345.6	370.5	395.3	420.0	444.7	469.2	493.7	518.1	542.5	566.8	591.2	615.4
25.9										444.9	471.0	496.9	522.9	548.8	574.5	600.4	626.3	651.9
27.4										469.7	497.2	524.7	552.1					

APPENDIX B

Red pine plantation volume growth (m^3/ha)[a]

Site index = 19.8 (m)

Percent thinning = 25

Dom ht (m)	Basal area per hectare (m^2) 7.4	8.4	9.3	10.2	11.1	12.1	13.0	13.9	14.9	15.8	16.7	17.7	18.6	19.5	20.4	21.4	22.3	23.2
7.6	93.7	92.6	91.6	90.6	89.6	88.5	87.5											
9.1	92.4	91.2	89.9	88.7	87.6	86.4	85.3	84.1	83.0	81.8	80.7	79.6						
10.7	91.1	89.7	88.4	87.0	85.7	84.3	83.0	81.7	80.4	79.1	77.9	76.6						
12.2	89.9	88.3	86.8	85.2	83.7	82.2	80.7	79.2	77.8	76.4	74.9	73.5	72.0	70.6	69.2			
13.7	88.6	86.9	85.1	83.4	81.8	80.1	78.4	76.8	75.2	73.6	72.0	70.4	68.8	67.3	65.7	64.1	62.5	
15.2		85.4	83.5	81.7	79.8	77.9	76.2	74.4	72.6	70.8	69.0	67.4	65.6	63.8	62.1	60.4	58.6	56.9
16.8		83.9	81.8	79.9	77.9	75.9	74.0	72.0	70.0	68.1	66.1	64.2	62.3	60.4	58.5	56.7	54.7	52.9
18.3			80.3	78.0	75.9	73.8	71.6	69.5	67.4	65.3	63.3	61.1	59.1	57.0	55.0	53.0	50.8	48.9
19.8			78.6	76.3	74.0	71.6	69.4	67.1	64.8	62.6	60.3	58.1	55.8	53.6	51.4	49.2	47.0	44.8
21.3				74.5	72.0	69.6	67.1	64.7	62.2	59.8	57.4	55.0	52.6	50.3	47.8	45.4	43.1	40.7
22.9				72.7	70.0	67.4	64.8	62.2	59.6	57.0	54.5	51.9	49.4	46.8	44.3	41.7	39.2	36.7
24.4						65.3	62.6	59.8	57.0	54.3	51.6	48.9	46.2	43.5	40.7	38.0	35.3	32.6
25.9									54.4	51.6	48.7	45.8	42.9	40.0	37.2	34.3	31.4	28.6
27.4									51.8	48.9	45.8	42.7						

[a] Complete tables for thinning percentages of 0, 10, 20, 25 and 33 for site indexes 19.8 (65), 21.3 (70), 22.9 (75), 24.4 (80), 25.9 (85) available from author in English units.

APPENDIX C

Red pine plantation basal area growth (m^2/ha)

Site index = 19.8 - 25.9 (m)

Percent thinning = 25

Dom ht (m)	Basal area per hectare (m^2) 7.4	8.4	9.3	10.2	11.1	12.1	13.0	13.9	14.9	15.8	16.7	17.7	18.6	19.5	20.4	21.4	22.3	23.2
7.6	4.8	5.3	5.7	6.0	6.4	6.9	7.1											
9.1	4.6	5.1	5.5	5.7	6.2	6.4	6.7	7.1	7.3	7.6	7.6	7.8						
10.7	4.4	4.8	5.3	5.5	5.7	6.2	6.4	6.7	6.7	6.9	7.1	7.1						
12.2	4.4	4.6	5.1	5.3	5.5	5.7	6.0	6.2	6.2	6.4	6.4	6.4	6.4	6.4	6.4			
13.7	4.1	4.6	4.8	5.1	5.3	5.5	5.5	5.7	5.7	5.7	5.7	5.7	5.5	5.5	5.5	5.3	5.1	
15.2		4.4	4.6	4.8	5.1	5.1	5.3	5.3	5.3	5.3	5.3	5.1	5.1	4.8	4.6	4.4	4.1	3.9
16.8		4.1	4.4	4.6	4.6	4.8	4.8	4.8	4.8	4.6	4.6	4.4	4.1	4.1	3.7	3.4	3.2	2.8
18.3			4.1	4.4	4.4	4.4	4.4	4.4	4.4	4.1	3.9	3.7	3.4	3.2	3.0	2.5	2.1	1.8
19.8			3.9	4.1	4.1	4.1	4.1	3.9	3.9	3.7	3.4	3.2	2.8	2.5	2.1	1.6	1.1	.7
21.3				3.9	3.9	3.9	3.7	3.7	3.4	3.2	2.8	2.5	2.1	1.8	1.4	.9	.2	0
22.9				3.7	3.7	3.4	3.4	3.2	3.0	2.5	2.3	1.8	1.6	1.1	.5	0	-.5	-.9
24.4						3.2	3.0	2.8	2.5	2.1	1.8	1.4	.9	.2	0	-.7	-1.4	-2.1
25.9									2.1	1.6	1.4	.9	.2	-.5	-.7	-1.4	-2.3	-3.2
27.4									1.6	1.4	.9	0						

APPENDIX D

Red pine plantation height growth[a] (m)

Site index = 19.8 (m) | Percent thinning = 25

Dom ht (m)	Basal area per hectare (m^2) 7.4	8.4	9.3	10.2	11.1	12.1	13.0	13.9	14.9	15.8	16.7	17.7	18.6	19.5	20.4	21.4	22.3	23.2
7.6	6.7	5.8	4.9	4.3	3.7	3.4	3.0											
9.1	6.4	5.5	4.6	4.0	3.4	3.0	2.7	2.1	2.1	1.8	1.5	1.5						
10.7	6.1	5.2	4.3	3.7	3.4	2.7	2.4	2.1	1.8	1.5	1.5	1.2						
12.2	5.8	4.9	4.0	3.4	3.0	2.4	2.1	1.8	1.5	1.5	1.2	1.2	.9	.9	.9			
13.7	5.5	4.3	3.7	3.0	2.7	2.1	1.8	1.5	1.5	1.2	1.2	.9	.9	.9	.9	.6	.6	
15.2		4.3	3.4	2.7	2.4	2.1	1.8	1.5	1.2	1.2	.9	.9	.9	.9	.9	.9	.6	.6
16.8		4.0	3.4	2.7	2.4	1.8	1.5	1.5	1.2	1.2	.9	.9	.9	.9	.9	.9	.9	.9
18.3			3.0	2.4	2.1	1.8	1.5	1.2	1.2	1.2	.9	.9	.9	.9	.9	.9	1.2	1.2
19.8			3.0	2.1	1.8	1.5	1.2	1.2	1.2	1.2	.9	.9	1.2	1.2	1.2	1.2	1.2	1.5
21.3				2.1	1.8	1.5	1.5	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.5	1.5	1.5
22.9				1.8	1.5	1.5	1.2	1.2	1.2	1.2	1.2	1.5	1.5	1.5	1.8	1.8	1.8	2.1
24.4						1.5	1.5	1.2	1.2	1.5	1.5	1.5	1.5	1.8	1.8	2.1	2.4	2.7
25.9									1.5	1.5	1.5	1.8	1.8	2.1	2.1	2.4	2.7	3.0
27.4									1.5	1.8	1.8	2.1						

[a] Complete tables for thinning percentages of 0, 10, 20, 25 and 33 for site indexes 19.8 (65), 21.3 (70), 22.9 (75), 24.4 (80), 25.9 (85) available from author in English units.

APPENDIX E

Site index table for red pine

Stand age (yr)	Height[a] (m)												
	7.6	9.1	10.7	12.2	13.7	15.2	16.8	18.3	19.8	21.3	22.9	24.4	25.9
20	20.4	22.6	24.4	26.5									
25	17.4	19.2	21.0	22.9	24.7	26.5							
30		16.5	18.3	20.1	21.9	23.5	25.3	27.1					
35			15.8	17.7	19.5	21.0	22.9	24.4	26.2				
40					17.4	18.9	20.4	22.3	23.8	25.3			
45						17.1	18.6	20.1	21.6	23.2	24.7		
50						15.2	16.8	18.3	19.8	21.3	22.9	24.4	25.9
55						13.7	15.2	16.8	18.3	19.5	21.0	22.6	24.1
60							13.7	15.2	16.5	18.0	19.5	21.0	22.6

[a] Present height of dominant and codominant trees.

NOTE: Figures are based on 241 measurements from 38 P.S.P.s in red pine plantations in southern Ontario.

APPENDIX F

Field trial T-3A: Dufferin Forest, Compartment 8-A (western half) - Alternate rows of red pine and white pine, planted 1931, with scattered refills

DBH class (full cm)	Cruise sample					Marked to cut					Residual				
	Red pine		White pine		BA	Red pine		White pine		BA	Red pine		White pine		
	Grade A	Grade B	Grade A	Grade B	(m^2/ha)	Grade A	Grade B	Grade A	Grade B	(m^2/ha)	Grade A	Grade B	Grade A	Grade B	(m^2/ha)
	(stems/ha)					(stems/ha)					(stems/ha)				
10.2	-	10	-	44	.535	-	10	-	44	.535	-	-	-	-	-
12.7	10	15	-	15	.583	10	15	-	15	.583	-	-	-	-	-
15.2	5	5	10	5	.512	5	5	10	5	.512	-	-	-	-	-
17.8	10	-	5	5	.549	10	-	5	5	.549	-	-	-	-	-
20.3	44	10	25	-	2.828	44	10	-	-	1.944	-	-	25	-	.884
22.9	109	15	-	-	5.530	54	15	-	-	3.099	54	-	-	-	2.431
25.4	173	15	5	-	10.565	20	15	-	-	1.896	153	-	5	-	8.668
27.9	193	15	-	-	13.671	10	-	-	-	.652	185	15	-	-	13.019
30.5	64	-	-	-	5.007	5	-	-	-	.386	59	-	-	-	4.621
33.0	15	-	-	-	1.348	-	-	-	-	-	15	-	-	-	1.348
35.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	623	85	45	69		158	70	15	69		466	15	30	-	
	708		114			228		84			481		30		
Total:	822				41.128	312				10.156	511				30.971
Average diameter (cm)					25.15					20.32					27.94

Cruise sample by G. Greer and M. Irwin, 10 June 1977
Marked (raining) by G. Greer and M. Irwin, 7 July 1977

Prescriptions used: based on actual stand (sample not accurate)

1. Keep 12.5 white pine per ha of "A" grade and release for seed production.
2. Remove all red pine 22.9 cm and less in diameter and all "B" grade red pine.
3. Remove all white pine not needed for seed.

Method: thinning from below and above (on "B" grade)

Product: pulpwood and small poles

NOTE: Prediction based on sample indicates 284 trees with 17.130 m^2/ha residual.

Prediction based on actual plot is 457 trees and 28.926 m^2/ha residual.

(continued)

APPENDIX F (concluded)

Field trial T-4: Hendrie Forest, Compartment 192 (c) - Pure red pine, planted 1924

DBH class (full cm)	Cruise sample					Marked to cut					Residual				
	Red pine Grade A	Red pine Grade B	Red oak	Black cherry	BA (m^2/ha)	Red pine Grade A	Red pine Grade B	Red oak	Black cherry	BA (m^2/ha)	Red pine Grade A	Red pine Grade B	Red oak	Black cherry	BA (m^2/ha)
	(stems/ha)					(stems/ha)					(stems/ha)				
10.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12.7	-	25	-	-	.365	-	25	-	-	.365	-	-	-	-	-
15.2	54	44	-	-	2.048	54	44	-	-	2.048	-	-	-	-	-
17.8	151	54	-	5	5.836	124	54	-	-	4.943	27	-	-	5	.893
20.3	200	42	3	3	8.838	27	35	-	-	2.208	173	7	3	3	6.630
22.9	203	40	3	-	10.955	-	7	-	-	.333	203	32	3	-	10.622
25.4	121	27	-	-	8.127	-	3	-	-	.135	121	25	-	-	7.991
27.9	57	5	5	-	4.394	-	-	-	-	-	57	5	5	-	4.394
30.5	12	-	-	-	.964	-	-	-	-	-	12	-	-	-	.964
33.0	3	-	-	-	.225	-	-	-	-	-	3	-	-	-	.225
35.6	3	-	-	-	.259	-	-	-	-	-	3	-	-	-	.259
38.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	804	237	11	8		205	168				599	69	11	8	
	1041		19			373		-			668		19		
Total:	1060				42.011	373				10.032	687				31.978
Average diameter (cm)					22.61					18.5					24.4

Marked by M. Innes, M. Irwin, J. Greaves and A. J. Cox, 27 January 1977
Compiled by W. McNeice, 7 July 1977

Prescriptions used: based on cruise sample

1. Remove all red pine 17.8 cm and less, and half of B grade 20.3 cm red pine.
2. Spacing about 4 m.
3. Result should be residual basal area of 29.8 m^2/ha.

Method: primarily thinning from below

Product: pulpwood

NOTE: Prediction based on actual stands is 591-681 stems per ha residual
27.8-32.4 m^2/ha BA residual

APPENDIX G

Summary of results of prescription marking

Field trial	1. Cruise sample B.T.			2. Predicted from sample A.T.			3. Actual residual A.T.			4. Actual stand B.T.			5. Predicted from actual A.T.			Sample error	Pred'n error	Actual error
	Avg DBH (cm)	B.A. m^2/ha	SDI	Avg DBH (cm)	B.A. m^2/ha	SDI	Avg DBH (cm)	B.A. m^2/ha	SDI	Avg DBH (cm)	B.A. m^2/ha	SDI	Avg DBH (cm)	B.A. m^2/ha	SDI	Col 1 - 4 SDI	Col 2 - 5 SDI	Col 2 - 3 SDI
T-3	25.4	36.3	714	27.2	29.8	573	27.7	35.4	675	25.1	41.1	815	28.4	35.1	662	- 101	- 89	- 101
T-3A	-	-	-	-	-	-	27.9	31.0	588	25.1	41.1	815	28.4	29.2	549	N/A	N/A	N/A
T-4	22.6	37.2	768	24.6	30.1	600	24.4	31.2	625	22.4	41.3	857	24.4	28.0	561	- 77	+ 40	- 25
T-5	22.1	43.8	914	24.1	29.2	588	24.1	35.1	707	21.8	44.5	932	24.4	29.8	598	- 17	- 10	- 119
T-1	26.2	39.7	773	28.4	30.5	576	27.9	27.8	526	26.7	40.6	786	29.0	31.7	593	- 12	- 17	+ 49
T-2	25.4	36.3	714	26.7	30.5	591	26.9	27.8	536	26.2	37.6	734	27.4	32.4	618	- 20	- 27	+ 54
Average SDI			776			586			610			823			598	- 47	- 22	- 27

Field trial	Stand	Prescription	Result
T-3	Red pine and white pine, alternate rows planted 1931	Leave white pine seed trees; remove smaller trees for pulp.	Failure, sample error too big (B.A. difference 4.8 m^2/ha)
T-3A	Same plot as T-3	As above, based on actual	Satisfactory
T-4	Pure red pine planted 1924	Pulpwood	Acceptable
T-5	Pure red pine planted 1924	Pulpwood, spacing guide not applied adequately	Acceptable stand remains overstocked
T-1	Red pine and white pine, alternate rows planted 1931	Increase spacing and quality; leave white pine seed trees.	Pole operation accommodated
T-2	Adjacent to T-3A	Increase spacing and quality; leave white pine seed trees.	Pole operation accommodated

DISCUSSION

Question: If the initial spacing for planting were wider would the guideline have to be modified?

Answer: The spacings mentioned in the paper are the spacings after thinning, not the initial spacing at time of planting. Insufficient data are available on the different initial spacings to develop guidelines such as you are suggesting.

MANAGEMENT OF PINE INSECT PESTS

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*Sawflies, weevils, and shoot and tip moths are the major insects infesting established red pine (*Pinus resinosa *Ait.) and white pine (*P. strobus *L.) stands in Ontario and Quebec. Suppression methods in high-value forests are expensive and labor-intensive; hence, knowledge of potential damage and of appropriate treatments for population control is prerequisite to the formulation of forest management plans.*

*Les principaux insectes qui infestent les peuplements établis de Pin rouge (*Pinus resinosa *Ait.) et de Pin blanc (*P. strobus *L.) du Québec et de l'Ontario sont les tenthrèdes, les charançons, puis les papillons nocturnes qui s'attaquent aux pousses et aux extrémités des branches. Les méthodes de répression employées dans les forêts de grande valeur sont dispendieuses et exigent une main-d'oeuvre trop nombreuse. Bien connaître les dégâts probables et les traitements appropriés pour lutter contre les populations d'insectes seront donc requis pour entreprendre la planification de l'aménagement forestier.*

INTRODUCTION

Pine forests, whether natural or man-made, require intensive management primarily because they have been established as monocultural stands. Silvicultural practices, including the control of insect pests, are essential for the maintenance of desired stocking and tree quality. The period most critical for the protection of pines from insect attack is during the first 20 to 30 years (i.e., the period prior to the first commercial thinning) when straight stems and optimum foliage densities are required. Most of the pest species injurious up to this growth stage usually can be ignored by the forest manager thereafter. Crown closure about this time also creates a different microenvironmental effect which may be detrimental to the proliferation of a number of pests of younger trees.

A large number of insects damage both native and exotic species of pine in Canada and the United States (Baker 1972, Rose and Lindquist 1973, Johnson and Lyon 1976). Fortunately, few of these are considered pests of economic or aesthetic importance. Major insects injurious to red pine (*Pinus resinosa* Ait.) and white pine (*P. strobus* L.) are well known, and tactics for the suppression of outbreak populations have been evolved for most of them.

The intent of this paper, then, is to review briefly the current status of insect pests of red and white pines occurring primarily in Ontario and Quebec, to discuss current tactics and options for their management, and to project the requirements and trends for the protection of pine stands in the immediate future.

A FEW IMPORTANT PESTS OF RED AND WHITE PINES

Defoliating Insects

The major defoliators of red and white pines are members of the sawfly genera *Diprion* and *Neodiprion*. Of the 14 or more species occurring in eastern Canada, only the redheaded pine sawfly (*Neodiprion lecontei* [Fitch]) and the European pine sawfly (*Neodiprion sertifer* [Geoff.]) have caused extensive defoliation. Other sawflies, the jack-pine budworm (*Choristoneura pinus pinus* Free.), needle miners, scale insects, midges, and aphids occasionally infest foliage of red and white pines but damage surveys to date have reported neither continuous nor widespread growth loss and mortality.

Both the introduced and redheaded pine sawflies are midsummer colonial feeders on older foliage, although when the latter occur in outbreak proportions they may consume new foliage as well. A single year of severe attack can result in tree mortality. At present, the introduced pine sawfly is a serious threat to Scots pine (*P. sylvestris* L.) in southern Ontario. The redheaded pine sawfly is the major defoliator of young red pines in Ontario and Quebec. Christmas tree farmers and foresters in charge of red pine reforestation programs should be fully cognizant of the potential damage to young trees and familiar with the life histories and habits of these species. Left unchecked, outbreaks of these sawflies will subside only after 3-5 years because of inclement weather, parasites, disease, or starvation.

Shoot and Tip Insects

A wide variety of insects attack the growing tips and shoots of branches. The most serious attack occurs when the terminal leader is deformed or destroyed. Many crooked and stunted trees across Ontario and Quebec may be attributed directly to attack by one or more insect species. The most notorious insect attacking leaders is the white pine weevil (*Pissodes strobi* [Peck]). Shoot and tip moths, including the eastern pineshoot borer (*Eucosma gloriola* Heinr.), the European pine shoot moth (*Rhyacionia buoliana* Schiff.), and several species of *Rhyacionia* tip moths may also cause serious damage.

The white pine weevil, which occurs across Canada, has been the major obstacle to the successful establishment of white pine plantations in eastern North America. By girdling the leader during the early summer months, weevil grubs effectively destroy two years of vertical growth. Successive attacks result in crooked and stunted trees that are often of no commercial value. More than 50% of the trees in some Ontario and Quebec plantations have been infested annually during recent years.

Similar damage may be caused by shoot and tip moths in certain regions, but generally leader loss is somewhat less serious as only one year's growth is lost and the intensity of attack is not as severe as that of the weevil (Fig. 1).

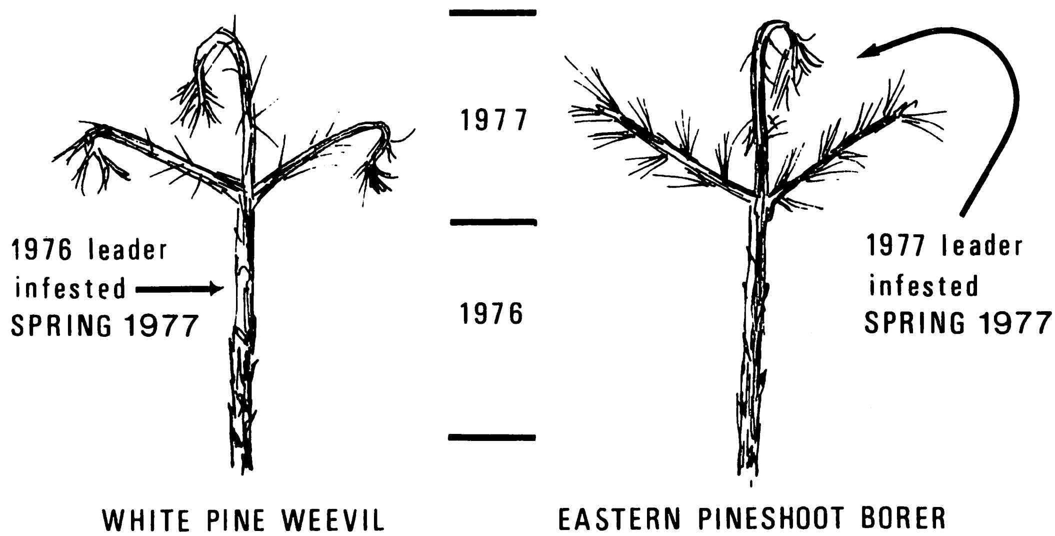

Figure 1. Late summer symptoms of leader damage.

As for pine sawflies, shoot and tip insects should be considered inevitable pest problems in the formulation of forest management plans. Many hundreds of hectares of once-valuable young trees have been abandoned because of the repeated loss of annual vertical increment and lack of appropriate treatment.

Trunk, Root and Root-collar Insects

By far the most difficult pests to control are those which attack the trunk and root systems of trees. White grubs (*Phyllophaga* spp.), root collar weevils (*Hylobius* spp.), bark aphids (e.g., *Pineus strobi* [Htg.]), bark beetles (e.g., *Ips pini* Say), and wood borers (*Monochamus* spp.) can pose serious problems for the forest manager. White grubs, root collar weevils and bark aphids either kill trees outright or seriously curtail growth. Bark beetles and borers can kill weakened trees (e.g., those weakened by drought conditions) although they are more commonly associated with dead and dying stands and stored logs. Usually, when damage by these insects is detected, very little can be done to protect infested trees. Efforts should be concentrated on protecting uninfested trees.

PEST MANAGEMENT TACTICS

Most species of insects attacking forest trees are of little importance when susceptible host trees occur in mixed, uneven-aged stands. Unfortunately, as red and white pines are grown primarily as pure, even-aged forests, the most important criterion--food supply--will not be a limiting factor in preventing initial attack. As in agricultural crop protection, expensive and labor-intensive silvicultural practices must be employed for pest management in pure stands of red and white pines. However, much can be accomplished by detecting infestations early and incorporating practical and effective treatments as required. The key to successful management of pine insect pests may be found in the following procedures:

a) Inspect trees regularly and thoroughly for symptoms of infestation.
b) Collect specimens of suspect insect larvae, nymphs or adults as well as samples (including photographs if necessary) of damaged portions.
c) Consult available literature and/or obtain professional advice on the pest species and control methods.
d) Establish a protection program immediately or prepare action plans for the following growing season if damage is detected too late.
e) Budget financial and manpower resources accordingly.
f) Use common sense!

Only two types of pest management can be employed in established stands: (1) corrective silvicultural techniques, and (2) application of insecticides. The choice of treatment will depend on a variety of factors including cost and labor requirements, current and projected values of the stands to be treated, the threat to the quality and survival of trees under attack, and the potential need for repetition of treatments.

The decision to treat must also be related to the reasons for which the trees were planted in the first place. Often these reasons are unclear and, not surprisingly, the need for protection from pest attack is not obvious. Examples of pest management tactics have been outlined in Table 1; common insecticides used for pest management in pine plantations are listed in Table 2.

The White Pine Weevil Problem

Currently, infestations of the white pine weevil are being treated by both leader clipping and applications of the chemical insecticide methoxychlor. Annual surveys for weevil infestation are conducted in many plantations. When leader damage occurs within the range of 2-5%, infested leaders of young trees 91.4-365.8 cm tall can be clipped easily with hand or pole pruners during July and August. These leaders, containing weevil grubs, must be destroyed and a lateral shoot selected as a replacement. Some plantations seriously threatened by weevil attack can be sprayed in the spring with various types of ground application equipment. Past experience has shown that up to 100% of all trees can be protected with careful applications of spray to the leaders.

Trees taller than 365.8 cm usually must be treated with aerial sprays of methoxychlor. Repeated applications can reduce the incidence of leader mortality significantly (Table 3), but some damage is bound to occur during each year of treatment. The difficulty with applications of oil-based methoxychlor sprays is related primarily to the poor coverage on the bark of the leaders and to the reduced residual activity of the chemical when it is dispersed as small droplets. It is therefore essential when planning aerial applications by fixed-wing aircraft to consider up to three successive years of spraying to reduce annual leader loss to 5% or less when weevil populations are well established and densities are high. Chances for resurgence of the weevil populations in subsequent years must also be considered. At present, annual corrective leader clipping, occasional ground spraying and from three to five aerial applications may be required to permit the vigorous and straight growth required for the cropping of the few hundred trees that are 914.4 cm tall and taller. After the required trunk quality and height increments are attained, weevil attack is not as prevalent and can usually be ignored.

Insecticides - What to Do

At present, the use of insecticide sprays is the most important silvicultural practice in the management of pine insect pests. Too often other pest management options (such as leader clipping for the white pine weevil, mixed species plantations and the growing of pines under a hardwood overstory) may be too expensive or impractical. The forest manager must realize that, regardless of the objectives and countermeasures emotionally promoted by individuals and groups opposed to

Table 1. An abbreviated red and white pine insect pest management calendar.

Pest	Location of damage	Impact	Treatment	Methods	Time
White pine weevil	leader	stunted/crooked trunk	insecticide applications	Methoxychlor @ 1.1 (ground) to 2.75 kg AI/ha	April to early May
			cultural	clip and destroy infested leaders	June to early August
White grubs	roots	mortality of seedlings	insecticide applications	root dip planting stock in 6% Chlordane clay slurry	preplanting time
			cultural	do not plant when populations excessively high	-
Eastern pineshoot borer	leader and lateral shoots	stunted/crooked trunk (after leader attack)	cultural	clip and destroy infested shoots	May to early July
Root collar weevils	root collar	mortality by girdling	insecticide applications	Lindane @ 18.6 g AI/100 L water (drench root collar)	May to October
			cultural	remove and burn infested trees including infested root collar	May, June

Table 2. Insecticides used for control of pine insects

Common name	Trade name	Registered for use against
Azinphos-methyl	Guthion	aphids, cone midge, coneworm, seedworm, European pine shoot moth, Nantucket pine tip moth
Carbaryl	Sevin	webworm, sawflies, scale insects, June beetles, bagworm
Carbophenothion	Trithion	European pine shoot moth, Nantucket pine tip moth
Diazinon	Basudin	European pine shoot moth, scale insects
Dimethoate	Cygon	aphids, bagworm, Nantucket pine tip moth, pine needle scale, Zimmerman pine moth, European pine shoot moth, pine sawflies
Disulfoton	Di-Syston	aphids, pine tip moths
Endosulfan	Thiodan	pine needle scale
Ethion	--	pine needle scale
Fenitrothion	Sumithion	jack pine budworm, sawflies
Lindane	--	root weevils, cutworms, cereal leaf beetle
Malathion	Cythion	aphids, bagworm, European pine shoot moth, pine needle scale, sawflies, scale insects, spider mites
Methoxychlor	Marlate	June beetles, webworms, weevils
Phosphamidon	Dimecron	aphids, jackpine budworm
Superior Oils	--	scale insects

Table 3. Results of spray applications of methoxychlor for control of the white pine weevil at the Orr Lake Forest, Simcoe County, Ontario

Year	Treatment	% Leader infestation	
		Treated trees	Untreated check trees
1970	untreated	38	45
1971	methoxychlor @ 2.2 kg A.I./ha (groundspray)	(4)[a]	46
1972	methoxychlor @ 2.75 kg A.I./ha (aqueous spray)	15	45
1973	untreated	23	22
1974	methoxychlor @ 2.2 kg A.I./ha) (oil base airspray)	3	23
1975	methoxychlor @ 2.2 kg A.I./ha) (oil base airspray)	4	36
1976	methoxychlor @ 2.2 kg A.I./ha) (oil base airspray)	2	24

[a] Only portions of the plantation sprayed during 1971.

chemical and biological insecticides, the Canadian record in the use of insecticides for the protection of small, high-value forests is unsurpassed. By using extreme caution and common sense in the selection, mixing and application of registered products, most objectives have been attained and no reasonable objections have been voiced.

The insecticide evaluation, registration and recommendation process for forest use in Canada is very explicit in eliminating uneffective and/or environmentally hazardous products. Only after intensive and expensive studies of efficacy against target pests and companion studies or impact on non-target organisms are insecticides registered for use in this country. In fact, more products have been withdrawn from commercial use in recent years than have been registered for the control of insect pests of trees and shrubs. This dwindling supply situation has created many problems (notably in the protection of trees and logs from bark beetle and borer attack) as most insecticides used today have very short residual activity.

The forest manager, when faced with the need for an insecticide application, should plan the operation with care and confidence--not in fear of failure or frustration.

Important Silvicultural Considerations

Several important factors in pest management practice should be considered, especially for the establishment of young plantations. A few of these are outlined below.

1) Access to trees along peripheral fire guards and central roadways, and to all other young trees, is essential, particularly for the successful use of groundspray equipment. Trails should be cut every 10-20 rows to permit the use of power sprayers for the delivery of insecticides against most pest species.

2) Stands should be thinned as required to prevent stagnation and the buildup of pest problems; all cull trees should be destroyed as soon as possible, especially trees infested by root collar weevils. If necessary, all trees can be destroyed and a different species planted.

3) Red and white pines should not be established where sawflies, weevils or other pest species occur periodically in outbreak proportions and pest management is not practised. The plantation will be threatened constantly by invasion from these adjacent stands, regardless of attempts to protect the trees.

4) Cooperative pest control programs via forestry associations and tree farmers' groups should be organized to ensure treatment of *all* high value forests within a given region or district. Per hectare costs for aerial applications, for example, decrease with increased area as does the need for annual treatment after a successful spray operation over a large area.

5) Costs associated with pest management in pine forests are high. Labor, equipment and supplies may total more than $25.00 per

ha per year. Therefore, consideration must be given to the importance of silvicultural practices and the associated expenditures when planning new reforestation or afforestation programs. Pest management estimates *must* be included in all budgetary planning.

6) Annual surveillance of the occurrence of important pest species is essential. Estimates of insect population numbers and of damage can be readily obtained through the use of a few well-trained pairs of eyes.

A PEST MANAGEMENT FORECAST

It is anticipated that several areas of insect pest management will achieve prominence through the use of new materials and methods in the years ahead:

1) Pesticides: The application of synthetic organic insecticides will continue to be the most important means of protecting pines from established infestations. Strict government regulations, including guidelines for the use of insecticides in high-value forests, are either forthcoming or already in effect. Several uses of insecticides currently registered may be withdrawn (because of their ineffectiveness or because of suspected deleterious consequences of application), but several promising new products (e.g., acephate, chlorpyriphos-methyl, permethrin) most likely will be registered for specific uses within the next few years. The list of chemical insecticides will most likely include 10 to 20 different products, each of which will be selected for efficacy against a few target pests and for the fact that they have been proven to cause minimal injury to non-target organisms.

Probably the most interesting area of potential change in the near future will be the widespread use of natural disease organisms such as viruses, fungi, and bacteria. Two potent nuclear polyhedrosis viruses are known to be very effective in curtailing infestations of sawflies. Semi-operational field experiments during the past 10 years have indicated that these host-specific viruses can be used economically in plantations. Data have also been accumulated, and more are expected, on their harmless effects on non-target organisms, particularly mammals. The disappointing results obtained with commercial preparations of the bacterium *Bacillus thuringiensis* against the spruce budworm (*Choristoneura fumiferana* [Clem.]) should not occur with lepidopterous pests of pine such as the jackpine budworm. Current research would indicate that the different feeding habits of this budworm and the crown characteristics of pines would permit better spray penetration to the feeding sites and result in far greater infection levels. Preliminary results of field experiments using the fungus *Beauvaria bassiana* against several pine pests, including the white pine weevil, have been extremely encouraging. Small-scale treatments using spore suspensions have been as effective as conventional treatments with methoxychlor.

2) Spray applications: Conventional spray equipment, notably knapsack sprayers, shade tree mist-blowers, and boom-and-nozzle equipped aircraft, will most likely be replaced largely by sprayers equipped specifically for application to high-value forests. Motorized equipment developed by Christmas tree growers can be used successfully for precision groundspray applications in small blocks of young plantation trees. Helicopters specially equipped for the dispersal of fine-droplet insecticide sprays are being explored and evaluated for use in parks, plantations, woodlots and other high-value stands. It is expected that the selection of proper spray delivery equipment will be as important as the proper choice of the toxicant. Dosages of insecticides and spray volumes per unit area will be minimal, but spray coverage will be superior to that attained with most equipment currently in use. Good weather (high humidity, low windspeed) will still be important as will the exact timing of the treatments.

3) The pest manager: Possibly the most important factor in successful forest management will be the emergence of the practising pest control specialist. Employed by the provincial forestry authority, and supported by trained commercial spray operators, experienced foresters and tree farmers, these specialists will, it is hoped, put an end to the dark age of inactivity by 1980. The allocation of staff at the district level to specialize in pest problems is a major requirement for complete stand management and modern silvicultural practice. Plans, unlike past proposals, will include all practical cultural techniques to prevent widespread pest outbreaks and sound operational alternatives to minimize the impact of those species indigenous to pine forests.

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DISCUSSION

Question: You make no mention of cone and seed insects in pines. Up to 100% of the cones in a poor crop year may be infested. We don't know a great deal about seed yield losses, and natural control by parasites appears to be limited. Could you comment on the use of systemics in tree protection?

Answer: There is nothing being done at the present time on the use of systemics for the control of cone and seed insects. Probably the reason that no work is being done now is that past results have been very spotty, and systemics do not operate in conifers as they do in the broadleaf trees.

Question: Do you have any suggestion as to the level of white pine weevil damage we should accept before taking any protective measures?

Answer: This is a very debatable area: no guidelines are available on exactly when to apply control measures. One must consider the objectives when talking about control measures.

Question: What do you do when you are requested to spray small areas for a landowner and his neighbor doesn't want any drift of the chemicals onto his land? Is there any policy in Ontario regarding this?

Answer: This is one of the problems in the application of chemicals. There is no policy in Ontario at the present time.

The point was raised that white pine blister rust (an important disease of white pine) had not been mentioned. And the question was asked: Do managers have problems with blister rust in their plantations or natural stands?"

The replies seemed to indicate that blister rust was very variable in its occurrence in Ontario. In some areas it presented no problem while in others it was rampant, and as a result no white pine planting was being done.

At the termination of the symposium, the chairman, Phil Anslow, summed up by outlining briefly what had been done over the three days, and he repeated the question posed by our keynote speaker, Ewan Caldwell: "WHITHER NOW, O PINUS?"

SUMMARY

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Opeongo Forestry Service
Renfrew, Ontario

Mr. Chairman and fellow foresters. I have been assigned the pleasant task of delivering a summary of the events of the last three days. Since all of you have read the papers and we have participated in a lively discussion of the important aspects of pine management covered in the papers, I feel that my time could perhaps be put to better use if I were to speculate on the future of pine management rather than give a detailed summary of our accomplishments here.

Perhaps we should begin by asking ourselves a few questions, and attempting to answer them.

Why did we come to the Petawawa Forest Experiment Station?

Obviously because we are interested in the management of these important species. The fact that over one hundred foresters were sufficiently interested to spend the better part of a week discussing this one topic indicates a considerable level of interest.

What did we do while we were here?

As I recall we began with a discussion of the historical aspects of pine utilization in this part of the world. Ewan Caldwell pointed out to us that much of the early development of our country was paid for by the exploitation of the immense pine forests of the Ottawa Valley during the period prior to 1910.

Later we dwelt on what might be termed the research and pilot project phase. This covered the period 1910 to the present and included the research and experimental work that were necessary to develop management systems and forest protection methods. While much work remains to be done, it is safe to say that much progress has been made and in the broad sense the essential tools of forest management are now available.

This brings us pretty well up to the present. Where do we go from here? We are now prepared to enter the third phase which could be termed the operational management phase. This is the phase where the results of research and experimentation are put to work on a broad operational basis. It is the application of the management systems that have been developed over the last 30 or 40 years.

For some reason this phase seems to be rather slow getting off the ground. Granted, we have done some tree planting, some ribes control, some tree marking, and a bit of forest tending, but we see little evidence of any broad application of these silvicultural tools.

Why have we been so slow to apply the knowledge we have already gained?

Why is there such a gap between the development of management systems and the wholesale application of these systems?

Why are we hesitating?

Is it a knowledge that is lacking or is it rather a lack of commitment?

Most of us would probably say that it is a lack of commitment. I am wondering if this commitment is lacking because most people are convinced that tree growing is "poor business". In other words, the cost of establishing, tending and protecting good-quality stands is likely to be higher than the stumpage value to be realized.

If the growing of white and red pine were a highly profitable business venture, does it not seem strange that no one during the course of this symposium presented us with figures on production costs and rate of return on investment?

What is the challenge that now presents itself to foresters?

I feel that the challenge at the present time involves convincing those who make forest management decisions that there is a dollar to be made in the production of white and red pine trees. We must examine cost and revenue figures and devise ways of producing our product at a profit. This may involve higher stumpage fees and it may involve developing cheaper methods of management. Unless the cost-revenue figures can be adjusted to show a profit it is unlikely that landowners, be they private, industrial or governmental, will be in any hurry to spend money for the management of pine lands.

If we are to avoid timber shortages and a crisis situation in our pine-based forest industries we must rise to the challenge that is now presented to us. We should, however, remain optimistic for we are dealing with a species whose inherent value and growth capacity make it a prime candidate for intensive management.