JACK PINE SYMPOSIUM

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C.R. SMITH and G. BROWN, COCHAIRMEN

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FOREWORD

The Jack Pine Symposium, cosponsored by the Ontario Ministry of Natural Resources (OMNR) and the Great Lakes Forest Research Centre of the Canadian Forestry Service, was held from 18 to 20 October, 1983 in Timmins, Ontario. It was the twelfth in a continuing series of symposia conducted under the auspices of the Canada-Ontario Joint Forestry Research Committee (COJFRC). The intention of these symposia is to provide a forum for discussions and interchange of ideas among provincial and industrial forest managers, educators and researchers in the field of forestry in Ontario. About 175 delegates participated in the symposium, at which 29 papers were presented.

The purpose of the Jack Pine Symposium was to provide researchers and forest managers with an opportunity to discuss the state of the art of jack pine management in Ontario and to present findings from some of the more recent and more relevant research into the species. Invited speakers from the Maritimes, Quebec, Manitoba, Saskatchewan and the Lake States provided an overview of the current status of jack pine covering the biological range of the species outside Ontario. In addition, papers were presented on subjects ranging from seed collection and management through the various aspects of plantation management. Representatives of the four northern administrative regions of OMNR presented summaries for their respective areas and a final overview of management in Ontario concluded the proceedings. There were short question and answer periods at appropriate points in the discussion.

The second day of the symposium consisted of a field tour through natural and manmade stands of jack pine to demonstrate local successes and failures in jack pine management. Throughout the symposium six posters and five commercial exhibits remained on display.

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

Except for the correction of typographial errors and misspellings, the checking of references, and the redrawing of some figures, the papers in these Proceedings appear as they were submitted by the authors.

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STATUS AND POTENTIAL OF JACK PINE IN ONTARIO

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Abstract.--Jack pine (Pinus banksiana *Lamb.) has attributes that make it a candidate for increased fibre production under intensive management--site, seeding habit, seed production, germination and early growth are factors in its favor when natural or artificial regeneration methods are used. Ranging broadly across northern Ontario, it has historically been utilized for sawtimber, but in the last two decades, particularly, its use in pulp manufacture has brought utilization levels closer to the allowable cut in our commercial forests. Future management options should include genetic selection to improve growth characteristics, replacement of hardwoods on poor sites with jack pine where economically practicable, and juvenile spacing of naturally or artificially seeded stands, if we hope to increase yield and benefit from the growth potential of the large area of new forest now being established.*

Résumé--Le pin gris (Pinus banksiana *Lamb.) a des qualités qui font de lui un candidat pour l'accroissement de la production de matière ligneuse en aménagement intensif--ses caractéristiques au niveau du site, de l'ensemencement, de la production de graines, de la germination et de la croissance initiale sont des facteurs en sa faveur, qu'il s'agisse de régénération naturelle ou artificielle. Répandu dans tout le nord de l'Ontario, il a déjà servi à produire du bois de sciage, mais depuis une vingtaine d'années surtout, son emploi pour la fabrication de pâte a porté son niveau d'utilisation plus près de la possibilité réalisable dans nos forêts commerciales. Afin d'accroître la production et les avantages qui peuvent être retirés de la vaste étendue de forêt en voie d'implantation, les futures stratégies de gestion devraient inclure la sélection génétique pour améliorer les caractéristiques de croissance, le remplacement des feuillus sur les sites médiocres par le pin gris là où c'est économiquement réalisable, et le desserrement des jeunes plants dans les peuplements ensemencés naturellement et artificiellement.*

I understand my role in this symposium is to present an overview of the species--specifically, to sketch its status at this point in time, and to outline its place in the forest of the future. In order to do this, I will draw heavily on the past, since trends are a guide to projection. As I have been involved in the forest products industry all my working life, forest management has had special appeal for me, and the recent developments in silvicultural practices have been particularly gratifying. That is why I feel honored to have the opportunity to speak to you today.

Jack pine (*Pinus banksiana* Lamb.) is the most widely distributed pine in Canada, extending from Nova Scotia across New Brunswick, Quebec, Ontario and the Prairie provinces to northern British Columbia and the MacKenzie Valley in the Northwest Territories. It would be difficult, if not impossible, to survey and report adequately on national management options and practices, on the "state of the art", so to speak. I confess I suffer from the same myopia when I adjust my horizon to the boundaries of Ontario--the amount of real estate involved is bewilderingly large and the range of site, climatic and economic factors equally variable. As well, I approach the subject from my vantage point as an operations forester, one responsible for planning harvesting and regeneration programs on several management units, as large as 5,000 km^2 with annual cuts of thousands of hectares. The scenario I am about to sketch, then, must be extensive, broad-ranging in the provincial context, dealing with a major component of the boreal forest, but representative of most regions of central and northern Ontario.

I hope to review the ecology of jack pine quickly to establish its diversity, and to outline utilization trends and silvicultural accomplishments of past years, but I will not consult my crystal ball and look far into the future. My feeling is that projections, except in a general supply sense, are not only foredoomed to misrepresentation, but they can obscure the trends from which an individual observer can draw his own conclusions.

The organizers of this meeting, the Great Lakes Forest Research Centre and the Ontario Ministry of Natural Resources, expect to accomplish a transfer of technical information on jack pine management by means of a review of recent developments. No doubt the expertise is here to do that. Perhaps still another objective, if I may be so bold as to put it in crass commercial terms, is to polish the image of this species: jack pine needs to be marketed in a manner befitting its position as Ontario's second ranked commercial softwood. Jack pine has been ignored for too long by scientists and foresters, although not by its users. Utilization has increased greatly in recent years in both the solid products and pulp industries.

Tree improvement programs in spruce *(Picea* spp.) and poplar *(Populus* spp.) captivate the professional's enthusiasm, but we don't hear much about jack pine. It is high time this homely species was promoted so that foresters will sit up and take notice.

In the past 20 years, private land owners, government foresters and industrial managers alike have contributed to new stand establishment and have seen the area in second-growth jack pine accelerate at an ever quickening pace as overmature stands were liquidated and replaced with juvenile timber. Under sustained yield management a growth surge will result, which should clear the way for higher levels of utilizaton after the year 2000. This fibre, in turn, should help support the expansion of pulp and paper and solid wood products predicted by both the Canadian Council of Resource and Environment Ministers and the Canadian Pulp and Paper Association in the past several years. Both Scandinavia and the southern United States have gone through this sequence and are now benefitting from increased growth; we must play our cards right during the next 20-year period in order to realize the potential.

Let's go back to the drawing board for a few minutes and recall a few of the basics of jack pine silvics. I expect such an overview will remind you that this species has many desirable characteristics that make it a leading contender for fibre production in the future.

Site

Throughout its range in central Canada, jack pine is associated with several minor vegetation communities which permit easy recognition of site quality. Very dry sites support only reindeer lichens *(Cladonia* spp.), dry sites have blueberry *(Vaccinium angustifolium* Ait.), bearberry *(Arctostaphylos Uva-ursi* [L.] Spreng.) and wintergreen *(Gaultheria procumbens* L.). Brown (1976) suggested that a light prescribed burn is the most economical site preparation method for low productivity sites and that it will eliminate competition for up to three years. However, mechanical treatments are often used today in conjunction with natural or broadcast seeding, with the result that the severity of ground disturbance becomes critical in the success of the subsequent regeneration.

Fresh sites support herbaceous cover, of which twinflower *(Linnea borealis* L.), false lily of the valley *(maianthemum canadense* Desf.), bunchberry *(Cornus canadensis* L.) and bracken fern *(Pteridium aquilinum* L.) are easily recognized. Mechanical site preparation can induce aspen and other woody plants to sucker, often creating a need for subsequent tending. Moist sites display Labrador-tea *(Ledum groenlandicum* Oeder) and leatherleaf *(Chamaedaphne calyculata* [L.] Moench) as indicators. Failure to control competition through site preparation similar to a slow fire will induce severe grass and brush growth on the high-productivity soils, and subsequent tending will be required.

In preparing highland cutover for regeneration, the intensity of the treatment required increases with the productive capacity of the site. This is true for natural as well as artificial regeneration since the objectives of site preparation are:

- to expose mineral soil
- to eliminate lateral and overtopping competition with the seedling, which can suppress height growth and root development

- to control spacing and stocking in the area.

Moderate success has been achieved in the development of methods to carry out these objectives and in the adaptation of machinery imported from Scandinavia and the southern United States. New initiatives can be expected now that industry is involved in silviculture.

Jack pine is a highland species that tends to grow in extensive, pure, even-aged stands and does well in mixtures with other trees, particularly spruce and poplar, on fresh sites. It is a pioneer that invades locations where mineral soil is exposed; hence, the role of fire in natural jack pine regeneration. Optimum height and diameter are usually found on moderately moist, sandy loam and clay loam soils.

Most cones are serotinous and open only after being exposed to high temperatures. Seeds are dispersed when the resin that bonds the scales melts and the scales flex outward. The melting point of the bonding material at the tip of the cone scales has been found to be 50°C. Cones in slash open and disperse seed readily when within 30 cm of the ground. Above this level cone opening is reduced until, at 120 cm above the ground, opening is negligible. Seed dispersal is heavy the first year after logging, and the period of greatest dispersal is during June, July and August. However, seed dispersal from slash can take place over the first three years following site preparation of cutover stands.

Germination of jack pine seed takes place once moisture content of 10 to 20% is attained and a relatively brief exposure to light is achieved. Conditions which favor germination include a fine-textured seedbed such as exposed mineral soil. Undisturbed litter and leaves provide very poor seedbeds. Site affects germination; the best results occur on moist, sandy soils; results decline as moisture regime decreases.

Seeding

Broadcast seeding from the air has become a standard supplement to natural seeding on many site-prepared areas in northwestern Ontario. Early spring sowing onto snow cover is often prescribed. Results vary with degree of site preparation, but seedfall pattern is difficult to control with aerial application and is an important factor in subsequent stocking levels.

Spot seeding has come into wide use in conjunction with patch scarifiers. Weather conditions must be favorable for germination and initial survival and this means limiting the seeding operation to the May-June period and seeding only from July to mid-August, during cool, wet summers. Currently, our company is conducting an experiment on seeding throughout the spring, summer and fall months to try to establish the parameters that will in future control the time of direct seeding.

Broadcast seeding onto burned cutover can be successful when carried out soon after the fire to take advantage of favorable seedbeds.

Seedling Survival and Development

Optimum conditions for growth are provided by mineral soil and burned seedbeds. Emergent and first-year seedlings can be destroyed by summer drought on dry sites and frost can also cause mortality. Vegetative competition from herbaceous growth, especially from grasses on heavier soils, can suppress and bury seedlings which grow slowly for an initial period of about three years. Thereafter, jack pine shows a rapid increase in growth and seedlings will attain a height of 3 m in 10 years on better sites.

Studies have illustrated a relationship between early growth and exposure to direct sunlight. Shoot weight and diameter and root collar diameter have been shown to increase with increases in light.

Growth and Yield

The prolific seeding ability of jack pine after fire in natural stands results in a high number of stems per hectare and substantial volume at an early age, up to 85-115 m^3 per 0.4 ha, depending on site quality at 40-60 years. After 90 years, jack pine stands open up and merchantable volumes decrease rapidly as trees die, blow down or develop excessive rot. Forest managers have had little information on which to base future yield predictions for regenerated stands, although such studies are now under way, including one at Lakehead University.

Field experience over many years has shown that site preparation before seeding or planting is essential to duplicate original volume on jack pine cutover. Planting and tending, where required, have the potential for increasing yield and shortening the rotation. Spacing of juvenile stands after natural seeding is required to attain the same control of stocking.

In other parts of the world and particularly in the southern United States, pine species have attained dramatic increases in yield by controlling stocking and shortening rotations. With intensified management, we should expect similar results with jack pine.

Range in Ontario

Natural stands occupy a larger proportion of the productive forest land in northwestern than in northeastern Ontario (Table 1). There is, as well, a higher percentage of the species in the boreal forest than in the Great Lakes-St. Lawrence forest region where deciduous species are more numerous and widespread. This can be illustrated by inventory data for four of the Great Lakes Forest Products management units which lie in the same longitudinal corridor extending from the American border in the south, centred approximately on Upsala, to Lake St. Joseph. In this example, jack pine volume ranges from 11% of the total in the south to 30% in the north.

The natural potential for growth is also far from evenly distributed within site regions. Jack pine performs best in silty sands and clays: glacial tills and outwash do not possess the productivity of finer sediments deposited by ancient glacial lakes.

In part, natural occurrence of the species has been shaped by fire history. Silvicultural systems now being used favor jack pine re-establishment through the use of site preparation and direct seeding techniques.

Utilization Trends

Utilization of jack pine from Crown lands in Ontario increased dramatically in the 35 years from 1946 to 1980 (Table 2). Although demand for wood fibre generally grew steadily over that period, jack pine use more than tripled while spruce demand increased only 150%.

Table 1. Volume in jack pine working group compared with gross total growing stock in Ontario (m^3).

OMNR Region		Crown Land	
	Jack pine working group	All working groups	Percentage
Northeastern	78,343,032	1,707,710,832	11.83
Northern	123,623,371		
North Central	156,436,867	1,960,655,542	21.37
Northwestern	262,544,968		
Algonquin and Central	1,422,581	204,817,727	.07
	622,370,819	3,873,184,101	

OMNR Region		Patent Land	
	Jack pine working group	All working groups	Percentage
Northern	2,669,497	174,234,851	.03
Northeastern	2,292,944		
Northwestern	1,710,747	60,430,425	14.43
North Central	7,009,623		
Central	153,874	185,077,473	0.4
	13,836,685	419,742,749	

Source: Production Policy
Summary of Forest Resources Inventory (Management Unit ledgers)
Ontario Ministry of Natural Resources

Table 2. Utilization of jack pine from Crown lands in Ontario from 1946 to 1980 (m^3).

Year	Jack pine	Spruce	Softwoods	Hardwoods	Total
1946	1,850,004	5,701,937	9,091,428	372,526	9,463,954
1947	2,329,438	5,565,028	9,199,428	639,530	9,838,958
1948	2,523,578	6,156,001	10,117,054	642,510	10,759,564
1949	2,414,929	5,152,234	9,108,450	702,306	9,810,756
1950	1,716,162	3,962,145	6,905,891	490,526	7,396,417
1951	2,525,318	6,115,881	10,134,135	685,315	10,819,450
1952	3,211,340	7,429,014	12,535,612	1,973,741	13,609,353
1953	2,408,498	4,598,254	8,653,884	840,248	9,494,132
1954	2,226,896	4,822,572	8,454,848	841,812	9,296,660
1955	2,412,480	5,182,147	9,136,858	739,890	9,876,748
1956	2,556,588	6,056,940	10,276,384	930,312	11,206,696
1957	2,949,912	6,118,064	10,662,008	992,085	11,654,093
1958	2,307,638	5,310,177	8,891,005	1,045,716	9,936,721
1959	2,018,242	4,647,548	7,795,464	924,972	8,729,436
1960	2,308,168	5,514,140	9,212,614	1,057,486	10,270,100
1961	2,267,282	5,635,886	9,189,810	1,049,994	10,239,804
1962	2,091,638	5,252,858	8,492,873	1,112,356	9,605,230
1963	2,315,308	5,378,646	8,931,361	1,271,214	10,202,575
1964	2,426,050	5,420,802	9,167,568	1,454,350	10,621,918
1965	2,643,584	5,753,002	9,794,413	1,303,753	11,098,166
1966	2,932,005	5,839,082	10,094,782	1,287,528	11,382,310
1967	3,297,834	6,593,309	11,186,194	1,306,142	12,492,336
1968	3,182,312	6,506,786	11,165,986	1,692,946	12,858,932
1969	3,367,897	5,869,969	10,337,006	1,349,035	11,686,041
1970	3,581,034	6,533,896	11,156,635	1,538,690	12,695,325
1971	3,400,878	6,014,637	10,266,649	1,408,979	11,675,628
1972	3,755,674	5,398,824	10,010,324	1,484,971	11,495,294
1973	4,084,128	6,379,700	11,534,294	1,548,898	13,083,192
1974	4,646,516	7,128,144	13,054,606	1,863,082	14,917,678
1975	5,443,207	7,360,427	13,135,376	1,991,044	15,126,420
1976	2,840,319	4,478,926	8,367,203	1,281,568	9,648,476
1977	3,983,060	6,861,730	12,017,208	1,565,514	13,673,722
1978	5,220,261	7,825,436	14,472,641	2,047,624	16,420,265
1979	5,299,380	7,884,465	14,529,428	2,526,380	17,055,808
1980	5,973,366	8,565,826	16,044,047	2,618,538	18,662,585
1981	5,704,356	8,364,843	15,703,352	2,317,284	18,020,636
1982	5,160,494	7,433,469	14,065,954	2,767,248	16,833,202

Source - Ontario Ministry of Natural Resources

The end products to which this volume was directed are shown for the 20 years from 1961 to 1980 (Table 3). A major expansion in kraft pulping capacity took place in the two decades from 1960 to 1980, supplementing the traditional use of jack pine for lumber manufacture, ties and poles, and created a whole new market for what was previously waste wood. Chip deliveries increased from 17,250 ODT in 1961 to 585,000 in 1980. The technology which developed in pulping sawmill chips and other residues was matched by comparable developments in sawmilling technology, and allowed lumber production from small logs in which a higher proportion of the volume ended up as chips.

A substantial part of the increase in lumber production came about from integration in the pulp and paper sector. For instance, the Great Lakes stud lumber mill in Thunder Bay ranks number one in volume output among Ontario sawmills today. This pattern of growing demand and reorganization of production facilities to facilitate better resource utilization is also evident in other competing supply areas such as the southern United States.

On most commercial timber limits good progress has been made in the past two decades in salvaging the older wood, but in the western region particularly, the Ontario jack pine forest is excessively imbalanced in age structure. The result of stands established by fire during the decades 1880-1990, 1910-1920 and 1930-1940, large blocks of immature wood contribute to fuel buildup as they pass rotation age and mortality exceeds growth. Considerable volumes in the 60- to 80-year and

Table 3. Jack pine volumes and products in Ontario.

Year	Total volume cut (m^3)	Pulpwood (m^3)	Sawlogs (m^3)	Lumber (MBF)	Chips (ODT)
1961	2,267,282	1,518,660	748,622	159,201	17,207
1962	2,091,638	1,366,499	725,139	122,420	38,142
1963	2,315,308	1,388,831	926,477	147,155	44,899
1964	2,426,050	1,474,587	951,463	140,793	54,062
1965[a]	2,643,584	1,586,156	1,057,428	157,718	81,556
1966	2,932,005	1,755,722	1,176,283	177,514	116,003
1967	3,297,835	2,134,414	1,163,421	184,329	139,391
1968	3,182,312	1,529,368	1,652,914	209,306	122,043
1969	3,367,897	1,347,147	2,020,750	274,816	163,970
1970	3,581,034	1,468,215	2,112,819	201,916	175,436
1971	3,400,878	1,530,401	1,870,477	276,603	280,205
1972	3,755,674	1,591,318	2,164,356	358,174	349,107
1973	4,084,128	1,794,662	2,289,466	334,778	230,342
1974	4,646,516	3,040,958	2,605,558	398,341	393,896
1975[a]	4,553,207	2,003,404	2,549,803	398,817	394,366
1976[a]	2,840,319	1,249,738	1,590,581	243,170	240,456
1977[a]	3,983,060	1,752,536	2,230,524	341,006	337,201
1978	5,220,261	2,414,958	2,805,303	508,757	538,393
1979	5,299,380	2,099,840	3,199,540	580,861	627,363
1980	5,973,366	2,824,536	3,148,830	571,057	586,275

[a]Interpolated (breakdown by product not available)

Source: Ontario Ministry of Natural Resources

40- to 60-year age classes will likely show up as inventory declines by the time the majority of such stands are harvested, rather than as deliveries to the mill, unless decisions are made as to the continued utilization of decadent jack pine while thrifty rotation-age timber deteriorates. Site quality is critical in maintaining growth and vigor after 80-90 years of age. Decisions on which stands to carry past rotation should therefore be based on knowledge of those site factors which prolong fibre accumulation.

What the Future Holds

Future supply is partly a function of history. An operational jack pine management program began in Ontario only 20 years ago, when the first scarification drags were fashioned and tried out on local sandflats. We have come a long way since then, both in technique and in coverage. In 1983 we enter only the third decade of this active phase. Recorded statistics of this and earlier decades appear in Table 4 for bare-root planting, container planting and direct seeding. Although there is a large increase in all categories of treatment over the years, direct seeding of jack pine can be singled out both for size of area regenerated and the proportion of total species that it comprises. To these treated hectares can be added substantial areas burned in the drought years 1974 to 1980, many of which were uncut and will come back to jack pine naturally.

Growth projections of a forest in a particular area can be estimated with reasonable confidence (Hagler 1983) after careful consideration of four key factors:

1) changes in the commercial forest land base due to agriculture and urbanization

2) changes in the growth rate of trees as genetically improved first- and second-generation superior trees are planted and increase yield

3) changes in the growth-per-hectare ratio between hardwood and softwood as unmanaged stands revert to hardwood because of failure to replant, selective harvesting and lack of natural fire

4) changes in growth per hectare as inventories build up toward full stocking because of a continuing surplus of growth over removals in some areas.

To the first point we can add withdrawals of Crown land for recreation and for parks. Land dedicated to commercial forestry has been

Table 4. Bare-root conifer stock planted in Ontario ('000 trees).

Years	Jack pine	Other conifers	Total conifers	Jack pine as % of total
1934-1940	6,236	70,315	76,551	8.1
1941-1950	7,279	106,785	114,064	6.4
1951-1960	18,996	272,512	291,508	6.5
1961-1970	77,491	435,735	513,226	15.1
1971-1980	139,045	482,457	621,502	22.4

Coniferous container stock planted in Ontario ('000 trees)

Years	Jack pine	Other conifers	Total conifers	Jack pine as % of total
1966-1970	19,302	45,706	65,008	29.7
1971-1980	24,354	43,116	67,470	36.1

Areas seeded in Ontario (ha)

Years	Jack pine	Other conifers	Total conifers	Jack pine as % of total
1956-1960	1,732	187	1,919	90.3
1961-1970	27,706	4,769	32,475	85.3
1971-1980	191,675	12,887	204,562	93.8

Source: Ontario Ministry of Natural Resources

shrinking as other users stake their claims through the political process. This phenomenon may show up also in so-called "deferrals" where second cuts may not be practicable for economic or other reasons.

Intolerant hardwoods occupy many sites in northern Ontario that could produce better-quality wood and higher yields if planted to conifers. Many are in close proximity to mills and urban centres. Northern Ontario was historically a costly production area, in terms of labor, transportation and climatic factors, resulting in high wood costs and a concentration of harvesting close to mills and transportation corridors. I use the term "historically" in referring to the period before World War II. Transport corridors were rivers and waterways in those days, although rail lines also provided a means of access to remote limit areas.

Harvesting was only one factor in the establishment of low-quality hardwoods; land clearing and fire played a bigger part near settlements. Now, mixed stands continue to revert to hardwoods because of the difficulty and high cost of regeneration and tending.

The jack pine forest as a whole was underutilized, despite tight timber supplies in local areas. This underutilization was more in terms of cubic metres of pulpwood and tons of chips than board feet of quality sawlogs. The picture changed with expansion in kraft pulping and with integration of sawmilling in the 1960s and 1970s, which brought the actual cut levels closer to allowable cut on licensed lands and Crown units. Now, aspen is being more widely used in the manufacture of short-fibred hardwood pulps, and in some cases is replacing jack pine as mill furnish.

Operationally, jack pine tree improvement programs are at a relatively early stage of development. The provincial jack pine tree improvement program is described as being in a "strategy development phase" in northwestern

Ontario. In the northeast, I understand seedling seed orchards are in the process of being established. Natural variation has long been known to be reflected in growth performance, and differences in cold hardiness and time of spring flushing due to latitude of seed origin were recognized early. Such knowledge has led to close control of seed collection and a seed zone concept appropriate to the province.

Jack pine can, however, display inconsistent quality: poor stem form, heavy branching and poor pruning. Improved types are required. Genetic selection for superior growth characteristics will be carried out, but much has yet to be done to establish the heritability of other desirable traits. Tree improvement should be expected to contribute to higher yields in future since the large-scale silvicultural expenditures now being contemplated will demand the best seed and planting stock available.

Juvenile spacing will be required in those stands established by natural seeding in order to optimize yield. The area of juvenile stands established by natural and artificial seeding since 1970 is large, as illustrated in Table 4. Many are overstocked and would benefit from spacing. While spacing does not increase gross stand volume, it can significantly increase merchantable volume. That which would otherwise be lost through natural mortality and unmerchantable trees is concentrated on those stems remaining. Increased growth rate and larger tree size reduce rotation age, improve wood quality and enhance logging productivity.

Jack pine is a species with good potential under intensive management. It has an assured market for lumber, for rail ties and for poles, and is widely used in the manufacture of kraft pulps. It ranges right across the Great Lakes-St. Lawrence and boreal forest regions of northern Ontario and performs well on a broad range of upland sites. It possesses characteristics that make it favorable for regeneration by natural or artificial seeding. It is a fast grower in early life, is fairly resistant to disease--if precautions are taken in the presence of Scleroderris canker (*Gremmeniella abietina* [Lagerb.] Morelet)--and to insect attack.

Utilization statistics indicate that the jack pine component of our northern forest has been underutilized in the past. Now that much accessible mature wood has been removed, growth is accelerating on juvenile stands. Before the year 2000, Ontario will have undergone a transition from rationing the natural forest to managing the second crop. Increased allowable cut and higher utilization should result. Jack pine will be a key component in the new forests. Our share of expanding markets for wood products will depend on our ability to manage for optimum yield and to protect our investment. I trust that we will be heading in this direction during the next couple of days.

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THE GENETIC BASIS OF JACK PINE MANAGEMENT

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Abstract.--Critical genetic differences among jack pine populations in winter hardiness, susceptibility to disease, and growth are associated with seed origin and climate. Individual tree characteristics affecting wood quality and fibre yield are under strong genetic influence. Strict provenance control, including planned seed production, collection, and distribution, combined with breeding for increased productivity in the future, will ensure full returns on the major reforestation investments undertaken with this species.

Résumé.--Les différences génétiques critiques parmi les populations de pin gris quant à la rusticité hivernale, à la vulnérabilité aux maladies et à la croissance sont liées à l'origine des semences et au climat. La qualité du bois et le rendement en matières ligneuses de chaque arbre sont soumises à une forte influence génétique. Une surveillance stricte de la provenance, y compris la planification de la production, de la récolte et de la distribution des semences, en plus de l'amélioration génétique pour une productivité accrue, assureront leur plein rendement aux gros investissements en création de forêts de cette essence.

Jack pine (*Pinus banksiana* Lamb.) has exceptional advantages for wood production and forest renewal within the boreal forests of Canada (Moore 1984). Over the 5-year period from 1978 to 1982 it constituted some 30% of the wood volume harvested in Ontario. It is a versatile species, with 55% of the volume harvested for sawlogs, ties and poles, and the remaining 45% used for pulp production. Among the conifers, jack pine is the most responsive to intensive forest management with regard to costs and success of regeneration and tending, rate of juvenile growth, and early returns on management investments. It is not valued as highly as white pine (*P. glauca* [Moench] Voss) and red pine (*P. resinosa* Ait.) for timber, largely because of its limited log dimensions, but also because of greater variability in log quality. The latter is a reflection of the great variability of jack pine in stem and crown form from tree to tree. Stem straightness and branching characteristics are under strong genetic control and consequently offer excellent opportunities for improvement through selection and breeding (Yeatman 1975a). Marked genetic differences among provenances, related to climatic adaptation, determine limits for distribution of seed and plants as well as setting boundaries for breeding regions (Rudolph and Yeatman 1982).

The purpose of this paper is to outline the scientific basis for genetic management and improvement of seed used for planting and direct seeding of jack pine in the boreal forests of Canada. An example of applied tree improvement of jack pine is given by Miller (1984).

Species and Hybrids

Jack pine is a two-needle hard pine in subgenus *Pinus*, section *Pinus* and subsection *contortae* along with lodgepole pine (*Pinus contorta* Dougl.), Virginia pine (*P. virginiana* Mill.), and sand pine (*P. clausa* [Chapm.] Vasey) (Critchfield and Little 1966). It is most closely related to lodgepole pine with which it forms natural hybrids where the ranges coincide in western Canada. However, both lodgepole pine and hybrids with jack pine are highly susceptible to sweetfern blister rust *(Cronartium comptoniae* Pk.) when planted on jack pine sites in eastern Canada. Neither lodgepole pine nor its hybrids with jack pine should be planted within the natural range of jack pine because of the high probability of failure and the capacity of surviving diseased trees to degrade adjacent jack pine genetically through pollen dispersal (Yeatman 1974). Lodgepole pine has been planted successfully in eastern Canada and, on a small scale, in areas and on sites where neither jack pine nor the alternative hosts sweetfern *(Comptonia peregrina* [L.] Coult.) and sweet gale *(Myrica gale* L.) are found naturally. Lodgepole pine trees are especially susceptible to infection as nursery seedlings and such seedlings will fail wherever they are planted (Ziller 1967).

Genecology

Jack pine is highly variable in climatic adaptation as has been amply demonstrated in field and laboratory provenance tests at numerous locations covering a wide range of environments. Growth, cold hardiness, and disease susceptibility of jack pine provenances are related to environmental gradients in latitude (photoperiod) and in length and temperature of the growing season associated with seed origin (Yeatman 1974, Rudolph and Yeatman 1982). Local provenances are commonly among the top-ranking sources in the series of range-wide trials planted in 1966 at 12 locations from New Brunswick to western Ontario (Holst 1967, Yeatman 1974). Provenance transfers across latitudinal/climatic gradients frequently result in reduced growth and increased susceptibility to winter damage and disease (Yeatman 1976). The consequences of wide lateral transfers along latitudinal or climatic bands are unpredictable. An important discovery from the range-wide tests was the consistent resistance to Scleroderris canker *(Gremmeniella abietina* [Lagerb.] Morelet) of jack pine provenances from central Quebec, from the north shore of the St. Lawrence in the east to the headwaters of the Ottawa River in the west. Western Quebec sources have exhibited superior growth as well as disease resistance at northern locations. This is particularly evident in the area north of Lake Superior and east of Lake Nipigon where boreal Quebec provenances are substantially superior to local sources in both growth and Scleroderris resistance (Yeatman 1984).

Serious losses may be incurred by using an improper seed source or by moving seed beyond the limits of recognized ecological zones. These losses will be perpetuated in future generations derived from sub-optimal plant or seed stock. The first step in genetic management of jack pine is to identify good natural stands within defined regions for collection and production of seed on the basis of forecasted requirements. Seed zones may be used to set limits for seed and plant distribution.

Selected stands cut for seed collection may be regenerated with seed or seedlings of the same origin. These stands will remain identifiable genetic resources (gene pools) with very close to original gene frequencies responding to environmental influences (climate, soil, cultural practices) within the original setting. As such they will remain standards against which genetic gain can be measured. They will also remain consistent sources for seed collection and for future selection of trees required for breeding.

Seed Production

Jack pine also has natural advantages of early sexual maturity, fecundity, and regularity of flowering. The serotinous, closed cones facilitate cone collection and production of seed. Flowering of jack pine spans three growing seasons, from bud initiation in the summer of year one to seed maturity in late summer or fall of year three. Female flowers are borne on multinodal shoots at or adjacent to branch whorls. Clusters of male flowers appear at the bases of elongating shoots lower in the crown than the seed flowers. Jack pine flowers emerge from buds and release pollen (male) or become receptive (female) in late May or early June, the time depending on the season and the location. Open pollination is by wind and basic methods for controlled pollination are similar to those employed with other conifers and pines in particular (Rudolph and Yeatman 1982). Fertilization occurs in the spring of the year following pollination, following which the conelets grow rapidly to full size and reach maturity by late September or early October. The current year's cones may then be harvested, together with cones from previous years to a recommended maximum age of six years (Baker 1980). Germinability is likely to be reduced for filled seed from older cones.

Squirrels are highly destructive of cones of jack pine from juvenile to sapling stage. Cone and seed production may appear to be very inconsistent in young jack pine if judged only from counts or collections of mature cones. Cones borne by open-grown trees and in mature stands are less subject to predation (personal observation).

Cone yield in older stands varies with stocking and age (Roe 1963, Baker 1980). Individual trees growing in heavily stocked stands yield relatively few cones because of the high proportion of trees with suppressed or intermediate crowns and as a result of crown reduction through abrasion among neighbors during high winds in winter when the twigs are brittle. The fecundity of individual cone-bearing trees is very consistent: some have large numbers of cones almost every year while others in the same crown class are consistently unproductive (Baker 1980).

Baker (1980) found that the number of filled seed ranged from 500,000 to 6,000,000 per ha in stands growing in the Gogama District, Ontario. Yield was highly variable and only loosely related to stand age, with stands in the 70- to 80-year age class having the highest numbers of stored seeds. Annual seed production averaged 250,000 seeds per ha, but also varied greatly and ranged from 34,000 to over 1,000,000 filled seeds per ha per year. Better seed yield and quality are provided by cones from the upper crown (Beaudoin 1973). Except for very small cones, cone size has little bearing on seed size and quality but straight cones have a higher yield of filled seed than do curved cones (Beaudoin 1973, Baker 1980, Rudolph and Yeatman 1982).

Seed Germination

Jack pine seed has no requirement for stratification. Laboratory germination of cleaned, filled seed exceeds 95% if good practices for cone and seed management have been followed (Cayford et al. 1967). It has been demonstrated that short exposure to light enhances germination of jack pine seed (Ackerman and Farrar 1965). Germination presents no unusual problems in nursery beds or in containers grown in greenhouses.

When sown in the open, as in direct seeding, jack pine seed germinates best in partial shade on mineral soil or consolidated organic matter where moisture is adequate and daily maximum air temperature exceeds 17°C (Beaufait 1960). Seedbeds prepared mechanically or by burning are generally favorable for germination whereas undisturbed litter and humus are very poor seedbeds. Similar conditions affect seedling survival. Severe losses are caused by heat and drought. Freezing temperatures, particularly summer or early fall frost, may cause mortality of late germinants in the first year. A variety of insects, diseases, rodents and other animals may cause seedling mortality. Vegetative competition for light and moisture and smothering by fallen leaves are important causes of failure of spot seeding on scalps (Chrosciewicz 1960, and Yeatman, personal observation).

Genetic Improvement

Close regulation of seed collection and distribution, and identification and designation of natural populations for seed production and genetic conservation, secure the genecological base for regional reforestation. The next stage of genetic management is to initiate genetic improvement so as to increase the quality and quantity of wood production within defined breeding zones. Increasing levels of genetic improvement will be achieved over generations by systematic selection, testing and breeding. The rate of improvement and choice of properties subject to gain will depend on their inherent variability, industrial objectives, and levels of scientific, technical, and material resources that are applied. Forest productivity, species importance, regeneration imperatives, economic opportunities and social and administrative factors determine priorities in forest management for each region. In addition, changing technology, e.g., introduction of clonal reproduction of conifers on an operational scale, will dictate significant changes in strategy. However, the quantitative genetic structure of the species, i.e., genetic variability and heritability of technically significant characters, will remain the essential framework for genetic improvement.

A range of options for genetic improvement may be considered, from the simplest case of repeated mass selection to the technically demanding ideal of strict pedigree breeding. In all but the simplest program, the breeding and seed production (seed orchard) populations must be considered as separate entities, the latter being derived from the former from time to time.

The basis for improvement of jack pine is the high level of genetic variability from tree to tree as is clearly evident from family and clonal tests (Rudolph and Yeatman 1982). Improvements in stem straightness and branching characteristics are particularly promising in view of the high heritability of these traits and their impact on wood quality and yield of pulp. Increased survival, disease resistance, and growth can also be expected (Yeatman 1975a, b).

Strategies chosen for genetic improvement are varied and reflect local choices and responses to the geographic, technical, economic, and political factors referred to above. Common to all is the need to employ good to superior jack pine sites for all cultural and testing operations in order to ensure full genotypic expression, healthy, vigorous growth, and high seed production. Substantial seed production can be expected in well managed orchards some 6-8 years after planting and full production should be reached by age 14 years.

Seed for direct seeding should be the best obtainable at moderate cost. Modest genetic improvement can be achieved in plantations created from bulked open-pollinated seed of superior phenotypes (plus-trees). Planting at close spacing (5,000-10,000 trees/ha) will permit elimination of poorer trees and retention of better trees in successive thinnings to leave trees of better-than-average form at wide spacing (300-500 trees/ha) for seed production (Type "B" orchards, Yeatman and Rudolph 1982). In due course, subsequent generations of mass-selection seed orchards can be created from seed generated by the previous orchard or from pedigreed (Type "A") orchards when available.

Container or bare-root planting stock is normally used for reforesting the better sites and is subject to more intensive management than seeded or naturally regenerated areas. Greater investment in genetic improvement is warranted to increase the rates of gain in quality and productivity, and thereby increase returns on the larger regeneration investments. Higher rates of gain are obtained in seed orchards planted with families (seedlings) or grafts tested and selected for high breeding value.

Progeny tests are essential for genetic evaluation of the breeding stock and as a source of material for future breeding. Jack pine permits relatively fast generation turnover in the breeding and seed production populations and, therefore, a plan to create successive generations of short-term, relatively low-cost, seedling seed orchards is frequently favored over reliance on grafted (clonal) orchards for production of genetically improved seed of this species. Grafts of jack pine offer no advantage over seedlings in earliness or quantity of cone production. Grafts grow more slowly than seedlings in the early years and some clones fail because of physiological graft incompatibility (Rudolph and Yeatman 1982). Grafted clones of jack pine plus-trees may be established in breeding orchards (clone banks) for generation of fully pedigreed families by controlled pollination. Such families from trees of proven breeding value will be used for advanced-generation seed production and breeding.

Genetic improvement remains the most effective means of maximizing economic response to forest management that employs artificial regeneration, whether by seed-generated plants or by clonally propagated plants, or a combination of both. Genetic improvement is particularly applicable to jack pine for which the returns are both assured and rapid in comparison with those from other boreal conifers. The means will vary with time and place according to need, opportunity, resources and knowledge and skill of the responsible breeders and foresters.

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STATUS REPORT ON THE MANAGEMENT OF JACK PINE IN THE PROVINCES OF NEW BRUNSWICK AND NOVA SCOTIA

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Abstract.--Jack pine (Pinus banksiana *Lamb.) from natural stands has accounted for less than 1% of the wood harvested in New Brunswick and Nova Scotia in recent years and this rate is not expected to change. It is anticipated, however, that in New Brunswick an additional 20% of the future softwood supply (beginning in the year 2020) will be jack pine from artificially regenerated stands; Nova Scotia will derive 1% from this source. Regeneration is primarily by planting after mechanical site preparation. Early survival and growth have been excellent and there are no serious threats from insects or disease at the present time.*

Résumé.--Ces dernières années, le pin gris (Pinus banksiana *Lamb.) des peuplements naturels a représenté moins de 1% de la récolte de bois au Nouveau-Brunswick et en Nouvelle-Écosse, et cette situation ne devrait pas changer. Toutefois, on prévoit que dans le futur (à partir de l'année 2020), le Nouveau-Brunswick tirera 20% de plus de son approvisionnement en résineux du pin gris des peuplements régénérés artificiellement; la Nouvelle-Écosse tirera 1% de son approvisionnement de cette source. La régénération se fait principalement par plantation après préparation mécanique du sol. La survie et la croissance après la plantation ont été excellentes, et les insectes et les maladies ne posent pas de menaces sérieuses à l'heure actuelle.*

Introduction

Jack pine *(Pinus banksiana* Lamb.) occurs in natural stands throughout eastern New Brunswick and north-central Nova Scotia. It grows in mixture with black spruce *(Picea mariana* [Mill.] B.S.P.), white spruce *(Picea glauca* [Moench] Voss), red spruce *(Picea rubens* Sarg.), balsam fir *(Abies balsamea* [L.] Mill.) and various hardwoods or may occur as pure stands after fire. Its commercial significance has been rated far below that of spruce and fir as reflected by the most recent forest inventory volumes where jack pine represents 0.2% of gross merchantable softwood volume in Nova Scotia and 1.7% in New Brunswick. Naturally occurring jack pine can be expected to play an even lesser commercial role in the future because jack pine cutovers tend to regenerate more readily to other species. Conversely the future for jack pine in artificially established stands is of considerable importance, especially in New Brunswick. Regeneration by planting, seeding or scarification exhibits good growth characteristics on a wide range of sites. Jack pine has been planted in the two provinces since the early 1960s. Large-scale operations began in the mid-1970s. In New Brunswick jack pine is one of the species being considered to replace part of the forest susceptible to spruce budworm (*Choristoneura fumiferana* [Clem.]). The jack pine component in New Brunswick silviculture planning represents nearly 30% whereas in Nova Scotia it is approximately 1%.

Economic Importance

Accurate volume statistics for the jack pine harvest over the past 10-12 years are not available. In some instances, especially in recent years, jack pine was recorded as part of the annual "softwood" harvest of either pulpwood or sawlogs. However, the harvest reported for Crown land in New Brunswick from 1970 to 1980 (Table 1) enables some inferences to be derived.

Records show the proportion of logs and pulp as being approximately equal, or approximately 80,000 m^3 of each prior to 1976 and 40,000 m^3 of each from 1976 to 1980. There has been no increase in jack pine volume cut since 1980.

The volumes shown in Table 1 would also be little influenced by the freehold land cut since large freehold is located largely in the western part of New Brunswick where jack pine is not common and the jack pine cut from small freehold is small and insignificant in this context.

A further inference indicating the relatively small current importance of jack pine in both provinces is derived from the well known fact that traditionally much less jack pine has been cut in Nova Scotia than in New Brunswick.

Table 1. Harvest statistics for New Brunswick Crown land 1970-1980[a].

	Softwood harvest (m^3)	Hardwood harvest (m^3)	Total harvest (m^3)	Jack pine harvest (m^3)	Jack pine harvest (%)	Jack pine as sawlogs (%)
1970	2,438,038	239,299	2,677,377	72,430	3	46
1971	2,916,466	288,894	3,205,360	154,117	5	49
1972	2,989,812	414,235	3,404,047	186,337	5	35
1973	4,011,810	464,889	4,476,699	240,126	5	47
1974	3,889,405	598,338	4,487,743	172,799	4	25
1975	2,946,550	286,416	3,232,966	121,710	4	53
1976	3,102,992	380,670	3,483,662	35,737	1	na
1977	2,983,736	357,347	3,341,083	50,477	1	na
1978	3,659,723	397,237	4,056,960	47,008	1	na
1979	3,898,631	622,849	4,521,480	47,415	1	na
1980	3,586,619	496,726	4,083,345	66,580	2	na

[a]Inaccurate after 1975; note comments in following paragraph.

Although after 1975 a proportion of the jack pine harvest accounted for in Table 1 was included as softwood we know that there was in fact a significant decrease in the volume cut due to emphasis on cutting of budworm-susceptible fir stands rather than non-susceptible species such as jack pine. Further, a large proportion of the high-volume jack pine stands had been depleted. Therefore, the Crown harvest from 1975 until 1980 was undoubtedly less than the average of the six previous years and has been estimated at 80,000 m^3 per year.

In summary, it is estimated that less than 100,000 m^3 is being cut annually in New Brunswick and Nova Scotia with the majority originating in the former. The sawlog and studding component is approximately equal to the pulpwood and chips.

The economic importance of jack pine in the future is another matter. Current levels of jack pine silviculture in the two provinces indicate an annual jack pine cut of 1,391,000 m^3 by the year 2020 (Table 2).

Table 2. Estimated jack pine volume derived from reforestation.

	Annual reforestation (ha)	Growth rate (m^3/ha/yr)	Volume beginning year 2020 (m^3)
New Brunswick	6,600	5.25	1,386,000
Nova Scotia	30	4.20	5,000
Total			1,391,000

Table 2 volume estimates indicate that by 2020 jack pine will represent 20% of the total softwood volume harvested in New Brunswick and less than 0.2% in Nova Scotia. This assumes the current harvest objectives for the year 2020 of approximately 7,000,000 m^3 in New Brunswick and 3,500,000 m^3 in Nova Scotia and a conservative estimate of growth rate.

Regeneration

In New Brunswick and Nova Scotia there is little relationship between area of jack pine working group (jack pine species association) harvested and the area regenerated to jack pine. Table 3 indicates the total area of jack pine working group in each province.

The area of jack pine working group regenerated annually is negligible in Nova Scotia and is not meaningful in New Brunswick. Except in the minor instances of scarification for natural seeding, artificial regeneration can and does occur in New Brunswick on sites which previously supported little or no jack pine. Conversely, spruce is often planted successfully on jack pine sites.

The principal method of jack pine regeneration in New Brunswick and Nova Scotia has been planting. Seeding has been carried out successfully but is not a method often implemented. There is no good explanation for this other than the universal reluctance of foresters to take on the added risks from seeding even with attractive costs. Seeding with a cyclone seeder mounted on a snowmobile and aerial applications have been popular. Scarification for natural seeding has also proven successful, but because of the small area of pure jack pine cutovers in recent years, it is not a common technique. When this method is required the equipment most often used is shark-finned barrels and chains, towed by a large crawler tractor.

Manual planting of bare-root (2-0) and container stock has been carried out on scarified sites since the early 1960s. Bare-root stock is planted in the spring whereas containers are planted throughout the planting season. It is of particular note that paper-

Table 3. Jack pine working groups (species associations).

Nova Scotia		New Brunswick	
Species association	(ha)	Species association	(ha)
white pine[a], jack pine	1,085	white pine, jack pine	176
spruce[b], jack pine	2,710	jack pine, larch[e]	29
spruce, jack pine, gray birch[c]	1,310	jack pine, hardwood spp.	9,985
jack pine	1,310	jack pine	45,507
red pine[d], jack pine	3,280	red pine, jack pine	122
spruce, balsam fir, jack pine	1,265	spruce, balsam fir, jack pine	21,776
Total jack pine working group	10,960		77,595
Total productive forest land	3,772,000		6,080,000

[a] *Pinus strobus* L.
[b] *Picea* spp.
[c] *Betula populifolia* Marsh.
[d] *Pinus resinosa* Ait.
[e] *Larix laricina* (Du Roi) K. Koch.

pots have been planted successfully on New Brunswick Crown land throughout the month of September. Nearly all the scarification equipment in use in eastern Canada has been used to prepare jack pine planting sites. These include the Finnish Plow, rolling choppers, the Letourneau Crusher, the C&H Plow, shark-finned barrels, Rome discs, disc trenchers and Bräcke scarifiers. All prepare an acceptable planting area when matched to specific site conditions. Container types are paperpot, styroblock, and multipot, and all have proved successful for their respective owners. Container jack pine to date has been the 70 cm^3 size class grown as a winter or summer crop in greenhouses.

The number of jack pine being planted is indicated in Table 4.

The success rate of jack pine plantations has been satisfactory. Nova Scotia reports survival figures in excess of 75%. New Brunswick plantation survival and development have been measured intensively on Crown land since 1974. Table 5 indicates the success for jack pine from 1977 to 1981 and presents a comparison with spruce.

Table 4. Total[a] seedlings shipped, New Brunswick and Nova Scotia.

	Total stock shipped 1978-1983	Jack pine shipped 1978-1983	Jack pine container (%)
N.B. Crown and small freehold	152,000,000	54,000,000	78
Large freehold[a]	106,000,000	9,000,000	50
	258,000,000	63,000,000	
N.S. Crown	26,000,000	1,600,000	27
All freehold	20,000,000	700,000	100
	46,000,000	2,300,000	

[a] Freehold component is approximate.

Table 5. First-year survival by species, 1977-1981, on New Brunswick Crown land plantations.

	Area of plantation sampled (ha)		Jack pine area in 81-100% survival class (%)		Spruce area in 81-100% survival class (%)	
	paperpot	bare-root	paperpot	bare-root	paperpot	bare-root
1977	4,943	1,530	86	33	98	38
1978	3,525	2,107	81	79	93	2
1979	7,288	2,733	99	63	97	40
1980	6,489	3,134	88	79	82	62
1981	6,000	2,395	78	19a	85	26

[a] Only 46 ha of jack pine bare-root stock planted in 1981.

Development measurements are taken in a representative number of plantations at 5-year intervals. Data are available only for the years 1975, 1976, 1977, coinciding with the beginning of large-scale reforestation in New Brunswick (Table 6).

Table 6. Average height of 5-year-old New Brunswick plantations by species.

Year planted	Black spruce (cm)	Jack pine (cm)
1975	80	140
1976	60	120
1977	60	120

The jack pine height growth shown in Table 6 easily meets the 1982 New Brunswick standard of 1 m, 5 years after treatment, for all plantations. The spruce does not meet the standard, and although these are preliminary data, the results may indicate an overly optimistic target.

No attempt has been made to present stocking results since this is a measure of planter performance or plantation planning and not species performance. The New Brunswick Crown land standard which addresses stocking states that, in the year of establishment, each plantation must have at least 2,000 planted trees/ha, with at least 80% stocking; 5 years after treatment, each plantation must have at least 1,500 and not more than 3,000 trees/ha, with at least 75% stocking and an average height of at least 1 m.

Plantations which do not meet survival standards have resulted from poor nursery stock, animal damage (rabbits and porcupines) and improper planting techniques. These are probably all controllable with the exception of rabbits, against which no totally satisfactory protection method has been identified. Jack pine regeneration problems requiring research are as follows:

- definition of soil textures and/or bulk densities suitable for planting of bare-root stock;
- effect of ribbed containers on the development of jack pine root systems after outplanting (Initial observations have indicated that the roots tend to grow vertically rather than spreading out, resulting in increased risk of frost damage.);
- acceptable outplanting season relative to seedling development;
- degree of mineral-soil exposure required from scarification;
- seedling growth and inter-relationships of shade, direct sunlight and soil temperature;
- continued research concerning the optimum container type;
- optimum nursery stock standards;
- rabbit damage control in plantations;
- use of herbicide in jack pine plantations; type of chemical and application techniques.

Protection

Protection of recently established jack pine from competing vegetation is a serious problem in New Brunswick and Nova Scotia. In Nova Scotia not only does the competition interfere with growth of the planted trees but it provides cover for foraging rabbits. New Brunswick has recently noted this same problem from rabbits and the damage is serious. However, the basic concern is severe competition from one or more of the following: raspberry (*Rubus* spp.), pin cherry (*Prunus pensylvanica* L.), maple (*Acer* spp.), poplar (*Populus* spp.), various grasses and weeds. This usually occurs 1-4 years after planting and requires the use of herbicide during that period. The chemicals 2,4,5T and 2,4,D are used in both provinces although there have been severe limitations in Nova Scotia due to recent controversy and court action. In New Brunswick approximately half of the jack pine plantations require treatment. (Approximately 2,300 ha were sprayed in 1983.)

Usually one application is sufficient although some industry plantations receive two or more. Herbicides are generally applied by aircraft in New Brunswick and by both aircraft and ground sprayer in Nova Scotia. In New Brunswick there is a 3.2 km no-spray zone around any human habitation. This no-spray zone seriously hinders the program because of the accessibility of the forests and scattered nature of communities, camps, etc.

Jack pine is particularly sensitive to 2,4,5T and necessitates spraying late in the season, after active jack pine top growth has ceased but before deciduous growth activity has ceased. This creates the precarious situation whereby weather (availability of flying hours) may mean that the program will not be completed. The herbicide Roundup would allow application earlier; however, there is no guarantee that Roundup will be registered for forestry use in the future.

Manual cleaning in plantations is being considered as an alternative to chemical sprays. New Brunswick is currently carrying out extensive trials with respect to cost. Preliminary data indicate four to 10 times the cost of herbicide depending on site condition and season. The equally important concern of manual cleaning creating more prolific growth of undesirables is also being investigated.

Disease and insects have not been a problem to date in jack pine plantations. Minor *occurrences of Scleroderris canker* (*Gremmeniella abietina* [Lagerb.] Morelet) were reported in New Brunswick plantations in 1971 and again in 1978. Both the North American and more serious European races were present in the 1978 occurrences. The disease has not yet proved to be a serious threat.

Root deformities of planted bare-root stock and different types of container stock have continued to create controversy over the stability of pine as it matures. In fact, several New Brunswick plantations 8 to 10 years of age have been observed suffering severely from windthrow. In 1980 an intensive survey was made of jack pine plantations in this age class and the problem was determined not to be significant. Further monitoring of older plantations will be required.

Tree form, growth rate and branchiness are being monitored and studied. There is concern that these characteristics may be less than desirable in mature plantations. Most plantations are now too young to permit meaningful conclusions to be made.

Thinning

Commercial thinning of jack pine stands has not been a common practice in New Brunswick or Nova Scotia. Precommercial thinning has been carried out in New Brunswick on an operational basis since 1974. However, the area is small as evidenced by Crown land areas for 1978-1982 of 90, 200, 260, 420 and 440 ha, respectively. The usual method has been brush saws with payment at an area-density "piece rate". The average age of stands thinned has been 15-20 years.

Tree Improvement

No tree improvement (orchard) program is planned in Nova Scotia for jack pine. This reflects the relatively minor role of this species in the forest and planned forest management program.

In New Brunswick jack pine has been selected as one of four species for a major improvement program. The other species are *black spruce. white spruce and larch. The* program began in 1974 for Crown land and shortly after several companies became involved. In 1976 a Tree Improvement Council was formed. In essence the Council encourages a cooperative effort for the improvement of jack pine and consists of input from provincial and federal governments, the University of New Brunswick and industry. Each agency is free to pursue individual programs but all of them benefit from combining related materials and test results. It is estimated that some 60 ha of first-generation orchards will be required to meet the future demand for seed. To date, 35 ha of seedling orchards have been established. Volume increases of 10-12% are expected from the first-generation seed with improvements in other characteristics such as stem form, branchiness and wood properties. The first seed production from orchards is expected in 1990. Similar gains of another 10-12% are expected from second-generation clonal orchards.

Conclusion

Jack pine will play an important role as a plantation species contributing to the future wood supplies of New Brunswick. In Nova Scotia its present and expected future importance is minimal. It will have special significance in New Brunswick where it has demonstrated its ability to thrive and serve as an alternative to budworm-susceptible species. Intensive management of the species is required.

STATUS REPORT ON THE MANAGEMENT OF JACK PINE IN THE PROVINCE OF SASKATCHEWAN

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Abstract.--Although the major emphasis is on white spruce (Picea glauca *[Moench] Voss) and mixedwood sites, a portion of government work is being done on pine* (Pinus *spp.) sites. In addition, some companies, notably Prince Albert Pulpwood, are putting a lot of effort into pine regeneration and improvement. Jack pine has potential for development in Saskatchewan.*

Résumé.--Même si la majeure partie des études gouvernementales portent sur les sites à épinette blanche (Picea glauca *[Moench] Voss) et à essences mélangées, une partie est également consacrée aux sites du pin* (Pinus *spp.). De plus, quelques compagnies, notamment la Prince Albert Pulpwood, consacrent beaucoup d'efforts à la régénération et à l'amélioration du pin. Un potentiel existe pour la mise en valeur du pin gris en Saskatchewan.*

Management of Jack Pine in Saskatchewan

Although jack pine *(Pinus banksiana* Lamb.) was one of the earliest species tried and planted by Dominion foresters (Anon. 1912-1921), historically in Saskatchewan it has played second fiddle to white spruce *(Picea glauca)* [Moench] Voss). Early industry development was in the form of sawmills aimed at the large, old, overmature white spruce. Later, some pine was taken for power poles and railroad ties and eventually an export pulp market developed, and next a demand arose for treated posts. It was only during the 1970s that studmills started taking any meaningful quantity of jack pine, at the same time that the Prince Albert Pulp Company Ltd. (constructed in 1967) switched its emphasis towards pine. Table 1 shows that the percentage of pine harvested has remained at about one-third of the provincial harvest between 1970-1971 and 1980-1981, but Table 2 shows that the balance between products has changed in the last 10 years (Teskey and Smyth 1975). Lumber production is six times what it was, and posts bounce up and down. Although the table shows pine pulp at slightly above levels of 10 years ago, the total pulp roundwood has diminished,

Table 1. Pine as a proportion of the provincial harvest.

Year	Total harvest (m^3)	Pine harvest (m^3)	Pine harvest (%)
1970-1971	2,752,040	923,590	33.5
1971-1972	1,968,960	650,780	33.0
1972-1973	2,547,840	787,330	30.9
1978-1979	2,894,220	855,930	29.6
1979-1980	3,431,920	1,110,500	32.4
1980-1981	2,816,240	991,360	35.2

and more is now obtained from sawmill chips. Thus, although the roundwood pulp harvest has diminished, the pine portion of this has now increased to 65%.

Productive forest under pine stands is 28% of the total area and produces one-third of the harvest. However, if we consider softwood forest alone, pine comprises 40% and white spruce (although it is the major species

Table 2. Pine products produced.

Year	Lumber[a] (m^3)	Pulp (m^3)	Ties (pieces)	Roundwood (lineal m)	Posts (pieces)	Poles (pieces)
1970-1971	16,900	652,290	139,760	6,690	5,132,000	106,900
1971-1972	13,650	446,360	36,800	40,180	3,819,550	40,600
1972-1973	47,700	538,530	45,350	27,070	3,726,790	28,590
1978-1979	77,870	546,610	50,910	78,440	4,868,370	16,720
1979-1980	125,420	659,890	23,110	53,190	4,097,870	9,600
1980-1981	104,610	609,600	49,890	44,490	4,868,370	2,530

[a] 1,000 fbm x 1.623 = m^3

harvested) comprises only 17% of the productive forest. Pine has potential for development in the future (Kabzems et al. 1972, 1976).

Softwood yields from pine stands range from 92 m^3/ha (mixedwood stands) to 125 m^3/ha (pure pine). Thus the harvested areas will be in the vicinity of 9,000 ha per year. These areas will require a variety of treatments depending on the stand of origin (Table 3) and upon the "strategy region" of the province (Table 4).

Table 3. Estimated ranges of needs for regeneration activities by percentages of harvested areas[a].

Natural regeneration	Percentage of harvested areas (%)
SjP[b]	nil to 35
SH/HSjP[c]	nil to 25
SbSjP/jPbS[d]	nil to 35
Scarification	
SjP	50 to 64
SH/HSjP	25 to 35
SbSjP/jPbS	50
Planting	
SjP	15 to 50
SH/HSjP	50 to 70
SbSjP/jPbS	15 to 50

[a] These are summarized from a more detailed table of six strategy regions.
[b] SjP - pure jack pine stands
[c] SH/HS - mixedwood stands with hardwoods and pine
[d] SbSjP/jPbS - mixed black spruce *(Picea mariana* [Mill.] B.S.P.) and pine stands

Table 4. Estimated needs for regeneration activities by percentages of harvested areas for each strategy region.

	Strategy region (%)					
	1	2	3	4	5	6
Natural regeneration						
SjP	-	21	35	35	35	12.5
SH/HS	-	25	15	15	20	15
SbSjP/jPbS	-	14	35	35	35	22.5
Scarification						
SjP	50	64	50	50	50	50
SH/HS	30	25	35	35	30	35
SbSjP/jPbS	50	50	50	50	50	50
Planting						
SjP	50	15	15	15	15	37.5
SH/HS	70	50	50	50	50	50
SbSjP/jPbS	50	36	15	15	15	27.5

In addition to this harvest figure, most of the major forest fires occur on jack pine sites, and the pine areas denuded by fire may range from 0 to an additional 20,000 ha. Of this pine land denuded by fire, 95% regenerates naturally, so the additional needs for planting are small.

Regeneration of Pine Areas

There are two agencies involved in regenerating pine areas: Saskatchewan Parks and Renewable Resources (SPRR) and Prince Albert Pulpwood (The logging arm of Prince Albert Pulp Co. Ltd.). These two agencies have adopted different approaches to pine regeneration, but laudable results have been achieved by both. In addition, Simpson Timber Company and Saskatchewan Forest Products Corporation carry out scarification on pine sites.

Prince Albert Pulpwood scarifies 75-80% of its pine cutovers and plants the rest. Although natural regeneration may take place on one-third of their area, they scarify at once rather than leaving it to chance and then finding they have to plant. They machine plant 3-0 stock and hand plant 2-0 stock. Prince Albert Pulpwood's present policy is to treat at least as many hectares as their annual harvest, and for 3 years they have been achieving this goal. Thus, the majority of the pine cutover sites are dealt with by them.

SPRR, on the other hand, tends to concentrate on spruce sites, areas of mixedwood forest in the Hudson Bay area, and burnover areas which need planting. This concentration on spruce, coupled with recent budgeting restraints, has directed SPRR's activities almost exclusively towards planting. One change which has taken place in this planting is that machine planting has decreased and hand planting has increased. This is primarily due to the high purchase price and maintenance costs of equipment. Hand planters can adequately plant 2-0 pine instead of 2-2 or 3-0, although improved nursery practices have increased stock size over the last few years. Container stock has always been of interest to us, and we have gone from the Ontario tubeling to Japanese paperpots and are now using Swedish multi-pots. However, containers are a minor part of our planting program at the moment.

SPRR planting is mostly done on contract on a bid price per tree. Prince Albert Pulpwood's planting is done by employees on an hourly wage basis.

Ground preparation and seeding is a third method of regeneration which is also sometimes used. Saskatchewan has tried some 25-30 seeding projects over the last 30 years. Results have generally been good in the first year, but become poor later due to seedling mortality (moisture deficit), snowshoe hare *(Lepus americanum)* damage or other reasons. One which shows promise is the ripper plow. This was used in 1982 and the area was aerially seeded. Seeding remains more an experimental technique than a regular tool, but in future may well provide answers to planting areas inaccessible for planting.

Fire should also be mentioned as one method to achieve regeneration through removal of duff layers and by opening up the natural cones. Prescribed burning is not used in Saskatchewan, and natural fires tend to produce an overabundance of trees.

Equipment Used

For site preparation a great variety of equipment is used, and each has its own merits. Equipment used includes the Bräcke, Leno, C&H V-plow, straight blade, drum chopper, TTS disc trencher, and various blades. SPRR prefers the TTS as it is fast and mobile.

For scarification three main pieces of equipment are used. Chains and/or barrels are used by smaller operators or else in rocky terrain, but overstocking tends to result if extreme care is not taken during operations. The Leno patch scarifier and the Bräcke cultivator are preferred equipment. Prince Albert Pulpwood prefers patch scarification as it reduces thinning requirements and appears better in heavy moss conditions. The Leno has proven effective on mixedwood sites with poplar remaining on site, as it can negotiate tight turns better.

Prince Albert Pulpwood uses C&H planters on some of the pine sandflats.

Successes and Failures

Some 85-90% of scarified areas regenerate successfully, although care must be taken lest too heavy a growth is initiated.

Between 1963 and 1978 survival in plantations was 62% at 1 year and 48% at 5 years. Since then things have been improving, and of measurements taken in 1982, planted areas had an initial success rate of 85-90%, and a 5-year success rate of 75-80%. The success in year 1 seems to depend more on the weather and time of planting than on any other factor, and in subsequent years it is most dependent upon the hare population cycle.

All regeneration techniques have failures and these seem mainly due to weather extremes, hares, competing vegetation and other unknown reasons. We have in the past also had failures due to planting stock inadequacies. Now that we are keeping better control of top:root ratios, cold storage conditions, and timing of lifting, we feel that our stock is not causing field failures. Failures were evident on fall plantings of pine, so we no longer plant this species in the fall. We also had failures due to competing vegetation, but more care in scarification and in planting microsites is helping overcome failure for these reasons.

Finally, it should be noted that the results which class the "inadequate survival" of plantations are based on planted trees. Some of these poor survival plantings do have natural regeneration on them so that there is, in fact, adequate stocking.

Regeneration Problems

There are many regeneration problems which require research, and these may be categorized as nursery problems, technique problems and field problems.

Among the nursery problems, such items as cone insects, pitch nodule maker *(Petrova albicapitana* [Busck.]) and terminal weevil *(Pissodes terminalis* Hopk.) (Rose and Lindquist 1973) in seed orchards need to be addressed, and the size, type and provenances of trees planted in certain areas need to be investigated. We feel that our nursery stock has improved in recent years, but there may yet be room for improved methods in this area. Field problems include growth defects due to root deformities after planting, insect infestations, competition from herbs and shrubs, and transport of seedlings and coolers.

Problems that Require Research

Among many problems that require research, the ones relating to actual regeneration are few. These include such items as monitoring stock quality and form from nurseries, keeping track of and taking advantage of provenance differences, root deformities due to poor planting, logistics of handling container stock (distribution in the field and carrying while planting), suiting size of stock to certain sites, and adequate site preparation. Most of these are being studied, and improvements are being implemented as they are identified.

Protection problems seem to be by far more serious and more important than regeneration problems. These include insects previously mentioned as being problems and also root collar weevil *(Hylobius warreni* Wood) and the jack pine budworm *(Choristoneura pinus pinus* Free.) (Moody and Cerezke 1983). Of great importance to the west is to learn the susceptibility of jack pine to the mountain pine beetle *(Dendroctonus ponderosa* Hopk.). Also resistance to diseases such as the western gall rust *(Endocronartium harknessii* [J. P. Moore] Y. Hirat.), the dwarf mistletoe *(Arceuthobium americana* Nut.) and Armillaria root rot *(Armillaria mellea* [Vahl ex Fr.] Kumm.) are important and should be researched.

The hare is a major factor in survival of pine stands, which varies with the cycle of the hare. In some cases 100% of the trees in a plantation have been affected by them, and major emphasis should be on this problem. The porcupine *(Erithizon dorsatum)* is also a minor pest.

Competing vegetation is probably second only to the hare. Support must be given to the Forest Pest Management Institute for continuing research, testing and registration of chemical sprays for forestry purposes.

Intensive Forest Practices

There are no commercial thinning operations in jack pine stands in Saskatchewan, and not very many precommercial operations either. SPRR has done comparatively little in this regard despite attempts to obtain some funding. This year an Indian band is thinning forest stands using Local Employment Assistance Program (L.E.A.P.) funds, and we have a little money for thinning about 350 ha this winter.

Prince Albert Pulpwood has been leading the way in this, and they thin about 600 ha/year using Husquvarna thinning saws on early (1970) scarification sites, thinning to 3,000/ha from as much as 20,000/ha.

Tree Improvement Program

SPRR efforts to date consist mainly of provenance testing and instituting nursery methods which allow for proper provenances to be delivered to various planting sites. In cooperation with the Canadian Forestry Service at their facilities in Edmonton, grafting of pine scions has taken place using Dr. J. Klein's selected material for eventual inclusion in a clonal seed orchard.

Klein started a breeding program for jack pine in 1967, and is beginning to show that his selected stock had 5-year progeny heights 7-9% above the mean test and straighter stems (Klein 1982). A clone bank will occupy the next 5 years of this project.

Prince Albert Pulpwood began establishing a clonal seed orchard in 1978 and has grafted 3,500 trees from 32 super-trees from around their licence area. They hope to begin seed collection in 1984. Stock will be selected for form and growth, and inferior clones will be rogued out. Progeny tests are also being conducted on open-pollinated seed collected from plus-trees, and will be the foundation of future orchards (Orynik 1979, Roddy 1981).

Summary

In many ways the jack pine is a problem child, but on the other hand it has some assets of which we, as careful managers, can take advantage. It will take a long time, dedicated people and detailed studies to obtain a super jack pine, but hopefully the many frustrations will be rewarded.

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STATUS REPORT ON THE MANAGEMENT OF JACK PINE IN THE PROVINCE OF MANITOBA

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Abstract.--Jack pine (Pinus banksiana *Lamb.) is found with all soil types in Manitoba but is most productive on moist, sandy loam sites. It is the second most important species next to the spruces* (Picea *spp.), with an estimated 8,000 to 9,000 ha of the working group harvested annually. Jack pine is regenerated in various ways, and approximately 3,000 ha are regenerated annually. Regeneration is not a problem if proper prescriptions are followed.*

Résumé.--Le pin gris (Pinus banksiana *Lamb.) se trouve sur tous les types de sols au Manitoba, mais il est plus productif sur les loams sableaux et humides. Avec 8,000 à 9,000 ha environ de la récolte annuelle, c'est l'espèce la plus importante après les épinettes* (Picea *spp.). Sa régénération est pratiquée de diverses façons et porte sur approximativement 3,000 ha chaque année. Elle ne pose pas de difficultés lorsque les prescriptions appropriées sont respectées.*

The total area of Manitoba comprises 65,036,500 ha, of which 84.1% is land and 15.9% is water. On the basis of land productivity for forestry, 29.4% of the total land area is classified as productive forest land, 33.9% as non-productive forest land and 36.7% as non-forested land.

The forest zone, where forestry is or could be the major or one of the major uses, includes 25,730,800 ha of land area. Productive forest represents 52.3%, non-productive land 38.4% and non-forested land 9.3%.

The topography varies from the flat lands of the prairie to the rocky Shield terrain on the eastern border and the hilly terrain of the Duck and Porcupine Mountains on the western border.

Soil conditions vary, and include sandy textures, heavy clay loam, gravel tills, deep and shallow peat and rocky outcroppings. Jack pine *(Pinus banksiana* Lamb.) is found in association with all these soil conditions and terrains, with the more productive sites of the working group located on moist, sandy loam sites.

Jack pine is the second most important species in Manitoba next to the spruces *(Picea* spp.). Of the total softwood volume harvested between 1971 and 1981, 33.4% was jack pine. During this period the jack pine products consisted of 61% pulpwood, 33% lumber and 6% other products. The total jack pine production increased from 550,000 m^3 in 1977-1978 to 760,000 m^3 in 1980-1981.

It is difficult to put a figure on the average area harvested annually for the jack pine working group as at present Manitoba does not keep these types of records. It is estimated that 8,000-9,000 ha of the jack pine working group are harvested annually.

Regeneration

Jack pine is regenerated in various ways in Manitoba, with activity carried out on 2,800 to 3,000 ha annually. Activity depends on moisture and soil conditions, location and availability of planting stock. Bare-root planting is carried out on 975 ha annually by hand and machine. Container stock is not used for jack pine as the 408 paperpots used in Manitoba have not proven successful in dry, sandy conditions.

The C & H plow and planter are used in southern Manitoba on the dry, sandy sites with large 2-0 jack pine stock, with a one-pass method being employed on old and fresh cutovers. There are few problems, and survival exceeds 75%. This machine can plant up to 15,000 seedlings per day and up to 400,000 over the spring season. It will not work in heavy clay or gravelly soils; the area must be stone-free and sandy.

Hand planting with 2-0 jack pine is carried out on a variety of sites but mainly on light, sandy soils that have been site-prepared with either a TTS disc trencher or a Bräcke scarifier. On certain areas that are heavy in jack pine slash the 7- and/or 8-ft (2.1- and/or 2.4-m) Fleco drum chopper is used prior to the disc trencher. Success is usually in excess of 75%.

On the Shield areas east of Lake Winnipeg and in the northern parts of the province where soil conditions are heavy, large wheeled skidders with anchor chains are used to scarify the jack pine cuts to promote natural regeneration. Approximately 1,900-2,000 ha of this type of area are treated annually, and full stocking is generally achieved. There are problems when seed source is uncertain, but these are being identified by regeneration surveys and, where necessary, planting is carried out.

Certain cutovers in Manitoba are left to regenerate on their own. Various criteria are used in selecting these cutovers, but usually they include the areas that are inaccessible during the period when scarification is required, or those that, because of the time and type of harvest, will be sufficiently scarified to regenerate on their own.

It is difficult to place a figure on the number of hectares that are regenerated annually by this means, as regeneration surveys on such areas have not been compiled at this time.

Equipment Used and Preferred

Manitoba uses a variety of equipment for jack pine renewal, including shovels, C & H plows and planters, TTS disc trenchers, Bräcke scarifiers, 7- and 8-ft (2.1-m and 2.4-m) Fleco drum choppers, anchor chains and shark-finned barrels. It is not a matter of preferred equipment but rather the suiting of the techniques to the terrain and soil condition.

On light soils the TTS disc trencher is used, followed with hand planting by shovel. If slash is a problem the Fleco drum chopper is used prior to the trencher.

Light, sandy soils in the southern portion of the province are not suited to scarification for natural regeneration. Although germination occurs when these soils are scarified, the germinants do not survive because temperatures are extreme here and rainfall is uncertain. These areas must be planted. In the northern portion of the province where conditions are not as extreme, we have had success with scarification.

On the heavier soils, anchor chains are used and success is achieved by suiting the type of disturbance to the site condition and availability of cone-bearing slash.

Success Rate

In Manitoba the standard for success is to obtain 75% stocking per ha. All plantations normally achieve this goal and if problems occur the plantation is refilled to obtain the desired stocking or, if failure has occurred, the area is replanted.

Normally planting is not a problem except in the case of a severely dry spring, when excessive mortality may necessitate curtailment of the program. This has happened in certain areas over the past few years when spring rains failed to occur.

Hand seeding with cyclone seeders was tried on a variety of sites in the southern portion of the province but was not successful.

With the establishment of the Manitoba Forest Resources pulpmill at The Pas in the late 1960s, anchor chaining was developed for use in the jack pine working group and this equipment was modified to obtain the desired results.

Large wheeled skidders with three units of anchor chains and tractor pads are used to obtain regeneration. Previous results indicated that four units of anchor chains produced too high a stocking, and disturbance was reduced to obtain desired seedling density.

This type of scarification normally results in immediate regeneration of jack pine, with the spruces regenerating a few years later. Aspen (*Populus* spp.) also occurs on the cutovers and regeneration surveys indicate that at least 75% of the jack pine cover type areas have achieved the desired stocking of hardwoods and softwoods.

These scarified areas in the north regenerate to approximately 50% jack pine, 25% spruce and 25% hardwood. In the eastern portion of the province regeneration is 90% jack pine, with small amounts of spruce and aspen.

These are estimates, as the information is identified in the regeneration surveys but is not tabulated at the time of this presentation.

Failure Rate

Generally speaking the renewal of the jack pine working group in Manitoba would be considered successful and where stocking has not been successful the reasons are known. The planting programs are at least 95% successful with failure occurring on areas planted without site preparation on a trial basis or areas planted late in spring when the weather turns hot and dry. Fall planting of jack pine has not been successful, and is not carried out in Manitoba.

Scarification is generally 75% successful, with failure occurring if excessive clay mineral soil is exposed or seed availability is poor. These conditions are controllable with good on-site management.

Regeneration Problems

Regeneration of jack pine in Manitoba is not a problem if the proper prescriptions are followed for the various site conditions.

In the mixedwood type the area can be overgrown very quickly with aspen if a treatment for jack pine regeneration does not follow immediately after logging. If not treated the area will regenerate mainly to hardwood with only a scattering of jack pine. To restock these areas to softwood (jack pine) would require increased expenditures on shear blading, herbicides, etc., and subsequent site preparation and planting would be necessary.

Jack pine 408 paperpots do not do well in dry, sandy soil conditions. The dry sand draws the moisture from the container, survival is poor, and the paperpot does not decompose.

The plug method has not been tried in Manitoba for jack pine but it is anticipted that trials will take place in the near future.

Protection

There are a few insect and disease problems associated with jack pine in Manitoba but these are not deemed serious at the present time.

Western gall rust (*Endocronartium harknessii* [J.P. Moore] Y. Hirat.) is common throughout the province, but steps are taken to ensure that nursery stock is not infected and that infected areas are not permitted to spread. All jack pine shelterbelts in the Hadashville nursery have been removed.

Jack pine mistletoe (*Arceuthobium americanum* Nutt. ex Engel.) is serious in specific locations which have been identified and mapped, but steps are being taken to eradicate it, and to renew these areas with alternative species such as red pine (*Pinus resinosa* Ait.) where possible.

Jack pine budworm (*Choristoneura pinus pinus* Free.), though not a major problem, can occur periodically in specific areas in epidemic proportions, remain for a year or so and then disappear as quickly as it came. Usually the trees are under stress from mistletoe or drought when the budworm appears and mortality may occur in the areas under the greatest stress.

The eastern pine shoot borer (*Eucosma gloriola* Heinr.) caused minor problems on trees 0.9-1.8 m high in regenerated natural areas. Loss of one year's leader usually results but the trees recover and overgrow the damaged area.

Competing vegetation is not usually a problem with jack pine. Aspen occurs in the scarified areas and the two species grow well together. Usually these are the most productive areas.

Thinning

In the late 1950s and early 1960s the 7-ft (2.1-m) Fleco drum chopper was used to thin anually approximately 1,200 ha of young jack pine and from 1965 to 1970 approximately 400 ha of young jack pine were thinned annually.

Strips 2.1 m wide were cut (with 2.1-m leave strips), and some areas were cut in the other direction to form a grid pattern in an effort to reduce the number of stems per ha. The Canadian Forestry Service has published a report on this program (Bella 1974).

In 1978, approximately 300 ha of jack pine were thinned with hand-held brushsaws at 1.8- x 1.8-m spacing. In 1980, 4 ha of jack pine were thinned with brushsaws at 1.8- x 1.8-m spacing. No other work has been carried out to date as funds have not been available to carry out stand improvement.

Jack Pine Tree Improvement

Local provenance trials of 17 seed sources were established on five different sites in the province. Seven provenances have been segregated as promising seed sources. A progeny-tested seedling seed orchard was established in Bird's Hill in 1970. In all, 40 clones have been identified as superior seed sources; scions taken from these 40 clones are being established in a 1.5-ha clonal seed orchard of 1,2000 ramets (40 x 30). A clone bank of extra jack pine grafts has been established and will be subjected to gibberellin treatments for flower induction.

Summary

Jack pine has been planted in the southern portion of the province since the 1950s when a nursery was established at Hadashville. All areas have been renewed and present activity is keeping pace with yearly cutovers.

In the other areas of the province jack pine was not harvested to any great extent until the late 1960s and the jack pine utilized at that time was obtained from the spruce working group.

With the greater use of jack pine in the north, scarification is unable to keep pace with the cutting program as funds are not available at this time.

It is anticipated that, eventually, genetically improved jack pine seed will be used for all planted stock in Manitoba.

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STATUS REPORT ON THE MANAGEMENT OF JACK PINE

IN THE PROVINCE OF QUEBEC

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*Abstract.--If we consider Quebec forests as a whole, jack pine (*Pinus banksiana *Lamb.) is a marginal species since it makes up only 6% of standing softwood reserves. Nevertheless, from a silvicultural viewpoint, the species plays an important role since it accounts for approximately 40% of the artificial regeneration program. The authors report on the extent to which jack pine reforestation efforts have been successful, and describe the research program and the jack pine genetic improvement program in Quebec.*

*Résumé.--Au niveau de l'ensemble des forêts du Québec, le pin gris (*Pinus banksiana *Lamb.) occupe une place marginale puisqu'il ne constitue que 6% des stocks résineux sur pied. Toutefois, au niveau sylvicole, le pin gris occupe une place importante puisque cette essence constitue environ 40% du programme de régénération artificielle. Les auteurs font aussi état du degré de réussite des travaux de reboisement avec le pin gris, et décrivent le programme de recherche et le programme d'amélioration génétique du pin gris au Québec.*

Introduction

In Quebec, jack pine (*Pinus banksiana* Lamb.) has been given special attention by foresters over the last decade. For example, 1974 saw the establishment of a jack pine genetic improvement program by the "Conseil de la recherche et du développement forestiers". Then, in September 1977, a workshop on jack pine management at Val d'Or brought together various participants from the forestry sector. The marked interest in jack pine is probably due to the fact that, in comparison with other species, it exhibits numerous advantages from a silvicultural point of view. As noted by Dancause (1977), the main advantages associated with jack pine are ease of obtaining seed, ease of nursery production, adaptability to different soils, very rapid juvenile growth, a root system capable of exploring soils in depth, and ability to germinate in mineral soils.

Because of these characteristics, jack pine plays an important role in the reforestation program of the Ministère de l'Energie et des Ressources de Québec (MERQ) even though the species has only sporadic distribution in Quebec forests.

We are pleased to take part in this symposium, since we feel that such meetings can help us, in both the short and the long term, to improve our knowledge of very specific subjects such as that being dealt with here. Accordingly, insofar as possible, we will attempt, in our presentation, to bring you up to date on the results of efforts made in Quebec in the various facets of jack pine management.

Prevalence of Jack Pine in Quebec

Gross Merchantable Volume

It is not easy to assess the prevalence of a species like jack pine. At the present time in Quebec, the most reliable source of such information is the gross merchantable volume calculated from the most recent forest inventory data for both public and private forests (Table 1).

If we consider Quebec forests as a whole, jack pine is a marginal species since it makes up only 6% of softwood reserves. It is also important to note that, in terms of geographical distribution, jack pine is concentrated mainly in three administrative regions: Saguenay—Lac St-Jean, Trois Rivières, and Abitibi—Témiscamingue (Appendix 1). These regions account for nearly 90% of jack pine reserves (Appendices 2 and 3). It should also be noted that jack pine is concentrated almost entirely in public forests.

Table 1. Distribution of jack pine gross merchantable volume in public and private forests and jack pine volume expressed as a percentage of total volume and softwood volume for all species.

Tenure	Reserves (1,000 m^3) Total	Softwood	Jack pine	% of total	% of softwood	% of tenure
Public forests	3,606,101	2,831,279	175,551	4.9	6.2	97.3
Private forests	435,883	189,645	4,850	1.1	2.5	2.7
Total	4,041,984	3,020,924	180,401	4.5	6.0	100

Area and Merchantable Volume Harvested

In Quebec, in government or industry, there is not, to our knowledge, a mechanism for calculating the volumes of jack pine harvested. Generally, data are compiled on an overall basis for the three main species harvested: fir (*Abies* spp.), spruce (*Picea* spp.), and jack pine. This is very understandable, since there is little practical justification for specifically accounting for a species like jack pine. Cutting rights are the same for the species mentioned above and, in terms of use, jack pine does not enjoy any special status in comparison with species like fir and spruce.

In order to estimate the area of jack pine harvested in Quebec, we used forest accounting data, i.e., the compilation of clearcut areas for the three major working groups where jack pine is present, for the year 1979-1980. The results obtained by working group are:

Pure jack pine stands	9,281 ha
Jack pine/spruce mixed stands[a]	1,313 ha
Spruce/jack pine mixed stands[a]	2,167 ha
Total	12,761 ha

[a]Predominant species listed first.

It should be noted that more than 90% of these areas are located in the three regions indicated earlier. With regard to the volumes of jack pine harvested, MERQ does not have any precise statistics. Labreque (1977), after making extrapolations, estimated that jack pine accounted for about 10% of the total volume of softwoods harvested in Quebec public forests for the years 1975-1976 and 1976-1977. In spite of our efforts, we were unable, for the reasons cited earlier, to obtain precise estimates for more recent years.

Use of Jack Pine

At the outset, we must note that there are no specific data, within government or industry, on the use of jack pine. We can nevertheless assert that the lumber industry and the pulp and paper industry are the two major users of jack pine in Quebec. More than 60% of the roundwood volume harvested in Quebec public forests is destined for the sawmill industry (Lefebvre and Parent 1983), and it is known that the residues from this industry are used by the pulp and paper industry. In addition, a limited quantity (about 50,000 m^3) is used for making poles[1].

[1]Brunet, J. 1983. Min. Energie Ressour. Qué., Serv. Alloc. Bois (pers. comm.).

Natural Regeneration of Jack Pine

In 1977, MERQ began an extensive regeneration inventory program for sites disturbed by fire or harvesting in order to determine the quantity and quality of current regeneration and direct reforestation efforts on inadequately regenerated sites. Under this program, between 1977 and 1980, some 370,000 ha of Quebec public forest were inventoried. The report published in 1981 (Im and Paquet 1981) clearly established that jack pine stands are very poorly regenerated. Out of 21,286 ha of inventoried land, only 3% showed stocking levels of more than 60% and were therefore considered to be well regenerated. The age of the disturbances ranged from 1 to 10 years, although about 50% of the lands had been harvested 6 or more years previously.

On the basis of these results, the authors recommended that regeneration inventories in jack pine stands be abandoned and that the areas be reforested (by planting or seeding) as soon as possible after cutting.

Since 1981, MERQ standards for regeneration inventories after disturbances (Paquet 1981) have specified that it is not necessary to proceed with a regeneration inventory for stands where jack pine occupies at least 50% of the basal area of the softwood portion of the stand.

Statistics on Reforestation Techniques Used for Jack Pine

To carry out its reforestation program on public and private forests, Quebec uses the following methods: planting of bare-root or containerized seedlings and aerial or ground seeding.

In 1982, some 29,600 ha were artificially regenerated. Jack pine accounted for 51.8% of this total (Table 2). It should be noted, however, that direct seeding was used for 44.5% of this area and that 98.5% of the total seeded area was reforested in jack pine.

By 1986, the reforestation objective will be 51,707 ha including 15,500 ha reforested by direct seeding (Table 3). Jack pine will account for 40.0% of the total reforestation objective. Moreover, 93.5% of all seeding efforts will involve this species.

Tables 2 and 3 indicate that the use of jack pine will increase by 5,328 ha or 34.7% between 1982 and 1986. There will be increased utilization of all three methods, but the biggest increase will be in the use of containerized seedlings. Most planting of jack pine is and will be done in public forests, and seeding is and will continue to be carried out exclusively in these forests. It should be noted that 91.0% of the jack pine reforestation objective for 1986 will be applied to the three regions mentioned earlier.

Table 2. Area reforested with jack pine in 1982, by technique and as a percentage of total area.

	Planting (ha)			All species	
Tenure	Bare-root	Container	Total	Total	% jack pine
Public forest	695	581	1,276	6,334	20.1
Private forest	947	132	1,079	10,110	10.7
Total	1,642	713	2,355	16,444	14.3
	Seeding (ha)			All species	
Tenure	Bare-root	Container	Total	Total	% jack pine
	Aerial	Ground			
Public forest	3,971	9,004	12,975	13,175	98.5
Grand total (planting and seeding)			15,330	29,619	51.8

Table 3. Jack pine reforestation objectives for 1986, by technique and as a percentage of total objective.

Tenure	Bare-root	Container	Total	All species Total	All species % jack pine
	Planting (ha)				
Public forest	1,004	3,090	4,094	20,120	20.3
Private forest	2,091	--	2,091	16,087	13.0
Total	3,095	3,090	6,185	36,207	17.1
	Seeding (ha)				
	Aerial	Ground			
Public forest	8,000	6,500	14,500	15,500	93.5
Grand total (planting and seeding)			20,685	51,707	40.0

Techniques Used in Jack Pine Reforestation

Site Preparation

The selection of site preparation equipment depends mainly on soil texture and the reforestation method to be employed.

Generally, preparation of sandy sites for planting is carried out with disk trenchers such as the TTS or the Equisyl, cultivators such as the Bräcke, and barrels and chains. For mechanical and partially manual ground seeding, the Bräcke cultivator is used. For aerial seeding on this type of soil, principally mechanical disk trenchers are used.

For clay soils, preparation is the same as for sandy soils. However, seeding of the clay soils is becoming increasingly rare because of the poor results obtained.

In preparing sites for planting, the goal is to establish some 2,500 suitable microsites. For aerial seeding, the goal is to leave approximately 25% of the mineral soil exposed and to obtain an even distribution of exposed soil.

Bare-root Seedlings

Until recently, 2-0 and 3-0 seedlings were generally used. However, for several years now, in order to obtain better balanced seedlings (stem:roots), northern nurseries have been producing 2-1 or 1.5-1.5 transplants on a trial basis.

Containerized Seedlings

Introduced several years ago, the use of containerized seedlings is playing an increasingly important role in efforts to meet our reforestation objectives. In 1986, seedlings of this type will be used in reforesting 6,600 ha. Jack pine will account for 46.8% of this area.

The main containers used to date for jack pine are the Styroblock 8, the MERQ tube, and a plastic container produced in Quebec.

Aerial Seeding

Aerial seeding is carried out by aircraft with Brohm or Stardust seeders. The seeding rate is about 50,000 viable seeds per ha.

Spot Ground Seeding

Mechanical seeding is done with a Bräcke cultivator fitted with a seeder. This apparatus disperses some 20,000 viable seeds per ha. Manual shelter spot seeding, on the other hand, is performed with a specially designed apparatus. For conventional direct seeding, we use homemade seed dispenser equipment. In both cases, we use approximately 12,000 viable seeds per ha.

Plantation Tending

For a number of years, jack pine plantation tending was performed by means of mechanical cleaning and, more recently, phytocides. However, following public hearings on the subject of aerial phytocide spraying, a departmental decision was made to limit 1983 activities to mechanical ground spraying trials and to step up mechanical cleaning with chainsaws or circular saws.

Assessment of the Success Rate of MERQ Reforestation Efforts and Explanatory Notes

As we saw earlier, the major methods used in Quebec for artificial regeneration of jack pine are planting of bare-root or containerized seedlings and aerial or ground seeding. The assessment of success rates for projects in public forests involves the establishment of sample plots in each of the projects carried out by MERQ.

Planting of Bare-root and Containerized Seedlings

For bare-root seedlings (Table 4), results were compiled from data collected in plantations established between 1978 and 1981. Almost all planting was done manually with 2- or 3-year-old seedlings.

For containerized seedlings (Table 4), results were compiled for plantations established in 1981 in which the MERQ tube was used. It should be noted that the paper was removed at the time of planting.

From the above tables we can see that, after two growing seasons, containerized seedlings perform significantly better than bare-root seedlings, especially with regard to survival rate. It is important to note that the bare-root seedlings were planted only in the spring, while the containerized seedlings were planted between 15 June and 15 August.

It is also interesting to note that the results obtained in plantations established before 1978 with bare-root seedlings (Dancause 1977) are similar to those presented here. We must therefore conclude that it is still difficult to obtain an acceptable survival rate (in the order of 85% after five years) with bare-root seedlings. The main causes of this difficulty are premature budding of the species, susceptibility to extended cold storage, and production of seedlings with unsuitable crown to root ratios.

We feel that, for improving plantation results for species like jack pine, the production of containerized seedlings is an avenue that merits special attention. Seedlings of this type provide an acceptable solution to the various problems listed above.

Aerial and Ground Seeding

Our results were compiled from data collected on seeding operations conducted between 1974 and 1980 (Table 5) (Bergeron and Paquet 1982). Jack pine was the major species used in seeding operations, although trials were conducted with black spruce *(Picea mariana* [Mill.] B.S.P.). It should be noted that the

Table 4. Results for jack pine plantations established in public forests between 1978 and 1981.

	Survival rate (%)	No. of seedlings sampled	Annual growth (cm)	No. of seedlings sampled
		(Bare-root)		
1st growing season	75.6	12,794,000	4	9,641,000
2nd growing season	60.7	8,745,000	10	7,147,000
		(Containerized seedlings)		
1st growing season	97.3	1,705,689	3.9	1,705,689
2nd growing season	94.2	1,097,709	10.7	1,097,709

Table 5. Results of seeding operations by technique, species, and soil type (1974 to 1980).

Seeding technique	Species	Area (ha)	Stocking (%) Sand	Clay	Silt
Aerial	Jack pine	15,812	47	31	--
	Black spruce	1,438	39	23	--
	Jack pine and black spruce	1,186	47	33	--
Ground, mechanical (Bräcke)	Jack pine	6,897	47	35	24
Ground, manual	Jack pine	2,535	44[a]	13[a]	37[a]
	Spruce	477	--	--	--

[a]All species but mainly jack pine

results show the stocking percentage for artificial regeneration at the time of the latest measurement. Data are collected at the end of the first, second, and fifth growing seasons.

As Bergeron and Paquet (1982) noted, the results obained to date with this regeneration technique are disappointing. Accordingly, in order to improve the chances of success, seeding operations are conducted whenever possible on sandy sites. On an operational basis, jack pine is the only species used. Moreover, projects are to be carried out in spring as far as possible, since this yields superior results (42% vs 34%).

In summary, direct seeding of species like jack pine is a silvicultural practice that offers numerous advantages, in both technical and economic terms. We must therefore step up our efforts to determine the main causes of our limited success (degree of site preparation, seeding rate, climatic conditions, etc.) and take action with respect to controllable factors.

Jack Pine Research Program

At present, the main jack pine research projects are centred on genetic improvement of the species and upgrading of silvicultural knowledge.

The first aspect of the program will be dealt with later. The second has the following components:

- comparison of different jack pine reforestation methods
- dendrometric and pedological studies of jack pine plantations in Quebec
- intensive culture of pioneer species like jack pine
- study of the combined effects of thinning and fertilization in natural stands
- study of the effects of fertilization in plantations
- study of the effects of fertilization in natural forests.

Clearly, this list is not exhaustive. In the future, research should be stepped up in the areas of intensive culture and development of suitable techniques for successfully regenerating jack pine in clay soils.

Methods of Protecting Jack Pine Against Disease and Insects

MERQ performs annual qualitative and quantitative surveys of insects and tree diseases. Inspections are carried out in natural forests, plantations, and nurseries. According to the 1982 survey (Bonneau et al. 1982), the two major enemies of jack pine are Scleroderris canker (*Gremmeniella abietina* [Lagerb.] Morelet) and the Swaine jack pine sawfly (*Neodiprion swainei* [Midd.]). For the canker, we are currently engaged in our first large-scale control attempts. Treatment consists of pruning infected trees and spraying them with a fungicide. For the Swaine sawfly, several areas were sprayed in 1982 with an insecticide. Contacts have recently been established between MERQ and the Laurentian Forest Research Centre with a view to mounting a combined effort to control the insect by means of viral techniques[2]. In addition to operational programs, there are currently a number of research projects on methods of controlling the

[2]Benoit, P. 1983. Min. Environn., Serv. can. for., Ste-Foy, Qué. (pers. comm.)

canker. These include provenance tests, projects on chemical control of the disease in nurseries and silvicultural treatments to control the canker in jack pine, and research into the behavior of the disease in red pine (*Pinus resinosa* Ait.) plantations in the Outaouais region, the results of which may be adapted to jack pine[3].

Finally, research should be conducted into rust cankers of jack pine.

Stand Tending Operations

Precommercial cutting or cleaning is the only silvicultural technique currently used by MERQ in young jack pine stands. This type of cutting can be described as thinning from above for the purpose of liberating desirable subjects from among the dominant or codominant stems.

MERQ tended about 365 ha in 1980-1981 and 623 ha in 1981-1982. The principal methods used, in order of importance, were shears and axes (468 ha), circular saws (385 ha) and chainsaws (137 ha).

It should be noted that MERQ carries out precommercial cutting (thinning and cleaning) on about 6,000 ha per year. Hence, jack pine represents about 10% of the total. The operations take place mainly in the Abitibi-Témiscamingue region.

Genetic Improvement Program

The jack pine genetic improvement program set up by the "Comité de recherche en génétique forestière" contains several phases. The long-term program consists mainly of testing trees from at least 150 provenances within Quebec and a number from outside the province. In addition, plans have been made to carry out provenance-progeny tests on a regional basis with a view to setting up first-generation tree seed orchards and gaining the necessary insight into heritability and inheritable characteristics for the satisfactory establishment of second-generation seed orchards. At present, MERQ has three test designs for 153 provenances, one for interprovenance hybrid progeny, five progeny-provenance tests related to seed orchards, and one clone bank with 174 selected trees (Anon. 1983).

At the operational level, MERQ has, to date, selected 1,500 plus-trees in natural forests. These trees are represented (or will be in 1984) in six seedling seed orchards. The total area of jack pine orchard will then be 143 ha. These orchards are located in four of the province's nine administrative regions.

[3]Laflamme, G. 1983. Min. Environn., Serv. can. for., Ste-Foy, Qué. (pers. comm.)

Conclusion

This symposium has given us an opportunity to present an update on jack pine management in Quebec. From what we have said, it should be clear that jack pine plays a major role in MERQ's reforestation program. In operational terms, however, the results obtained to date have been only partially satisfactory.

We hope that the presentations and discussions that will take place at this symposium will bring to light findings that will help us to improve our results.

In closing, we would like to congratulate the organizers for having made the symposium possible and to thank them for their gracious invitation.

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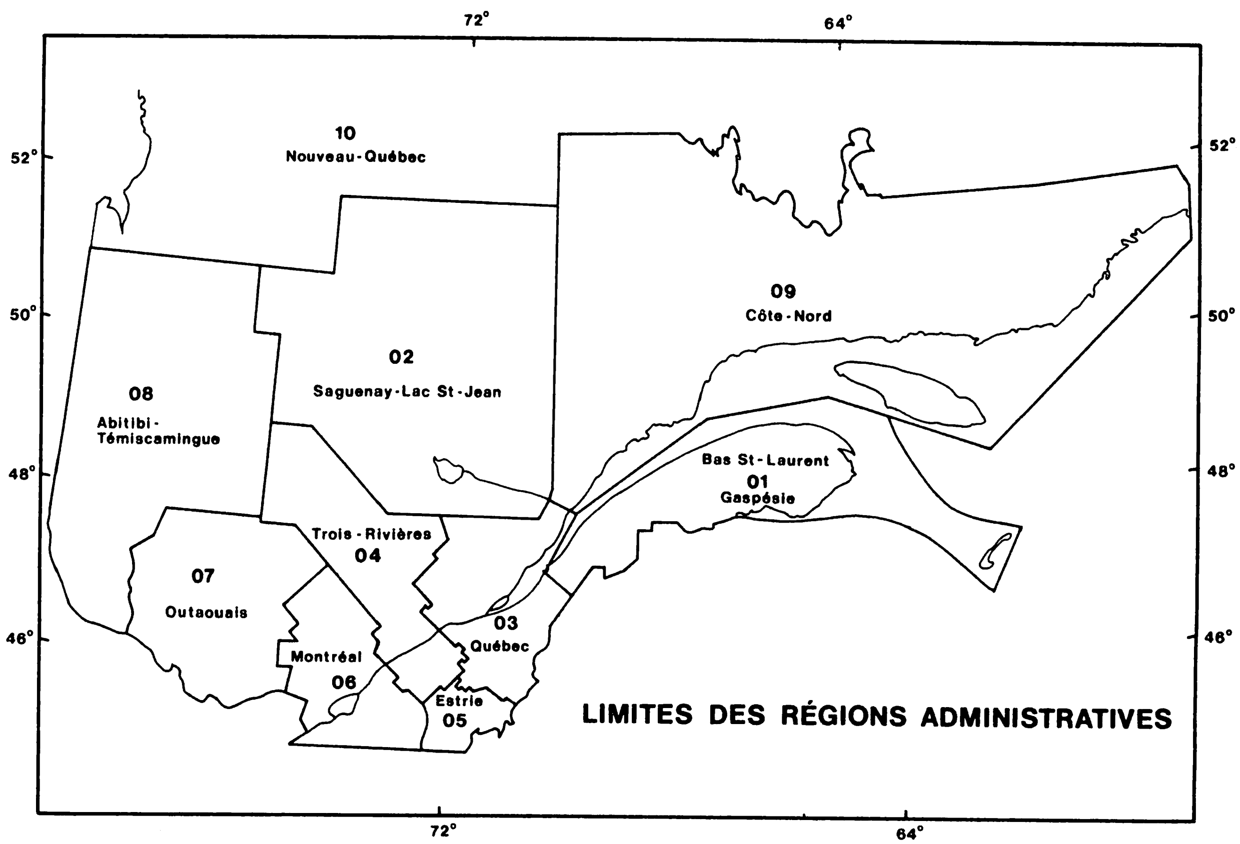
APPENDIX 1



Appendix 2

Jack pine gross merchantable volume broken down by region and expressed as a percentage of total reserves (softwood and hardwood species) and softwood reserves.

(Public forests)

Region	Reserves (1,000 m^3) Total (1)	Softwood (2)	Jack pine (3)	% of total 3 ÷ 1	% of softwood 3 ÷ 2	% of provincial reserves
01	236,888	201,028	278	0.1	0.1	0.2
02	838,030	720,302	55,249	6.6	7.7	31.5
03	94,400	70,588	306	0.3	0.4	0.2
04	260,186	164,086	34,593	13.3	21.1	19.7
05	6,898	2,831	--	0.0	--	--
06	87,749	39,350	1,837	2.1	4.7	1.0
07	401,497	196,218	8,714	2.2	4.4	5.0
08	640,069	480,996	67,160	10.5	14.0	38.3
09	1,021,810	946,712	7,163	0.7	0.8	4.1
Total	3,587,527	2,822,111	175,300	4.88	6.21	100.0

Appendix 3

Jack pine gross merchantable volume broken down by region and expressed as a percentage of total reserves (softwood and hardwood species) and softwood reserves.

(Private forests)

Region	Reserves (1,000 m^3) Total (1)	Softwood (2)	Jack pine (3)	% of total 3 ÷ 1	% of softwood 3 ÷ 2	% of provincial reserves
01	69,371	45,684	17	--	--	0.3
02	22,477	13,103	1,545	6.9	11.8	28.6
03	95,545	43,660	348	0.4	0.8	6.4
04	43,034	19,890	1,432	3.3	7.2	26.5
05	44,066	13,201	--	--	--	--
06	43,033	10,633	48	0.1	0.5	0.9
07	66,454	19,336	119	0.2	0.6	2.2
08	12,735	5,188	868	7.2	16.7	16.1
09	11,012	6,611	1,024	10.7	15.5	19.0
Total	407,727	177,306	5,401	1.3	3.0	100.0

STATUS REPORT ON THE MANAGEMENT OF JACK PINE IN THE LAKE STATES

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Abstract.--This paper reviews the status of jack pine (Pinus banksiana *Lamb.) management in the Lake States, including its economic importance, the volume harvested, products produced, methods of regeneration, area regenerated, equipment used, regeneration success and failure rates, regeneration problems needing research, the amount of thinning and methods used, and tree improvement programs.*

Résumé.--On examine la situation de la gestion du pin gris (Pinus banksiana *Lamb.) dans les États des Grands Lacs, y compris son importance économique, le volume de la récolte, les produits obtenus, les méthodes de régénération, l'étendue de la régénération, l'équipment employé, les taux de succès et d'échec de la régénération, les problèmes de la régénération pour lesquels des recherches sont nécessaires, l'importance des éclaircies pratiquées, les méthodes employées pour les éclaircies et les programmes d'amélioration des arbres.*

Economic Importance

The area of jack pine *(Pinus banksiana* Lamb.) in the Lake States (Michigan, Minnesota, Wisconsin) increased as a result of wildfires following the early pine logging and extensive planting programs in the 1930s. Among pine forests it accounts for the greatest area (992,000 ha), but this area is decreasing as jack pine stands are converted to other species (Benzie 1977).

However, jack pine is the major softwood species for pulpwood production (Table 1) and is exceeded in pulpwood production only by aspen *(Populus* spp.). In 1970 it accounted for 63% of the softwood pulp production but by 1980 this percentage had decreased to 36%. The 1970 production figure may be inflated because it includes a small but unknown quantity of red pine *(Pinus resinosa* Ait.) and white pine *(P. strobus* L.). The volume of jack pine pulpwood harvested decreased from 1,876,000 m^3 in 1970 to 1,274,000 m^3 in 1980. At the same time, total softwood pulp production increased from 2,991,000 m^3 to

Table 1. Trends in pulpwood production of the four major softwoods in the Lake States ('000 m^3).

Species	Year	Mich.	Minn.	Wisc.	Total	%
Jack pine	1970[a]	625	576	675	1,876	62.7[d]
	1980[b]	412	315	547	1,274	36.4
Balsam fir	1970	172	117	180	469	15.7
	1980	284	289	263	836	23.9
Red pine	1970	n.a.[c]	n.a.	n.a.	n.a.	n.a.
	1980	240	60	412	711	20.3
Spruce	1970	133	472	42	646	21.6
	1980	151	443	83	677	19.4
Total	1970	930	1,165	897	2,991	100.0
	1980	1,087	1,107	1,305	3,498	100.0

[a]Blyth 1971.
[b]Blyth and Smith 1982.
[c]Data not available.
[d]Includes small quantity of red and white pine.

3,498,000 m^3, with much of the increase due to a larger volume of balsam fir (*Abies balsamea* [L.] Mill.) harvested. Between 1974 and 1980, the average annual volume of jack pine pulpwood harvested in the Lake States was 1,438,000 m^3 (Table 2). An average of 36% was produced in Michigan, 30% was produced in Minnesota, and 34% was produced in Wisconsin. Production gradually declined in Minnesota, that in Wisconsin increased, and that in Michigan fluctuated, with no clear directional trend. Jack pine pulpwood was harvested during this period at an annual rate of about 3% of the growing stock volume.

Table 2. Jack pine pulpwood harvested in the Lake States between 1974 and 1980[a] ('000 m^3).

	Mich.		Minn.		Wisc.		Total
Year	m^3	%	m^3	%	m^3	%	m^3
1974	498	31	581	36	513	32	1,592
1975	513	38	472	35	380	28	1,362
1976	529	38	412	30	443	32	1,383
1977	477	34	422	30	495	36	1,394
1978	500	33	432	29	568	38	1,500
1979	685	44	359	23	516	33	1,560
1980	412	32	315	25	547	43	1,274
Average	516	36	427	30	495	34	1,438

[a]Blyth,J. Data on file at North Central For. Exp. Stn., St. Paul, Minn.

In 1975, 210,000 m^3 of jack pine saw logs were harvested in the Lake States--about triple the 72,500 m^3 harvested in 1965. About two-thirds of the 1975 volume was harvested in Minnesota. The large increase in saw log production probably reflects the developing market acceptance of jack pine lumber in the building construction industry in the Lake States.

Trends in Available Growing Stock, Annual Cut and Annual Growth

Forest inventory figures, compiled for the three Lake States at different times between 1962 and 1980, indicate that the growing stock volume increased dramatically in Michigan and Wisconsin but decreased sharply in Minnesota (Table 3). The most recent figures indicate that the available growing stock volume is about the same in the three states. During this time the volume cut annually from the growing stock remained nearly constant (Table 4). More of the growing stock was removed annually in Minnesota than in Michigan and Wisconsin, which probably accounts for the decline in available growing stock in Minnesota. Net annual volume growth showed an increasing trend in Michigan and Wisconsin and a decrease in Minnesota (Table 5). Net annual growth in Wisconsin was more than double the annual cut. Net annual growth in Michigan and Minnesota exceeded the annual cut by substantial but lesser amounts than in Wisconsin (Tables 4 and 5).

Table 3. Trends in available jack pine growing stock in the Lake States ('000,000 m^3).

Mich.		Minn.		Wisc.	
1966[a]	1980[b]	1962[c]	1977[d]	1968[e]	1979[e]
10.3	17.6	22.8	16.6	11.7	16.4

[a]Chase et al. 1970.
[b]Spencer, J.S. Data on file at North Central For. Exp. Stn., St. Paul, Minn.
[c]Stone 1966.
[d]Spencer 1982.
[e]Raile and Smith 1982.

Table 4. Trends in annual cut from jack pine growing in the Lake States ('000,000 m^3).

Mich.		Minn.		Wisc.	
1965[a]	1980[b]	1960[c]	1976[d]	1967[e]	1968-1979[f]
0.49	0.45	0.61	0.60	0.37	0.37

[a]Chase et al. 1970.
[b]Spencer, J.S. Data on file at North Central For. Exp. Stn., St. Paul, Minn.
[c]Stone 1966.
[d]Spencer 1982.
[e]Spencer and Thorne 1972.
[f]Raile and Smith 1982.

Regeneration

Seedling Production

State and federal nurseries in the Lake States produced about 7,600,000 jack pine seedlings in 1980-1981 (Table 6). In state nurseries, Michigan accounted for nearly two-thirds of the seedling production; Wisconsin accounted for less than 4%. Federal nurseries produced about one-third of the total produced in the Lake States.

Table 5. Trends in net annual growth of jack pine in the Lake States ('000,000 m^3).

Mich.		Minn.		Wisc.	
1965[a]	1979[b]	1962[c]	1976[d]	1967[e]	1968–1979[f]
0.61	0.75	0.80	0.72	0.77	0.84

[a]Chase et al. 1970.
[b]Spencer, J.S. Data on file at North Central For. Exp. Stn., St. Paul, Minn.
[c]Stone 1966.
[d]Spencer 1982.
[e]Spencer and Thorne 1972.
[f]Raile and Smith 1982.

Table 6. Jack pine seedling production in state Department of Natural Resources (DNR) and federal nurseries in the Lake States, 1980-1981 ('000 seedlings).

Mich.[a]	Minn.[a]	Wisc.[a]	Federal[b]	Total
3,340	1,608	199	2,454	7,601

2,450 seedlings per ha;
3,100 ha planted annually

[a]Johnson, L.C. Data on file with USDA For. Serv., Northeastern Area, State and Private Forestry, St. Paul, Minn.
[b]Murphy, J. Data on file with USDA For. Serv., R-9, Milwaukee, Wisc.

Planting and Seeding in Lake States National Forests

From October 1980 to September 1982, 2,428 ha of jack pine were planted on national forests in the Lake States (Table 7), which is representative of recent planting efforts in these forests. The largest areas were planted in national forests in Michigan, in the Superior National Forest in Minnesota, and in the Chequamegon National Forest in Wisconsin. About one-third of the jack pine type area available for planting was planted to other species, primarily red pine. Planting of jack pine type to red pine exceeded that planted to jack pine in the Chequamegon, Nicolet, and Ottawa national forests. Such conversion of the jack pine type to red pine appears to represent a recent trend in the Lake States, at least on what are considered to be the better jack pine sites (Benzie 1977). During the same period, only 318 ha of other forest types were planted to jack pine. Some researchers have questioned the large-scale conversions of jack pine areas to red pine plantations to create large, contiguous areas of "monocultures" that are more susceptible to pest outbreaks (Nicholls 1979). The lack of genetic variability in red pine offers little opportunity for increasing genetic resistance to pests. Jack pine, on the other hand, has much genetic variability and potential for selection and breeding for pest resistance (Rudolph and Yeatman 1982).

From October 1980 to September 1982 about the same area was direct seeded to jack pine as was planted on national forest land (Table 7). Direct seeding was done in the

Table 7. Planting and seeding in the jack pine forest type in Lake States national forests from October 1980 to September 1982.[a]

National forest	Former jack pine type planted to jack pine (ha)	Former jack pine type planted to oak (*Quercus* spp.) (ha)	Former jack pine type planted to red pine (ha)	Other types planted to jack pine (ha)	Direct-seeded jack pine (ha)
Chequamegon	108	15	469	34	0
Chippewa	66	0	0	23	0
Hiawatha	607	0	0	91	580
Huron-Manistee	926	1	63	54	139
Nicolet	90	11	132	16	0
Ottawa	29	10	145	8	0
Superior	284	94	72	92	1,620
Total	2,110	131	881	318	2,339

[a]Murphy, J. Data on file with USDA For. Serv., R-9, Milwaukee, Wisc.

Hiawatha, Huron-Manistee, and Superior national forests. More than two-thirds of the direct seeding was done in the Superior National Forest.

Planting, Seeding, and Natural Regeneration on Lake States DNR Land

A total of about 3,600 ha of jack pine is being regenerated annually on DNR land in the Lake States (Table 8). About twice as much area is being regenerated in Michigan as in either Minnesota or Wisconsin. More than two-thirds of the regeneration in Michigan is by planting. In Minnesota about the same area is regenerated by planting as by direct seeding but natural regeneration is relied upon on only about 13% of the area. In Wisconsin, planting and natural regeneration account for only 10% each of the area regenerated and 80% of the regeneration is by direct seeding. Thus, the regeneration strategies on state land are quite different in the three states.

Table 8. Average annual planting, seeding, and natural regeneration of jack pine on Lake States DNR land.

Type of regeneration	Mich.[a] (ha)	Minn.[b] (ha)	Wisc.[c] (ha)
Planting	1,296	425	81
Seeding		385	648
	526		
Natural		122	81
Total	1,822	932	810

[a]Botti, W. Mich. Dep. Nat. Resour., East Lansing, Mich., pers. comm.
[b]ZumBahlen, B. Minn. Dep. Nat. Resour., St. Paul, Minn., pers. comm.
[c]VandiHei, G. Wisc. Dep. Nat. Resour., Madison, Wisc., pers. comm.

Direct seeding is most often done by helicopter at a sowing rate of 210 to 285 g of seed per ha. Cyclone seeders are also used either directly or from the rear of snowmobiles for winter seeding. A modified corn planter pulled by a small tractor that plows a furrow and covers the seed has been used in Michigan.

Most planting is with bare-root seedlings but use of containerized seedlings is increasing.

A literature review on jack pine regeneration in the Lake States has been prepared recently by Hacker et al. (1983).

Site Preparation in the Jack Pine Forest Type on Lake States National Forests

From October 1980 to September 1982, an area of 3,559 ha of jack pine forest type received site preparation treatment in Lake States national forests (Table 9). Although the area treated for a specific type of regeneration can be expected to vary among years and among forests, the areas given here are likely representative of the magnitude of current site preparation activities on jack pine land in the national forests in the Lake States. More than 70% of the site preparation is on sites to be planted. Sites prepared for natural regeneration and direct seeding account for less than 15% each of the total area treated. These figures contrast with those for DNR land (Table 8), which indicate that less than half of the regenerated land is planted, and they contrast particularly with those for Wisconsin state land where only 10% of jack pine regeneration is by planting.

Table 9. Site preparation in the jack pine forest type in Lake States national forests from October 1980 to September 1982.[a]

National forest	Site-prepared for natural regeneration (ha)	Site-prepared for planting (ha)	Site-prepared for seeding (ha)
Chequamegon	76	669	0
Chippewa	2	33	0
Hiawatha	12	458	145
Huron-Manistee	318	489	0
Nicolet	17	378	0
Ottawa	25	269	0
Superior	72	249	347
Total	522	2,545	492

[a]Murphy, J. Data on file with USDA For. Serv., R-9, Milwaukee, Wisc.

Mechanical Site Preparation Equipment Used

No information is available on the area of jack pine sites treated with specific types of site preparation equipment. However, Sajdak (1982) conducted a survey of forestry agencies in the Lake States to determine the types of site preparation equipment used in conifer regeneration in general. The results probably apply to jack pine site preparation as well. About one-fourth of the area treated was brush-raked (Table 10) and one-fifth was prepared by KG blading. The V-blade and planter, disk, Bräcke scarifier, and drum chopper were each used on about one-tenth of the area treated. The smallest area (8%) was treated with the TTS trencher. Mechanical equipment alone was used on 78% of the area treated. Combinations of mechanical and chemical treatments were used on 20% of the area. Of the total area site-prepared, 78% was harvested by commercial roundwood operations. This harvesting system leaves large amounts of slash on the site, making site preparation difficult and expensive. The whole-tree system, used on only 14% of the area harvested, was the preferred system to facilitate site preparation for regeneration. The use of full-tree skidding is increasing, especially in Minnesota.

Table 10. Types of mechanical site preparation equipment used in 1981 in the Lake States and the percentage of area treated with each type of equipment.[a]

Type of equipment	Percentage of area treated
Brush rake	26
KG blade	20
V-blade and planter	13
Disk	12
Bräcke scarifier	12
Drum chopper	10
TTS trencher	8

[a]From Sajdak (1982).

Chemical Site Preparation

Sajdak's (1982) survey showed that the use of herbicides for site preparation has been increasing in the Lake States. Of the total area treated with herbicides for the combined years 1981 and 1982, 38% was for site preparation and 62% for release. This compares with only 18% treated with herbicides for site preparation for the combined years 1978 and 1979. In 1981 the most frequently used herbicide was Weedone 170, which accounted for more than half of the area treated (Table 11). Tordon 101 was used on one-fourth of the treated area, and Roundup was used on one-eighth. Velpar and 2,4-D combined accounted for less than one-tenth of the area treated. There is some evidence that Velpar is toxic to jack pine (J. Benson, pers. comm.). With the ban on the use of 2,4,5-T, many agencies reported that they were testing additional herbicides and herbicide combinations.

Table 11. Herbicides used for site preparation in the Lake States in 1981 and the percentage of area treated with each herbicide.[a]

Herbicide	Percentage of area treated
Weedone 170	52
Tordon 101	27
Roundup	12
2,4-D	7
Velpar	2

[a]From Sajdak (1982).

Regeneration Success Rates

The limited information available indicates that regeneration success rates have been highly variable and reasons for failures seldom can be fully defined. Planting has been the most reliable method of jack pine regeneration in the Lake States but also the most expensive one. Success rates for planting have commonly been greater than 80% but have been lower in limited fall planting attempts, in areas of high animal predation, and in areas with inadequate site preparation and lack of control of competing vegetation.

Regeneration success rates following scarification have been about 70% in Michigan in the Lake Superior watershed. Failures are due to unidentified factors.

Direct seeding results have been highly variable because they depend on a combination of numerous factors. They include seed quality, site conditions, dates and rates of sowing, treatment of seed, populations of seed-eating birds and rodents, weather conditions, and follow-up control of competing vegetation (Benzie 1977). The development and use of chemical repellents to protect seed from birds and rodents have increased direct seeding success. Direct seeding has failed most frequently on inadequately prepared sites and on sites where the water table is more than 2 m deep.

Regeneration Problems Requiring Research

An informal survey of a representative sample of Lake States foresters concerned with the management of jack pine has revealed numerous regeneration problems requiring research. Those most frequently cited are described here but without an attempt to establish research priorities. Those priorities will depend upon the means, capabilities, and objectives of research organizations and the demands of forest managers or the research users.

Improved methods of direct seeding are needed to conserve seed, especially high-value or genetically improved seed. More efficient site preparation methods could reduce the cost of direct seeding. The best time to direct seed needs to be defined more precisely. Methods for controlling stocking levels following direct seeding need to be developed.

Efficient and cost-competitive production systems for containerized seedlings would extend the planting season and improve planting success. The optimum age and/or size and physiological state of containerized seedlings for planting needs to be determined.

Costs of site preparation need to be reduced. More efficient mechanical site preparation methods are needed whereby smaller, less costly, and more economically maintained equipment can be used. Mechanical site preparation methods used in combination with whole-tree harvesting, on-site chip harvesting, fire to reduce slash loading, and herbicides to control competing vegetation need to be investigated. Coverage and timing of herbicide application need to be refined to reduce the cost per unit of area treated. A public relations effort is needed to gain public acceptance of the use of herbicides and fire in jack pine regeneration and management. A similar effort is needed to gain acceptance of the use of insecticides to control the numerous insects that affect the survival and growth of jack pine seedlings and established stands as well as to control the many conelet, cone, and seed insects that cause serious losses of seed required for regeneration (Rudolph 1983, Rudolph and Laidly 1984). Effective measures are needed to control animal predation that in many cases seriously reduces the success of otherwise adequate regeneration efforts.

The potential of fertilization and its cost-to-benefit effectiveness on various site types are essentially unknown for jack pine. The economic feasibility of precommercial and commercial thinning on different sites and at a range of stand densities needs to be determined.

Little is known about matching genetically improved material to specific sites. Future genetics, breeding, and improvement research should address this problem so that gains may be maximized.

Precommercial and Commercial Thinning

On the basis of very limited information, precommercial thinning of jack pine in the Lake States has generally been considered uneconomical, particularly when in competition with other management activities for limited budgets. Very limited precommercial thinning is done on national forest land in overly dense natural stands regenerating after fire and in stands resulting from occasional overly successful direct seeding. Both mechanical and hand methods are used. In Michigan, about 120 ha per year are precommercially thinned with power brush cutters.

Commercial thinning on Minnesota DNR land is limited to cases where a logging contractor is willing to do the work according to DNR management standards in unmarked stands or by row thinning in plantations. In Wisconsin, commercial thinning is done on approximately 1,200 ha per year, usually at about age 30, but this depends on the site. No significant commercial thinning of jack pine is done on Michigan DNR land or in the national forests in the Lake States. In general, regeneration and management efforts are being directed toward avoiding the need for thinning, especially precommercial thinning.

Tree Improvement Programs

Tree improvement programs are and must continue to be an integral part of jack pine regeneration and management activities in the Lake States. The programs are based on the best available provenance test information for delineating breeding zones and seed zones. The oldest Lake States jack pine provenance study, containing 29 provenances, was established in field tests at 17 locations in the Lake States in 1954. Twenty-year results for 14 of the locations have been published (Jeffers and Jensen 1980) and clearly indicate genetic differences in volume growth. Volume among locations ranged from 72.8 m^3 to 140.7 m^3 per ha. Basal area ranged from 17.1 m^2 to 29.5 m^2 per ha. These yields are comparable with those in published yield tables for site indices 18.3 to 21.3 (Benzie 1977). Volume in the best provenance at each location ranged from 15% to 87% higher than the location mean for all provenances. Volume ranged from 96.1 m^3 to 196.5 m^3 per ha. The yield of the best source at the best location was comparable with that in published yield tables for age 40 at the highest site index with a basal area of 27.5 m^2 per ha. Preliminary analyses of recently completed 30-year measurements are even more encouraging (D. Riemenschneider, pers. comm.). The results demonstrate the wood volume production that can be obtained by properly matching provenance to regeneration site. Conversely, the catastrophic losses in yield that can be sustained if an unadapted provenance is used are dramatically demonstrated as well.

The provenance test results were used in the first level of tree improvement--the delineation of seed zones. This step was followed by the designation of better-than-average stands and their management for seed production and collection. The next step in the existing improvement programs was to establish open-pollinated progeny tests that could be rogued, on the basis of family and individual tree performance, and converted to interim seedling seed orchards. A 6% gain in growth is anticipated from such orchards (Mohn and Berndt 1981). This is the current stage of most jack pine improvement programs in the Lake States.

In Minnesota, the DNR has identified a number of potentially superior stands to be used for seed collection areas. In addition, the agency has established two plantings totaling 1.2 ha of selected families provided by the USDA Forest Service for use in future breeding work and for possible conversion to interim seedling seed orchards. The DNR has also developed 7.3 ha of seed production area (Mohn and Berndt 1981). Plans call for a minimum of 6.5 ha of first-generation seedling seed orchards, 1.6 ha of cooperative project breeding populations, and about 8 ha of second-generation open-pollinated seed orchards (Mohn and Berndt 1981). The Minnesota DNR's annual production of seedlings by the year 2000 is estimated at 4.3 million, which will all come from seed orchard seed. Seed for the 2,025 ha expected to be direct seeded annually by that time cannot be supplied by seed orchards, so seed from source-identified natural stands will continue to be used for this purpose.

In Wisconsin the DNR and the University of Wisconsin-Madison established breeding and index populations between 1979 and 1980 as the first step in the development of improved jack pine. A mix of local Wisconsin and Lower Peninsula Michigan seed has been used by the DNR in nursery and direct seeding practices in recent years on the basis of provenance test results. A Forest Tree Improvement Plan for the Wisconsin DNR is being prepared (R.P. Guries, pers. comm.).

The Michigan DNR, in cooperation with Michigan State University, is roguing large half-sib progeny test plantations established in the 1960s for conversion to interim seed orchards. Controlled pollinations will be made on selected trees in the test plantations to establish the next-generation seed orchards (W. Botti, pers. comm.).

The USDA Forest Service's Region 9 has established eight evaluation plantations of jack pine in the national forests of the Lake States. In addition, three half-sib progeny test plantations of about 4 ha each have been established at the Oconto River Seed Orchard in northeast Wisconsin. These progeny test plantations will be rogued for conversion to seed orchards on the basis of performance in the evaluation plantations located in the planting zones. One orchard will be rogued to supply seed adapted to national forests in Minnesota, the second to Wisconsin and Upper Michigan, and the third to Lower Michigan (R. Meier, pers. comm.). Seed production has begun and is expected to be adequate in the near future to supply the seedling production needs in the interim before advanced-generation seed is available from the Lake States Jack Pine Cooperative Improvement Program.

The emphasis in most of the improvement programs described above is on short-term selection, improvement, and seed production. However, tree breeding and improvement cannot be limited to a short-term or one-generation effort. The problems, needs, and opportunities of a long-term selection and breeding effort must also be considered. For this reason a Lake States Cooperative Jack Pine Breeding Program has been established (Riemenschneider 1980). It combines both short- and long-term breeding and improvement objectives and is based on the coordinated population concept formulated by Kang (1980). A base population of 400 half-sib families was selected in the Lake States and randomly divided into 20 subsets of 20 families each of index or research populations and breeding populations, which will be used to develop production populations or seedling seed orchards. For a number of important reasons, seedling orchards rather than clonal seed orchards are recommended for jack pine (Rudolph 1982, Rudolph and Yeatman 1982). The 20 populations have been distributed to and established by the University of Minnesota, University of Wisconsin, Michigan State University, the USDA Forest Service, state DNRs, and private corporations. Results obtained from the randomly comprised index or research populations will be used to predict the average performance of the breeding populations and to develop general breeding prescriptions for additional genetic gains in subsequent generations.

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JACK PINE SEED COLLECTION, EXTRACTION AND MANAGEMENT IN THE NORTHWESTERN REGION OF THE ONTARIO MINISTRY OF NATURAL RESOURCES

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Abstract.--*The seed collection, extraction and management of jack pine* (Pinus banksiana *Lamb.) in the Northwestern Region of the Ontario Ministry of Natural Resources (OMNR) are described. The unique self-containment within the Northwestern Region from cone collection to seed use is made possible because of a regional extractory. Collection and extraction approach 12,000 hl annually.*

Résumé.--*On décrit la récolte des cônes, l'extraction des graines et la gestion du pin gris* (Pinus banksiana *Lamb.) dans la région du nord-Ouest du ministère des Richesses naturelles de l'Ontario. L'autonomie unique de la région, de la récolte des cônes jusqu'à l'utilisation des graines, est rendue possible par la présence d'une usine régionale d'extraction. La récolte et l'extraction atteignent près de 12,000 hl par année.*

INTRODUCTION

The Northwestern Region of the Ontario Ministry of Natural Resources (OMNR) depends heavily on the jack pine (*Pinus banksiana* Lamb.) species for regeneration of the 25,215 ha of all species harvested annually and the periodic treatment of wildfire-burned areas. Jack pine accounts for 50% of the annual harvest volume and 94% of the annual regeneration treatments. To meet the large seed requirements, the six districts in the Northwestern Region have active year-long collection programs and a regional extractory was established at the Dryden Tree Nursery to handle all extraction, cleaning and storage of the 12,000 hl annual requirement of jack pine for the Northwestern Region. To undertake a program of this magnitude, special consideration must be given to seed collection, extraction, and management.

COLLECTION

The genetic improvement gained by seed source identification is the underlying basis for the cone collection program in the Region. In recognition of its importance 39 seed sources covering four site regions have been registered for use in the provincial identification system. The identification system utilizes the forest site regions delineated by Hills (1961) for Ontario as the initial subdivision, then the administrative districts, and a final subdivision by extensive gene pool areas (seed source). Prior to acceptance of this system by the province, the Region utilized the system for 2.25 years because of the unique self-containment for jack pine.

The objective in utilizing the smaller seed sources is to provide limits to seed movement. In this manner, the return of seed to the locale of collection preserves the gene pool until the Regional Tree Improvement Program for jack pine, building upon the gene pool areas, refines these areas and improves seed quality.

The various identification systems which have been used by the Northwestern Region are shown in Table 1.

Table 1. Seed source identification.

	Component	Time frame
1.	Hills' site regions	to 1976-1977
2.	Hills' site regions and administrative districts	1977-1978 to 1979-1980
3.	Hills' site regions, administrative districts, and regional gene pool areas	1980 to 1982
4.	Hills' site regions, administrative districts, and provincial registered seed source areas	October 1982 to present

The provincial identification system utilizes a 10-digit number as follows:

000-00-00-0-00

Species
Site region
Geographic location
Agency
Category and area number

The collection of jack pine cones within the Region is built upon the cottage industry of local pickers who collect cones from the jack pine slash following harvest activities; contracts are not issued. The majority of the cones are picked manually although several local entrepreneurs have attempted to mechanize separation of cones from the branches.

The most successful mechanization of cone separation was developed by a local entrepreneur in the Ignace District. Following several successes with separation, a system utilizing a rotating drum powered by a V-8 car engine, with the front half of the drum padded, has overcome the problem of mechanical damage to the seed.

The organizational effort for collection today is minimal as past efforts have increased the jack pine collection by 2,522% since 1973 as shown in Table 2. The objective of each district's collection program is to achieve a collection of clean, 1- to 3-year-old cones for a minimum 2-year seed supply. The 2-year supply is essential to meet the fluctuating demands caused by the high incidence of large wildfires within the Region which require regeneration.

Cone pickers deliver their cones year-round to the various district collection locations where the cones are inspected for quality, measured, bagged in 0.5-hl quantities in jute bags, and labelled.

With the numerous seed source areas it was found that manual labelling with the provincial tags was impracticable because of the need to read each tag for identification purposes. To overcome this problem the Region has devised a color-coded, prelabelled, reusable linen tag for visual identification. The color coding assigns each district a solid color which is located adjacent to the hole in the tag. The other end of the tag utilizes a system of a single color of dots, solids, or stripes to identify site region and seed source. Each tag, therefore, utilizes two colors and provides for easy visual identification.

Table 2. Northwestern Region jack pine cone collection and extraction.

	Collection			Extraction	
Year	Implementation target (hl)	Actual collection (hl)	Purchase price ($/hl)	Extracted (hl)	Cost ($/hl)
1973	958[a]	472.85	18.00		
1974	1,593[a]	4,276.45	30.00		
1975	1,800[a]	3,500.69	30.00		
1976	1,957[a]	5,015.10	33.00		
1977	4,500[b]	6,413.60	35.00	Extractory constructed	
1978	6,700[b]	8,809.45	35.00	1,301[a]	5.42
1979	8,200[b]	7,948.11	35.00	6,218[a]	8.33
1980	7,200[b]	9,367.08	40.00	7,019[a]	10.22
1981	7,500[b]	8,462.31	45.00	8,415[a]	10.57
1982	7,800[b]	11,927.51	45.00	10,135[a]	10.79
1983	8,100[b]		45.00		

[a] Jack pine only
[b] All species

Cones are held in the district until there is a minimum 10-hl volume per seed source, sufficient overall shippable volume, or low inventory at the extractory. Costs for shipping and purchase are funded through the district budget. Transport to the nursery is dependent upon the volume to be shipped and utilizes primarily OMNR 5-tonne vehicles and the bare-root reefers pulled by regionally contracted tractors.

Although cone volumes are received year-round, the quantities peak in September/October and February/March of each fiscal year. Picking can be related directly to weather, season, and level of harvesting activities.

Each year the Regional Forests Technical Committee establishes the purchase price per hl of jack pine cones, considering a variety of criteria, e.g., adjacent region and Manitoba prices, economy, seed inventory, etc. Establishing a uniform regional purchase price prevents trafficking in cones and allows individual members of the public to deliver cones from any location to the most convenient district collection location without loss of seed source. The districts pay each picker the same day they receive the cones.

Consideration has been given to bulk containerized handling of jack pine cones to reduce the labor cost associated with bagging, loading, and unloading cones and the cost of the jute bags. In such a system cones would be purchased by weight. Measurements from January to March, 1981 involving 6,460 hl of cones revealed that the overall average weight per hl of jack pine cones across all site regions was 48.5 kg. The weights for the three site regions were as follows:

Site region 3300 - 47.79 kg
3400 - 47.01 kg
4300 - 49.19 kg
5300 - 48.53 kg

The bulk handling system and the purchase by weight have not been implemented because the capital funding required is not currently available.

SEED EXTRACTION

Facilities

The extraction of jack pine seed from the Northwestern Region was done by the Ontario Tree Seed Plant in Angus, Ontario until the fall of 1977. Following recommendations by the Tree Seed Committee of the Division of Forests, an auxiliary seed extraction plant was contructed at the Dryden Tree Nursery and began operations in January 1978.

The extractory consists of a single-level building 12.1 m by 45.7 m and houses the cone storage area of 12.1 m by 18.3 m, the cone preparation area, the kiln, and a tumbling area.

The cleaning facilities are located in the bare-root shipping barn, seed storage is within the existing cooler and testing is completed in the laboratory areas of the nursery.

Cones from the 39 seed sources are kept separate within the 12 stalls of the cement block storage area. The 0.5-hl bags from a seed source are placed on steel pallets which may be piled three high and recorded as to location and quantity on a map. Total storage capacity is therefore 1,800 hl. Extra storage capacity is available in the bare-root reefer vans, which are also used by some districts to ship cones to the extractory. One in every 25 bags is randomly selected and checked for quality and quantity for each seed identification area in each shipment received.

Cone Preparation

Extraction begins with the movement of 60 hl (120 bags) from general cool storage into the warmer part of the extractory one day prior to extraction. This action is especially important during the colder months of the year to remove frost from the cones. Two and a half bags of cones (1.25 hl) are dumped into each of two metal wire baskets for immersion in 60-70°C hot water tanks for two minutes, and are then raised and drained. The moist, drained cones are then loaded onto a screened tray for placement on one of three 20-trayed carts. To allow for proper air circulation in the kiln the upper eight trays on a cart receive more cones than the lower 12 trays. To avoid seed source mixing each cart is loaded with seed from only one source. For this reason, districts are required to ship cones to the nursery in 10-hl quantities.

Cone Drying

The cement block kiln can hold three carts of 10 hl each, for a total capacity of 30 hl. The daily capacity is 60 hl or 300 hl per 5-day week. Currently 12,000 hl per year are extracted.

Drying is completed in 10 and 13 hr for the 06:00-hr and 16:30-hr daily charges, respectively. This drying time to open the cones is approximately half the time used at the Ontario Tree Seed Plant and is achieved by using the dipping process to crack the exterior cone resin.

The 65-70°C hot air requirement for the kiln is supplied by a Lennox 207,000 B.T.U. oil-fired, forced-air furnace. The hot air enters from above the carts and rises. Therefore, the volume per tray arrangement mentioned earlier provides for better air circulation.

Seed Removal

A continuous process cone tumbler is used to remove the seed from the cone. The tumbler is a paddled, cylindrical screen approximately 3.7 m long by 1.2 m in diameter, on a 2° slope rotating at nine revolutions per min. The seed falls into tubs below the screen.

Cones are placed in the hopper of the tumbler at a rate which allows the cones to tumble as they travel the length of the tumbler. Overloading will cause the cones to roll rather than tumble. The tumbling rate in use allows 10 hl or one cart of 20 trays to be processed per hour.

The empty cones are removed from the extractory for burning by means of a mechanical vacuum utilizing gravity and forced air. Investigation of the possibility of utilizing the cones as a heating source for the kiln or greenhouses showed that insufficient daily quantities were available to make this viable. Stockpiling sufficient quantities of spent cones close to the extractory was found not to be feasible.

Seed Cleaning

The winged seed is "moist dewinged" by tumbling in a standard cement mixer for approximately 20 min. The mass of seed, wings, and dirt is then placed in the hopper of the scalper, Model 36S-2, from which it is passed down over two vibrating screens. The top screen (No. 9) removes the larger debris of wings by allowing seed to drop through to the lower second screen (1/20) through which fine particles of debris pass.

The separated, cleaner seed travelling over the second screen of the scalper is caught and manually loaded in the vacuum Missoula Dewinger hopper for further seed cleaning. Following this process the seed is basically free of wings, larger debris, and dirt.

In the final cleaning step, the seed is passed through the clipper fanning mill (Super 47B) three times. The mill utilizes number 9, 8, and 1/19 screens in a similar fashion to the scalper, but with the inclusion of forced air, any particles similar in size to the seed but lighter (e.g., hollow seed), are removed.

Seed Storage and Testing

Prior to storage, the seed is dried in a home-built drier capable of handling 40 kg of seed at a time, requiring 24 hr at 27°C to reduce seed moisture content 5-7%. The moisture content is measured with the Radson Moisture Meter.

Following drying, random samples are taken from each seed batch at a rate of one sample per drier tray. The samples are mixed and a 5-g smaller sample is taken. This sample is then separated into two components of clean seed and remaining debris (dirt) to determine their relative percentages by weight. Then 1 g of the separated cleaned seed is measured out and the number of seeds counted to obtain the number of seeds per g.

From the remaining cleaned 5-g seed sample, two 100-seed samples are taken for germination tests using the moist blotter paper technique. Germination conditions used in the Percival Germinator (Model 135VL) for jack pine are 27°C for 8 hr with light, 17°C for 16 hr in darkness and a relative humidity of 80%. Germinants are counted once a week for 4 weeks. A germinant is counted when the radicle equals four times the seed length. Germination percentages run 90%+.

Seed is stored in 9-L or 22.7-L sealed plastic jugs in the nursery cooler at -2 to -3°C.

Records

Throughout the extraction, cleaning and testing process, records are maintained for each batch of seed as follows:

- % of old cones, stems and branches
- date of receipt
- dipping date
- kiln temperature, time in and out, temperature
- tumbling date
- cleaning date
- % dirt for cleaned seed
- total cleaned seed per g
- germination %

The information is maintained utilizing a 13-digit number in which the digits 1 and 2 are the fiscal extractory year, digits 3 to 8 are that portion of the provincial identification system with the exception of species, and the last four digits are reversed for a consecutive batch number.

A semi-annual seed inventory is calculated in March and September of each year. The inventory for 31 March 1983 had the following results:

H1	- collected	11,927.51
	- extracted	10,135.00
	- on hand	1,766.90
Seed inventory	- kg	6,925
	- viable seed	1,239,539,300

The Region is currently computerizing the seed inventory and cone collection in a program similar to that in use by the Ontario Tree Seed Plant.

Extraction quantities and costs since implementation of the extraction are shown in Table 2. It is expected that for 1983 the extraction costs will remain relatively constant.

SEED MANAGEMENT

In the Northwestern Region there is no reliable data base from which jack pine populations may be defined. In the absence of such a delineation the approach has been to follow the philosophy that "local is best". The unique self-containment for the jack pine seed, from collection to extraction to use, in the Northwestern Region has provided the opportunity to initiate the delineation of populations and preserve the gene pool at the same time.

The building blocks for the population delineation and preservation of the gene pool have been in place in the Region since 1980-1981 for jack pine. The use of the 39 gene pool areas (seed sources) has allowed the Region to start small, realizing that amalgamation is easier than separation for the purpose of population delineation.

Complementing the data base compiled from the bulked seed from the existing seed source areas will be the information from the recently initiated jack pine tree improvement strategy. The objectives of this program are to produce superior jack pine seed for all planting stock production as well as 3% of the direct seeding requirements from first-generation seedling seed orchards. As an interim measure, jack pine seed collection areas will be developed along with the use of the gene pool area system.

The basis for the improvement program will be the selection of 400 plus-trees from 12 breeding zones which are defined on the basis of site regions in administrative regions. The analysis of information from the progeny trials supporting the 12 orchards, in which the individual family morphological characteristics are considered, will be coupled with the family gene pool area location to define better the population boundaries from the gene pool boundaries in use and to define the best genotypes from the selected phenotypes.

Until the results of the above programs are available, the current regional management objective is to minimize the movement of seed from its collection point in the implementation of regeneration projects, thus maintaining the local gene pool; hence the use of the previously defined 39 seed sources.

The districts project their basic regeneration requirements on a "rollover" 5-year summary by species for stock and seeding requirements. Each district is responsible for ensuring that an adequate seed supply is procured for each seed source area in advance of its needs. Such an advance supply is required if the gene pool preservation objective is to be achieved by minimizing the movement of seed from its collection point.

In varying circumstances such as initial harvesting or extremely large wildfires, a particular seed source may not have a sufficient seed inventory or may have had its inventory depleted. Although the current regional seed inventory of 1,239,539,300 viable jack pine seed is twice the average regional use as shown in Table 3, there are 2 years in which use has equalled the inventory. The districts, therefore, strive to have a minimum of 2 years' seed inventory for each seed source.

What is not shown in the current inventory figure presented is the distribution of seed by district and seed source in which two districts have extremely low inventories caused primarily by the treatment of cutover/regeneration burned by wildfire. Should a district's inventory be unable to meet its requirements either in total or by seed source, a regional procedure is used to secure the required seed. This procedure allows for the movement of seed between districts on the basis of minimal movement and compensation to the district from which the seed is borrowed in order that it may bring its inventory back to the same level.

Requisitions for jack pine seed are approved by the regional forester in advance of filling by nursery staff. Adhering to guidelines requires the use of the oldest seed first. The nursery's requirements for stock production have first priority on seed with the highest germination rates. The gravity table is used to separate seed by size, primarily for stock production, with all other requirements being met by "all size" seed.

Table 3. Jack pine seed use in Northwestern Region ('000 viable seeds).

Year	Seeding[a]	Container stock	Bare-root	Total
1982/83	561,930.8	19,456.0	---	581,386.8
81/82	618,573.6	1,475.7	765.4	620,814.7
80/81	1,608,397.6[b]	19,200.0	3,162.6	1,630,760.2
79/80	733,604.8	1,900.0	4,615.0	740,119.8
78/79	1,004,710.0	5,379.7	---	1,010,089.7
77/78	582,080.0	---	6,535.2	588,615.2
76/77	330,589.0	---	2,620.2	333,209.2
75/76	297,135.0	---	3,214.5	300,349.5
74/75	207,745.0	---	1,362.9	209,107.9
Total	5,944,765.8	47,411.4	22,275.8	6,014,453.0

[a] Includes aerial, hand, spot c/w site preparation.
[b] Portion of quantity from 1979-1980 Dryden shipments included.

SUMMARY

Jack pine seed source identification uses 39 seed sources within the Northwestern Region to preserve the local gene pool by minimizing seed movement to be consistent with the philosophy that "local is best". A Regional Tree Improvement Program for jack pine has been started to provide genetically improved seed from seedling seed orchards and to define populations. The 12,000 hl of cones collected annually are extracted, cleaned, and stored by an extractory located at the Dryden Tree Nursery.

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THE PERFORMANCE OF 1-0 JACK PINE BARE-ROOT STOCK UNDER FIELD CONDITIONS

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Abstract.--The outplanting of 1-0 jack pine (Pinus banksiana *Lamb.) bare-root stock at the Dryden Nursery and in the Northwestern Region is described as a biologically and economically feasible operation. The increase in the survival of 1-0 jack pine over its 2-0 counterpart, along with the better height growth of the 1-0 pine, appears to favor the production of the younger age class.*

Résumé.--La plantation de semis 1-0 à racines nues du pin gris (Pinus banksiana *Lamb.) à la pépinière de Dryden et dans la région du Nord-Ouest est décrite comme une opération biologiquement et économiquement réalisable. La survie supérieure des semis 1-0 par rapport aux semis 2-0, ainsi que la meilleure croissance en hauteur des premiers, semblent plaider en faveur de la production de la plus jeune classe d'âge.*

Introduction

The survival of bare-root planted stock in the Northwestern Administrative Region was very poor during the 10-year period from 1962 to 1971. The average survival noted by MacKinnon (1974) covering all species and all age classes was 38%, with an average survival for jack pine *(Pinus banksiana* Lamb.) of 54%.

An analysis of the causes of the poor survival indicated that the tops of the planting stock were out of proportion with the root systems even though the stock appeared to have met provincial standards (Reese and Sadreika 1979). Another apparent problem was the planting of the stock on sites where the soil depth seldom exceeded 30 cm, resulting in the improper placement of the root system. Poor stock handling, poor planting and poor site preparation were also key causes of the low survival rates of the planted stock.

After analyzing the apparent problems, it was concluded that every facet of the bare-root regeneration program from stock production to the tree planting operation would have to be improved before an increase in the survival of the planted stock could be anticipated.

Methodology

Since it is not possible to increase the soil depth or alter the weather conditions that prevail in the Northwestern Region, it was decided to produce bare-root stock that would be compatible with these two major limitations and the resultant competition. The concept of matching planting stock with the competition was a new approach to solving the survival problem in Ontario and possibly in the rest of Canada, but to do it by reducing the stock rotation and the parameters below the minimum standards for the province of Ontario was a sacrilege. In the case of jack pine this meant a reduction in the rotation age from 2-0 to 1-0 and from an average height class of 37 cm to 10 cm. Dry weights and root-collar diameters were adjusted on the basis of our growing experience with greenhouse-grown container stock which served as a benchmark (Brown 1971).

In comparing the growing conditions in the greenhouse with those in the nursery beds, it was discovered that most of the conditions affecting plant growth were the same and in some cases could be manipulated by the grower. The growing media, amendment rate and irrigation rate were all easily controlled and the amount of natural light was the same in both cases. Only the amount of heat generated by the sun and the desiccating effect of the winds were beyond control in the nursery.

On the basis of these growing factors an experimental trial was laid out across two nursery beds at the Dryden Nursery in the spring of 1976 to determine the nature of the growing media required to attain the goals. Decomposed peat in the form of black muck was applied to the beds in 10-cm, 20-cm, and 30-cm depths on 30-m strips and worked into the nursery soil to determine which of the applied peat rates would produce the best stock in comparison with the control plots. On the basis of the experiment, which has been documented (Brown and Myland 1978), it was decided to apply the peat at the 30-cm depth on all fields and proceed with the production of nursery stock to meet the new Regional standards. Although we have never been able to duplicate the height of 11.0 cm, diameter of 2.9 mm and oven-dry weight (ODW) of 1.1 g with our production stock, the performance of the various types of stock for the 1977 production year can be compared in Table 1.

Table 1. Jack pine parameters from the Dryden Nursery.

Stock type	Age class	Height (cm)	Diameter (mm)	ODW (g)
Natural	16 wk	6.5	1.38	0.44
Container	16 wk	13.8	1.41	0.34
Bare-root	1-0	9.1	1.44	0.66
Bare-root	2-0	27.8	3.76	3.71

Results

During the 3-year period from 1977 to 1979, 2,334,700 1-0 jack pine trees were planted by five of the six districts in the Region. The performance of these trees compared with 2-0 jack pine, grown and planted under the same conditions, is shown in Table 2. In accordance with the provincial standards plots were laid out to measure a sample of 1,592 trees, of which 822 were 1-0 stock and 770 were 2-0 stock.

The survival of the 1-0 pine exceeded that of the 2-0 control during all 5 years of the study period. In height growth, 1-0 pine overtook and surpassed the 2-0 control in the second year and maintained its lead for the duration of the study.

Table 2. Survival and performance of jack pine by years and age classes.

Year	Age class	No. of plots	Survival (%)	Height (cm)
1	1.0	14	95.5	13.3
	2.0	11	83.0	20.9
2	1.0	11	86.5	56.3
	2.0	8	78.1	31.1
3	1.0	6	76.8	61.2
	2.0	3	68.3	39.5
4	1.0	1	74.0	71.5
	2.0	1	60.0	56.2
5	1.0	1	76.0	121.2
	2.0	1	52.0	103.6

Observations and Discussion

1) The average germination date of fall-sown jack pine at the Dryden Nursery is 24 May, with 8 May the earliest and 29 May the latest recorded dates.

2) Spring-sown jack pine germinates on average 11 days after sowing at the Dryden Nursery.

3) Spring sowing of jack pine should therefore be completed not later than 2 weeks preceding the average germination date for any nursery. Sowing after the average germination date will result in correspondingly smaller seedlings.

4) The initial 20-cm application of peat supplemented with 10 cm every 2 years is enough to prevent the leaching of the artificially applied amendments.

5) Production costs of 1-0 stock are approximately one-third lower than those of 2-0 stock.

6) The time required to grow 1-0 stock in a nursery is only half that required for 2-0 stock.

7) Shipping costs of 1-0 stock are much lower than those of 2-0 jack pine, as 1,500 1-0 pine can be packed in the same bag that holds 300 2-0 pine.

8) Planting of 1-0 stock is easier as it does not require a deep cut, and therefore there are no club or J roots.

9) A service organization is not required for 1-0 stock at the planting site as each planter can carry a half-day's supply of trees (500-600) instead of the 100 2-0 stock per pail.

10) Since 1-0 stock does not suffer the transplant shock of 2-0 stock, higher survival and better growth are achieved.

Conclusion

The growing and planting of 1-0 jack pine bare-root stock could become an economically viable operation for the reforestation of some of our low-yield areas that are now being planted with 2-0 bare-root or container stock.

Biological and economic gains similar to those attained with 1-0 jack pine are being effected with red pine (*Pinus resinosa* Ait.) and the spruces (*Picea* spp.) at the Dryden Nursery.

The requirement of the Regional nurseries to produce stock that will compete with and overtop the competition has also been demonstrated for all the boreal species produced at the Dryden Nursery.

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CUTOVER CLASSIFICATION FOR SITE PREPARATION

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Abstract.--The importance and objectives of site preparation in the boreal forest are summarized. Technological and economic limitations restrict our ability to site-prepare mechanically all areas requiring artificial regeneration. An organized and uniform approach to planning is necessary if silvicultural objectives are to be met. The system of cutover classification is very useful in this respect.

Résumé.--L'importance et les objectifs de la préparation du sol dans la forêt boréale sont résumés. À cause des contraintes techniques et écomoniques, il est impossible de préparer mécaniquement tous les terrains devant être régénérés artificiellement. Pour atteindre les objectifs sylvicoles, une planification structurée et uniforme est requise. À cet égard, le système de classification des terrains déboisés est très utile.

Introduction

Forest managers generally agree that some form of site preparation is essential to the success of most artificial and some natural regeneration in the boreal forest. To be effective, site preparation must provide (a) a suitable microsite or seedbed that is relatively free from light, moisture and nutrient competition, and (b) proper spacing and stocking to assist early crown closure and subsequent stand development. Several methods of site preparation are currently available, including mechanical and chemical site preparation, prescribed burning, and a combination of these methods.

In Ontario, fundamental management objectives are the maintenance of the permanent working groups--jack pine *(Pinus banksiana* Lamb.), spruce *(Picea* spp.), upper site class poplar *(Populus* spp.)--and the conversion of transition working groups--balsam fir *(Abies balsamea* [L.] Mill.), white birch *(Betula papyrifera* Marsh.), lower site class poplar (Anon. 1977).

It has become increasingly evident that valid silvicultural treatments are essential for the maintenance of the permanent working groups. For example, a 1978 field survey carried out by Ontario Ministry of Natural Resources (OMNR) field staff in the Northwestern Region determined that 78% of the silviculturally treated jack pine, and only 22% of the untreated jack pine cutovers, remained in the jack pine working group 5 years after cutting (Brown 1979).

Currently we are unable to carry out silvicultural treatments on all cutovers in the boreal forest for reasons related primarily to technological and economic limitations. Some treatments have resulted in failure, more often than not because the objectives of site preparation were not achieved. Some plantations have been established at considerable cost, in terms of both dollars and subsequent site damage, and often unnecessarily so. In order to meet these objectives of site preparation the method chosen must be related to the physical conditions and productive capacity of the site, and to the silvical characteristics of the preferred species. Anything less will reduce the likelihood of success and may result in failure; anything more is not only uneconomical but could also adversely affect site productivity. Careful consideration must be given to all alternatives before choosing the best option. Our regeneration objectives can be better met if we are willing to adopt a more uniform and organized approach to silvicultural planning.

Site Preparation Classification Criteria

Before the annual silvicultural work program is prepared the locations and quantity of treatable area must be determined and silvicultural prescriptions developed. For site preparation, this involves the examination of cutovers, existing backlog areas, and possibly other disturbances such as wildfires, blowdown and budworm-damaged stands. Some homogeneous areas such as jack pine sand flats can be silviculturally planned and treated rather easily, but most forest managers are now encountering considerably more difficult areas which require detailed planning if objectives are to be met. While it is likely that precut and cut inspections can provide some site specific information on these areas, it is only after harvesting operations are completed that the determination of treatable area and subsequent prescriptions can be finalized.

During the late 1970s, a system of cutover classification was developed by the Northwestern Region as a means of standardizing the process of silvicultural planning. The system is a more formalized approach to planning than is currently used in most areas, but it is not a complex process and provides a uniform framework upon which silvicultural operations can be planned and subsequently carried out (Clark 1981).

The process of the cutover classification system is intended to:

1) define the annual cutover with due consideration to original working groups, and their maintenance or conversion in accordance with the *Manual of management planning requirements for the province of Ontario* (Anon. 1977).

2) determine, through field inspection, the location and number of:
   a) areas that will require no silvicultural treatment,
   b) areas that will be withdrawn from timber production for an indefinite period,
   c) areas that cannot be mechanically treated because of technological or economic limitations,
   d) the remaining area that requires treatment and can be treated.

3) prepare valid silvicultural prescriptions on the treatable areas. Consider alternative regeneration methods on areas that are currently untreatable by mechanical methods.

Classification Requirements

The availability of up-to-date information, and the use of qualified staff, are essential to the completion of the cutover classification process.

Each year, supplementary aerial photography is taken to provide cutover information, and can be used for cut classification purposes. To be of value, this aerial photography should be done early in the spring, as soon as the snow disappears, and should provide complete coverage of all cutovers, backlogs, or disturbances where treatment is to be considered.

Personnel involved are responsible for the determination of treatable area and the preparation of valid silvicultural prescriptions, and therefore must have considerable silvicultural expertise. A knowledge of the silvical characteristics and requirements of species to be managed is necessary. Staff must be familiar with the capabilities and limitations of all types of mechanical site preparation equipment and prime movers. The unit forester, and competent technical staff such as the senior and/or silvicultural technicians, must be directly involved in the process.

Cutover Classification Procedures

Cutover classification is a three-step process which combines office and field work to produce, for each planning area (i.e., each cutover or disturbance), a report consisting of a brief introduction, three maps and tables, and a short summary.

Step 1: Office Preparation

Up-to-date information should be available from supplementary aerial photography, which can be done in conjunction with cutover mapping procedures.

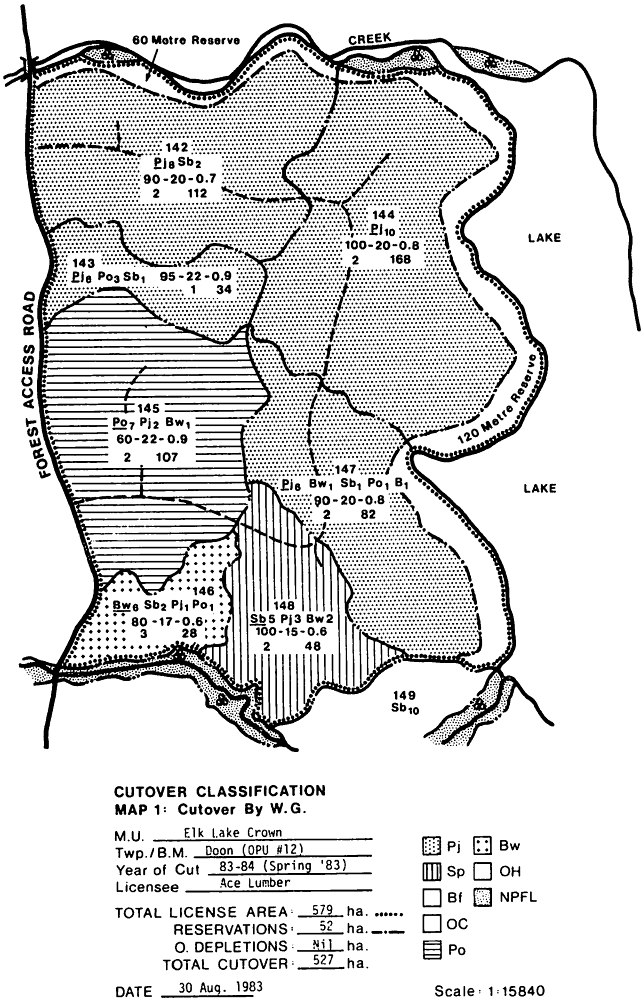

Figure 1. Cutover classification.

CUTOVER CLASSIFICATION AND PROPOSED SILVICULTURAL TREATMENT

Year of Cut	1983-84 (Spring 1983)	Company	Ace Lumber
Mgt. Unit	Elk Lake Crown	Licence	493200
Operating Unit	Doon Twp - 12	Camp No.	-
Technician	J. Smith	Forester	P. Jones
District	Kirkland Lake	Date	2 Sept. 1983

TABLE 1 - AREAS CUT BY WORKING GROUP

Site Class	Pine	Pj	Sw	Sb	Bf	O.C.	Po	Bw	O.H.	NPFL	Total	%
X											-	-
1		34									34	7
2		310		48			107				465	88
3								28			28	5
4											-	
B & S											-	
Total	-	344	-	48	-	-	107	28	-	-	527	100

TABLE 2 - CLASSIFICATION FOR MECHANICAL TREATMENT ONLY

	Pine	Pj	Sw	Sb	Bf	O.C.	Po	Bw	O.H.	NPFL	Total	%
Too Wet											-	
Too Rocky		24									24	5
Too Rough											-	
Too Small											-	
Residuals								15			15	3
Inaccessible											-	
Withdrawn		7					2				9	2
Treatment Not Req'd							103				103	20
Treated											-	
Mech.Treat. Required		313		48			2	13			376	70
Total	-	344	-	48	-	-	107	28	-	-	527	100

TABLE 3 - PROPOSED SILVICULTURAL TREATMENTS

	Pine	Pj	Sw	Sb	Bf	O.C.	Po	Bw	O.H	NPFL	Total	%
Cut Only							103				103	20
Cut & P.B.												
Cut & Scar.												
Cut & Plant												
Cut & S.I.P. & Seed		24									24	5
Cut & S.I.P & Plant		313		48			2	13			376	75
P.B. & Seed												
P.B. & Plant												
PB & S.I.P. & Seed												
Chem S.I.P												
Chem & PB & Seed												
Chem. & P.B & Plant												
Chem.&PB S.I.P.& Seed												
Chem.& PB S.I.P.& PLANT												
Total	-	337	-	48	-	-	105	13	-	-	503	100

Figure 2. Cutover classification and proposed silvicultural treatment.

The boundaries of the planning area (cutover or disturbance) are transferred from the photos to a suitable Forest Resource Inventory cover-type map, and coded by working group (Fig. 1). The area is summarized by working group and site class in Figure 2 (Table 1).

Step 2: Field Survey

A comprehensive field inspection of the planning area is carried out by experienced staff, using the map and photos as aids. The purpose of the survey is to determine the amount and location of mechanically treatable area, to prepare valid silvicultural prescriptions on these areas, and to consider alternative regeneration methods on mechanically untreatable areas.

The entire planning area, portions of which may be classified in the following categories, is surveyed.

1) Area not requiring treatment--includes those portions within the planning area that are expected to regenerate naturally to satisfactory levels of stocking.

2) Withdrawn area--portions of the area that will be removed from timber production for an indefinite period, and could include landings, roads or borrow pits. The field survey will identify and/or verify their existence and size.

3) Area untreatable by mechanical methods--We are currently unable to site prepare all cutovers or disturbances mechanically

because of technological and/or economic limitations. These areas are identified and classified according to why they are untreatable. Most factors contributing to untreatability relate to the physical conditions of the site, and could include areas that are too wet, too rough or rocky (topography), or contain too much residual material. Other areas may be too small to treat economically or may be inaccessible. This classification information is collected during the field survey and summarized in Figure 2 (Table 2) and in Figure 3.

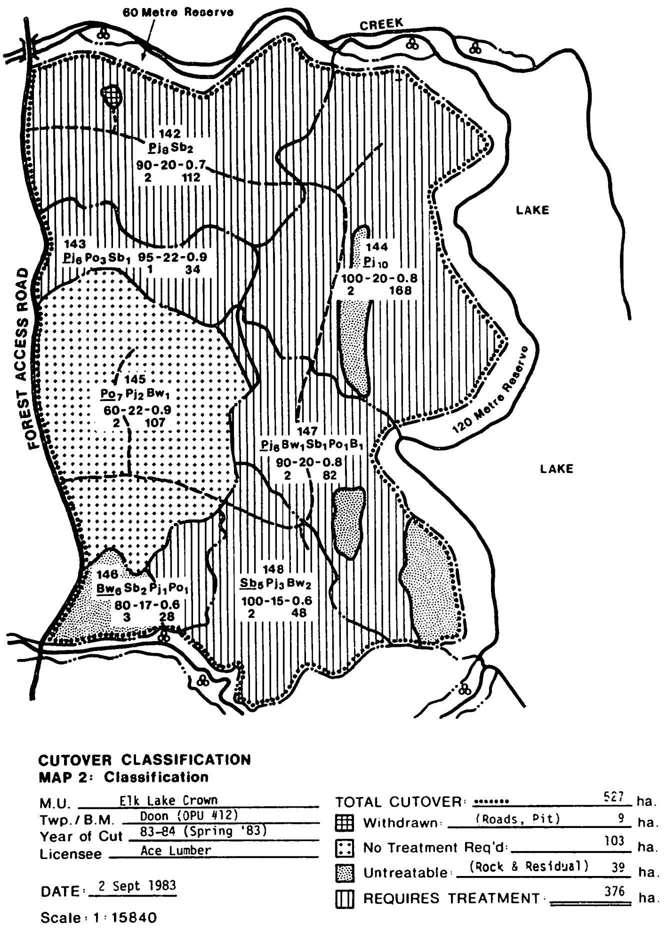

Figure 3. Cutover classification.

Although these areas are mechanically untreatable, other methods of regeneration may be feasible, and therefore should be given due consideration during the field survey.

4) Treatable area -- A valid silvicultural prescription is prepared for those portions of the planning area that have been determined to be mechanically treatable. A relatively uncomplicated area, such as a jack pine sand flat, would likely require one treatment prescription for its entire treatable portion. Other planning areas, which are more complex in nature, may require more than one prescription on various portions of the treatable area. In any case it is recommended that at least one alternative prescription be prepared, in the event that the first choice becomes unattainable. The alternative choice could be of particular value if the use of chemicals or prescribed burning is part of the first choice, if the availability of planting stock becomes limited, or if more than one prime mover is proposed for site preparation within a particular planning area.

Step 3: Report Preparation

As noted earlier, when the field survey is completed, the results of the classification are summarized by working group in Figure 2 (Table 2), and a coded classification map (Fig. 3) is prepared which identifies those parts of the planning area that are withdrawn, require no further treatment, are untreatable, or require treatment.

Figure 2 (Table 3) is then completed, with the preferred silvicultural treatments that have been chosen during the field survey summarized by working group, and a prescription map is prepared (Fig. 4).

The report for the planning area can now be completed. It will consist of a brief introduction, the completed maps and tables, and a short summary.

The introduction will state the purpose of the survey, and should include a brief description and history of the area, and a summary of field survey methodology.

The summary briefly outlines the results of the classification survey, and provides a more detailed silvicultural prescription than that shown in Figure 2 (Table 3).

<u>Example</u>

Classification Summary

Total cutover 527 ha

No treatment required	103 ha	(site class 2 poplar)
Withdrawn	9 ha	(roads, one gravel pit)
Untreatable	39 ha	(rock; white birch residual)
Total untreated	151 ha	
Mechanical treatment required	376 ha	

Silvicultural treatment summary: cut, site-prepare and plant jack pine.

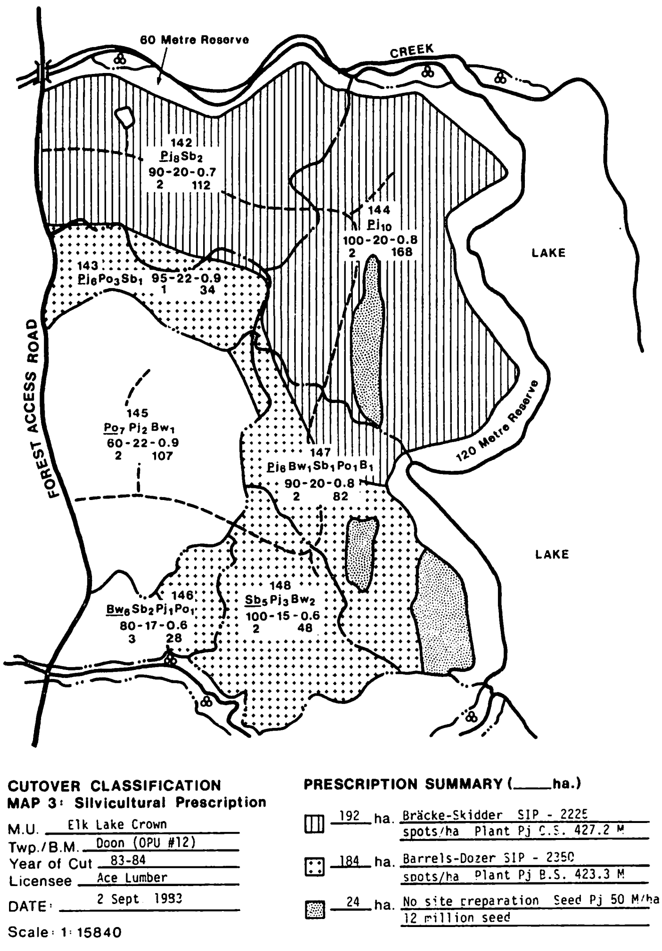

Figure 4. Cutover classification.

Preferred Prescription Detail:

a) Site-prepare 192 ha using 90-110 hp skidder and Bräcke cultivator or TTS disc container stock at rate of 2,225/ha (total seedling requirement 427,200).

b) Site-prepare 184 ha using D-8 or equivalent pulling shark fin barrels on 2.4-m drawbar. Plant jack pine nursery stock at a rate of 2,350/ha (total seedling requirement 432,300). Aerial tending with 2,4-D likely required on 184 ha 2 or 3 years after planting.

c) Seed 24 ha of mechanically untreatable rocky area with jack pine at rate of 50,000/ha (12 million seeds).

Alternative 1: Use D-8 or equivalent barrels and 4.3-m drawbar on 192 ha instead of skidder. Cost will likely be higher.

Alternative 2: Use skidder plus disc trencher on 192 ha and tractor plus Youngs Teeth on 184 ha, seed 192 ha + 184 ha + 24 ha (no mechanical treatment) + 9 (withdrawn) = 409 ha, with jack pine seed at rate of 50,000/ha, (20.5 million seed). The completed tables (Fig. 2) and maps (Fig. 1,3,4) illustrate the above example. The maps are generally color-coded; however, in this report, a system of hatching has been used for convenience in printing. The map legends are for illustrative purposes only, and can be modified to reflect the local situation as required.

On most management units, it is likely that more than one planning area will require classification. When the field surveys and reports for all areas have been completed, the classification and prescription results can be summarized for the entire management unit, and the completed package placed in a suitable binder. This information will allow the forest manager to prepare a comprehensive silvicultural work program proposal for the following year.

The annual report on cutover classification should be kept on file, as it will provide valuable information to the forest manager during a subsequent analysis of cutting and silvicultural operations. Classification reports can then be compiled by District and Region, to allow each level of administration the opportunity to evaluate its regeneration ability, to audit levels of silvicultural expertise, and to determine staffing and funding requirements.

Summary

The cutover classification system is a simple, formal approach to silvicultural planning. The system allows the forest manager to analyze the annual cutover with due consideration for working group maintenance, to determine treatable areas, and to prepare valid silvicultural treatment prescriptions on these areas. The system thus provides a uniform method for determining regeneration potential on a local and regional basis.

The two basic requirements are up-to-date information and qualified staff. Both are now available in all districts, and the only other requirement appears to be the commitment of time and effort that will be required to get the job done.

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SITE PREPARATION

STANDARDS AND MEASUREMENTS

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Abstract.—*The development of mechanical site preparation in Ontario and the establishment of site preparation standards are outlined. The application of the standards by the project foreman and the methods of measurement required to monitor the application of the standards of site preparation performance are described.*

Résumé.—*La mise au point d'une méthode préparation mécanique du sol en Ontario et l'établissement de normes à cette fin font l'objet d'un bref exposé. L'application des normes par le superviseur et les méthodes de mesure nécessaires au contrôle de l'application des normes sont décrites.*

INTRODUCTION

Tree planting in Ontario has changed very little since its inception at Guelph in 1905. Over 95% of all trees are still planted manually 78 years later. Tree planting was initially confined to the severely burned sandy lands of southern Ontario where, because of the frequency and intensity of wildfires, the competitive vegetation was almost nonexistent. In the years between the two world wars, tree planting operations were extended to the sand flats north of Thessalon for the same reasons (MacDonald 1966).

After World War II, tree planting was expanded to include all of the districts of northern Ontario with the same technology that was so successfully employed in the south for over 40 years. Unfortunately a single burn is seldom severe enough to permit tree planting on more than 10% of the burned over area. On the remaining 90% the race was on each spring and fall to plant the burns before the pioneers, the natural regeneration or the competition smothered the artificially introduced invaders. This race was usually lost nine times out of ten in the period between 1950 and 1962, in the absence of mechanical site preparation. Hand scalping or plowing a furrow with horses on these burns was impossible because of the density of the burned timber. Yet it was furrowing, or, as it is now known in agriculture, "minimum tillage or cultivation" that was required to disturb the deep slash and the root- and seed-containing layer of the organic seedling to survive (Brown 1966).

THE OBJECTIVES OF SITE PREPARATION

Site preparation in Ontario was first carried out in the spring of 1962 to prepare a site for planting. A 60-ha site was prepared mechanically on an experimental basis to achieve the following objectives:

1) the elimination of competition for sunlight between the planted tree seedling and all other vegetation,

2) the elimination of all competition for moisture and nutrients between the roots of the seedling and those of vegetation,

3) the control of spacing and stocking of all planted seedlings,

4) the provision of assistance to the seedlings in attaining apical dominance and early crown closure over the competing vegetation,

5) the inducement of height growth and the initiation of self-pruning at the earliest possible date after planting.

The objectives of site preparation reflect the silvicultural requirements of the species, which in this particular case is jack pine.

THE STANDARD OF SITE PREPARATION

The first project was carried out with a 1955 Caterpillar D8 (170 HP) towing a 16-link string of 53-kg anchor chains at 1.8-m centres in a furrow created by the two outside teeth of a Fleco root rake, directly in front of each tractor track. The site was in McEvay Township, in the Watabeag Crown Management Unit, about 45 km south of the town of Matheson. Although the quality of site preparation was not quite adequate, two such units were used in 1963. The same year saw the appearance of the shark-finned barrels that became the standard site preparation equipment used by the province during the next 15-year period (Brown 1966).

The equipment was designed to meet the light requirements of the planted trees by breaking up the heavy slash and residuals according to the minimum till concept. It was also designed to remove the root- and seed-bearing organic layer, thereby eliminating root competition with the planted seedling. The width of the mineral-soil exposure (MSE) required was deemed to be 60 cm or twice the height of the competition on sites 2 and 3 of the jack pine working groups.

Although a 50-cm width of strip was prepared, the mineral-soil exposure (MSE) obtained was only 30 cm wide. Both standards were high enough to ensure seedling survival of both planted and sown stock with the judicious application of hand or chemical tending when required. The 50-cm width was also designed to eliminate mechanical suppression by the combined action of competition and snow during the first winter after planting. Site preparation finally became part of forestry terminology when it first appeared in "A Statistical Reference of Lands and Forests Administration 1964" (Anon. 1964). The definition of site preparation was subsequently recorded by J.D. Hughes as: "disturbance of the forest floor and the topsoil to create suitable conditions for natural regeneration, seeding or planting" (Anon. 1977). Hughes stated further: "The treatment may include prescribed burning and the removal of undesirable growth" (ibid.).

THE APPLICATION OF THE STANDARDS OF SITE PREPARATION

Site preparation equipment was initially operated on the site in a concentric pattern then in use with scarification equipment for the natural regeneration of jack pine (Fig. 1). During the second year of site preparation it was discovered that the land pattern produced less operator fatigue, prepared 10-15% more area and produced better stocking through a higher percentage of area coverage and better supervision of the tree planters. The optimum lineal spacing between trees was found to be 2 m, with a lateral spacing of 1.8 m based on a spacing trial by D. Scott in 1960, and recommendations of 2500 trees/ha for the planting of jack pine in the Lake States (Rudolf 1950).

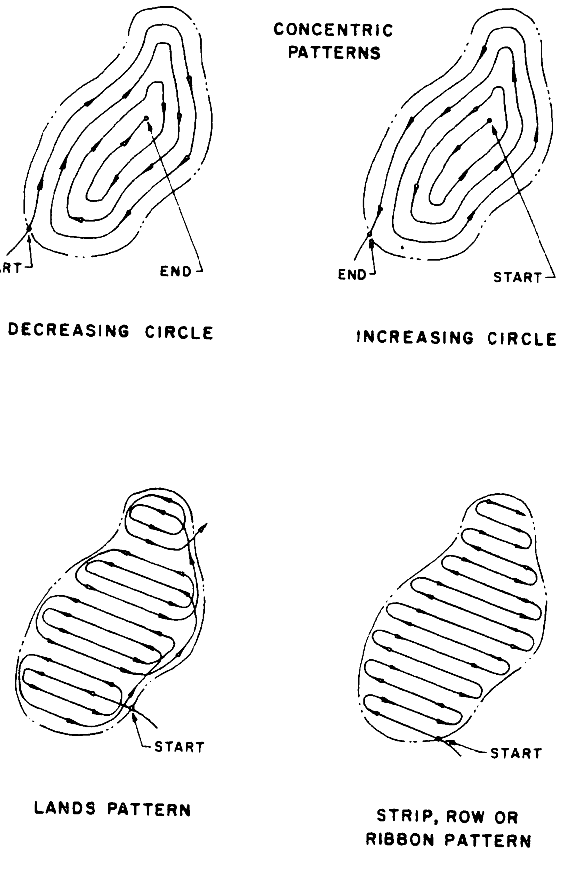

Figure 1. Seeding and site preparation patterns.

MONITORING THE QUALITY OF SITE PREPARATION

There is no difference between a *gross* hectare and a *net* hectare in that both contain 10,000 m^2 of area. The proponents of the gross and net theory simply do not understand the concept of area coverage, productive and non-productive sites. These are explained below.

1) Area coverage is expressed as a percentage of the laterally spaced rows, corridors or scalps that are prepared on an area as compared with those that could be prepared under ideal conditions, to meet the predetermined stocking and spacing needs of the species to be regenerated. The coverage is monitored by the project foreman at least twice a day per machine shift in the following manner:

   a) Starting at the halfway point between two rows, a 100-m line is laid out at right angles to the direction of the site-prepared row.

   b) The rows or corridors are counted as they are crossed.

   c) The number of rows prepared is divided by the number of predetermined rows and the result is multiplied by 100 to obtain the percentage of area coverage. For example, the foreman counted 36 rows (Item A).

At a 2-m centre spacing of the rows there should be 50 rows in the 100-m line (Item B). The area coverage is thus:

$$\frac{A}{B} \times 100 \text{ or } \frac{36}{50} \times 100 = 72\% \text{ of the area.}$$

In the absence of difficult site conditions such as heavy slash, too many residuals, steep, rocky or bouldery terrain, the operator must maintain a minimum site coverage of at least 85%. Under ideal working conditions the area coverage should be at least 90%.

2) Mineral-soil exposure (MSE) is not a critical factor for all species on all sites. MSE could be detrimental on clay soils, particularly if the root- and seed-bearing layer of the organic soil could be removed without exposing the underlying clay. MSE is very important in the artificial regeneration of some species by seeding, including jack pine on sandy soils. On the basis of past experience, a 30-cm width of MSE on every 50-cm length sampled is large enough to produce at least one tree seedling from aerially broadcast or row-sown seed on every metre length of prepared area.

The MSE is measured and the nonproductive sites encountered are tallied in the following manner by the project foreman on his return trip over the area coverage line:

   a) He tallies the length of MSE to the nearest half metre for 1 m on every 5th line crossed, unless directed to measure every line.

   b) He tallies the nonproductive sites encountered in a similar manner, e.g., in the 36 rows counted for coverage, he would arrive at a sample length of 36 ÷ 5 = 7 rows x 1 m = 7 m of prepared line (L).

   c) If at the end of the return trip the project foreman tallied 4.7 m of exposed mineral soil and 1.1 m of bedrock and/or water or other non-productive site, along with 1.2 m of unsuitable seedbed, i.e. stumps, rotten logs, etc. (total of 2.3 m nonproductive) he would calculate MSE thus:

$$\frac{EMS}{L} \times 100 = MSE \text{ or } \frac{4.7}{7} \times 100 = 67.14 \text{ MSE}$$

On the basis of experience, MSE of less than 65% of the prepared area severely reduces the future stocking of seeded areas. On sandy sites, 95% MSE should be aimed for on the prepared strips with jack pine regeneration.

The percentage of nonproductive site on the prepared area can be calculated as:

$$\frac{NPS}{L} \times 100 = \frac{2.3}{7} \times 100 = 32.8\% \text{ NPS}$$

The percentage on the treated area can be calculated as follows:

$\frac{A}{B}$ x width of the prepared furrow or corridor x 100, where A = the rows prepared and B = the potential rows in the 100-m sample.

$\frac{36}{50}$ x 0.5 m x 100 = 36% at the 72% area coverage, where 0.5 m is the width of the furrow, strip or corridor.

3) The production rate of the site preparation equipment should be monitored at least twice per machine per shift or as often as changes are noted in the external factors affecting the production rate. To calculate the production rate of the site preparation equipment, the project foreman must be aware of:

   a) the length (L) of the course in metres,

b) the width (W) of the equipment coverage in metres,

c) the time (T) it takes the prime mover to cover the course. For example, if the site preparation is carried out over 1.5 km in one direction and it has taken the tractor 20 min. to cover the course, including the return trip and the two turns on the ends, using 4-m-wide site preparation equipment, the production rate per hour would be:

$$\frac{L \times W}{10,000} \times \frac{60}{T} = \frac{3,000 \times 4}{10,000} \times \frac{60}{20} = 3.6 \text{ ha/hr.}$$

The actual production rates should be determined after the project area is completed.

CONCLUSION

Over the past 20 years a system has been developed within the Ontario Ministry of Natural Resources as a guide to enable the project foreman to evaluate the quality and quantity of the site preparation being carried out under his supervision, and to adjust the performance of the contractor to meet the biological and economic standards of the contract on the site. The information collected can be compiled by (a) project, (b) district, (c) region, (d) prime mover, and (e) site preparation equipment. The system may not be statistically sound but it is practicable, economical and can be audited on the job.

Many other systems for evaluating the performance of silvicultural equipment have been developed since the middle of the last decade. Most of them are statistically sound and some of them are even practicable. It is difficult to compare them, however, since scientific authorities do not use the same benchmarks for performance evaluation.

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MOUNDING SITE PREPARATION: EVALUATION OF JACK PINE OUTPLANTINGS IN A BOREAL ONTARIO STUDY

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Abstract.--Evaluation of a mounding method of site preparation in boreal Ontario was begun in 1979. On four sites in each of 1980, 1981, and 1982, bare-root jack pine (Pinus banksiana *Lamb.) were outplanted on five microsites. The outplantings included two manually simulated types of Bräcke mounder site preparation. Performance data for 1980-1982 do not justify mounding for jack pine. Planting on the shoulder of the unmodified Bräcke patch has so far given the best results.*

Résumé.--On a commencé à évaluer une méthode de préparation du sol en buttes dans la région boréale de l'Ontario en 1979. En 1980, 1981 et 1982, à quatre endroits chaque année, on a planté des pins gris (Pinus banksiana *Lamb.) à racines nues à cinq microstations, avec deux types simulés manuellement de préparation du sol en buttes (engin Bräcke). Les résultats ne justifient pas la plantation en buttes du pin gris. Jusqu'à présent, la plantation sur l'épaulement de places type "Bräcke" non modifiées a donné les meilleurs résultats.*

Introduction

Satisfactory plantation establishment often depends on site preparation prior to planting or seeding to ameliorate one or more constraining factors, including competing vegetation, unfavorable forest floor, unsuitable soil and/or soil moisture conditions, pests, impediments to access, and fire hazard.

Mounding methods of site preparation (McMinn and Van Eerden 1977, Söderström 1977, Söderström et al. 1978, Edlund 1980a,b, Bäckström 1981, Parolin et al. 1981, McMinn 1982, Sutton 1983) would seem to offer the potential for improving sites in various ways: by reduced competition, raised root zone temperatures during the growing season (because of the absence of an insulating mat of organic matter), improved drainage (in cases where the water table is high), conservation of what otherwise would be run-off water (in the pits that provided the material for making the mounds), and the opportunity for placing tree root systems close to an augmented source of nutrients, where the biologically most active part of the overturned organic layer contacts the relatively warm capping of mineral soil.

There should be no misapprehension about the nature of mounding site preparation: it is not one thing but many. Quite apart from any unintentional variation among mounds of a given type, mounds may differ in volume, areal extent, surface topography, composition, and the nature and condition of the substrate. Mounds may be formed of mineral soil on a mineral-soil substrate, mineral soil on inverted surface organic matter, mineral soil on *in situ* surface organic matter, organic soil on mineral soil, organic soil on organic soil, or various mixtures of mineral and organic soil on undisturbed or variously disturbed substrate. The effect of mounding site preparation on outplant performance must be expected to vary with both mounding type and site conditions as well as with the interaction between them. McMinn[1] emphasizes the

[1]McMinn, R.G. 1983. Department of the Environment, Canadian Forestry Service, Pacific Forest Research Centre, Victoria, B.C. (pers. comm.).

importance of inverting the surface organic matter and of capping this with a layer of mineral soil insofar as his experimentation (McMinn and Van Erden 1977, McMinn 1982, 1983) in central interior British Columbia is concerned. In Sweden, Söderström (1977) and Södertröm et al. (1978) found that mounding was beneficial whether or not the organic substrate was inverted.

A study was begun in 1979 to provide a basis for evaluating one mounding method of site preparation in the regeneration of boreal forest sites in Ontario using spring-lifted, bare-root jack pine (*Pinus banksiana* Lamb.) and black spruce (*Picea mariana* [Mill.] B.S.P.). The work described in this paper forms part of the Ontario Ministry of Natural Resources (OMNR) forest research project "Mineral mound and humus mound planting in the boreal forest of Ontario", which is being conducted collaboratively with the Great Lakes Forest Research Centre of the Canadian Forestry Service under the Canada-Ontario Forest Management Subsidiary Agreement.

Objectives

Specifically, the objectives of the study include the investigation of relationships between root growth capacity (RGC) determined in the growth chamber and field root growth (FRG) of outplanted stock, and between RGC and FRG on the one hand and, on the other, survival and growth of outplants on a variety of representative sites as influenced by site preparation effected by the Bräcke scarifier, with and without the sort of mounding produced by the Bräcke mounding attachment. The overall aim is to generate data to enable the value of this mounding method of site preparation in boreal Ontario to be determined.

Material and Methods

Mounds, simulating those produced by the Bräcke mounding attachment, were made by hand in the autumn of 1979 on clearcut sites that earlier in the year had been treated with the standard Bräcke scarifier.

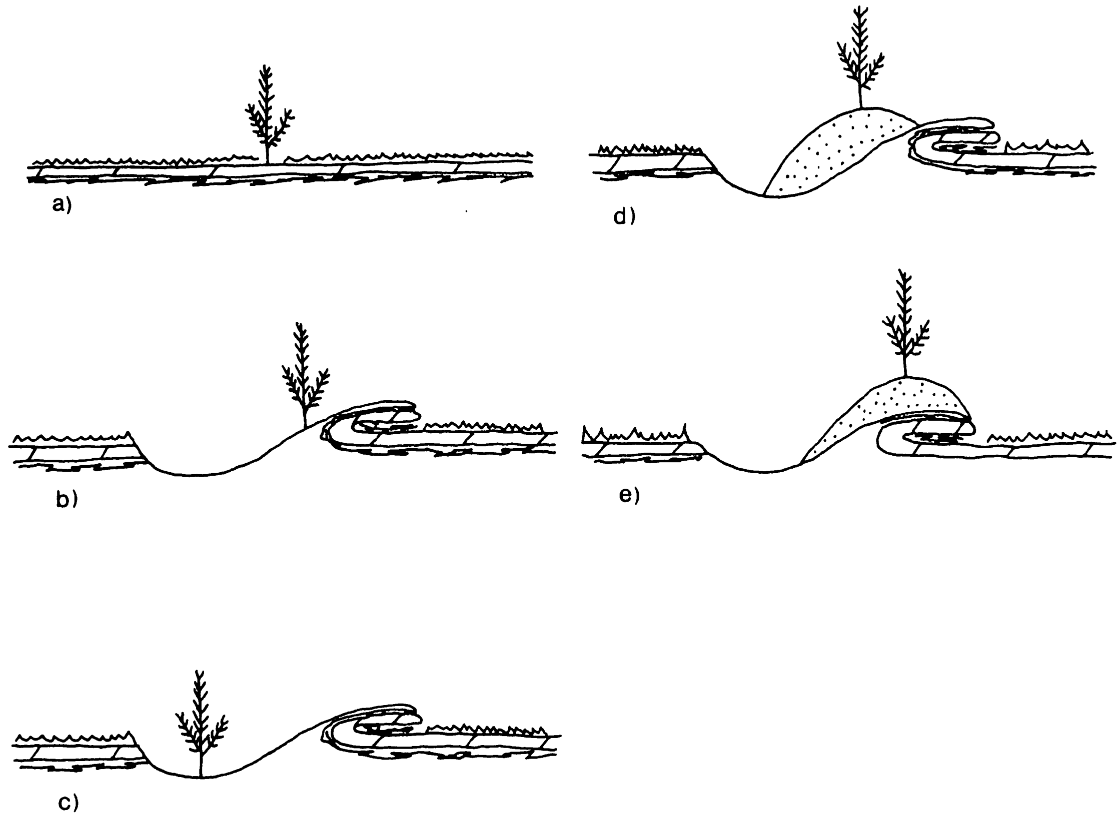

Figure 1. Diagrammatic representation of the five treatments (after Edlund 1980a,b) showing planting positions: (a) untreated; (b) upper part (shoulder) of the standard Bräcke patch; (c) lower part (bottom) of the standard Bräcke patch; (d) a 20-L mound of mineral soil heaped on the shoulder of the Bräcke patch; and (e) a similar mound but placed on the double layer of organic matter (original forest floor + inverted LFH layer scuffed out of the Bräcke patch by the scarifier) distal to the patch.

Table 1. Location, elevation, and main soil texture characteristics of the P80, P81, and P82 jack pine outplanting sites.

P year, site	Latitude (N)	Longitude (W)	Elevation (m)	Soil texture
P80				
Cochrane	49°55'	81°42'	275	very fine sand
Foleyet	48°25'	82°26'	310	medium sand
Savant Lake	50°22'	90°45'	425	fine/medium sand
White River	48°38'	85°22'	390	loamy sand
P81				
Chapleau[a]	47°40'	83°24'	465	gravelly sandy loam
Ignace	49°49'	92° 2'	425	silt loam over varved silts
Thunder Bay	49°34'	89°54'	440	loamy sand, locally gravelly
White River	48°28'	85°10'	396	silt loam
P82				
Ignace	49°51'	92° 3'	425	medium sand over gravel
Savant Lake	50°15'	90°58'	425	medium sand
Thunder Bay	48°48'	89°12'	425	gravelly cobbly medium/coarse sand
White River	48°44'	85°16'	425	medium sand

[a]Before 3rd-year data could be collected in the fall of 1983 from the jack pine on this site, the plots were destroyed in error by further site preparation.

Five planting spot treatments (Fig. 1) were compared: (a) untreated; (b) upper part (shoulder) of the standard Bräcke patch; (c) lower part (bottom) of the standard Bräcke patch; (d) a 20-L mound of mineral soil heaped on the mineral soil of the shoulder of the Bräcke patch; and (e) a similar mound placed on the double layer of organic matter (original forest floor + inverted LFH layer scuffed out of the Bräcke patch by the scarifier) distal to the patch.

On each of four sites in each of 1980, 1981, and 1982 (Table 1), 600 spring-lifted bare-root 2+0 jack pine (Table 2) were hand-outplanted by the operational slit method during the conventional spring planting season. By chance, there were some significant differences in height and stem diameter between the stock lots used on the various sites. There were four replications of 30-tree plots on each of the five microsites on each site.

All outplanted trees were assessed 30 days after planting. Tree condition was scored as follows: 1 = tree in good condition, developing normally; 2 = tree in good or moderately good condition, but with leading shoot defective; 3 = tree alive but in poor condition; and 4 = tree dead or virtually so. At this time, five randomly selected trees were excavated in each plot of 30 trees, and the number and aggregate length of unlignified root tips > 1 cm long were determined for each excavated tree. The remaining 25 trees per plot were assessed for survival, annual height increment, ground-level stem diameter, and condition at the end of the 1980, 1981, and 1982 growing seasons.

A subsample of the planting stock used on each site was planted in the Thunder Bay Forest Station Nursery to determine both the viability of the planting stock at the time of planting and the comparative first-year performance of the stocks when grown in the low-stress nursery environment. The condition of these trees was determined 30 days after planting, and condition and growth were determined at the end of the first growing season.

Also, the stock lots that were used in the P80 Savant Lake and White River, the P81 Ignace and White River, and the P82 Thunder Bay and White River plantings were subsampled immediately after pickup at the nursery to provide trees for RGC determinations.

Table 2. Details of 2+0 jack pine planting stock outplanted at the designated sites.

P year, site	Seed lot	Site region	RGC[a] lot no.	Lift date	Storage[b]	Pickup date	Planting date	Mean top ht (cm)	Mean diam stem ground level (mm)
P80									
Cochrane	M77-147[c]	3215		1 May	N-R	23 May	30 May	16.0a[g]	3.9b
Foleyet	M77-147	3215		1 May	N-R	23 May	27 May	16.5b	3.5a
Savant Lake	M77-147	3215	1	1 May	N	14 May	16 May	16.4b	4.3c
White River	M77-147	3215	2	1 May	N-B	20 May	22 May	17.0c	3.6a
P81									
Chapleau	77-990[d]	3215B[e]		27 Apr	N	21 May	27 May	14.1a	3.4a
Ignace	77-990	3215B	1	27 Apr	N	15 May	18 May	14.0a	3.6a
Thunder Bay	77-990	3215B		27 Apr	N	12 May	14 May	13.7a	3.4a
White River	77-990	3215B	2	27 Apr	N	21 May	24 May	13.9a	3.3a
P82									
Ignace	78-748[f]	25-3414		8 May	N	10 May	15 May	20.2c	3.8c
Savant Lake	78-748	25-3414		8 May	N	10 May	13 May	20.4c	3.7b
Thunder Bay	78-748	25-3414	1	8 May	N	8 May	9 May	19.6b	3.6b
White River	78-748	25-3414	2	12 May	N	18 May	18 May	18.4a	3.4a

[a] Root growth capacity determinations made on subsamples of two lots/year.
[b] N-R = stored at nursery at 1° to 2°C with low relative humidity until 8 May then shipped by reefer van to White River and there transferred to another reefer van at 3°C: N = stored at nursery at 1° to 2°C with low relative humidity: N-B = cool-stored at nursery until 9 May then shipped by reefer van to the Beardmore mine shaft at 3°C with high relative humidity, and returned to the nursery on the day of pickup.
[c] Wawa District, Acton Township, 1976 collection.
[d] Wawa District, Acton Township, 1977 collection, tested 93% germination.
[e] B designation indicates that seed was of medium size.
[f] Thunder Bay District, Spruce River Seed Collection Area, 1978 collection, tested 93% germination.
[g] Within columns within P years, values not followed by the same letter differ significantly (P 0.05) according to Tukey's Multiple Comparison Test.

The statistical analysis of data has included analyses of variance, Tukey's Multiple Comparison Tests, chi-square tests, and correlation analyses.

Field work for the study was carried out under contract by KBM Inc., Forestry Consultants, of Thunder Bay, Ontario. RGC determinations were subcontracted to professor R.J. Day, Lakehead University, Thunder Bay, Ontario.

Results and Discussion

Nursery Test Plantings

The viability of the planting stocks used in the field outplantings is confirmed by the performance of the jack pine in the nursery plantings (Table 3). Even in the absence of irrigation, the poorest first-year survival rate was 94% (for the P80 Foleyet stock), and in 10 of the 12 stock lots survival was 98% or higher. There were no significant differences in survival between stock lots either within or between years.

In each year of planting, first-year growth in the nursery differed significantly (P 0.01) among the stock lots. There were significant (P 0.01) differences between years, too, the P81 stock being particularly inferior in terms of stem diameter increment (Table 4).

Within the size limits of the planting stock used in this study, initial size of the stock in the nursery test plantings was poorly correlated with the performance of those trees. The highest correlation between initial top height and height increment during the ensuing growing season occurred in the P82

Table 3. Nursery test plantings of jack pine in 1980 (P80), 1981 (P81), and 1982 (P82): survival.

P year	Stock lot	Survival (%): 30 days after planting	Survival (%): End of 1st growing season
P80	Cochrane	100	100
	Foleyet	98	94
	Savant Lake[a]	100	100
	White River[b]	98	98
P81	Chapleau	100	100
	Ignace[a]	100	98
	Thunder Bay	100	98
	White River[b]	100	100
P82	Ignace	100	100
	Savant Lake	100	100
	Thunder Bay[a]	98	95
	White River[b]	100	100

[a] Another subsample of this stock lot was tested as Lot 1 for RGC.
[b] Another subsample of this stock lot was tested as Lot 2 for RGC.

Table 4. Nursery test plantings of jack pine in 1980 (P80), 1981 (P81), and 1982 (P82): details of planting stock and first-year performance. Figures within parentheses are overall means for field outplanted stock of the same stock lots.

P year and stock lot	Initial top ht (cm)		Initial stem diam[a] (mm)		1st-yr ht increment (cm)		1st-yr stem diam[a] increment (mm)	
P80								
Cochrane	14.0a[b]	(16.0)	3.7a	(3.9)	14.2b	(6.3)	3.0b	(1.0)
Foleyet	15.3ab	(16.5)	3.5a	(3.5)	12.2a	(9.5)	2.5b	(1.4)
Savant Lake	15.9a	(16.4)	4.8b	(4.3)	14.7b	(9.5)	1.6a	(0.7)
White River	16.3a	(17.0)	3.8a	(3.6)	14.5b	(7.8)	2.9b	(1.2)
P80 over all	15.6NS		3.9**[c]		13.9**		2.5**	
P81								
Chapleau	12.7a	(14.1)	3.5ab	(3.4)	9.9a	(6.7)	1.0ab	(0.7)
Ignace	15.5b	(14.0)	3.5ab	(3.6)	13.1b	(7.3)	1.5c	(0.7)
Thunder Bay	13.4a	(13.7)	3.8b	(3.4)	11.9ab	(7.7)	0.7a	(0.6)
White River	13.4a	(13.9)	3.3a	(3.3)	11.1ab	(6.5)	1.1b	(0.6)
P81 over all	13.8**		3.5**		11.5**		1.1**	
P82								
Ignace	20.8a	(20.2)	3.8b	(3.8)	12.8b	(8.4)	3.0ab	(1.0)
Savant Lake	20.5a	(20.4)	3.8b	(3.7)	12.0b	(8.5)	2.9ab	(0.8)
Thunder Bay	19.8a	(19.6)	3.1a	(3.6)	10.2a	(9.8)	3.3b	(1.0)
White River	19.8a	(18.4)	3.6b	(3.4)	12.2b	(9.5)	2.6a	(0.9)
P82 over all	20.3NS		3.6**		11.8**		2.9**	

[a] Ground-level stem diameter.
[b] Within horizontal rows, values not followed by the same letter differ significantly (P 0.01) according to Tukey's Multiple Comparison Test.
[c] Within years of planting, ** indicates that differences between the values contributing to the mean are significant at the P 0.01 level; NS = not significant.

White River stock lot, for which $r^2 = 0.58$. For the P82 nursery plantings over all, however, only 34% of the first-year height increment is associated with initial top height; for the P80 and P81 plantings the comparable figures are 2% and 21%. There was essentially no correlation between initial top height and first-year diameter increment.

In the nursery plantings, correlations between initial stem diameter and first-year height increment varied between $r^2 = 0.20$ in the P81 plantings over all and $r^2 = 0.07$ in the P80 plantings. What little correlation there was between stem diameter at the time of planting and the diameter increment made during the ensuing growing season was negative, with $r^2 = 0.21$, 0.01, and 0.04, respectively in the P80, P81, and P82 plantings over all.

Root Growth Capacity (RGC)

RGC values gave even less indication of nursery performance potential than did planting stock morphology (Table 5). Up to fivefold differences in mean RGC were found between planting stock lots of the same provenance; between years, up to tenfold differences occurred. Within a given lot, tree size was poorly correlated with RGC.

useful in predicting performance potential. McMinn (1980) reached a similar conclusion with white spruce (*Picea glauca* [Moench] Voss) in outplantings in the central interior of British Columbia; low or high RGC "predicted survival and growth somewhat independently of morphological parameters".

Field Performance

(a) Survival: Survival was lowest in the P81 plantings, particularly on microsite e, the mound-on-minimound treatment (Table 6). At P81 Ignace, for instance, 46% of the jack pine on microsite e had died within 30 days of planting, whereas 30-day mortality on microsite d (mound-on-mineral) was only 9% and on the unmodified Bräcke patch and untreated microsites only 1% or nil. Mortality at 30 days on microsite e at P81 Thunder Bay was also high (24%), and at P81 Chapleau and P81 White River it was substantial (8% and 9%, respectively).

In contrast, only at Foleyet among the P80 plantings did 30-day mortality on microsite e exceed 6%. In the P82 plantings, not one jack pine died on microsite e during the 30 days following planting.

Table 5. Root growth capacity: means of determinations on subsamples of jack pine planting stocks after 30 days in growth chamber. n = 60 (P80, P82) or 30 (P81).

	Initial morphology						Root growth capacity		
					Unlignified root tips		Unlignified root tips		
P year and stock lot	Top ht (cm)	Stem diam (mm)	Root vol[a] (cm^3)	RAI[b] (cm^2)	>1cm (no.)	<1 cm (no.)	>1 cm (no.)	>1 cm (cm)	<1 cm (no.)
P80									
Savant Lake	17.0ac	3.9a	3.4b	36b	0	>25	59.4b	444.0b	>25
White River	18.0a	3.2a	1.9a	24a	0	>25	18.1a	91.3a	>25
P81									
Ignace	14.3a	3.9a	2.9a	19a	0	93	14.3a	44.9a	45a
White River	14.1a	3.8a	2.9a	20a	0	101	20.4b	73.3b	156b
P82									
Thunder Bay	21.1b	3.5b	2.1b	16a	0	111	14.7a	80.3a	45a
White River	19.8a	3.1a	1.5a	13a	0	79	25.9b	146.2b	108b

[a] By displacement.
[b] RAI = root area index (Morrison and Armson 1968).
[c] Within columns within years, values followed by the same letter do not differ significantly (P 0.01) according to t-test.

On this evidence, the main value to be obtained from RGC determinations would seem to be that viability is demonstrated in a general way. It seems likely that only very low, and perhaps exceptionally high, values may be

The lowest mortality rates generally occurred in the unmodified Bräcke patch microsite treatments b and c. In the four P80 plantings, for instance, cumulative mortality on these microsites at the end of the third growing season varied between 0 and 7%.

Table 6. Field outplantings: cumulative mortality (%) to the end of the 1982 growing season, by P year, site, and microsite. n = 100.

P year	Site	Assess-ment	Microsite[a] a (%)	b (%)	c (%)	d (%)	e (%)
P80	Cochrane	30-day	0	0	0	0	1 NS[b]
		1st-yr	0	0	0	1	1 NS
		2nd-yr	0	0	1	1	1 NS
		3rd-yr	0	0	1	1	1 NS
	Foleyet	30-day	1	2	5	0	**11** **bc
		1st-yr	5	3	5	1	**11** *b
		2nd-yr	5	3	6	2	11 *
		3rd-yr	7	3	6	2	11
	Savant Lake	30-day	0	1	0	3	3 **
		1st-yr	3	1	0	3	4 NS
		2nd-yr	3	1	1	3	4 NS
		3rd-yr	5	1	3	4	5
	White River	30-day	**14**	3	2	1	6 **
		1st-yr	**19**	6	2	4	6 **
		2nd-yr	**21**	7	3	5	6 **
		3rd-yr	**21**	7	3	5	6 **
P81	Chapleau	30-day	4	1	2	1	**8** **
		1st-yr	11	4	5	4	**13** **
		2nd-yr	13	7	5	4	**14** **
	Ignace	30-day	1	1	0	**9**	**46** **
		1st-yr	2	4	1	**14**	**50** **
		2nd-yr	3	4	1	**15**	**50** **
	Thunder Bay	30-day	2	0	0	**7**	**23** **
		1st-yr	6	1	3	**10**	**24** **
		2nd-yr	7	1	3	**10**	**24** **
	White River	30-day	**5**	0	1	2	**9** **
		1st-yr	**14**	4	5	9	**23** **
		2nd-yr	**18**	6	5	9	**23** **
P82	Ignace	30-day	2	0	0	1	0 NS
		1st-yr	4	1	0	2	3 NS
	Savant Lake	30-day	2	0	0	1	0 NS
		1st-yr	**4**	**4**	0	2	0 NS
	Thunder Bay	30-day	**3**	0	0	0	0 *
		1st-yr	**14**	1	0	0	2 **
	White River	30-day	**4**	0	1	0	0 *
		1st-yr	**13**	2	2	0	0 **

[a] See text for details of microsite.
[b] NS, *, and ** indicate that differences between microsite values are respectively non-significant, significant (P 0.05), and highly significant (P 0.01).
[c] Values shown in boldface contribute significantly (P 0.05) to significant chi-squares.

Site-specific data on weather and soil moisture were not collected for this study, but there was an obvious relationship between mortality and soil moisture stress. Mounds of predominantly sandy material of low water-holding capacity dried rapidly after any rain, and, especially in 1981, were insufficiently replenished by precipitation to avert periods of sustained water deficiency. Such mounds were vulnerable to erosion by wind as well as by water. Erosion was further facilitated by the swaying and twizzling of the trees, under the influence of wind, planted in the mounds. Exposure of roots, attrition of the mound by erosion, and the non-cohesiveness of sandy material, combined to undermine the stability of the trees planted on mounds. Microsite e mounds were considerably more subject to these influences than were the mounds of microsite d because the minimound layer of partially decomposed organic matter prevented any capillary continuity between the mineral soil above and below.

Mounding, therefore, did not improve survival: in many cases it was detrimental, especially with microsite e. None of the jack pine sites had drainage problems that might have been alleviated by mounding, and there were thus no compensating improvements to drainage to offset the disadvantages already noted.

(b) Growth (Height increment): In each of the three years of planting, mean first-year height increment over all varied significantly among sites; values ranged from 6.3 to 9.5 cm in the P80 plantings, from 6.5 to 7.7 cm in P81, and from 8.4 to 9.8 cm in P82 (Table 7). These values were 46 to 83% of those recorded in the comparable nursery test plantings.

Mean second-year height increment over all also varied significantly among sites in the two years of planting for which analyses of second-year data are available. Data from the P80 plantings show very wide differences in mean third-year height increment, from 18.7 cm at Cochrane to 45.1 cm at Foleyet.

Table 7. Field outplantings: mean height at planting, and mean annual height increments of jack pine, microsite treatments over all, by year of planting and site. n = 600 initially.

P year	Variable[a]	Site 1 (cm)	Site 2 (cm)	Site 3 (cm)	Site 4 (cm)	Mean (cm)
P80		Cochrane	Foleyet	Savant Lake[b]	White River[b]	
	Init ht	16.02a[c]	16.52ab	16.42a	16.96b	16.49**[d]
	Δh 1	6.28a	9.46c	9.46c	7.82b	8.25**
	Δh 2	10.08a	27.77d	24.90c	20.85c	20.82**
	Δh 3	18.67a	45.09c	35.48b	37.10b	33.85**
P81		Chapleau	Ignace[b]	Thunder Bay[b]	White River[b]	
	Init ht	14.08a	13.98a	13.68a	13.92a	13.92NS[d]
	Δh 1	6.71ab	7.30bc	7.69c	6.52a	7.06**
	Δh 2	14.08c	9.90a	12.47b	13.30bc	12.46**
P82		Ignace[b]	Savant Lake[b]	Thunder Bay[b]	White River[b]	
	Init ht	20.22c	20.36c	19.56b	18.41a	19.94**
	Δh 1	8.44a	8.50a	9.76b	9.52b	8.44**

[a] Init ht, Δh 1, Δh 2, and Δh 3 = height at planting and height increments in the 1st, 2nd, and 3rd growing seasons after planting, respectively.
[b] Sites bearing the same name in different P years are not replications of a site but merely indicate the general geographical area in which they are situated.
[c] Within rows, site values not followed by the same letter differ significantly (P 0.05) according to Tukey's Multiple Comparison Test.
[d] ** indicates that differences between site values contributing to the mean are significant at the P 0.01 level. NS = not significant.

At the one site, P81 White River, where the silt-loam to clay-loam soil is cohesive because of its high content of silt plus clay, microsite e mounds, once they had dried, were highly resistant to rewetting. First-year mortality on microsite e was 23%, in comparison with only 9% on microsite d, where capillary continuity was reestablished.

Neither type of mounding improved height growth in comparison with that made by trees on the unmodified Bräcke patch treatments, microsites b and c (Table 8). In general,

Table 8. Field outplantings: mean height at planting and mean annual height increments of jack pine, by year of planting, site, and microsite. n = 100 initially.

			Microsite[b]					
P Year	Site	Variable[a]	a (cm)	b (cm)	c (cm)	d (cm)	e (cm)	Mean a - e (cm)
P80	Cochrane	Init ht	15.8ab[c]	15.7ab	16.7b	16.4ab	15.5a	16.02* [d]
		Δh 1	6.5a	6.3a	5.8a	6.8a	6.0a	6.28 NS[d]
		Δh 2	9.9ab	10.9b	8.7ab	10.9b	9.0a	10.08*
		Δh 3	14.8a	20.4b	24.9c	18.5b	14.8a	18.67**[d]
	Foleyet	Init ht	16.6a	16.6a	16.6a	16.9a	15.9a	16.52 NS
		Δh 1	8.8a	9.0a	10.3ab	10.6b	8.7a[e]	9.46**
		Δh 2	29.5a	28.0a	26.2a	27.2a	28.0a	27.77 NS
		Δh 3	46.5a	47.8a	43.5a	43.2a	44.4a	45.09*
	Savant Lake	Init ht	15.5a	16.1ab	17.0b	16.9b	16.6ab	16.42*
		Δh 1	6.4a	9.8ab	11.1b	10.4ab	9.6a	9.46**
		Δh 2	22.9a	25.4ab	28.4b	24.0ab	23.8a	24.90**
		Δh 3	30.1a	37.0b	38.3b	36.8b	35.2b	35.48**
	White River	Init ht	16.1a	17.0ab	17.2ab	16.8ab	17.7b	16.96**
		Δh 1	7.7ab	9.3b	6.9a	8.4ab	6.8a	7.82**
		Δh 2	19.6a	23.9b	19.3a	21.6ab	19.8a	20.85**
		Δh 3	35.4ab	40.4b	36.5ab	38.2ab	34.9a	37.10*
P81	Chapleau	Init ht	13.7a	13.6a	13.7a	15.1b	14.2ab	14.08**
		Δh 1	6.0ab	7.1ab	7.0ab	7.6b	5.6a	6.71**
		Δh 2	12.9a	14.7ab	14.7ab	15.7b	12.2a	14.08**
	Ignace	Init ht	14.0ab	13.5a	13.6ab	14.8b	14.1ab	13.98*
		Δh 1	9.0d	8.4cd	7.2bc	6.6b	3.0a	7.30**
		Δh 2	10.5a	10.2a	10.2a	9.6a	8.2a	9.90*
	Thunder Bay	Init ht	13.8a	14.0a	13.4a	13.4a	13.9a	13.68 NS
		Δh 1	6.8a	8.8b	8.2ab	7.5ab	6.9a	7.69**
		Δh 2	11.6ab	14.3c	13.4bc	12.2ab	10.1a	12.47**
	White River	Init ht	13.4a	13.5a	14.1a	13.9a	14.7a	13.92*
		Δh 1	6.9b	7.4b	7.9b	5.4a	4.1a	6.52**
		Δh 2	15.0bc	17.3c	14.2b	10.9a	8.4a	13.30**
P82	Ignace	Init ht	20.9a	19.6a	19.8a	20.9a	19.9a	20.22*
		Δh 1	7.2a	8.4b	9.5b	8.5b	8.6b	8.44**
	Savant Lake	Init ht	19.5a	21.5b	20.2ab	20.9ab	19.7a	20.36**
		Δh 1	7.5a	8.4ab	8.4ab	8.9b	9.3b	8.50**
	Thunder Bay	Init ht	19.6a	19.5a	19.0a	19.8a	19.9a	19.56 NS
		Δh 1	8.2a	10.0b	10.5b	10.3b	9.5ab	9.80**
	White River	Init ht	18.4ab	19.4b	17.8a	17.6a	18.8ab	18.41**
		Δh 1	8.5a	10.0bc	10.9c	9.0ab	9.0ab	9.50**

[a]Init ht, Δh 1, Δh2, and Δh3 = height at planting and height increments in the 1st, 2nd, and 3rd growing seasons after outplanting, respectively.

[b]See text.

[c]Within rows, microsite values not followed by the same letter differ significantly (P 0.05) according to Tukey's Multiple Comparison Test.

[d]* and ** indicate that differences between microsite values contributing to the mean are significant at the P 0.05 and P 0.01 levels, respectively. NS = not significant.

microsite e (mound on organic minimound) was the poorest of all the microsite treatments, mostly on a par with the untreated microsite, sometimes significantly poorer. Mounds on mineral soil (microsite d) were somewhat more successful: the height increment of trees on these mounds was generally greater than that of those on microsite e, and in several instances mean annual height increments on microsite d were significantly higher than those on untreated microsites.

However, the most consistently successful microsites with respect to height growth were the unmodified Bräcke patch microsites b and c. Planting on the shoulder of the patch (microsite b) was just a little more successful than was planting on the bottom (microsite c).

(c) Growth (Diameter increment): Mean ground-level stem diameter varied significantly among sites in each of the three years of planting, the differences tending to increase with time (Table 9).

In contrast with the lack of a positive effect of mounding on height increment, mounding had a pronounced positive effect on stem diameter; microsite treatments d and e gave the most consistent results in this regard (Table 10). Microsite a (untreated) was consistently poor, although microsite c (bottom of the unmodified Bräcke patch) was very little better. Trees planted on the shoulder of the unmodified Bräcke in general developed larger stem diameters than did those on microsites a and c and were almost as stout as those on the mounds.

Conclusions

Mounding had varied effects on the field performance of jack pine, in some cases significantly depressing survival rates, but often promoting stem diameter growth. Of the two types of mound that were examined, the mound-on-mineral-matter was generally superior to the mound-on-organic-minimound.

If we consider together three main aspects of field performance, viz., survival rates, height increment, and stem diameter, we see that the microsite b treatment promoted field performance more strongly and more consistently than any of the others.

The evidence from this study to date indicates strongly that, for outplanting bareroot jack pine on typical jack pine sites, the preferred treatment is to prepare a microsite such as that made by a Bräcke scarifier and plant on the shoulder of the patch.

Table 9. Field outplantings: mean ground-level stem diameter of jack pine at planting and at the end of the growing seasons 1980, 1981, and 1982, microsite treatments over all, by year of planting and site. n = 600 initially.

P year	Variable[a]	Site 1 (mm)	Site 2 (mm)	Site 3 (mm)	Site 4 (mm)	Mean 1 - 4 (mm)
P80		Cochrane	Foleyet	Savant Lake[b]	White River[b]	
	Init d	3.90b[c]	3.52a	4.34c	3.58a	3.83**[d]
	Diam 1	4.87ab	4.94ab	5.02b	4.82a	4.91*
	Diam 2	7.14a	10.42d	8.64b	9.85c	8.98**
	Diam 3	11.00a	17.46c	13.24b	17.52c	14.72**
P81		Chapleau	Ignace[b]	Thunder Bay[b]	White River[b]	
	Init d	3.43b	3.64c	3.42b	3.28a	3.44**
	Diam 1	4.10a	4.35b	4.05a	3.93a	4.11**
	Diam 2	6.09b	5.44a	7.11c	6.24b	6.23**
P82		Ignace[b]	Savant Lake[b]	Thunder Bay[b]	White River[b]	
	Init d	3.84c	3.71b	3.60b	3.42a	3.64**
	Diam 1	4.81c	4.54b	4.58b	4.35a	4.57**

[a]Init d, Diam 1, Diam 2, and Diam 3 = ground-level stem diameter at planting and after 1, 2, and 3 growing seasons, respectively.
[b]Sites bearing the same name in different P years are not replications of a site but merely indicate the general geographical area in which they are situated.
[c]Within rows, site values not followed by the same letter differ significantly (P 0.05) according to Tukey's Multiple Comparison Test.
[d]* and ** indicate that differences between site values contributing to the mean are significant at the P 0.05 and P 0.01 levels, respectively. NS = not significant.

Table 10. Field outplantings: mean ground-level stem diameter of jack pine at planting and at the end of the growing seasons 1980, 1981, and 1982, by year of planting, site, and microsite. n = 100 initially.

P year	Site	Variable[a]	Microsite[b] a	b	c	d	e	Mean a – e
			(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
P80	Cochrane	Init d	4.0a[c]	4.0a	3.8a	4.0a	3.7a	3.90*[d]
		Diam 1	4.8ab	4.8a	4.7a	5.2b	4.9ab	4.88**[d]
		Diam 2	6.3a	7.1b	6.9ab	8.0c	7.5bc	7.16**
		Diam 3	8.8a	11.0b	10.8b	12.7c	11.7bc	11.00**
	Foleyet	Init d	3.5a	3.5a	3.4a	3.6a	3.6a	3.52 NS[d]
		Diam 1	4.9ab	4.9ab	4.6a	5.2b	5.0ab[e]	4.92**
		Diam 2	10.1ab	10.3bc	9.2a	11.2cd	11.4d	10.44**
		Diam 3	16.7ab	17.5bc	15.4a	18.7c	19.0c	17.46**
	Savant Lake	Init d	4.1a	4.3ab	4.6b	4.4b	4.3ab	4.34**
		Diam 1	4.5a	5.0b	5.3b	5.2b	5.1b	5.02**
		Diam 2	7.3a	8.6b	9.0b	9.0b	9.3b	8.64**
		Diam 3	11.0a	13.2b	13.5b	14.0b	14.5b	13.24**
	White River	Init d	3.4a	3.8b	3.5a	3.6a	3.6a	3.58**
		Diam 1	4.7ab	5.0b	4.4a	5.0b	5.0b	4.82**
		Diam 2	9.2ab	10.4bc	8.3a	10.6c	10.5c	9.80**
		Diam 3	15.8a	18.3b	15.0a	19.6b	18.9b	17.52**
P81	Chapleau	Init d	3.4ab	3.3a	3.4ab	3.6b	3.4ab	3.43*
		Diam 1	3.8a	4.1ab	4.1ab	4.4b	4.0ab	4.10**
		Diam 2	5.5a	5.8ab	5.6a	7.2c	6.3b	6.09**
	Ignace	Init d	3.6a	3.5a	3.6a	3.8a	3.6a	3.64 NS
		Diam 1	4.4a	4.3a	4.3a	4.4a	4.2a	4.35 NS
		Diam 2	5.1a	5.3a	5.4ab	5.9b	5.6ab	5.44 **
	Thunder Bay	Init d	3.4a	3.5a	3.3a	3.5a	3.5a	3.42 NS
		Diam 1	4.1ab	3.9a	4.0a	4.4b	3.8a	4.05**
		Diam 2	6.4a	7.2bc	6.8ab	8.0c	7.2bc	7.11**
	White River	Init d	3.2a	3.3a	3.3a	3.3a	3.3a	3.28 NS
		Diam 1	3.9a	4.1a	4.0a	3.8a	3.9a	3.93 NS
		Diam 2	5.8a	6.9b	5.9a	6.3ab	6.2ab	6.24**
P82	Ignace	Init d	3.9a	3.9a	3.9a	3.8a	3.8a	3.84 NS
		Diam 1	4.6a	4.8ab	4.5a	5.0b	5.1b	4.81**
	Savant Lake	Init d	3.7ab	3.9b	3.7ab	3.8ab	3.5a	3.71*
		Diam 1	4.3ab	4.6bc	4.2a	4.8c	4.8c	4.54**
	Thunder Bay	Init d	3.6ab	3.6ab	3.8b	3.7b	3.4a	3.60*
		Diam 1	4.3a	4.6ab	4.3a	4.9b	4.8b	4.58**
	White River	Init d	3.3a	3.5a	3.3a	3.5a	3.5a	3.42 NS
		Diam 1	4.1a	4.5a	4.3a	4.4a	4.4a	4.35 NS

[a]Init d, Diam 1, Diam 2, and Diam 3 = ground-level stem diameter at planting and after 1, 2, and 3 growing seasons, respectively.
[b]See text.
[c]Within rows, microsite values not followed by the same letter differ significantly (P 0.05) according to Tukey's Multiple Comparison Test.
[d]* and ** indicate that differences between microsite values contributing to the mean are significant at the P 0.05 and P 0.01 levels, respectively. NS = not significant.
[e]Underlined values indicate mortality of at least 10%; see Table 6.

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AERIAL SEEDING REQUIREMENTS FOR JACK PINE REGENERATION

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Abstract.--A brief history of aerial seeding of jack pine (Pinus banksiana *Lamb.) in Ontario is presented and the importance of the prescription is discussed. Criteria for the success of the prescription, including seed distribution, application rates, mineral-soil exposure and weather information pertinent to the species characteristics, are outlined. The effectiveness of the prescription in the Northwestern Region of Ontario and the longevity and ingression of jack pine are discussed.*

Résumé.--Un bref historique du semis du pin gris (Pinus banksiana *Lamb.) par aéronef en Ontario est présenté, et l'importance de la prescription est examinée. Sont indiqués les critères de réussite de la prescription, comprenant la répartition des graines, les taux d'épandage, l'exposition du sol minéral et les conditions météorologiques, compte tenu des caractéristiques de l'espèce. L'efficacité de la prescription dans le nord-ouest de l'Ontario est examinée, ainsi que la longévité et l'ingression du pin gris.*

Introduction

Aerial seeding techniques have been used operationally in Ontario since the early 1960s to regenerate jack pine *(Pinus banksiana* Lamb.). In 1963, 432 ha were seeded with the Brohm seeder (developed in the same year) mounted on a helicopter. Since that year the Brohm seeder, and at least six other seeders, have been used on both helicopters and fixed-wing aircraft in Ontario. Most aerial seeding operations sice 1968 have used the Brohm seeder with a fixed-wing aircraft.

Importance of Aerial Seeding

Table 1 shows the number of hectares that were regenerated to coniferous species in Ontario, from 1956 to 1982, by aerial seeding methods and by all seeding methods combined. The aerial seeding of jack pine has increased from 432 ha in 1962 to 21,006 ha in 1982. The greatest area treated in a single year was in 1980, when 44,582 ha were seeded to jack pine.

From 1961 to 1970, 32,931 ha were seeded to coniferous species, of which 21,882 ha (66%) were aerially seeded. Jack pine was used on 91% or 20,008 ha of all the areas that were aerially seeded.

During the next 10-year period from 1971 to 1980, 203,928 ha were seeded by all methods combined, of which 143,955 ha (70%) were seeded aerially. Jack pine represented 96% or 138,594 ha of all aerial seeding.

During 1981 and 1982, aerial seeding represented 71% of all seeding methods, of which 98% was jack pine. It can be seen that the importance of jack pine seeding and aerial seeding on the whole has increased in the past 20 years.

Table 2 compares the number of hectares that were aerially seeded in the province with the number aerially seeded in the Northwestern Region from 1978 to 1982. Over the 5-year period, the Northwestern Region seeded approximately 64,000 ha to jack pine or slightly over half of the jack pine seeded aerially in the province.

Table 1. Aerial seeding of conifers in Ontario compared with all seeding methods combined.

	Aerial application			All seeding methods[a]			
Year	Jack pine (ha)	All conifers (ha)	Jack pine as a percentage of all aerial seeding	Jack pine (ha)	All conifers (ha)	Aerial as a percentage of all seeding	Jack pine aerial seeding as a percentage of all seeding
1961			0	131	134	0	0
1962	432	541	80	949	1,261	43	34
1963	366	574	64	1,167	1,733	33	21
1964	873	1,400	62	1,894	2,423	58	36
1965	2,318	2,431	96	3,414	3,971	61	58
1966	2,872	2,872	100	3,431	3,935	73	73
1967	2,993	2,993	100	3,885	4,189	71	71
1968	1,973	1,973	100	3,351	3,912	50	50
1969	2,925	2,925	100	4,086	4,309	68	68
1970	5,256	6,173	85	5,965	7,064	87	74
TOTAL	20,008	21,882	91	28,273	32,931	66	61
1971	5,237	5,284	99	9,025	10,751	49	49
1972	3,745	4,558	82	7,698	9,102	50	41
1973	4,879	4,980	98	7,316	7,670	65	64
1974	11,635	11,944	97	15,288	16,017	75	73
1975	14,647	15,291	96	22,710	24,076	64	61
1976	10,552	11,554	91	17,470	19,822	58	53
1977	10,438	11,278	93	16,409	17,834	63	59
1978	13,930	15,036	93	22,398	24,332	62	57
1979	18,949	19,225	99	22,079	22,548	85	84
1980	44,582	44,805	99	51,321	51,776	87	86
TOTAL	138,594	143,955	96	191,714	203,928	71	68
1981	21,134	21,680	97	29,700	30,680	71	69
1982	21,006	21,392	98	29,013	29,877	72	70
TOTAL	42,140	43,072	98	58,713	60,557	71	70

a Includes aerial seeding, ground seeding and ground seeding with mechanical site preparation.

Table 2. Aerial seeding of jack pine in Ontario and in the Northwestern Region.

Year	Ontario (ha)	Northwestern Region (ha)	Northwestern Region as a percentage of Ontario
1978	13,930	6,593	47
1979	18,949	10,711	57
1980	44,582	24,043	54
1981	21,134	13,104	62
1982	21,006	9,503	45
Total	119,601	63,954	53

During the summer of 1978, an assessment was made of 1972-1973 cutovers to determine the stocking and working groups. The information was used to assess the effectiveness of the silvicultural treatments. The majority (95% of the area) had been aerially seeded to jack pine. Table 3 shows the pre- and post-cutover working groups in the treated areas. Untreated cutover data are given in Table 4.

The success rate in maintaining the pre-cutover jack pine working group was 74% on the treated areas, but only 22% on the untreated areas. Nearly half of the untreated stands went through a natural conversion from coniferous to hardwood working groups, with jack pine experiencing the greatest loss.

The information is obviously not complete with respect to detailed stocking but does provide an answer to the question: "How suc-

Table 3. Summary of treated cutovers by working group.

	Jack pine	Black spruce[a]	Balsam fir[b]	Poplar[c]	White birch[d]	Non-productive forest lands	Total
Pre-cut	2831	688	1	527	13	17	4077
Post-cut	2093	620	42	1231	82	9	4077
Gains			+41	+704	+69		+814
Losses	-738	-68				-8	-814
Success rate (%)	74	90				54	

[a] *Picea mariana* (Mill.) B.S.P.
[b] *Abies balsamea* (L.) Mill.
[c] *Populus* spp.
[d] *Betula papyrifera* Marsh.

Table 4. Summary of untreated cutovers by working group.

	Working group (ha)						
	Jack pine	Black spruce	Balsam fir	Poplar	White birch	Non-productive Forest lands	Total
Pre-cut	3294	3201	1	1382	93	351	8322
Post-cut	746	2176	1523	3563	298	16	8322
Gains			+1522	+2181	+205		+3908
Losses	-2548	-1025				-335	-3908
Success rate (%)	23	68					

cessful are the silvicultural treatments at maintaining the desired composition of the second forest?"

Establishment Criteria

Aerial seeding has produced successful second-growth stands of jack pine, many of which are at or above the provincial density and stocking standards. The stands often exhibit density variability, with well stocked areas interspersed with poorly stocked patches.

With the increasing demand for fibre and the heavy losses due to fire and insects over the last few years, forest managers need to know more about the factors that affect the successful aerial seeding of jack pine and how to manipulate those factors to improve the success of regeneration. Scott (1966) identified the rate of seeding, degree of site preparation and weather conditions as the three most important factors affecting the success of aerial seeding.

Seed Distribution

Aerial seeding guidelines are found in Foreman and Riley (1979). The report contains recommendations for seed calibration, seed handling, inter-pass spacing and ground guidance. The guidelines should be referred to before aerial seeding projects are carried out. The Brohm seeder, mounted on Super Cub aircraft, is the most widely used equipment for aerial seeding in the province. The following seeders have been used with varying results with respect to stocking:

- the Chadwick seeder, built in California and used with a helicopter
- an agricultural grain seeder from the Prairie provinces
- two Venturi seeders from Minnesota and Manitoba.

When a new seeder or seeder and aircraft combination is tested, the manufacturer should provide a comprehensive operating manual with the tendering document. Attempting, without a manual, to calibrate, modify or adapt the seeders to meet our requirements is costly and time consuming.

When an acceptable combination of a seeder and aircraft arrives on site, checks should be completed to verify that the equipment is working correctly. The necessary procedures are as follows:

1) Calibrate the seeder on the ground as specified in the Appendix (Foreman and Riley 1979).

2) Establish a series of 4-m^2 (originally milacre) plots in a cutover using tarps cut to the appropriate size or set out in the snow during the winter months. There should be sufficient plots to cover several passes of the aircraft in both directions. A minimum of three passes in both directions, each with five plots along the line of flight and 12 across the line of flight, are required. The distribution of seed varies both along and across the line of flight. The variation across the flight line is the greater of the two. Therefore, more plots perpendicular to the flight line are required. The flight lines should be spaced between and not directly over the plots. The number of seeds per plot, at 50,000 seeds/ha, should be in excess of 20 viable seeds. The minimum number of seeds per plot should be adjusted if the viability is not 100%. If, for example, the viability is only 90%, the total number of seeds should be 20÷ 0.9 or 22 per plot.

3) If two seed lots are used in the hopper at the same time, a weighted average of the viability should be determined before steps 1) and 2) are carried out.

The seeder/aircraft combination should be tested at several rates of application. The current cost of seed is high and increasing, so it is important to consider, if the mineral-soil exposure is unusually high or if there is a large number of cones in the slash, whether the seeding rate should be adjusted to take advantage of the site conditions. If the rate is modified, no fewer than 25,000 seeds/ha should be applied. Foreman and Riley (1979) found that seeding below this minimum rate produced highly variable results.

Seed Application Rate and Mineral-soil Exposure

Riley (1980) found a direct relationship between the percentage stocking and the amount of receptive seedbed available on a site. Optimum stocking is achieved by seeding at the rate of 50,000 seeds/ha on sites with a mineral-soil exposure of 15-20%. As the amount of seed applied increases above 50,000 seeds/ha, stocking does not increase significantly.

A trial in the Burton Lake area of the Kenora District clearly established the importance of mineral-soil exposure. The site underwent prescribed burning in 1979, and 1-2 cm of duff. Half of the area was subsequently site-prepared mechanically with a skidder and light barrel drag combination, providing 17-18% mineral-soil exposure. The prescribed burn was then seeded aerially at 50,000 seeds/ha. In the mechanically site-prepared area the stocking to jack pine was 80% and in the control area the stocking was 30%.

Data from a 3,200 ha aerial seeding project in the Great Lakes Management Unit, Dryden District, are give in Table 5 and Figure 1. Third- and fifth-year stocking data show

Table 5. Mineral-soil exposure and percentage stocking in the Great Lakes Management Unit.

Year	Area (ha)	M.S.E.[a] (%)	Third-year stocking (% jack pine)	Fifth-year stocking (% jack pine)
1976	220	60	57	55
1976	66	40	15	27
1976	683	74	62	71
1976	266	62	24	33
1976	101	38	18	28
1977	164	54	29	32
1977	50	62	25	35
1977	228	87	62	63
1977	23	62	11	20
1978	466	77	53	n/a
1978	179	62	40	n/a
1978	176	63	39	n/a
1979	262	59	37	n/a
1979	304	62	52	n/a
TOTAL:	3,188			

[a] M.S.E. as calculated here is the mineral soil exposed within scarified strips. To compare with total M.S.E. over the area scarified, see Figure 1.

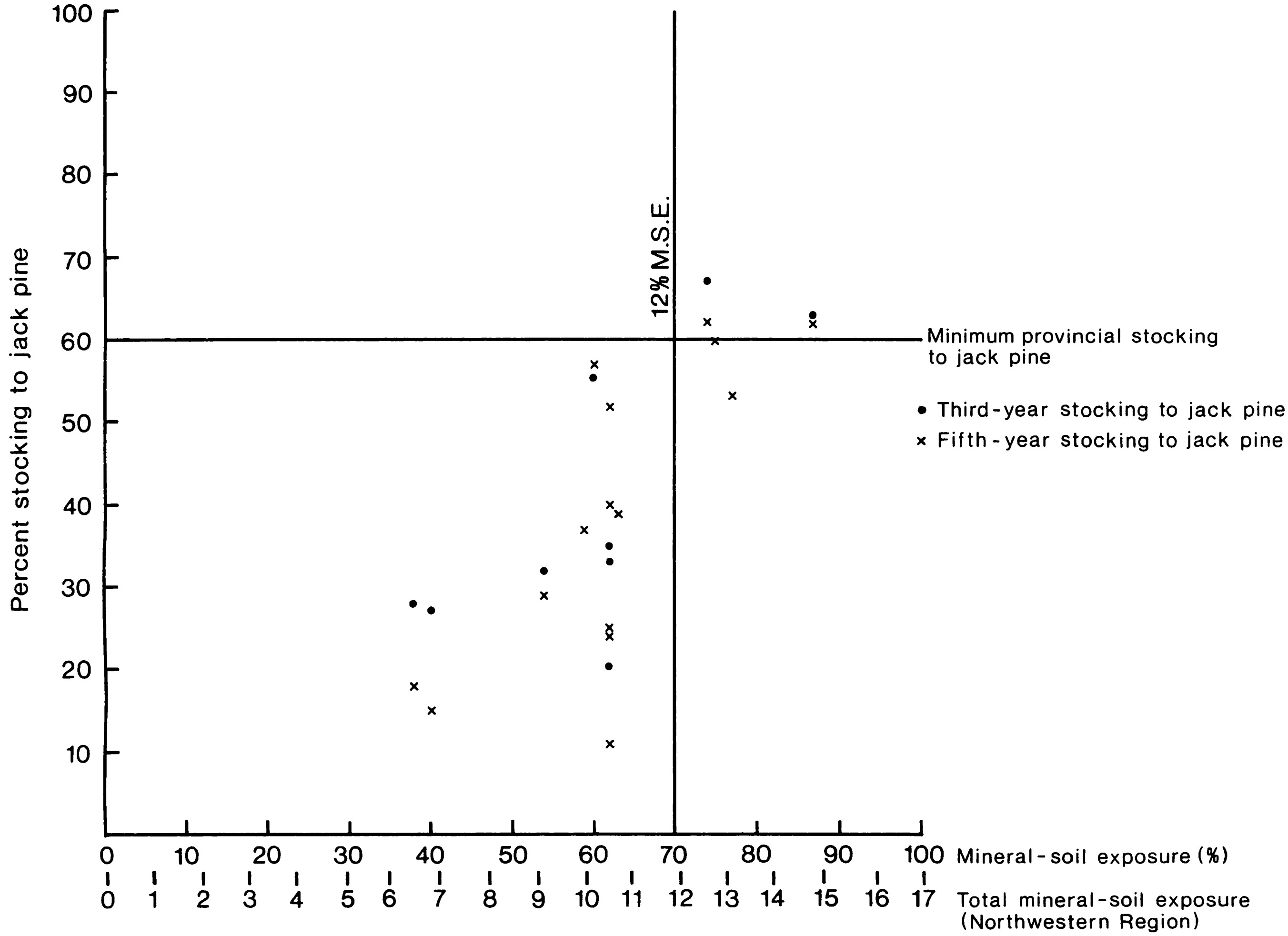

Figure 1. Mineral-soil exposure and stocking of 3,200 ha to jack pine, Great Lakes Management Unit, Dryden District.

that stocking increased during the two growing seasons by 1 to 12%. If the trend continues for those areas treated after 1977, a total of 1,380 ha or 43% of the treated area will meet the provincial stocking standards by 1984. The stocking is less than might be expected since 1976 was a severe drought year and mortality on the exposed sites was extreme. A second ingrowth usually occurs on these sites 10 years after sowing when the trees are old enough to produce their own seed. On sites where the mineral-soil exposure was greater than 60%, the stocking was only 24% after the third year and 33% after the fifth year--a direct result of the drought conditions.

All of the stocked areas had a total mineral-soil exposure over the entire area of 12 to 13%. These areas are typically found on sandy, well drained soils with little competition.

The Red Lake Fire 14-80 burned quite hot on 2,360 ha and left little, if any, seed source. Mineral-soil exposure reached 80% in some 4-m^2 quadrats and averaged between 20 and 40%. The current stocking is plotted against the mineral-soil exposure, at the time of seeding, in Figure 2. Within the burns, 22% of the area has reached the 60% stocking standard. Of this area, 88% has mineral-soil ex-

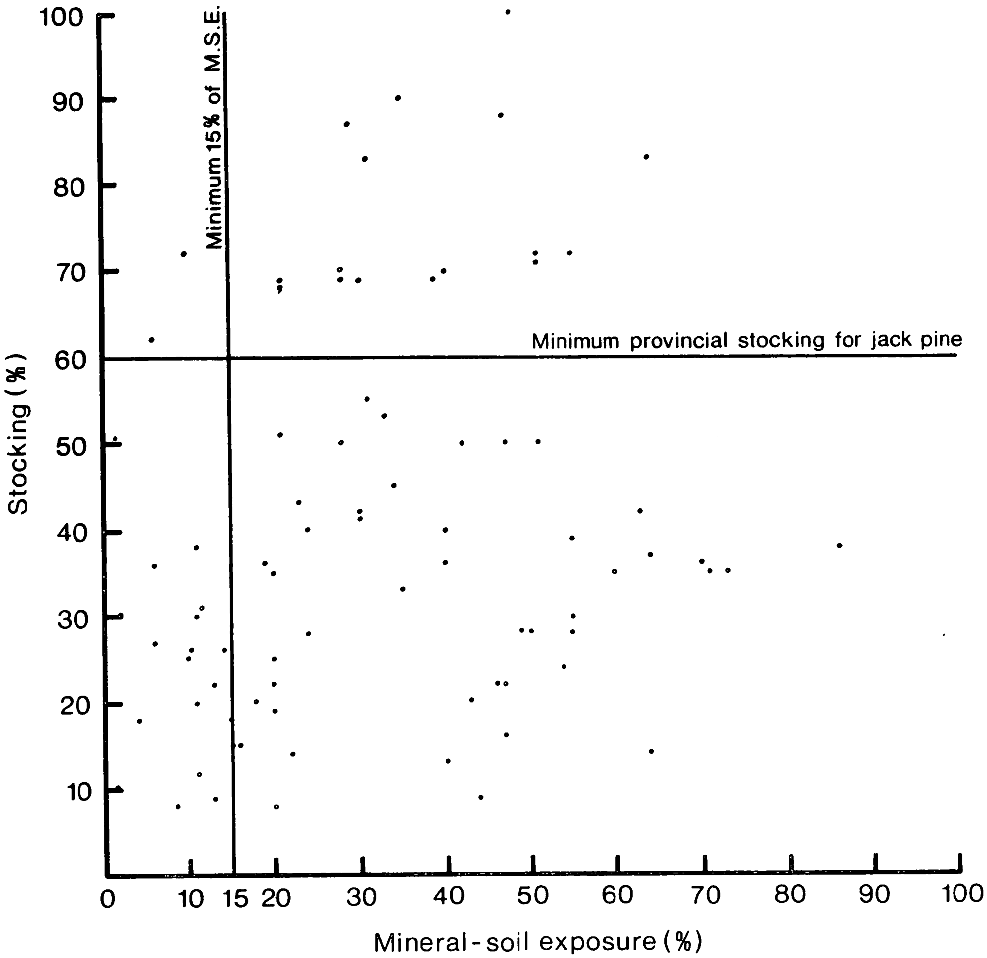

Figure 2. Percentage stocking and mineral-soil exposure on Red Lake Fire 14-80.

posure of at least 15%. In the remaining 1.845 ha, 1.420 ha or 78% of the area had a mineral-soil exposure greater than 15%, although stocking is not yet up to provincial standards. Further assessments are required to determine if the areas will reach provincial stocking standards. Riley (1980) has cautioned that the success or failure of jack pine seeding should not be determined too soon since the germination of seed is not predictable.

Delayed germination of jack pine is typical in the continental climate of northwestern Ontario. The delayed germination aspect should be considered when carrying out seeding projects. A typical example occurred on a site class 2 cutover consisting of 90% jack pine and 10% black spruce (*Picea mariana* [Mill.] B.S.P.), which was logged during 1966 and 1967. The volume removed (230 to 300 m^3/ha) produced a heavy slash loading and high numbers of cones. In late 1968 the area was scarified with barrels and chains, creating a mineral-soil exposure greater than 20%. The site was aerially seeded with 50,000 jack pine seed/ha in the late winter and early spring of 1969. Since germination and stocking were poor, a second seeding operation was carried out in the winter of 1970. After the third growing season, in 1971, stocking levels had risen to 40,000 stems/ha of jack pine and 4,400 stems/ha of black spruce. Since 2,500 stems/ha after 5 years represents 100% stocking, the area was considerably overstocked.

Influence of Weather on Success

One of the requirements for successful jack pine aerial seeding is adequate moisture. For germination to occur, some moisture must be available to the seed. Smith (1964) noted the importance of relating the success or failure of direct seeding projects to the amount and distribution of rainfall. He further stated that "the total amount is probably less important than the length of time elapsing between days with 6.35 mm or more of rainfall."

Brown (1970, 1973) reported that germination occurred in both trials for seeded jack pine immediately following the spring and summer drought periods. He also noted that, the younger the germinant, the more susceptible it was to winter kill, with nearly half of the winter mortality occurring in the previous year's late germinates.

Weather records clearly show the cyclical rainfall pattern which must be known in order to determine the optimum seeding periods. Data collected from records kept at the Dryden weather station from 1970 to 1978 are given in Figure 3. With the exception of 1973, a reduction of rainfall occurred from mid-June to July, continuing in some years until September but usually ending by the end of August.

The rainfall distribution at the Dryden weather station is typical of the Northwestern Region. The amount of rainfall differs at the various weather stations in the Region and the severity of the drought period may deepen in some areas, but in general, the rainfall increases from north to south and from west to east. The drought period reduces the total annual moisture by as much as 40% over that received in eastern Ontario. There are sites along the Manitoba-Ontario border, northwest of Red Lake, with unique semi-arid vegetation,

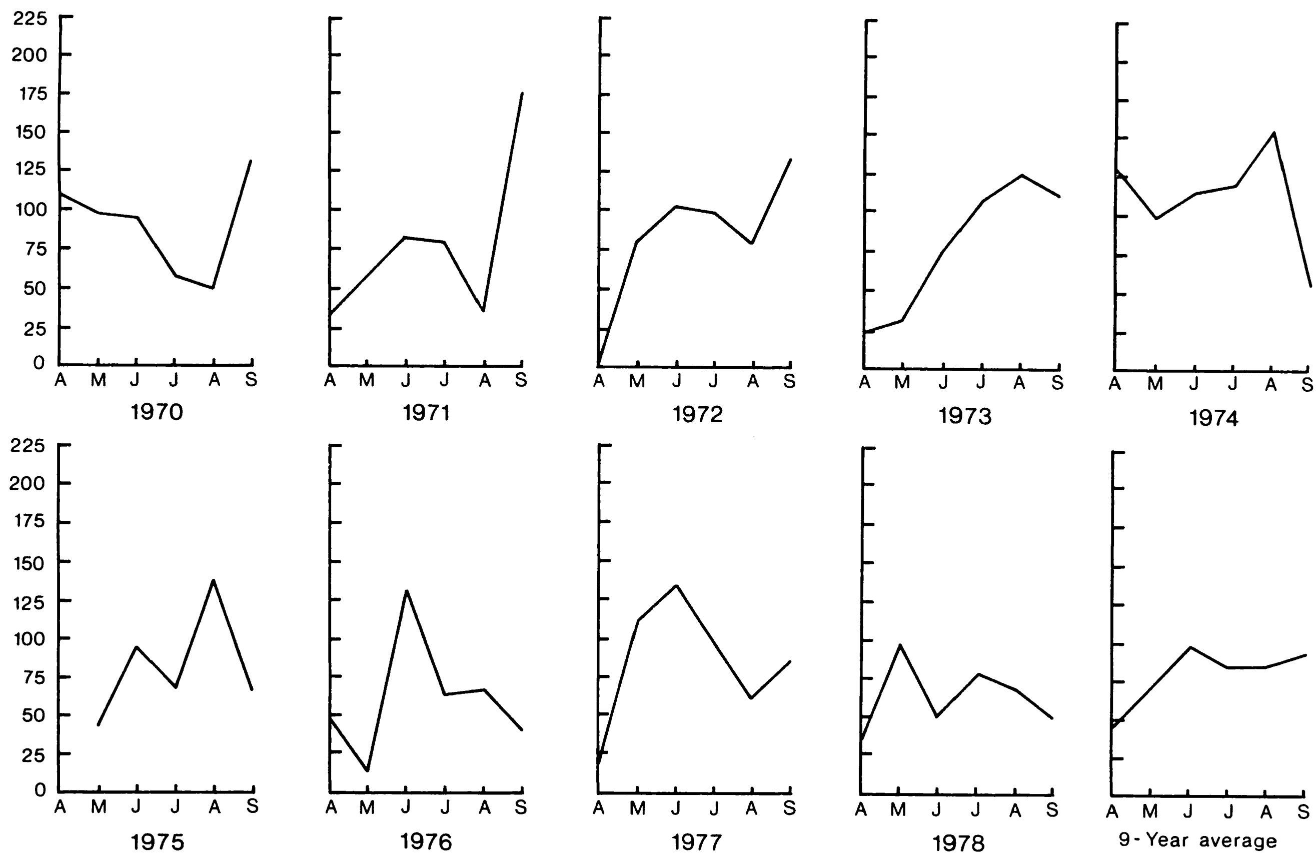

Figure 3. Monthly rainfall (mm), April to September 1970-1978, Dryden, Ontario.

and inside the Manitoba border, species of cacti can be found.

It is paradoxical that both the availability and the lack of moisture are important to the success of the aerial seeding of jack pine. The lack of moisture discourages dense competition on the jack pine sites, resulting in lower mortality. Since seed does not deteriorate as rapidly and remains viable for long periods, there is a greater volume of seed available to germinate in the subsequent growing seasons. The regeneration period is thus extended. The author has observed germinants 4 to 5 years after seeding in northwestern Ontario in areas where the seed source had been limited to aerial seeding.

Jack Pine Seed Longevity and Ingression

Baker (1980) found that a 55% germinative capacity remained in 10-year-old jack pine cones stored under natural conditions. Cold storage enables seed to be kept for more than 15 years with only a minimal drop in viability. Jack pine seed at the Angus Tree Seed Plant that was extracted in 1968 has a viability of 93%, a reduction of only 3% in 15 years.

Lyon and Thomson (1979) studied a site in the Nipigon District that had been burned repeatedly in 1949, 1955 and 1956. Since the natural seed source had been consumed by the fires, aerial seeding was carried out in 1957 to regenerate the site. Ingrowth was found to be significant during the first 9 years of the stand's development and after 12 years when the stand began to produce its own seed. The ingrowth occurring after 12 years was erratic and continued for only 5 years.

Jack pine ingrowth has also been reported to be common in fire-origin stands north of Pickle Lake in northwestern Ontario (Waldrum 1977).

Remarks and Conclusions

Aerial seeding is a very successful and comparatively cheap method of regenerating jack pine. Guidelines for improving the success of jack pine aerial seeding programs are given below.

1) The equipment (seeder and aircraft) must be reliable and produce a uniform rate of seeding.

2) Mineral-soil exposure of 15 to 25% and mineral-soil exposure distribution are critical. A heavier application of seed will not compensate for poor site preparation.

3) Jack pine germinants cannot penetrate soils that have been site prepared and subsequently compacted by heavy spring rains. Seed should be applied on the snow in the late winter so that it may percolate into the exposed, uncompacted mineral soil during the spring melt. Fall rains do have an effect on soil compaction but this effect is ameliorated by frost action.

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Appendix

The procedures used to calibrate the Brohm Seeder on fixed-wing aircraft are outlined below. The general approach is to calibrate the seeder to meter sufficient seed through the auger, and hence out the slinger outlets, for the proposed flying speed, height and swath width, to provide a seedfall at the prescribed rate.

EXAMPLE

Prescribed aircraft ground speed -128.75 km/hr
Prescribed inter-pass spacing - 18 m
Prescribed flying height - 22.9 m
Area covered per minute of flight

$$= \frac{\text{aircraft ground speed (m/min)} \times \text{inter-pass spacing (m)}}{m^2/ha}$$

$$= \frac{128.75 \times 1000}{60} \times \frac{18}{10{,}000} = 3.862 \text{ ha}$$

Weight of viable seed required per hectare

$$= \frac{\text{Prescribed seeding rate/ha}}{\text{no. of seeds /g}}$$

The seeder is calibrated on the ground over 30-second intervals. The speed of the auger is adjusted until the calculated weight of viable seed is obtained consistently over a series of 30-second intervals.

CALIBRATION EXAMPLE

Prescribed seeding rate:
50,000 viable seeds/ha
Weight of viable seed required per ha

$$= \frac{50{,}000}{282} = 177.3 \text{ g.}$$

(282 = no. of viable seeds/g from Ontario Tree Seed Plant).
Weight of viable seed which must be dispersed during the 30-second period

$$= \frac{3.86 \times 177.3}{2} = 342.2 \text{ g.}$$

GROUND SEEDING REQUIREMENTS FOR JACK PINE REGENERATION

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Abstract.--The recent increase in direct seeding in the province of Ontario and its importance in the regeneration program are presented. The developmental process of direct seeding in the Kenora District, culminating with the current level of technology, is reviewed. Seedbed requirements are reviewed as a prerequisite for the successful establishment of jack pine (Pinus banksiana *Lamb.). The relation between equipment performance and seeding success, and the future of direct seeding, are discussed.*

Résumé.--L'augmentation récente des semis directs en Ontario et leur importance dans le programme de régénération sont étudiées. L'évolution du semis direct dans le district de Kenora, jusqu'au niveau technique actuel, est examinée. Les exigences quant aux lits de germination nécessaires pour assurer l'implantation du pin gris (Pinus banksiana *Lamb.) sont décrites. La relation entre l'efficacité de l'équipement et la réussite du semis est examinée, ainsi que l'avenir du semis direct.*

Introduction

Seeding has long been an established practice with the agronomist. Such practices have inspired the imagination and spurred the ingenuity of the forester.

> "The practice of direct seeding of conifers has been reported as early as 1903 and carried out by the logging industry on a small operational scale. However, the bulk of direct seeding carried out between 1900-1955 was research oriented. It wasn't until the mid-1950s and early 1960s that the potential of direct seeding for regenerating burned area, and cutover area was taken seriously and large scale operational programs undertaken.
>
> Most of the direct seeding in Canada has been carried out in Ontario and Alberta and to a lesser extent in Quebec and British Columbia. Current programs are principally white spruce in Alberta and jack pine in Ontario." (Waldron 1973).

In 1973 at the time of the last direct seeding symposium, total direct seeding of jack pine (*Pinus banksiana* Lamb.) for the province of Ontario was reported at 1,743 ha, with the previous 10-year average at 504 ha. In 1982 it was estimated that 7,428 ha were direct seeded in this province (Anon. 1983), an increase of 900%. In the Northwestern Region direct seeding of jack pine was reported at 2,649 ha in 1983, with the previous 5-year average running at 1,830 ha (Anon. 1982). For the province the 5-year average for the same period was 4,455 ha. The Northwestern Region had contributed 41% to the total provincial scene.

It is obvious the increase in direct seeding of jack pine has been the result of changing technologies, an ever-increasing awareness of the sowing requirements for jack pine, and a need to improve our regeneration efforts at a reasonable cost.

Interest in Seeding

Why the continued interest in direct seeding? There are some obvious answers to this question. Planting of bare-root stock averages $392.45/ha while container stock averages $244.92/ha exclusive of site preparation costs. Direct seeding by comparison averages $108.75/ha (Bräcke scarifier) inclusive of site preparation. Currently there are limits to nursery stock production, availability of planters, access, and the influences of site parameters.

The influence of site in the Kenora District has been the main impetus behind our seeding program. Fifty-one percent of the total production forest occurs in site class III. These sites are characterized by shallow soils over bedrock less than 30 cm in depth, predominately dump tills of stony, loamy sands, continually changing relief, with rock outcrops and moderate slopes the salient features.

Seeding Establishment Criteria

The seeding requirements of jack pine have been well documented, but it is worth reviewing some of the most important ones.

1) Jack pine seed germinates best on mineral soil (Eyre and LeBarron 1944, Rudolf 1958, Arnott et al. 1971, Sims 1975, Mattice and McPhee 1979).

2) Germination takes place when air temperature reaches 15.5°C for a period of 4 to 7 days where moisture is adequate (Eyre et al. 1944, Baker 1950, Rudolf 1958, Fraser 1970). "Provenance of seed had little, if any effect on the response to constant temperature [and subsequent germination]" (Fraser 1970).

3) Adequate moisture levels of the seedbed must be maintained to assure the ultimate success of direct seeding (Smith 1964). This precise amount of rainfall is unknown but Smith (ibid.) has set the critical limit as the number of days elapsing between rainfalls of 6.4 mm or more while Alexander and Noble (1971), working with Englemann spruce *(Picea engelmannii* Parry), found that 25 mm of monthly rainfall was required for germination and establishment of seedlings.

4) Seedling establishment is best where there is some degree of shade (Farrar and Fraser 1953, Rudolf 1958, Brown 1970).

5) Sowing of jack pine in the spring will provide the greatest stocking and highest survival (Eyre and LeBarron 1944, Rudolf 1958, Cayford 1959, Armit 1969, Brown 1970).

Other factors do influence the establishment of the seed but I believe these to be the most important when considering direct seeding with mechanical site preparation. Our biggest hurdle for the successful establishment of a plantation from direct seeding is the operational translation of this information to practical limits expressed by current levels of technology.

Established Methods of Direct Seeding for the Kenora District

Seed Barrels

The first and most commonly practised method of mechanical site preparation and direct seeding of jack pine originated with the seed barrel. It was modified by many users, including staff of the Kenora District, to improve seed drop and distribution. The seed barrel was an integral part of the scarification system that employed rotating shark-fin or flange barrels pulled behind a tractor or skidder. The principle of the system was that the scarification barrels prepared a suitable seedbed while the rotating seed barrels continually applied the jack pine seed.

This method of seeding met with modest success but results were inconsistent and often dismal. It has not been employed in the Kenora District since 1978.

In reviewing the performance of this system it was obvious that we were unable to control the basic elements needed to assure seedling germination and establishment:

1) adequate seedbed preparation because of rock, heavy slash, or duff that interfered with the effectiveness of the scarification barrels,

2) erratic seed disposition (Since the barrels relied on gravity to feed the seed through the small holes of the seed nozzle they were very prone to blockage by high relative humidity, vegetation, moist soil, and mechanical damage.)

Bräcke Scarifier

By 1974 the Bräcke scarifier was introduced to the District. At the time it was a new development in site preparation equipment, designed in Sweden. It functions as a spot scarifier--a seeding device that scalps the soil with large rotating mattocks and then drops seed from an internal hopper onto the prepared seedspot.

Since its introduction it has undergone several changes, notably the addition of "machine frames" (from two on the original configuration to three or four). While the introduction of the machine frame or scarifying assembly changed to improve production or increase mineral soil exposure, the basic concept of the scarification remained the same.

As a spot scarifier and direct seeding device it is capable of creating the necessary seedbed, micro-climate and seed placement well suited to the demands of jack pine germination and early establishment. Because the functions of scalping and seeding are completely mechanical in nature this assures continuous site preparation and seed drop. Since spacing of the seed spot can be controlled within limits the forester can select the spacing that will permit the tree to optimize its capacity for growing and achieving the necessary crown closure to reduce competition (Brown 1976).

A review of Bräcke-seeded plantations in the Kenora District 4-7 years from time of seeding has provided the necessary information for linking some of the theoretical knowledge with actual results and allows us the opportunity to refine our techniques and improve the level of success. The method of assessment was that described by Bax and Charlesworth (1983).

Time of Seeding

To achieve the most consistent results and highest level of stocking, direct seeding of jack pine should be carried out in the spring from the end of April to mid-June (Fig. 1) (Eyre and LeBarron 1944, Rudolf 1958, Cayford 1961, Brown 1970). However, consideration must be given to the cyclical nature of the weather patterns since spring and summer droughts usually occur every 3 to 5 years throughout the boreal forest in Ontario (Brown and Ternent 1973).

The next best time for direct seeding was found to be late summer and early fall (from 15 August to 30 October). This period provided acceptable results (seed spots stocked 50-65% with jack pine) but with a greater variation in success. Summer sowing between the end of June and mid-August proved least successful.

A review of the climatic values (Anon. 1981) for Kenora over the growing season is useful to determine optimum sowing periods (Fig. 2). The information has been divided into three distinct periods:

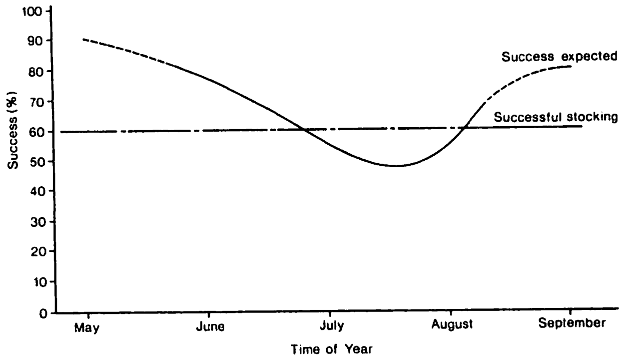

Figure 1. Jack pine establishment success by time of year.

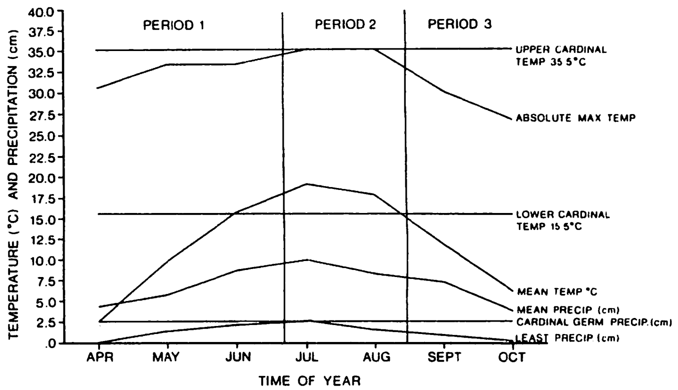

Figure 2. Jack pine seeding requirements for temperature and moisture regime.

1) period for optimum seeding success--highest stocking.

2) period of greatest variation--least success.

3) period of probable success--lower stocking.

There would appear to be a direct correlation between sowing date/species requirements and level of success. This relationship was also described by Beaufort (1960). I would suggest that period 1) is the most successful because the necessary parameters of moisture and temperature are met. As a general observation sowing on freshly scarified seedbeds resulted in higher stocking levels when compared with aerial seeding results for the same period. This theory is also expressed by Horton and Wang (1969) in their work on seeding of jack pine on freshly scarified and settled seedbeds. Period 2) often results in the greatest variation of climatic values and hence the erratic levels of stocking. Seedlings can and do germinate and grow during this period but are subjected to greater extremes of temperature and moisture. This often leads to seedling mortality through desiccation, heat injury, or frost damage. Period 3) will seldom allow the germination of seedlings during the current year and will result in a delayed germination the following spring. However, losses of seed are increased because of miscellaneous and unknown factors (Eyre and LeBarron 1944), and/or the washing effect of heavy rains burying the seed to a depth that will prevent germination (Cayford et al. 1967, Brown 1970).

Seed Placement

When considering seeding methods, the primary advantage of the Bräcke as a spot scarifier-seeder is the ability to control seed placement. We have found that the mid-slope position offers the best location for germination, establishment and vigorous growth (Fig. 3). This observation is supported by research completed by Keene (1983) in her work with seedling position on a Bräcke-prepared scalp.

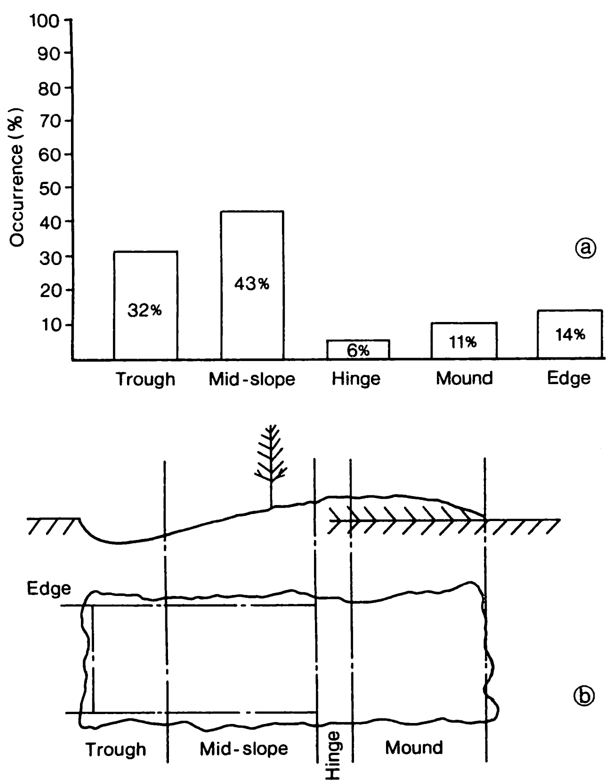

Figure 3. a) Occurrence of established jack pine within Bräcke scalps.
b) Cross-section of Bräcke scalp.

I would suggest the reason for this is the partial shading effect provided by the edge of the scalp and the increased exposure of the seed to soil moisture, an opinion expressed in the work of Beaufait (1960).

Surprisingly, the next highest level of success occurred at the bottom of the trough. However, the negative effects experienced through flooding were obviously offset by the more positive effects of shading and improved moisture relationships during drier periods.

The mound was actually the poorest location for the establishment of jack pine seedlings because of moisture deficits experienced at this location.

For this reason users of the Bräcke or any spot scarifier-seeder should be aware of the importance of seed placement and machine adjustment.

Site Selection

Jack pine is normally associated with the sandiest soils of the boreal forest (Eyre and LeBarron 1944) on dry-to-fresh sites (Hills 1961) and rather rarely on clay soils. This association on clay soils is usually owing to a long fire history (Rudolf 1958).

Since natural selection has relegated jack pine to the drier, coarser soils we are best advised to follow suit. Regeneration efforts must take advantage of this biological uniqueness.

Our first efforts with the Bräcke were confined to clay soils that had originally produced good sands of fire-origin jack pine. This was done because efforts with barrel scarifiers were totally ineffective in preparing an adequate seedbed. The Bräcke was capable of producing a good seedbed but all attempts at regeneration by direct seeding were dismal failures.

We have now contributed these early failures to severe competition by the grass and shrub communities found on these productive sites.

It is reported by Farrar and Fraser (1953) that "germination was not influenced by the kind of soil character". Beaufort (1960) found that "the intolerant nature of jack pine was apparently expressed very early in its development", and he goes on to say that "the shade level interaction becomes highly significant after the first growing season as evidence of survival under full light".

The direct seeding of jack pine should be confined to the drier sites characterized by coarse-to-fine sands or loamy sands. This will provide a seed spot that will be free from competition for a 3- to 8-year period after site preparation.

However, not all regions of the boreal forest are good candidates for direct seeding. Areas of southeastern Manitoba and northwestern Ontario experience severe droughts and overall lower moisture levels than are normally associated with much of the range of jack pine in the boreal forest[1] (Cayford 1959).

Degree of Success Expected

In the Northwestern Region, we have found that the satisfactory stocking levels for Ontario (Anon. 1981) of 60% or better can be achieved consistently if sowing is completed during the spring period at a seeding rate of 15 viable seeds per scalp. Results from fall sowing can be expected to be acceptable but more varied and seeding must be done at a rate of 20 viable seeds per scalp.

These sowing rates are required to produce at least one established seedling and are cited by other authors (Weetman 1958, Horton and Wang 1969) as providing the necessary "weather insurance".

Even at these rates, clumping does occur on approximately 40% of the plots stocked to jack pine from artificial and natural sources of seed. An occurrence of three or more seedlings on a scarified spot was considered a clump.

Since our plantations that have been successfully established through direct seeding are still quite young it is difficult to anticipate the overall effect of clumping. However, "there appears to be some evidence that the natural expression of dominance will ensure that only one tree will ultimately result from each little clump" (Smith 1964). This is often the case by the third to the fifth year from seeding. I would suggest that economically and genetically, this will be acceptable.

If the Bräcke scarifier is used as the spot scarifier-seeder the best combination for direct seeding to jack pine is the four-tooth mattock with the 17-tooth gear on the intermediate axle. This combination will create the greatest number of acceptable microsites over a variety of adverse conditions. This translates into 80% or 2,297 acceptable seed spots/ha from a theoretical value of 2,870 patches/ha at a prescribed spacing of 2 m x 2 m (Anderson 1982).

For spring sowing it can be expected that full germinative capacity will not be reached until the third growing season. It was observed that the greatest stocking was usually achieved in the first season, reaching 35% to 50% with decreasing levels of germination to the third year. Increased stocking beyond this point was minimal, less than 10%.

Fall sowing was less predictable, but usually the greatest stocking was achieved the first spring after sowing. Germinative capacity was often not achieved until the fourth year from seeding. For this reason, any sites being contemplated for fall sowing should be the drier pine sites that will remain free of competition during this establishment period.

Future of Direct Seeding

I believe that direct seeding through the use of spot scarifiers can now be considered a reliable method for regenerating jack pine. We must keep up with the state of the art and not continually reinvent the wheel.

What now remains is to reduce the effect from fluctuating weather patterns to make artificial seeding almost as certain as good planting. This may take the form of sowing seed into the soil, sowing with mini-shelters, or encapsulating seed with nutrient and moisture retention medium.

Currently a precision row air seeder is being developed that is capable of pressing the seed into the soil. The development, which is being guided by George Brown's group, underwent preliminary trials in Kenora District in the spring of 1983. The initial work looks promising. If it is successful we will have yet another tool for direct seeding.

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AERIAL SEEDING OF WILDFIRE AREAS IN THE NORTHWESTERN REGION

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Abstract.--The development of a technique of seeding 23 wildfire areas is described and the available results are given. Some observations concerning wildfires are included.

Résumé.--Une nouvelle technique employée pour ensemencer 23 brûlis est décrite, et les résultats disponibles sont présentés. Quelques observations concernant les incendies de forêts sont apportées.

Introduction

The westernmost part of Ontario that we know as the Northwestern Region of the Ontario Ministry of Natural Resources (Fig. 1) is unique in the province in the following respects:

1) Due to its proximity to the prairies, it enjoys a "continental climate" which is characterized by hot dry summers and cold dry winters with a light precipitation that is fairly uniformly distributed throughout the growing season (Chapman and Thomas 1968).

2) The surface area of the Region was so badly scoured during the last glacial period that almost 60% of the land base is covered with less than 60 cm of soil (Zoltai 1965).

3) The combination of hot dry summers, light precipitation and shallow soils was responsible for 26% of the fires and 69% of the burned-over area during the last decade in the Northwestern Region (Table 1). Ninety percent of the fires were caused by lightning as opposed to 10% for the rest of the province.

4) The continental climate has also been responsible for large areas of blowdown timber as shown in Table 2.

Figure 1. The northern regions of Ontario.

The intensity of Dryden Fire 18-74 which occurred in a 1973 blowdown prompted the Region to investigate the seeding potential of jack pine *(Pinus banksiana* Lamb.) where the fire had consumed the natural seed source.

Table 1. Forest fires and burned-over areas, 1971-1980.

Year	Frequency: Province (No.)	Frequency: Northwestern Region (No.)	Frequency: %	Area: Province (ha)	Area: Northwestern Region (ha)	Area: %
1971	1,782	315	17	14,617	2,491	
1972	1,604	465	29	31,866	5,853	18
1973	1,111	248	22	3,607	1,177	22
1974	1,625	516	32	525,624	436,603	83
1975	3,146	413	13	16,856	708	42
1976	3,985	1,358	34	544,126	360,465	66
1977	2,049	282	14	416,330	287,210	69
1978	940	117	12	7,523	952	12
1979	1,564	705	45	63,715	49,109	77
1980	1,779	721	40	560,306	374,367	67
Totals	19,585	5,140	26*	2,184,570	1,518,935	69[a]

[a]Averages

Table 2. Blowdown occurrence, Northwestern Region, 1971-1980.

Year	OMNR District	Location	Area (ha)
1973	Fort Frances and Dryden	Black Lake to Dryberry Lake	30,988
1974	Ignace	Sturgeon Lake	12,141
	Red Lake	Pipestone Lake	10,360
1975	Red Lake	Coli Lake	4,666
		Chikuni Lake	2,023
		Uchi Lake	1,983
	Total blowdown		62,161

The Problem

Dryden Fire 18-74 started out as two separate fires that joined together to form a 30,927-ha wildfire. Seventy-one percent of the fire area occurred in the 1973 blowdown, 3% of the area had been recently logged and 26% contained standing timber (Fig. 2). It was necessary to evaluate the burned areas for the following:

1) the various intensities of the burn under the different cover type conditions,

2) the location and extent of the areas where the seed source had been consumed by the fire,

3) the proposed method of treatment of those areas lacking a natural seed source.

Methodology

The first step in the problem-solving procedure was to photograph the burned area with a 35 mm black and white supplementary photography (SAP) camera.

The second step involved training the Dryden District timber staff to determine the intensity of the burns through a ground survey as described by Ahlgren (1960), Horton and Hopkins (1965) and Brown (1976). The areas were then delineated on the aerial photographs.

The final step was to identify the areas to be seeded on the basis of mineral soil

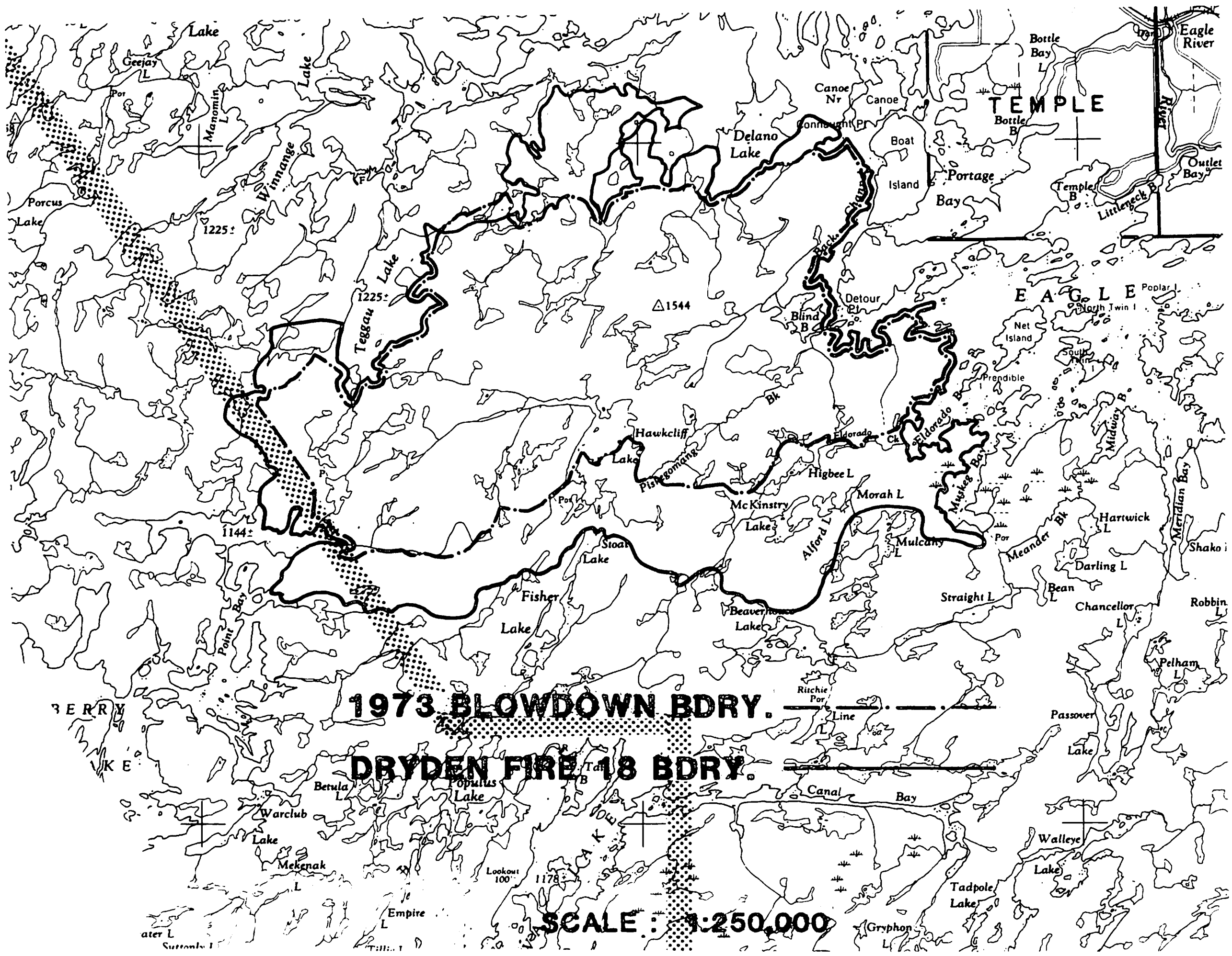

Figure 2. Relationship between 1973 blowdown and 1974 - 18 Dryden fire.

exposure (MSE) and to determine the time and the rate of seeding.

Upon completion of the survey, the following action was taken:

1) Areas with a light-to-moderate burn and a MSE of less than 20% were not seeded, because of limited time and funds to collect the required seed-bearing cones and have the tree seed extracted by the target date of 1 December.

2) Areas that had a hard burn and a MSE of 21-60% were seeded with 49,400 viable seeds (v.s.)/ha.

3) Areas that had been severely burned and had a MSE of 61-100% received, in addition to the jack pine seed, 1,960,000 v.s./ha of white clover (*Triplium repens* L.) seed. This is the first recorded occasion that an agricultural seed was sown as a nurse crop for forest trees as a forestry practice. White clover was chosen for this purpose for the following reasons:

1) White clover stabilizes shallow burned soils, which in some areas consisted almost entirely of ashes,

2) White clover seldom exceeds a height of 15 cm,

3) White clover prevents the desiccation of jack pine germinants and seedlings by providing them with shade and wind protection,

4) White clover is a nitrogen-fixing legume that provides the jack pine seedling with some nitrogen.

Thirty-four percent of the burned-over area (10,441 ha) was seeded with 24,700 v.s./ha of jack pine and only 378 ha or 1.2% of the area required the clover treatment which was applied from 1 to 15 December, 1974. It was not possible to seed at the recommended rate since the Ontario Tree Seed Plant in Angus did not have either the funds or the capacity to extract the seed required from the cones collected to meet the seeding target date of 1 December, 1974.

Seed processing problems have not recurred since the Region began operating its own extractory in 1978.

On Red Lake Fire 21-74, which was 1,036 ha in size, 225 ha were also seeded with jack pine.

In 1976, the burn-over classification system was formalized on a regional basis, and for each burn the following information is now compiled:

1) The loss of timber volume is classified by species, working group, age class and site capacity.

2) The susceptibility of the site to logging damage and the timber salvage potential are determined. Salvage of burned timber is recommended only if the logging damage to the site will be minimal and the area will be regenerated in less than 12 months after the salvage cut.

3) The intensity of burn is classified as light (L), moderate (M), hard (H) and severe (S) in relation to the MSE.

4) The disturbance of the forest cover type, i.e., cutover (CO), blowdown (BL), standing timber (ST), natural regeneration (NR) and artificial regeneration (AR) is classified in increments of 20 from 0 to 100%.

5) The resistance of the area to mechanical treatment is also determined.

By 1980, the evaluation and treatment of wildfires was a standard procedure in the Northwestern Region (Table 3).

Results

In the process of evaluating the results of the seeding operation on Dryden Fire-18, the following factors should be considered:

1) The natural seed source was almost entirely consumed by the fire on all the areas that were subsequently artificially seeded.

2) The seeding rate was only 24,700 v.s./ha or half the prescribed rate recommended by Brown (1972) and Riley (1980).

3) The control plots received a natural seed fall ranging from 1,054,000 to 3,449,600 v.s./ha according to Eyre (1944).

4) The first-year assessment of the seeded areas revealed one jack pine seedling, which was probably naturally seeded, and an abundance of clover on every plot. The absence of jack pine a year after sowing is a natural phenomenon in northwestern Ontario. Jack pine will fail to germinate in the spring of the first year after sowing if adequate moisture is not available. The dry continental climate will keep the sown seed viable and dormant for at least one year after sowing.

5) In the fall of the second year after sowing the stocking of the same plots ranged from 0 to 27%.

6) The fifth-year assessment of the seeded plots shown in Table 4 is 15% higher than that of the naturally seeded control, only 2 to 5% lower than that of unburned areas that are mechanically prepared and artificially sown.

7) The lowest stocking levels were found on the severely burned areas (Table 5). Stocking levels steadily decreased on areas with MSEs above 60%. Complete loss of both clover and pine germinants was reported by Ignace, Kenora and Red Lake districts on areas with a MSE greater than 80%. Desiccation caused by soil surface temperatures that exceeded 54°C was responsible for the losses. The author has observed the color change of jack pine seedlings in the primary cotyledon stage, from light green to

OPERATING UNIT English River

BASE MAP 501904

YEAR Fire 27-1980

Table 3. Ignace District forest stand disturbance.

				Silvicultural treatment difficulty in hectares[a]										Treatment in working group hectares[a]				
														Seed				
Stand number	Working group	Burn class	Disturb. class	Too wet	Too rocky	Too rough	Too small	Too many resid.	Inaccessible	Total untreatable	Total treatable	Treatment not req.	Grand total	Jack pine	Clover	Treat. total	Treat. not req.	Comments
1		S	1									105	105	105	105	105		
2		S	2								18	83	101	101	101	101		
3		H	1									111	111	111		111		
4		M	3									39	39	39		39		
5		H	2									17	17	17		17		
6		M	4									62	62	62		62		
7		M	1									21	21	21		21		
8		not burnt						95		95			95				95	residual white birch & poplar not burnt
9		M	3									81	81	81		81		
Total								95		95	18	519	632	537	206	537	95	

Burn class codes: L - Light, M - Moderate, H - Hard, S - Severe

Disturbance codes: 1-25% is 1, 26-50% is 2, 51-75% is 3, 76-100% is 4

[a]Converted from Imperial to SI units.

Table 4. Fifth-year stocking assessment of Dryden fire 18-74.

Artificially seeded areas			Naturally seeded controls		
Total plots (No.)	Stocked plots (No.)	Stocking (%)	Total plots (No.)	Stocked plots (No.)	Stocking (%)
4,440	2,714	61	1,361	624	46
2,788	1,848	66	748	355	47
1,242	711	57	461	223	48
222	103	46	109	42	38
97	17	17	69	30	43
53	9	17	12	1	8
8,842	5,402	61	2,760	1,275	46

Table 5. Areas seeded on wildfires with jack pine and clover in the Northwestern Region.

Year	OMNR istrict	Fire no.	Area (ha)	Seedbed Jack pine (ha)	Seedbed Clover (ha)	Site prep. (ha)	Stocking High (%)	Stocking Low (%)	Stocking Mean (%)	Assessment year
1974	Dryden	18	30,927	10,441	378	-	66	17	44	5
	Red Lake	21	1,036	225	-	-	87	46	66	5
1976	Dryden	30		324	-	324[a]	62		56	5
		133	445	446	-	-	98	27	55	5
	Ignace	7	6,024	584	-	584	92	20	54	5
	Kenora	117	981	297	-	297[a]	64	32	55	-
		265	291	291	-	291	53	28	39	5
		271	1,260	537	-	-	71	37	49	5
		272	4,528	648	-	648	68	19	50	5
1980	Dryden	11	324	93	-	-	-	-	-	-
		15	2,429	136	-	-	-	-	-	-
		30	101	101	-	-	-	-	-	-
		64	460	394	-	-	-	-	-	-
		65	95	95	-	-	-	-	-	-
		84	28	30	-	-	-	-	-	-
	Ignace	27	11,147	3,954	3,954	-	35	22	29	2
		31	662	273	273	-	34	15	28	2
	Kenora	20	1,117	988	988	-	-	-	-	-
		22	4,327	496	496	-	-	-	-	-
		23	113,518	11,193	10,353	-	-	-	-	-
		38	2,274	569	211	-	-	-	-	-
		114	992	609	609	-	-	-	-	-
	Red Lake	14	29,925	6,328	841	711	90	7	39	2
Totals		23	212,891	39,052	18,103	2,855				
%			100	18	8.5	1				

[a]Retreated

yellowish green, to yellow, to light brown and finally to dark brown in 4 days during the month of July. Foresters in Kenora and Red Lake observed the same phenomenon with both jack pine and clover in 1981.

8) The highest stocking on the artificially seeded areas occurred with 20-40% MSE.

9) The highest stocking on naturally seeded areas occurred on moderately burned sites with 0-20% MSE. The standing tree skeletons prevented the partially burned humus from completely drying out by providing it with partial shade.

10) The relationship between stocking and the degree of burn on wildfires when plotted by type of disturbance, i.e., cutover (CO), blowdown (BL), natural (NR) or artificial regeneration (AR), resembles a bell-shaped curve with the highest stocking between 20 and 40% MSE (Fig. 3).

11) The difference in jack pine stocking between clover-seeded and unseeded areas at Red Lake ranges from 60 to 90% for 68% of the clover seeded and from 0 to 40% for 60% of the unseeded area, based on a survey of 2,730 and 2,313 ha, respectively.

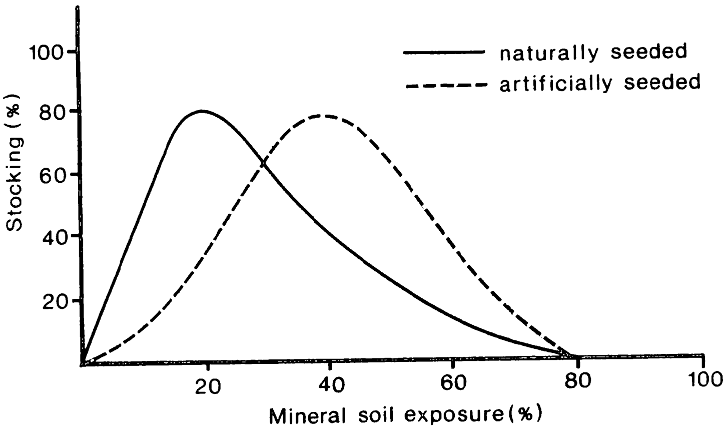

Figure 3. Relationship between stocking and degree of burn on wildfires.

Observations and Conclusions

1) A light burn will consume loose litter, slightly scorch the conifer foliage (Ahlgren 1960) and kill some shrub species (Horton and Hopkins 1965). These fires are not hot enough to open the jack pine cones or to prepare a receptive seedbed (Eyre 1944). The regeneration of jack pine is not required since there is usually no damage to the standing trees.

2) A moderate burn consumes all of the litter and duff and kills the trees by scorching (Horton and Hopkins 1965). Jack pine cones will not open but a receptive seedbed may be prepared on shallow soils and rocky sites. In the year following the burn the seedlings will be afflicted with needle cast and the understorey will be invaded by hardwood shrubs as the first step in the natural conversion process of the area from conifers to hardwoods. Mechanical site preparation followed by planting or seeding will maintain the conifer cover and prevent the conversion to hardwoods.

3) A hard or intense burn (Horton and Hopkins 1965) may consume all of the litter and duff and up to two-thirds of the humus which exposes the mineral soil. These burns are hot enough to open the jack pine cones and to prepare a receptive seedbed. Most of the natural regeneration of jack pine occurs after a hard burn. In the absence of a natural seed source, aerial seeding is the only requirement for the regeneration of these areas to conifers.

4) A severe burn may consume all of the litter, duff and humus regardless of its depth (Brown 1976). The aerial parts of trees may also be entirely consumed along with the seed source. This situation usually occurs on:

   a) blowdown areas of less that 20 years of age,

   b) cutovers from 1 to 20 years of age,

   c) artificially regenerated areas that are less than 20 years of age,

   d) naturally regenerated burns that are less than 20 years of age,

   e) areas that reburn,

   f) the tops of ridges regardless of the age class of the trees.

   Severe burns require a natural or an artificial nurse crop to ensure the establishment of the artificially introduced tree crop. The regeneration of very severe burns may be accomplished only by:

   a) waiting 1 to 3 years for the reinvasion of the area by grasses, sedges, shrubs and other pioneer species to act as a nurse crop by preventing the desiccation of the jack pine germinants,

   b) introducing clover as a nurse crop from 1 to 3 years after the burn at a rate not exceeding 0.4 kg/ha at 20% MSE, 0.8 kg/ha at 40% MSE and 1.2 kg/ha above 60% MSE,

   c) planting the area with bare-root or container stock 1 year after the cover crop is established.

5) In the absence of conifer seed, all classes of burns will be invaded by hardwoods unless the sites are mechanically prepared for artificial regeneration. After the fire, a single aspen (*Populus tremuloides* Michx.) seed may germinate and develop into a tree. An aspen tree will coppice and become a clone. Several trees or clones per ha can develop into an aspen stand.

Table 6. Monthly normal and actual precipitation (mm) at Kenora Airport.

Year	April	May	June	July	August	September
Normal	41.9	57.3	83.4	91.8	85.9	69.2
1971	51.5	47.6	113.2	86.6	53.1	81.3
1972	7.9	33.2	65.3	64.7	112.7	107.4
1973	25.4	35.8	88.6	103.5	80.4	181.2
1974	76.7	86.9	47.8	29.9	232.6	49.9
1975	22.9	39.1	128.7	56.9	64.0	56.7
1976	34.9	14.0	114.8	21.0	62.3	11.2
1977	15.7	125.1	137.5	117.2	89.1	106.7
1978	24.0	77.8	40.3	105.2	35.7	71.2
1979	54.9	75.8	64.5	60.6	65.0	34.5
1980	23.5	56.7	74.3	148.7	103.3	44.4
1981	13.8	7.3	171.8	89.1	53.2	162.4
1982	40.0	49.6	56.7	143.8	60.2	93.0

6) Most natural seed from standing trees is distributed from 1 to 10 days after the fire has passed. Seed distribution is triggered by cool, humid nights, followed by hot, dry days or by the first rainfall. Artificial seeding should take place as soon as possible, preferably before the advent of the first spring germination period following the fire.

7) "One weather extreme usually begets another" (Table 6). Drought years are usually followed by wet years that ensure the germination and establishment of the tree seedling during the most critical period of its life. Every effort should be made to take advantage of this phenomenon by spot, row or broadcast seeding up to the end of July following the year of the fire. Otherwise, seeding should be confined to the spring of the year to take advantage of the optimum germination period (Brown 1973).

8) A successful regeneration program with seeding, on artificially or naturally prepared ground, depends on the following:

   a) a source of viable tree seed,

   b) a receptive seedbed,

   c) weather conditions that are conducive to the germination of tree seed and the development of the germinants into healthy seedlings.

In short, if you can meet the silvical requirements of the species for heat, light and moisture, you will succeed. If not, you will fail.

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STOCK PRODUCTION STANDARDS

FOR BARE-ROOT AND CONTAINER JACK PINE

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Abstract.--Production standards for bare-root and container planting stock are important to the success of plantations. Physical standards for planting stock are well developed but physiological standards are few. The implications of these standards for plantation performance are poorly understood and apply mainly to nursery production controls. The standards being used in Forest Management Agreements will have to be better defined, particularly for bare-root stock.

Résumé.--Les normes de production du matériel de plantation à racines nues ou en récipients sont importantes pour la réussite des plantations. Les normes physiques sont bien établies, mais les normes physiologiques sont peu nombreuses. La signification de ces normes pour la performance en plantation est mal comprise, et elle s'applique surtout aux contrôles de la production des pépinières. Les normes employées pour les accords relatifs à l'aménagement des forêts devront être mieux définies, en particulier pour le matériel à racines nues.

Introduction

Standards are important to the success of our silvicultural practices. They establish the limits of quality within which a plantation can meet performance objectives. Each phase of planting and tending should be described so that it relates to a final yield per hectare and each component should be supported by data showing the impact of varying its intensity of treatment.

In industry, the standards are usually well developed for each component and have a safety margin to ensure that the final product is strong enough to perform satisfactorily in an operational environment. The designer, in this case the planter/silviculturist, selects from a range of planting products. The manufacturer, or the nurseryman, grows his product to meet certain specifications and the product is routinely tested during production to ensure quality.

When compared to quality standards which control the manufacturing processes in steel or pulp mills, forestry specifications are very crude. We are at a stage where some individual components have been quantified, such as cutover classification, site preparation, stocking and nursery stock, which are more concerned with establishment problems than the final yield at harvest.

The measurement of the morphological features of seedlings is easily determined and is becoming routine in some nurseries. For physiological features few tests that can be carried out by nursery staff are available. For the morphological and physiological tests which are being used, preliminary test plantings have recently been undertaken to assess their significance for establishment and early growth of the planted stock.

The Development of Morphological Planting Stock Standards

Considering that Ontario has been using significant quantities of reforestation stock, either imported or produced by our own nurseries since the turn of the century, attempts at rating a number of factors which describe the quality of seedlings have been fairly recent.

Since 1959, bare-root stock production in the provincial nurseries has been routinely assessed, physically and chemically, in the fall after most of the growth has been completed. The physical and nutritional working ranges for Ontario age-classes, based on this fall assessment, were first published by Armson and Carman (1961) and later revised by Armson and Sadreika (1974).

In the mid-1970s, it became policy for the field staff to forecast their bare-root stock requirements by heavy, medium and small size classes rather than by age classes. The new data from the 1974 publication confirmed that the physical sizes of the various age classes were widely overlapping and that a system for describing quality by age class was not reliable when used throughout the nursery system. The heavy, medium, and small size classes were described using the principal criteria of oven-dry weight, diameter and root area. Height and shoot:root ratio were not distinguishable features and were considered of secondary importance. The new standards were implemented at each nursery by selecting the age and size class which would most closely approximate the principal criteria.

Using jack pine *(Pinus banksiana* Lamb.) bare-root as an example we are producing only medium and small sizes of stock, with rotations of 2-0 and 1-0. Large bare-root stock and container stock are not produced.

It should be emphasized that the description of bare-root shipping stock, as prepared by Reese and Sadreika (1979) and adopted by some of the Forest Management Agreements (FMAs) as quality standards, is based on this fall assessment of nursery stock. The size criteria used for heavy, medium and small stock describe what the nurseries, on the average, can produce as a field crop. This field crop includes a sample of all the seedlings in the field including cull stock. It can therefore be expected that, after processing, the actual stock shipped will exceed the average description. It can also be expected that, since these features represent an average of several years, in half the years the crop size will be less than the average and can be said to be undersized.

One effect of these size standards is that many nurseries are attempting to produce a more uniform product from year to year, in spite of the considerable size differences that normally occur in successive crops. The technique being used requires that each type of stock be sampled several times during each season of the rotation and that these growth progression data be plotted against the normal growth curve. This system recognizes abnormal crops early enough to allow for adjustments in the growing schedule required to change the growth rate. Since nursery managers are usually concerned with increasing the growth rates of undersized seedlings, trials are now under way with fertilizers and control of irrigation to determine their effect on growth regulation.

A similar system of size standards and growth monitoring has been applied to containers. Since no heavy container stock is grown, only medium and small size classes exist, with the criteria being container size and rotation length. The application of growth monitoring in containers has been more successful since more environmental factors can be controlled in the greenhouses.

Physiological Stock Standards

Root regeneration work by Stone (1967) in California has aroused the interest of Ontario nurseries and encouraged them to develop operational techniques for measuring physiological quality of shippable seedlings. Techniques have been developed for sampling major batches of bare-root stock during shipping but the number of physiological tests is quite limited. They include the following:

1) Root regeneration: Prior to shipping, stock will be placed in root misting boxes and after 20 days will be rated for the number and length of new root tips.

2) Moisture content of seedlings will be measured during lifting and shipping using a pressure bomb to determine the level of water in the xylem.

3) Electrical conductivity tests using a square wave oscilloscope or an impedance meter will test the hardiness or dormancy of seedlings to be stored over the winter. The impedance meter assesses the cold hardiness of the summer crop of container stock prior to being moved from the greenhouse to the outdoor growing area for winter storage.

The existing working ranges for physiological tests are limited to the nursery area and represent the normal condition of seedlings in the nursery. For the most part, the effect of the readings on plantation performance is unknown. At present, they serve to warn the nurseryman of a potential problem if readings deviate from the normal.

Since physiological standards are in an early stage of development and a manual for their application to bare-root stock is still being drafted, these standards have little operational value in production control. We have not yet tried to apply most tests to container stock.

Standards for FMAs

Ten FMAs were reviewed to determine the standards used in describing their container and bare-root stock (Table 1).

The standards were compared with those used in British Columbia, Alberta and New Brunswick. The container stock used in eastern Canada is considerably smaller than that used in western Canada, at 350-700 mg and 700-1,300 mg, respectively. The western producers tend to use longer rotations, commonly overwintering stock or planting in the fall rather than in the summer. The bare-root stock used in Ontario compares favorably with that used

Table 1. Planting stock standards for pine.

		Containers			Bare-root		
			Oven-dry wt (mg)			Oven-dry wt (g)	
Location	Species	Size	Minimum	Optimum	Age class	Minimum	Optimum
British Columbia	lodgepole pine	PSB211	-	1300	2-0	4.0[a]	-
Alberta	lodgepole pine	SL6s	700	-	2-0	4.9	-
New Brunswick	jack pine	PP408	400	-	2-0	2.5	-
Ontario (FMA)	jack pine						
Quebec North Shore							
- Gardiner Forest		408	400	700	2-0	3.5	5.5
- Nagagami Forest		408	400	550	2-0	-	2.0-6.0[b]
Abitibi Price							
- Iroquois Falls Forest		408	500	700	2-0	-	-
- White River Forest		408	400	5-600	2-0	-	2.0-6.0[b]
E.B. Eddy							
- Upper Spanish Forest		408	400	550	2-0	-	2.0-6.0[b]
Pineland Timber							
- Pineland Forest		408	400	550	2-0	-	4.0-6.0[b]
Spruce Falls Power and Paper							
- Gordon Cosens Forest		408	-	500	2-0	-	4.0-6.0[b]
Waferboard Corporation							
- R. Malette Forest		408	400	550	2-0	-	4.0-6.0[b]
Great Lakes Forest Products							
- English River Forest		-	350	-	1-0	1.0	-
Boise Cascade							
- Seine River Forest		-	500	700	2-0	-	2.0-6.0[b]

[a]Proposed standards, estimated

[b]Based on description of bare-root stock

in the other provinces. The minimum standards for the other provinces are crop averages and can contain a percentage of smaller seedlings.

Within Ontario, FMA size standards for container stock are quite uniform. The minimum oven-dry weights, with one exception, range between 400 and 500 mg and the maximum between 500 and 700 mg. The bare-root standards, however, are quite variable. Two FMAs established minimum sizes; the remainder used an optimum size. Optimum oven-dry weights range between 2.0 and 6.0 g. Of the seven agreements using Sadreika's standards as a base, three seem to be attempting to upgrade the quality by dropping the "small" category. While it is clear that the minimum container size represents the crop and some smaller seedlings would be in the tray and presumably planted, the interpretation of the acceptable seedling for bare-root stock is not clear. It would appear that these standards will have to evolve considerably to become more definitive and, as is being attempted in New Brunswick, the contract may have to contain a clause describing an arbitration process when quality is substandard.

Future Directions of Standards

For planting stock standards to be more effective, the following changes should be implemented:

1) Standards for planting stock should be extended to include more growth and yield considerations rather than the present establishment phase.

2) Standards for planting stock should be more specific to the conditions and productivity of the forest sites, with data being available to show the effect of various sizes of stock on productivity for each site.

3) Standards for physiological criteria should be developed and understood more fully.

4) To meet the standards from crop to crop consistently, nurseries should determine the changes required in the elements of their growing schedule to effect a given change in the seedling growth rate.

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JACK PINE SYMPOSIUM

FIELD TRIP

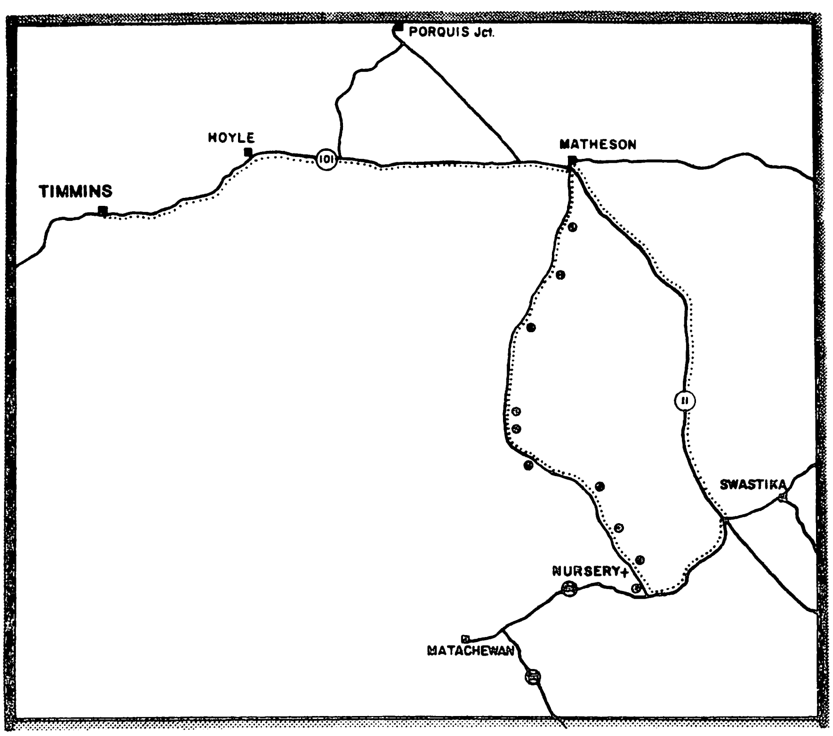
Wednesday, 19 October 1983

The tour began with a trip east of Timmins to Matheson, through the area that was burned by the 1911 Porcupine and the 1916 Matheson fires (see tour map).

At Matheson, the tour turned south through the Watabeag Lake and the Englehart crown management units to the nursery buildings of the Englehart River forestry station and nursery for lunch. En route, stops were made at 1-, 5-, 10-, 15- and 20-year-old jack pine plantations and a soil pit to demonstrate height and diameter growth at the different ages; the importance of relative stocking for crown closure, height growth and self pruning; the futility of alternate row planting of jack pine and black spruce on poor sites; and the requirement of a known seed source for sweetfern blister rust resistance and straight bole development. At the soil pit the root structure of jack pine and black spruce was demonstrated.

In the afternoon, provenance trials and growth and yield study plots in a jack pine plantation were visited, as well as a demonstration area containing spot seeding, grafting and pillow block planting trials with jack pine and black spruce. On the way to and from Timmins, natural stands of fire origin from 1955, 1948, 1920 and 1910 were pointed out to show the development of natural stands in comparison with the plantations that resembled them after age 20 years.

JACK PINE SYMPOSIUM TOUR MAP



BARE-ROOT JACK PINE: LIFTING, STORAGE, AND HOLDING PERIOD

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Abstract.--Successful handling and storage of jack pine (Pinus banksiana *Lamb.) depend upon its physiological response to lifting date, storage conditions and the planting environment. Overwinter storage of jack pine is unpredictable. Early spring-lifted stock performs well after outplanting and is essential when attempting to extend the planting season. Maximum storage holding periods are unconfirmed. Practicable, substantiated guidelines for monitoring stock quality through various handling procedures are urgently needed.*

Résumé.--La réussite de la manutention et de la conservation du pin gris (Pinus banksiana *Lamb.) dépend des effets physiologiques de la date d'arrachage, des conditions de conservation et du milieu de plantation. La conservation pendant l'hiver est imprévisible. Le matériel arraché tôt au printemps pousse bien après plantation en forêt et est essentiel lorsqu'on veut prolonger la saison de plantation. La durée maximale de conservation n'a pas été établie avec certitude. Des lignes directrices pratiques et éprouvées pour contrôler la qualité du matériel de plantation pour diverses méthodes de manutention sont requises de façon urgente.*

Introduction

Physiological quality of planting stock will be adversely affected by numerous handling operations and the result will be reduced survival and growth after outplanting. Maintenance of stock quality during lifting and storage is difficult, but as has been pointed out, deterioration of stock quality can be so gradual that even the nurseryman cannot see it (Armson and Sadreika 1974).

During the past 10 years or so we have heard many, and sometimes contradictory, recommendations for lifting times and techniques, packaging variations, storage environments, types of storage, holding periods, planting season extensions and stock monitoring techniques. As many options are available for handling and routing nursery stock from lifting to planting site, each step must be selected and modified to maximize the efficiency of each operation and thereby minimize reduction in stock quality.

Lifting and Handling

Attention should be directed toward a number of key areas that can affect the physiological condition of nursery stock during the lifting operation. Everyone should realize that the erosion of stock quality begins on the day the trees are lifted and increases from there on.

Root damage such as stripping and breakage and desiccation due to exposure are major problems regardless of whether or not the stock has been loosened by lifting machines or harvested by hand pulling.

Duration of exposure becomes more critical as the season advances (Mullin 1974). Desiccation can be minimal on days when relative humidity is over 80%, cloud cover is complete and there is no wind. Modifying lifting practices in concert with ambient weather conditions is not only difficult to predict but also impracticable.

Therefore, we should minimize exposure at all times. Damage to roots varies with exposure time (Hermann 1962), which can increase dramatically when lifting machines stall, a belt breaks on a culling table, lifting is interrupted with coffee and lunch breaks or the mechanical lifter (e.g., Egedal) undercuts the lifting beds hours prior to the actual pulling of the trees.

We also introduce maiming of the tree by root pruning at a set length for aesthetic reasons or the tree planters' convenience. Several studies have attributed reduced growth after planting to root pruning (Smith and Allen 1962, Sutton 1967, Mullin 1973). The important thing is that we be aware of potential causes of root damage and avoid them whenever and wherever possible.

Packaging

The multi-walled Kraft bag and cardboard carton, each with the polyethylene insert, are fairly well accepted as the most practicable and economical containers for the holding and storage of stock. Since we have replaced the open-ended or rolled bales with closed, moisture-tight containers, the need for a moisture-retaining material such as sphagnum moss in these containers with the bare-root stock has been questioned (Williston 1965, Mullin 1980). The purpose of a moisture-retaining material such as moss is to keep the humidity high in the container and hence reduce desiccation, but numerous studies, pertaining largely to southern species, have shown that moss could be omitted depending on storage conditions and species (Ursic 1963, Williston 1965, 1974). Further studies are required in Ontario to determine if moss is necessary for maintaining stock quality in packaging and storage. After all, it is another questionable step which causes a slight delay in sealing the containers, thus adding to root exposure time and cost (Mullin 1974).

Overwinter Storage

We have the option of lifting jack pine either in the fall or in the spring. Fall lifting for cold (0.5° to 1.0°C) or frozen (-3°C) storage has had, up to now, limited success and is not a recommended practice as yet (Mullin and Parker 1976, Mullin 1981).

The physiological state of a tree is influenced by a web of interrelationships such as day length, degree days, nutrition, internal water status, carbohydrate reserves, and plant growth regulators (Sutton 1979). Until better techniques for the detection of physiological conditions have been developed, particularly for frost hardiness and dormancy, fall lifting of jack pine should not be attempted.

Spring Lifting and Associated Options

The time of lifting for spring storage may be almost as important as that for fall storage (Simon 1961). Mullin and Forcier (1979) suggested that jack pine at Swastika nursery should be lifted prior to the accumulation of 140 degree days (°C) for either storage or direct planting.

When lifting is under way, many decisions have to be made by both nurserymen and field staff on the possible options for stock lifted early in the season. Consideration has to be given to when the stock is likely to be planted and the duration of the storage period, which is affected by the type of storage available. Field staff should receive information on lifting date, physiological condition of the stock at time of lifting and its storage history prior to transport. Field staff are then able to plan their field storage and stock distribution accordingly.

"Hot" Planting with Fresh-lifted Stock

The greatest potential for growth and survival comes from the same-day "lift and plant" programs carried out when weather and soil conditions permit and the stock is still dormant. However, this option is available mainly to field units that are adjacent to nurseries. "Hot" planting also has its drawbacks. Planting too early can reduce survival and growth largely as a result of desiccation (Mullin 1974). Soil water movement is very restricted in cold soils (Sutton 1969). Planting should not begin until soil temperatures at root depth reach at least 5°-6°C (Lyr and Hoffman 1967).

On the other hand, "hot" planting with fresh-lifted jack pine in late spring, summer or fall should be discouraged. In southern Ontario, Bunting and Mullin (1967) used fresh-lifted jack pine in 13 sequential outplantings at 2-week intervals beginning on 2 May 1951. The trees were usually lifted and planted on the same day. After 15 years, survival was 89%, 98% and 98% respectively, for the first three outplantings while in the other 10 plantings it ranged from 78% to 24% and averaged 57.9%. Height after 15 years averaged 6.04 m over the first three outplantings and 5.47 m over the last 10 outplantings.

In northern Ontario, Mullin and Forcier (1976) found that both survival and growth declined significantly with increasing lateness of planting. They established a series of five sequential fresh-lift "hot" plantings at 2-week intervals beginning on 9 May 1973. After 5 years, survival ranged from 85.6% for the 9 May planting to 25.2% for the final planting date of 5 July, with corresponding mean heights of 1.92 m and 1.19 m, respectively.

Spring Frozen Storage (-3°C)

Mullin and Forcier (1976) found that frozen storage was successful if jack pine was lifted very early in the spring, as soon as the ground was workable. Survival and growth of the stored stock were as good as those of the fresh-lifted stock for early plantings, and as the season advanced the frozen-stored stock was better than fresh-lifted stock. At present, we have no technical guidelines to assist us in the proper timing for lifts of spring-frozen jack pine, and this introduces a risk factor as lifting is done on an operational basis. However, with more testing the use of spring-frozen storage for jack pine could prove practicable and would allow us to plant late in the season. Sutton (1982) has shown that spring-lifted, bed-run, bare-root jack pine, even after primitive frozen storage, may be used to extend the planting season in boreal Ontario until the end of July.

Spring Cold Storage (0.5° to 1.0°C)

Spring cold storage with early season lifted stock (no bud or root swelling or elongation) is the next best option to "hot" planting at the proper time for the handling of jack pine. However, many problems can be encountered when cold storage is used. Some of these are: mould development on the stored stock, desiccation, cold injury, excessive holding time and the storage of stock which is in an unsuitable physical or physiological condition.

Maintenance of a constant temperature just above freezing (0.5° to 1.0°C) is probably the most effective way of minimizing the development of mould in cold storage (Hocking and Nyland 1971). It is also important to keep foliage dry and clean, to package trees properly and to apply effective sanitation practices to storage facilities (Navratil et al. 1975).

Transportation of cold-stored stock from the nursery to field storage or holding facilities is recommended in pre-cooled refrigerated trucks. This minimizes temperature fluctuations in the containers. All field holding facilities, whether curling rinks, "reefer" vans or other types of refrigerated units, should be capable of maintaining a constant temperature just above freezing (0.5° to 1.0°C). Temperature fluctuations above or below this optimum should be prevented. The ambient relative humidity should approach 100% in all storage units, and must be maintained at all times (Sutton (1982).

Stacking of containers in tiers more than two high must be avoided in both holding and transportation facilities. This will reduce the chances of breakage or crushing and if air spaces of 15 to 20 cm between tiers are maintained good air circulation will reduce the chance of heating.

Lifting dates and storage history of all stock should be known so containers can be rotated within the storage facilities to ensure the shortest possible holding period prior to planting.

Length of Storage

The major problem with stored stock during an extended planting season is to synchronize its physiology with the season. In late plantings the new growth has a short growing season in which to elongate, to set a bud and complete the hardening-off processes before the arrival of damaging frosts. The length of storage will affect the physiological development of the stock but recommendations on length of storage vary. The latest Ontario Ministry of Natural Resources guidelines (Dixon 1975) set the maximum length of storage for stock lifted within 1 week after the frost has come out of the ground at 6 weeks at 0.5°C to 1.0°C plus 1 week at 4.5°C. For stock lifted later than this, but before actual flushing (i.e., the emergence of needles from the bud) the guidelines suggest that jack pine may be cold stored for a period not exceeding 2½ weeks. Mullin and Forcier (1979) suggest a limit of 2 to 3 weeks for holding spring-lifted stock in cold storage. The manual "Nursery stock handling guidelines for the field" (Anon. 1980) prepared for the Northern Region is one of the most practical and realistic guides available. These guidelines recommend holding periods for stock received in various physiological conditions. The recent report by Sutton (1982) is also extremely useful to nursery and field staff, particularly with respect to guidelines for planting season extension, using stored stock.

Common sense tells us to expect inferior survival and growth in plantations established with late spring-lifted stock or stock that has swelling or elongating buds and roots, regardless of how the stock is handled. With the abundance of storage facilities in northern Ontario every effort should be made to lift early and get the stock into storage promptly. We would then be faced with problems associated with the better, early-lifted stock. In my opinion, we would be further ahead economically to plow under jack pine stock that is lifted after growth activity has begun.

The Monitoring Process

I cannot overemphasize the importance of stock monitoring during each step of the stock handling procedure. Monitoring relative moisture content and moisture stress prior to lifting, during storage and prior to outplanting can help detect physiological deterioration. Nursery quality control plantings established at time of lifting and shipping can provide information that pinpoints problem areas (i.e., causes of stock deterioration). Such outplantings can determine if the problem with a batch of trees occurred in the nursery or in the field. Controlled environment testing with growth chambers to test such parameters as root growth capacity can indicate expected plantation performance after prolonged storage or holding periods. Storage environment monitoring should include air and container temperatures along with relative humidity levels.

Many more stock monitoring practices are available and are being introduced each year to both nursery and field staff. However, I feel that field and nursery staff are approaching the limit of the monitoring they can do during a season. There also appears to be a widespread lack of confidence in some operational practices such as water dipping of tree roots to improve plant moisture stress which is being done in northern Ontario planting operations. This process is time-consuming and of questionable value but we need more documented evidence to this effect.

Summary

1) Stock handling and root exposure time can be reduced by field packaging and elimination of the questionable practice of root pruning. The benefit of a moisture-retaining material is questionable, e.g., when stock is packaged in moisture-tight containers or for short periods of time.

2) Overwinter storage of jack pine is at present not practicable. More advanced techniques for the detection of dormancy and frost hardiness are required.

3) The time of spring lifting can affect outplanting performance. "Hot" planting in early spring is ideal for good plantation establishment. Cold storage in spring of stock lifted early in the season will provide good establishment results but is dependent upon the storage environment and holding time. Evidence indicates the potential use of early spring-lifted, frozen-stored jack pine for extending the planting season.

4) Length of storage should be as short as possible with maximum duration being dependent upon time of lifting, storage environment and planting environment.

5) Problems with stock deterioration can be identified and the effects minimized by monitoring stock and following good storage environment procedures.

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TRANSPORTATION, HOLDING AND PLANTING OF JACK PINE

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Abstract.--Methods and procedures currently in use in the province of Ontario for transportation, holding and planting of jack pine (Pinus banksiana *Lamb.) are discussed. Reference is made to the techniques used for both bare-root and container stock. Field and on-site storage facilities and criteria are reviewed.*

Résumé.--Les méthodes employées à l'heure actuelle en Ontario pour le transport, la conservation et la plantation du pin gris (Pinus banksiana *Lamb.) sont examinées, et plus particulièrement les technqiues employées avec le matériel à racines nues et en récipients. Les installations et les critères pour la conservation sur le terrain sont passés en revue.*

Introduction

In the province of Ontario, the nursery production of jack pine *(Pinus banksiana* Lamb.) has been increasing steadily since 1934 (Anon. 1979) when jack pine represented 8.3% of all nursery stock grown. By 1982, the percentage of jack pine had increased to 30.9% or 25,830,821 trees (Anon. 1982). In reviewing the literature and through recent personal communications with many field staff members across the province it became evident that jack pine planting stock was not receiving special treatment in relation to other planting stock. As a result, this paper examines the methods and procedures currently in use for the transportation, holding and planting of nursery stock in northern Ontario.

Mechanical Planting Versus Hand Planting

Jack pine is planted mechanically and by hand, the latter representing 99% of the total trees planted. There is a great need for an effective mechanical planter for northern Ontario and hence it is important to review the status of mechanization briefly.

Mechanization of planting in northern Ontario has been slow for a variety of reasons. The furrow-type planters are difficult to operate in fresh cutovers because of the green slash and stumps. Dibble planters have not been developed to the point where they can adjust to the wide variety of conditions that occur on the majority of planting chances. Changing site conditions are common within the planting chance and may occur within a specific row. It appears that a successful mechanical planter will be one that is designed to operate effectively within a very limited range of sites and conditions. Unfortunately, the majority of mechanical planters that have been developed and tested are for too wide a variety of sites and conditions, and consequently the results have not been especially good.

Stock Handling From Nursery Cold Storage

For the purpose of this paper, it is assumed that jack pine bare-root stock is held at the nursery in a dormant condition and that no overheating occurs because the stock enjoys the benefits of proper refrigeration and aeration prior to pickup.

Dry, exposed tree roots pose a constant threat to the development of a successful plantation. Mullin (1976) reported that the critical period for root exposure is less than 30 minutes. Delays of 1 week between lifting and planting have been reported as the cause of reduced stand volumes (by as much as 12%) at age 20 (Mullin 1976). "Hot-planting", the daily lifting and planting of nursery stock, represents the best opportunity to avoid this loss of volume. As hot-planting is not always feasible, other methods are employed as well.

Trees that are in shipment for longer than 2 hours are transported by refrigerated units. Flexible shipping containers are never stacked more than two bundles high. Rigid shipping containers are piled to the strength limit of the containers. Within the refrigerated units, a temperature of 2 to 5°C and a humidity greater than 80% are desirable (Anon. 1983). The shipment of stock in non-refrigerated units occurs during the cooler part of the day, usually early morning. Stock is loaded immediately prior to shipment and carefully tarped to minimize the effects of exposure.

Field Holding Requirement of Jack Pine Bare-root Stock

Because of the long distances from nurseries to field offices, some districts require interim holding areas enroute to the planting site. Root cellars, caves, mine shafts and curling rinks can be used as holding areas. Because of the difficulty in maintaining the temperature below 5°C, cellars are not recommended. If an alternative holding area does not exist the maximum cellar storage time should not exceed 2 weeks. Temperature fluctuations for extended periods are not acceptable and stock should be moved to another holding facility if the temperature rises above 5°C and cannot be lowered.

Stock needs to be rotated regularly to ensure that the oldest seedlings and seedlings in damaged containers are planted first. Caves and mine shafts are generally more humid than root cellars but may exhibit similar temperature control problems depending on the cellar depth and amount of air leakage. All three facilities should be treated with a fungicide such as chlorothalonil prior to tree storage (Anon. 1983). Curling rinks with a ceiling of 2.4-3.0 m (a false ceiling is usually erected using plastic sheeting) equipped with circulating fans will maintain optimum temperature and humidity levels. Freezing of stock is prevented by constructing a bed above the ice level. Storage in curling rinks normally does not exceed 4 weeks with 2 weeks being average.

When refrigerated units such as mobile trailers and buildings are used, temperatures are maintained between 1 and 3°C. Storage in refrigerated buildings and vans normally does not exceed 28 and 20 days, respectively. Hygrothermographs placed in the front and rear of all cool storage facilities record temperature and humidity fluctuations. When major fluctuations are observed and cannot be corrected, alternative storage facilities should be considered. The requirements for stacking of shipping containers for storage are similar to those for shipping.

On-site Field Storage: Bare-root Stock

Black spruce (*Picea mariana* [Mill.] B.S.P.) and eastern white cedar (*Thuja occidentalis* L.) stands are often selected for on-site storage. Cool temperatures and high humidity levels are normal in these stands in the early spring. When these areas are not available, any shaded condition is preferable to open storage. Under warm sunny conditions, the maximum storage period to be expected is 2 days unless the storage containers lend themselves to easy watering to extend the holding period.

Field-storage Container Stock

Jack pine container stock, excluding overwintered seedlings shipped the following spring in a dormant condition, is normally shipped in an active growing state. To prevent roots from growing out of the container into the soil, the container trays are elevated, or placed on coarse gravel if the stock is stored for an extended period.

Pre-planting Requirements for Bare-root Stock

Roots must be kept moist before being placed in the stock carrier (pail, etc.). A minimum presoaking of the roots for 3 to 4 hours up to an optimum of 12 hours is recommended (Willcocks 1979).

Greater emphasis on the root moisture condition is required when high temperatures and winds and low humidity lead to the reduction of ground moisture.

Pre-planting Requirements for Container Stock

Container stock does not require any special pre-planting treatment provided that the stock is well watered.

Planter Attitude and Training

Without a proper attitude toward planting, all the emphasis placed on stock handling and planting will bear little fruit. Prior to the planting season, a reasonable amount of time is spent educating and training personnel and planters. This on-site training normally includes a brief talk on the importance of forestry in relation to the economy, site description and history, safety, stock handling, planting method, etc. If you were to ask me to single out one area of the planting program that would immediately increase planting survival, I would recommend additional emphasis on training and improving attitudes. In the case of tree planting contractors, a program to educate existing and potential contractors would be of assistance to field staff.

Handling by Tree Planters

When planting bare-root or container stock, the minimizing of root/plug exposure is critical. Trees are removed singly from their respective stock carriers and placed directly in the planting hole. Physical damage to the stem or root system can be minimized by careful handling.

Equipment for Hand Planting Bare-root Stock

A variety of equipment is available to plant bare-root stock. The primary tool used is the shovel, which is available in various sizes and shapes. Regardless of the type of tool selected, the objective is to place the root system in the mineral soil in as vertical a position as possible. Planter production is not as important as planting quality, but is considered. Stock carriers also vary, with the planting bag and pail being the most common. Again, it is not the type of carrier used but rather a suitable unit that provides protection from exposure and minimizes physical damage.

Equipment for Hand Planting Container Stock

Container stock planting tools range from the "Pottiputki" to various types of tubes and mattocks to a modified version of the shovel. The latter tools are used on the heavier soil conditions or by planters who prefer a particular tool and can demonstrate quality planting techniques while using it. Carriers for container stock vary with the type of stock being used but the requirements in terms of preventing root exposure and damage are similar to those of bare-root stock.

Field Culling

Mold and desiccation resulting from improper storage or handling occasionally necessitate the culling of stock. There are two types of field culling: that which is done by the unit forester and is generally on a major scale, and that which is done by the planter and may represent 10 to 20 trees per day. Despite the obvious benefits of not planting dead trees, planter morale and hence care may be affected if culling is not done. All the emphasis placed on stock handling will be of little use if the tree planters observe that a large percentage of all trees planted are dying regardless of the care they are giving them. Similarly, if the planter is not instructed to discard trees that are obviously defective, attitudes toward handling care will suffer.

Root Pruning

Changes in site condition may necessitate root pruning in the field to enable the planter to plant the tree properly. Pruning is completed with trained personnel who understand how the operation is done and why it is required. To minimize exposure, roots are pruned in a shaded location, preferably on a cool day or during the cooler portion of the day.

Planting Methods

Three bare-root planting methods are used in Ontario: the "L", the "T" and the "slit". Of the three methods, the L has the best potential for introducing the root system into the mineral soil in the most natural position. Descriptions and drawings of the methods are contained in Anon. (1978). The slit method is used when soil conditions or planting tools preclude the use of the L or T cut.

Planting Failures

Provided that the stock was in a healthy condition prior to leaving the nursery, an audit of planting failure or poor growth will generally reveal:

1) poor handling and transporting methods
2) improper planting techniques
3) a lack of training, education or motivation of the staff and planters

Outlook for Jack Pine Planting

Jack pine planting has been increasing in Ontario (Anon. 1982). If the rate of increase continues for the next decade, the province will be planting 40,000,000 jack pine seedlings annually by 1992.

Achievement of this potential will require additional manpower and mechanical planters. Long-term annual contracts for labor and planting contracts may provide sufficient incentive to plant that level of trees. Research on and development of suitable mechanical planters must be encouraged.

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VEGETATION MANAGEMENT IN JACK PINE PLANTATIONS

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Abstract.--The requirements for tending, time of herbicide application and vegetation management strategies are important factors in the successful regeneration of jack pine (Pinus banksiana *Lamb.).*

Summaries are given of the extent and cost of vegetation control, and the future for the application of herbicides is discussed.

Résumé.--Les exigences concernant les soins culturaux, l'époque des traitements herbicides et les stratégies de lutte contre la végétation indésirable constituent des facteurs importants pour la bonne régénération du pin gris (Pinus banksiana *Lamb.).*

L'importance et les coûts de la lutte contre la végétation indésirable, de même qu'une perspective de l'utilisation des herbicides, sont brièvement décrits.

Introduction

The successful establishment of new forest stands in cutover or burned areas, by either natural or artificial methods, involves more than just planting or seeding a site. The young tree seedlings must also be protected from light, moisture and nutrient competition from other plants. Weed competition will usually reduce the growth or cause mortality of young crop trees and much of the forest manager's effort should be directed towards managing undesirable species.

Weed control using hand labor is no longer economically or physically feasible. Hand tending is the most expensive and labor-intensive release treatment. Herbicides provide the forest manager with a highly effective, versatile and economical method of tending young conifer stands.

Philosophy of Herbicide Use

The purpose of weed control is not just to kill weeds, but to divert some of the nutrients of the site from weed species to the crop trees. "Growing trees is the ultimate objective, not killing brush; brush control is merely a phase of the reforestation procedure" (Sutton 1958).

Requirements for Tending

Nutrient resources released by weed control must be used by the tree crop if any benefits are to be derived. If the nutrients released are lost the site becomes impoverished. If the nutrients are released at a rate in excess of the ability of the crop trees to use them, no benefit is gained by the trees. In either case money is wasted. Weed control must be carried out on a sound ecological basis.

If overhead brush and hardwoods are killed before the conifers are capable of utilizing the extra space, additional herbaceous vegetation and brush species frequently develop, and this only increases the problem. The stage of stand development needs to be appraised carefully to be certain that the conifers can fully utilize the additional growing space made available to them.

It should be recognized that more than one spray may be required on the most productive sites to allow the seedlings to overtop the competition. Vegetation management should start before a stand is cut in order to determine not only the method and species required to regenerate the site, but also to anticipate the competition that is likely to affect the new crop.

Questions that should be answered in planning a spraying operation include:

1) On the basis of the species present and experience with similar sites, which species will most likely invade the site after harvesting?
2) Will mechanical site preparation increase or decrease the competition?
3) If poplar is likely to be the main competition on a good site, are there sufficient stems per hectare to allow a stand conversion?
4) On the basis of the competing species, which chemical and rate of application will be most effective?

Annual grasses and sensitive perennials may be controlled by Velpar (Hexazinone). Woody and herbaceous plants can be controlled by Roundup (Glyphosate) and phenoxy herbicides, including 2,4-D. A single formulation of two herbicides may be used to effect two treatments in one, such as the 2,4-D and the Roundup mixture that is now being tested.

Vegetation Management Strategies

Vegetation management strategies include:

1) manual cleaning
2) mechanical cleaning
3) prescribed burning before planting or seeding
4) chemical release of the plantation
5) any combination of the above
6) none of the above.

Manual cleaning is a labor intensive method with low productivity, usually requiring 26 to 40 man hours per ha. The costs are prohibitive. For example, a 30-ha block treated in 1983 cost $286 per ha. In northern Ontario, the large areas requiring release and the small population make it impossible to clean manually all areas requiring treatment.

Mechanical cleaning can be an effective but costly method, with low productivity, and can injure or damage the remaining crop trees.

Neither manual nor mechanical release removes root competition for moisture and nutrients in the annual and perennial plants.

Prescribed burning is the most economical method of weed control on nearly pure jack pine (*Pinus banksiana* Lamb.) and mixed jack pine and spruce (*Picea* spp.) stands. Unfortunately, burns require intensive planning, and because of wildfire management priorities, they are not always carried out.

Chemical release is cost effective with high productivity and long-term effectiveness, but results can be erratic if the treatment is not prescribed and applied properly and at the right time. The range of weeds that can be effectively controlled by 2,4-D is limited.

Although little is known about the interactions of mechanical, chemical and prescribed burning methods for site preparation, the wrong technique can aggravate the weed problem. A combination of mechanical site preparation with a poor prescribed burn may induce coppice growth and promote grasses. Chemical and mechanical treatments together can rid the site of weedy competition but create a problem with grasses and raspberries (*Rubus* spp.) that may require further and different chemical applications. A chemical spraying to dry out the slash, followed by a poor prescribed burn, may promote the growth of competing vegetation --especially on the moister and richer sites.

The choice and cost of these alternatives will depend upon the management objectives, species and age of vegetation to be controlled, topography, soil conditions and environmental constraints (Jaciw 1969).

Inadequate vegetation control before planting can cause great losses during the first year of the crop. If the site preparation method causes suckering and leaves numerous stems of woody vegetation such as hazel (*Corylus cornuta* [Marsh.]), willow (*Salix* spp.), alder (*Alnus* spp.) and cherry (*Prunus* spp.) on the site, the jack pine will become impoverished. A pre-plant spray as a secondary site preparation treatment can rid the site of these undesirable species.

Conversion of site classes 2 and 3 poplar to jack pine, using mechanical site preparation, will make the area susceptible to competing species and require at least one and probably two pre-plant treatments of 2,4-D to kill the wood competition. The site will probably be invaded with grasses and raspberries, on which 2,4-D has no effect. Therefore, one and possibly two tending treatments are needed on the moister and richer sites.

Excessive amounts of herbicide will cause contact damage and little or no translocation of the chemical. Top-kills will only increase the competition through heavy sprouting. Under certain conditions mortality or minor damage can occur in the released trees. Yellowing of the needles and spiraling of the current year's leader are considered light chemical damage from which the crop is able to recover by the following year. Control plots will yield data on how much of the mortality or damage is from natural causes and how much is from chemical causes. Phenoxy herbicides are slow-acting, so time must be allowed for downward translocation. If the area is burned or mechanically treated too soon after a herbicide application, heavy sprouting of shrubs will occur.

If the weather following a herbicide application is hot and sunny, damage to the weed species can be seen within two days, especially on willow, cherry and birch (*Betula* spp.). However, a valid appraisal of the herbicide's action cannot be made before the second growing season. In some cases, sprouts that develop after a treatment will die within a few years.

Time of Herbicide Application

The time of year of herbicide spraying is critical to its success. Spraying should be initiated when overtopping of the seedlings by shrubs becomes prevalent. Premature spraying will injure the exposed conifer seedlings while delayed spraying may be ineffective by decreasing the growth and survival of the stand (Jaciw 1969). Herbicides should be applied when the leaves on the competing vegetation are young and the transport of chemicals downward in the plant is the greatest. A few moderate applications are more effective than heavy dosages, which can kill the living tissue and prevent or retard the downward movement of chemicals.

Release treatments are best applied after the summer drought period when the current year's growth of jack pine has hardened off and the terminal buds feel sharp to the touch (Brown 1972). Spraying should be carried out from the end of July to mid-August although operations may continue until mid-September in wet years.

The best time for a total kill or site preparation treatment is when the vegetation is young and lush and all the tree's energy is directed to height growth (Brown 1972). Late June to early July is generally the best time for spraying.

The use of diesel fuel as 10% of the carrier, when using 2,4-D for site preparation, will decrease brush competition--especially from poplar (*Populus* spp.).

Extent of Vegetation Control in Ontario

Table 1 summarizes, by regions and for the province, the number of hectares that were sprayed with herbicides from 1977 to 1981. The majority, 78%, of spraying takes place in northern Ontario, and of this, 48% occurs in the Northern Region.

The methods used to apply herbicides in Ontario from 1973 to 1980 are shown in Table 2. In northern Ontario, 93% of spraying is done from the air and 7% on the ground. The reverse is true for southern Ontario where 93% of spraying is done on the ground and 7% is done from the air.

Table 1. Summary of herbicide spraying in Ontario by Region, 1977-1981 (ha).

Year	North-western	North-central	Northern	North-eastern	Total North	Algonquin	Eastern	Central	South-western	Total South	Total Ontario
1977	2,287	4,596	9,682	8	16,573	439	2,259	1,143	929	4,770	21,343
1978	2,873	3,321	11,264	4,021	21,479	177	2,947	812	1,749	5,685	27,164
1979	817	4,649	8,102	1,960	15,528	265	3,575	378	847	5,065	20,593
1980	1,868	1,588	19,125	2,771	25,352	431	3,007	641	1,442	5,521	30,873
1981	1,155	1,663	7,924	990	11,732	414	2,786	591	1,423	5,214	16,946
Total	9,000	15,817	56,097	9,750	90,664	1,726	14,574	3,565	6,390	26,255	116,919
Percentage	8	14	48	8	78	2	12	3	5	22	100

Excludes nurseries and, for 1980 and 1981, Forest Management Agreements

Sources: Pesticide use by the Ontario Ministry of Natural Resources, 1977 to 1981. Ont. Min. Nat. Resour., For. Resour. Br., Pest Control Section

Table 2. Use of herbicides in tending in Ontario, 1973 to 1980.

Application method	Northern Ontario (ha)	(%)	Southern Ontario (ha)	(%)	Total Ontario (ha)	(%)
Aerial	95,977	93	706	7	96,683	86
Ground	6,741	7	9,445	93	16,186	14
Total	102,718	100	10,151	100	112,869	100
Percentage	91		9		100	

Costs

The total expenditures for herbicide spraying in Ontario forests are shown in Table 3. From 1973 to 1980, 69% of provincial spraying costs were incurred in northern Ontario and 31% in southern Ontario.

Table 4 shows the cost per hectare of cleaning with herbicides from 1973 to 1980 in actual and 1973 constant dollars. The cost of aerial cleaning in northern Ontario dropped 42% from $23.18/ha in 1973 to $11.91/ha in 1980. In southern Ontario, where most chemical ground cleaning takes place, costs increased by $25.18/ha or 72%.

Table 3. Total expenditures on herbicide treatments in Ontario by administrative region, 1973 to 1980.

Region	Clearing: Aerial ($)	Clearing: Ground ($)	Site preparation[a] ($)	Total ($)	Annual average ($)	Annual average (%)
Northwestern	231,007	277	39,306	270,590	33,824	7
North Central	470,867	52,952	31,947	555,766	69,471	14
Northern	1,279,700	52,392	91,866	1,423,958	177,995	36
Northeastern	92,075	239,993	164,280	496,348	62,043	12
Northern Ontario	2,073,649	345,614	327,399	2,746,662	343,333	69
Algonquin	90	73,416	11,099	84,605	10,576	2
Eastern	269,859	592,345	168,243	1,030,447	128,806	26
Central	122	26,210	5,322	31,654	3,957	1
Southwestern	174	61,334	--	61,508	7,688	2
Southern Ontario	270,245	753,305	184,664	1,208,214	151,027	31
Total	2,343,894	1,098,919	512,063	3,954,876	494,360	100

[a] For years 1977 to 1980

Source: Forest production policy for Ontario--field program implementation schedule 1973/4 to 1976/7 and 1977/8 to 1984/5. Ont. Min Nat. Resour.

Table 4. Cost per hectare of herbicide cleaning in Ontario, 1973 to 1980.

	Northern Ontario		Southern Ontario		Total Ontario	
Year	Aerial	Ground	Aerial	Ground	Aerial	Ground
			(Actual $/ha)			
1973	57.28	-	-	86.83	57.28	86.83
1974	52.81	-	-	105.88	52.81	105.85
1975	75.83	-	-	130.37	75.83	130.37
1976	50.56	-	-	164.79	50.56	164.79
1977	42.80	96.59	128.22	123.28	44.08	111.24
1978	43.42	101.53	641.18	148.36	49.02	127.55
1979	63.55	104.28	1,4005.75	210.23	88.54	161.13
1980	57.20	155.94	747.28	289.53	65.46	220.49
			(Constant 1973 $/ha)			
1973	57.28	-	-	86.83	57.28	86.83
1974	45.79	-	-	91.82	45.79	91.82
1975	59.40	-	-	102.08	59.40	102.08
1976	36.15	-	-	117.89	36.15	117.89
1977	28.64	64.54	85.72	82.43	29.48	74.38
1978	27.28	63.80	402.97	93.23	30.84	80.16
1979	36.20	59.40	7980.47	119.79	50.43	91.82
1980	29.43	80.23	384.61	149.05	33.70	113.44

Chemical Site Preparation

Data are available only from 1977 to 1980. There has been about a 14% increase in chemical site preparation over 4 years on the basis of constant 1973 dollars (Table 5).

An earlier study (Brown 1972), using constant 1973 dollars, showed that chemical site preparation was the least expensive technique, costing $22.26/ha in comparison with $33.28/ha for prescribed burning and $70.25/ha for mechanical site preparation.

Ninety-four percent of all chemical site preparation is done in northern Ontario. The use of chemicals was more cost effective at $17.54/ha than were prescribed burning at $33.43/ha and mechanical site preparation at $70.57/ha. Herbicides are used on only 6% of the area, prescribed burning on 8% and mechanical equipment on 86% (Table 5).

Table 5. Cost per hectare of herbicide site preparation in Ontario, 1977 to 1980.

	Northern Ontario		Southern Ontario		Total Ontario	
Year	Actual dollars/ha	1973 dollars/ha	Actual dollars/ha	1973 dollars/ha	Actual dollars/ha	1973 dollars/ha
1977	24.12	16.11	65.04	43.46	31.92	21.35
1978	35.56	22.34	68.54	43.09	40.23	25.28
1979	20.81	11.86	72.70	41.41	29.65	16.90
1980	35.36	18.19	87.72	45.14	47.39	24.39

Source: Forest production policy for Ontario--field program implementation schedule 1977/8 to 1984/5. Ont. Min. Nat. Resour.

Future Outlook for Tending

Chemical weed control is a tool that will have to be used more in the future by foresters as its importance and cost effectiveness will continue to increase. There is a great need to release more conifer plantations in northern Ontario from competition. It is expected that Forest Management Agreements will further increase the tending requirements in an expanded provincial regeneration program.

Herbicide use for site preparation will increase if more of the effective chemicals are registered for forestry use. The use of chemicals in combination with prescribed burns will increase as the chemicals can be used to dry out fuel for improved ignition and achieve better and consistent results.

There are several problems associated with aerial spraying. Before herbicide use can increase in the northern regions, a wide range of registered chemicals is required to deal with a broad spectrum of competing vegetation and various crop tolerances. Roundup and Velpar in particular may reduce the need for future release treatment.

Many forest managers have decreased their use of herbicides because of the vocal anti-spray groups and resultant controversy. Foresters will have to become more knowledgeable about insecticides and herbicides and be prepared to inform the public about all aspects of application techniques and the chemicals being used. Senior staff must support the use of herbicides and make objective professional decisions as to how and where the chemicals are to be used.

Manufacturers are not interested in the small forestry market because of the high cost of having chemicals approved for forestry use when it is easier to approve the same chemical for agricultural use than for forestry use.

Some staff of the regulatory agencies have no concept of the conditions under which aerial spraying is carried out and may place restrictive conditions on forestry use. Certain chemicals have been approved for ground application but not for aerial application. We must therefore look ahead now and start developing ground spraying techniques for future use for northern Ontario conditions.

Because of limited research resources within the Ministry, districts or regions will be asked to generate data and documentation of efficacy and crop tolerance of herbicides and to test new herbicides and spraying equipment.

Aerial application technology and operational techniques have to be reviewed and improved. Documentation of results needs to be transferred within the profession. For example, for years tenders have specified to the aerial applicator the rate of herbicide to be delivered but they have never specified the type of nozzles to be used. Basically this is because the droplet spectrum required for the best results is not known. Operators have been known to come in and give "rain storms". Also, tenders have not stated the angles of the nozzles needed to get the proper shear for the best droplet size, nor is this angle known.

The controversy about delivering 3 or 6 gallons per acre of a 2,4-D mixture still rages on within the Ministry because of the lack of proper documentation of past trials and experiments.

The chemicals required for tending and site preparation could be made available if supporting data could be generated for registration by the regulatory agencies. A cooperative effort between all user agencies will be required if satisfactory forests are to be produced. I estimate that within a 5-year period sufficient information should be generated to provide us with another registered chemical--information that is 15 years late in coming.

It will also be necessary to develop a standard method of assessing herbicide treatments in order to determine if our objectives have been obtained. The normal overflight of the area to determine damage is fine after the second week, but what about the efficacy in the first and second growing season after treatment? You cannot just walk away and say "there, the job is done".

There is a need now, and it will be greater in the future, for vegetative management specialists. Experts on pesticides and application technology, who can train forestry staff to carry out and document research on particular weed control problems that vary from region to region, are required.

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PRECOMMERCIAL THINNING IN JACK PINE
WITH PARTICULAR REFERENCE TO EXPERIMENTS
IN NORTHEASTERN ONTARIO

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Abstract.--The growth response of jack pine (Pinus banksiana *Lamb.) to precommercial thinning is discussed. Special reference is made to the height and diameter response of individual trees in three different stands in northeastern Ontario thinned at ages 9, 22 and 33 years, respectively. Height response was not positive, but trees in all three age classes responded positively in terms of diameter growth. Because of lower treatment costs in the younger stands and a period of unproductive growth associated with older, over-dense stands, thinning is best done in stands that are between 10 and 15 years of age.*

Résumé.--L'effet des éclaircies non commercialisables sur la croissance du pin gris (Pinus banksiana *Lamb.) est examiné, compte tenu plus spécialement de l'effet observé sur la croissance en hauteur et en diamètre d'arbres de trois peuplements différents du nord-est de l'Ontario éclaircis à 9, 22 et 33 ans, respectivement. Il n'y a pas eu d'effet positif sur la croissance en hauteur, mais les arbres des trois classes d'âge ont répondu de façon positive en ce qui concerne la croissance en diamètre. Compte tenu des coûts plus faibles de traitement des peuplements plus jeunes et de la période de croissance non productive que connaissent les peuplements plus âgés trop denses, il est préférable que l'éclaircie soit pratiquée lorsque les peuplements ont entre 10 et 15 ans.*

Introduction

Precommercial thinning may be defined as a cutting made in immature stands to provide adequate growing space, to accelerate diameter growth, and, by suitable selection, to improve the average form of the remaining trees (Anon. 1982). An intensive silvicultural practice, thinning represents one of the principal means by which the productivity of stands can be increased beyond the "best" that might be achieved under purely natural conditions.

In 1969-1970, operational trials were conducted by the Great Lakes Forest Research Centre to determine both the best stage in stand development for conducting spacing treatments and the most efficient method of achieving desirable spacing in young jack pine (*Pinus banksiana* Lamb.) (Riley 1973). Results from the trials indicated much lower treatment costs in the youngest age class (9 years).

Since the original intent of the trials was to study the operational aspects of thinning, minimal provisions were made for a long-term study of growth response. However, follow-up growth measurements have been made over a 10-year period in light of the demand for data from precommercial thinnings in northeastern Ontario. The results of these measurements, though limited in scope and statistical validity, are presented in this paper to permit the relatively extensive research findings from outside Ontario to be applied to local conditions.

As pointed out by Johnstone (1981), the decision to thin or not to thin will depend not only upon the biological response but also upon consideration of a number of critical factors that have not been mentioned in this paper. These include the current and anticipated timber supply and market situations, distance from manufacturing facilities, availability of capital and manpower, presence of potentially damaging agents, and, ultimately, the potential economic gain from thinning.

Site and Stand Descriptions

Stands aged 9, 22 and 33 years were treated. All sites are typical for jack pine and are gently rolling, well drained sand plains of Site Class II (Plonski 1960). Further details regarding site and stand conditions, as provided by Riley (1973), are given in Tables 1 and 2.

Methods

All thinning operations were carried out on a piecework basis in late 1969 and 1970. Thinning tools and techniques used are described in detail by Riley (1973). All measurements were recorded in Imperial units and have been converted to S.I. units for this report.

Age Class I

To facilitate the application of work studies the treatment area was divided into 13 blocks, each 0.8-1.5 ha in area. Stocking and density were recorded on a 4-m^2 basis on all blocks. In the spring of 1970, 10 blocks were thinned with brushsaws and two with hand tools. One block was left as a control. Prescribed spacing was 1.8 m, whereas average spacing achieved was 1.6 m (Table 3). Stem heights for all species were measured to the 1970-1971 internode the next summer.

In the summer of 1975, stocking and density were recorded on a 4-m^2 basis for all jack pine stems and turnups (upturned lower branch whorls of living branches on the stump of cut stems). The dominant jack pine tree was marked and numbered on each stocked quadrat. The DBH and height of marked trees were recorded.

In May 1981, before bud break, all measurements carried out in 1975 were repeated. Black spruce (*Picea mariana* [Mill.] B.S.P.) stocking was also recorded at this time.

Table 1. Site descriptions.

Age class	Location	District	Forest section[a]	Site class[b]	Moisture regime[c]	Soil
I (9 yr)	Benneweis Twp	[Gogama]	B7	2	1	medium sand
II (22 yr)	Panet Twp	Chapleau	B7	2	2	fine sand
III (33 yr)	Mickey Creek	[Wawa]	B8/9	2	2	fine sand

[a]Rowe (1972)
[b]Plonski (1960)
[c]After Hills (1952)

Table 2. Stand descriptions (before treatment)[a].

Age class	Age (years)	Stocking (%)	Density (trees/ha)	DBH range (cm)	Avg DBH (cm)	Avg ht (m)	Stand origin
I	9	88[b]	13,170	< 7.6	2.5	1.8	scarification and aerial seeding
II	22	96[c]	10,428	2.5-12.7	5.1	5.8	wildfire
III	33	96[c]	5,560	2.5-15.2	7.6	9.8	wildfire

[a]Values converted from Imperial to S.I. units.
[b]Percentage of 4-m^2 quadrats with at least one tree.
[c]Percentage of 6-m^2 quadrats with at least one tree.

Table 3. Spacing, stocking and density after treatment.

Age class	Treatment	Prescribed spacing (m)	Avg spacing after treatment[a] (m)	Stocking[a] (%) After treatment	Stocking[a] (%) 1975	Stocking[a] (%) 1980	Density (stems/ha) Jack pine[a] After treatment	Density (stems/ha) Jack pine[a] 1975	Density (stems/ha) Jack pine[a] 1980	Density (stems/ha) Black spruce 1980
I (9 yr)	Thinned	1.8	1.6	80	78	76	3,906	3,608	3,412	3,558
	Control	-	-	-	85	84	-	13,376	13,232	3,252
II (22 yr)	Thinned	2.4	2.2	86	81	80	2,066	1,895	1,858	932
	Control	-	-	-	99	98	-	8,987	8,303	3,657
III (33 yr)	Thinned	2.4	1.9	89	78	78	2,770	2,350	2,202	4,737
	Control	-	-	-	97	94	-	5,881	4,539	7,655

[a]All live jack pine, turnups excluded.

Age Class II

The treatment area was divided into eight blocks, each 0.2-0.4 ha in area. In the summer of 1970, five blocks were thinned with chainsaws and two with hand tools to a prescribed spacing of 2.4 m and one block was left as a control. The average spacing achieved in the thinned stands was 2.2 m (Table 3).

In the early fall of 1970, the DBH of all jack pine stems was recorded in 2.54-cm classes on a 6-m^2 basis. Mean heights were derived from a height-over-diameter curve prepared in 1969.

In the summer of 1975, stocking and density were recorded on a 6-m^2 basis for all jack pine. The dominant jack pine tree was marked and numbered on each stocked quadrat. The DBH and height of each marked tree were recorded. Increment borings were taken with readings of double bark thickness, current annual increment and 5-year periodic increments before and after thinning.

In the late fall of 1980, after bud set, measurements carried out in 1975 were repeated. Current annual increments and periodic diameter increments for the second 5-year period were also measured. Black spruce stocking was also recorded.

Age Class III

The treatment area was divided into five 1-ha blocks. In the late summer of 1969, two blocks were chemically thinned with Silvisar (cacodylic acid) applied with hand-held hypo-hatchet injectors. In the late spring of 1970, one additional block was treated with Silvisar and one with Sandvik axes. The prescribed spacing was 2.4 m. In July 1975, the fifth block was established as a control and a control surround was established around each block.

In the early fall of 1969, stocking and density were recorded on a 6-m^2 basis for all jack pine stems in the two 1969-treated blocks. The dominant jack pine tree was marked and numbered on every fifth stocked quadrat. The DBH and height of each marked tree were recorded. In the late fall of 1970, the 1970-treated blocks were measured in the same manner.

In the summer of 1975, dominant jack pine trees were marked and numbered in the control areas. In the treated and control blocks, jack pine stocking and density were recorded on a 6-m^2 basis. The DBH and height of marked trees were recorded. Increment borings were taken to measure double bark thickness, current annual increment and 5-year periodic increments before and after thinning. Appropriate corrections were made for the 1-year difference in treatment time.

In the late fall of 1980, measurements carried out in 1975 were repeated. Current annual increments and periodic diameter increments for the second 5-year period following treatment were also measured. Black spruce stocking and the DBH and height of the dominant black spruce were also recorded.

Results and Discussion

The spacing, stocking and density data for stand conditions immediately after treatment and at 5 and 10 years after treatment are provided in Table 3. Results for the height and diameter measurements of the marked crop trees are provided in Table 4. Stand measurements of height and diameter were not taken. For this reason, stand basal area and volume estimates have not been made. For the purpose of this paper, treatments within age classes are lumped together.

The initial stocking and density of dominant and codominant black spruce stems was insignificant in all stands. A black spruce understorey was evident 10 years after thinning in all three areas, especially in the Age Class III stand (Table 3). However, jack pine was still clearly dominant, as is indicated by the height figures provided in Table 4. Similar figures are not available for the other treatment areas. However, from field observations it can be stated that jack pine clearly remains dominant in both the treated and control areas.

Table 4. Height and diameter response.

		Average height (m)				Avg DBH[e] (cm)			PAI (diam) (cm)			CAI (diam) (cm)	
		Jack pine			Black spruce								
Age class	Treatment	After treatment[c]	1975[d]	1980[d]	1980	After treatment	1975	1980	1966-1970	1971-1975	1976-1980	1975	1980
I (9 yr)	thinned	1.8	4.6	6.7	-	2.5[f]	6.1	8.4	-	-	-	-	-
	control	1.8	4.6	7.0	-	2.5[f]	4.8	6.6	-	-	-	-	-
II (22 yr)[a]	thinned	7.0	9.8	11.6	-	8.2[g]	10.3	12.4	0.41	0.42	0.42	0.45	0.45
	control	5.8	9.1	11.0	-	8.1[g]	9.2	10.1	0.36	0.21	0.20	0.30	0.27
III (33 yr)[b]	thinned	10.1	11.6	12.2	4.4	9.4	10.3	11.3	0.11	0.15	0.19	0.15	0.22
	control	-	10.1	10.4	5.1	8.2[g]	8.7	9.1	0.11	0.09	0.09	0.07	0.11

[a]Data aggregated from all blocks.
[b]Averaged on block basis.
[c]Stand height.
[d]Marked trees only.
[e]Quadratic mean.
[f]Estimated.

Spacing, Stocking and Density

The spacing achieved in each age class was lower than that prescribed (Table 3). The shortfall was greatest in the Age Class III stand where the actual spacing was 1.9 m instead of the prescribed 2.4 m. The reduction in density of live jack pine stems in Age Class III from 2,770 to 2,350 stems per ha 5 years after treatment (Table 3), a 15% loss, may be an indication that the treatment was not severe enough to reduce crown and root competition. The "delayed-action" removal of stems in the chemically treated blocks may have had a similar impact. Density was reduced by 8% in each of the other age classes over the same period.

Care taken during the thinning operation to cut stems below the lowest whorl of living branches in the Age Class I stand (Riley 1973) resulted in a low incidence of turnup. Stocking, 10 years after treatment, to living, multiple-stemmed trees that frequently result from improper cutting, was less than 1%.

Height

In the Age Class I area, average height growth was slightly greater in the control than in the treated stand over the 10-year period, i.e., the average incremental height growth was 5.2 m and 4.9 m, respectively (Table 4). Similarly, the average incremental height growth was greater in the control stand of the Age Class II area than in the treated stand, i.e., 5.2 m and 4.6 m, respectively. Height values for 1970 are not available for the Age Class III control area. The average incremental height growth in the treated area for the 10-year period was only 2.1 m.

It is apparent that neither the Age Class I nor the Age Class II stands have responded positively to thinning in terms of height growth. This is consistent with results elsewhere where thinning has generally not increased height growth (Wilson 1951, Buckman 1964, Cayford 1964, Steneker 1969).

Diameter

Average DBH and the periodic (PAI) and current (CAI) annual diameter increments of the marked sample trees are shown in Table 4. The PAIs and CAIs are illustrated in Figure 1. Trees in the Age Class I area were too small for increment cores to be taken.

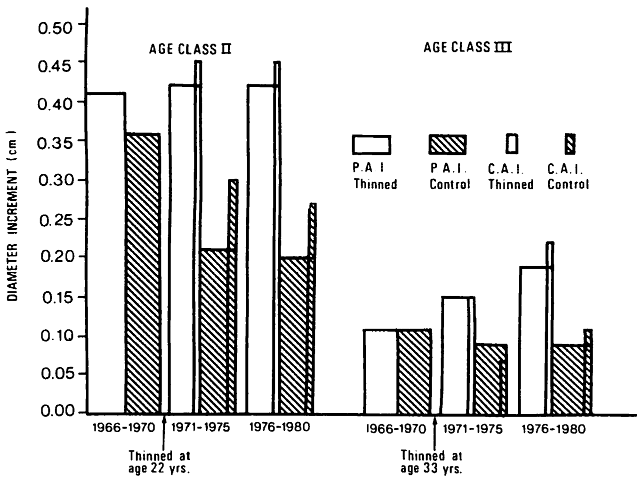

Figure 1. Periodic and current annual DBH increments of sample trees. The CAIs are for the years 1975 and 1980.

Thinning redistributes growth to the residual trees (Alm et al. 1979). As Peine (1981) states, a primary management objective in thinning operations is to speed up the growth of the potential crop trees. In this way, larger and more valuable trees can be grown on shorter rotations (Fasick 1965).

The extent to which rotations may be reduced is illustrated in the following discussion which expands on the analysis carried out by Riley (1973) and makes use of the 10-year growth response data. The sample trees selected as dominants and codominants are assumed to be the crop trees at the time of harvest.

Age Class I

In the thinned stand, the quadratic mean DBH[1] of marked sample trees increased from 2.5 to 8.4 cm over the 10-year period for a net increment of 5.9 cm, while the increase in the unthinned control was from 2.5 to 6.6 cm for a gain of only 4.1 cm (Table 4). Therefore, the thinned trees had a net gain of 1.8 cm or 44% over the control trees.[2]

According to Plonski's (1974) tables, it would be reasonable to expect that the density of the thinned stand would not approach normality for at least 10 more years. Therefore, it would be safe to project the 10-year DBH growth response data for a further 10 years from age 19 to 29 years (Fig. 2.). It is assumed that stand growth would thereafter approximate the normal rate. In the somewhat understocked control stand, it is assumed that the DBH growth rate would continue to follow the normal rate, more or less, from age 19 years onwards.

Hence, at age 60 years, the average DBH of the sample trees in the treated and control stands would be approximately 18.0 and 16.7 cm respectively, a difference of 1.3 cm. In other words, trees averaging 18.0 cm DBH could not be harvested in the control stand until the age of 70 years. Therefore, in this case, it appears that a reduction in the rotation age of about 10 years may be achieved by thinning the stand to a spacing of 1.6 m at age 9 years.

Age Class II

In the thinned stand, DBH increased from 8.2 to 12.4 cm for a net increase of 4.2 cm (Table 4). DBH increased from 8.1 to 10.1 cm in the control for a gain of 2.0 cm. Therefore, the thinned trees had a net gain of 2.2 cm or 110% over the control trees.

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[1]Quadratic mean DBH = $\sqrt{\dfrac{\sum_{i=1}^{n} DBH_i^2}{n}}$

[2]At the time of thinning, crown closure and the resulting decline in diameter growth had not begun. Therefore, growth advantage for the thinned areas was limited for several years following treatment, i.e., until density competition forced a reduction in growth in the control condition.

Figure 2. Predicted effect of thinning on DBH growth rate and rotation age of sample trees. Curves extended beyond actual and projected values are parallel to the "normal" growth rate curve for Site Class II (Plonski 1974).

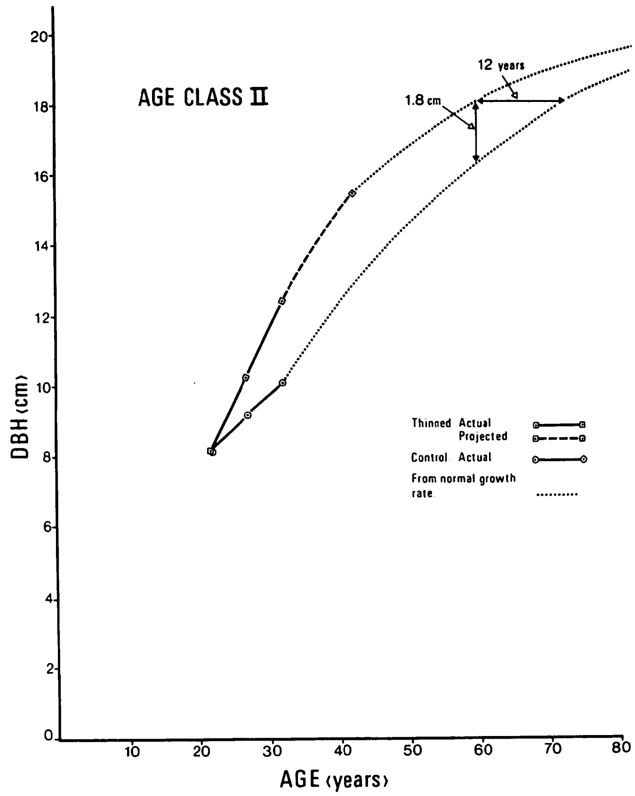

Figure 3. Predicted effect of thinning on DBH growth rate and rotation of sample trees. Curves extended beyond actual and projected values are parallel to the "normal" growth rate curve for Site Class II (Plonski 1974).

There was little change in the PAI of sample trees between the 5-year period before thinning and the first and second 5-year periods after thinning (Fig. 1). The CAI in the last year of the second 5-year period was slightly higher than the PAI, an indication that there was no sign of an immediate reduction in growth rate. In contrast, the rate of growth in the control declined significantly. The PAI of sample trees in the control fell by 42% in the first 5-year period in comparison with the 5-year period before thinning. In the second 5-year period, the PAI levelled off, with only a slight decrease from the previous 5 years.

As illustrated in Figure 3, the DBH of sample trees in both the thinned and control stands may be projected in a similar manner to that of the Age Class I stands if we assume that the density of the thinned stand will return to normal in a period of not less than 10 more years (Plonski 1974).

Hence at age 60 years, the average DBH of the sample trees in the treated and control stands would be approximately 18.1 and 16.3 cm, respectively, and it appears that a reduction in the rotation age of at least 12 years may have been achieved by thinning the stand to a spacing of 2.2 m at age 22 years (Fig. 3). Although it is difficult to compare the Age Class II and I treatments because of differences in location, etc., it is apparent from the similarities in the magnitude of these figures that thinning at age 22 years has resulted in a similar net gain. It should be noted, however, that treatment costs in the older stand were much higher (Riley 1973).

Age Class III

In the thinned stand, the DBH of sample trees increased from 9.4 to 11.3 cm for a gain of 1.9 cm while DBH in the control increased from 8.2 to 9.1 cm for an increment of only 0.9 cm (Table 4). Hence, the thinned trees had a 1.0 cm or 111% net gain over the control trees.

The PAI of sample trees in the thinned area increased by 36% in the first 5-year period after thinning in comparison with the 5-year period before thinning (Fig. 1). In the second 5-year period after thinning diameter growth continued to increase, with a 27% increase in PAI over that of the first 5-year period. The CAI in 1980 was 16% higher than the PAI for the preceding 5 years, an indication that diameter growth of the sample trees in the thinned area had not started to decline. In the control, there was relatively little change in the rate of diameter growth of the sample trees over the 15-year period for which measurements were taken.

As indicated in Figure 1, without thinning the rate of diameter growth had stagnated, as might be expected in dense sapling stands (Fowells 1965). Even with the increased rate of growth in the thinned stand, average DBH of the sample trees was increasing at a rate less than the normal rate for either Site Class II or Site Class III sites (Plonski 1974). Consequently, we have made simple straight-line projections of the 10-year DBH growth response data to age 60 years rather than basing projections on normal rates (Fig. 4). In the case of the treated stands, examination of the PAIs and the CAIs in Figure 1 would suggest that the projection in Figure 4 may be somewhat conservative.

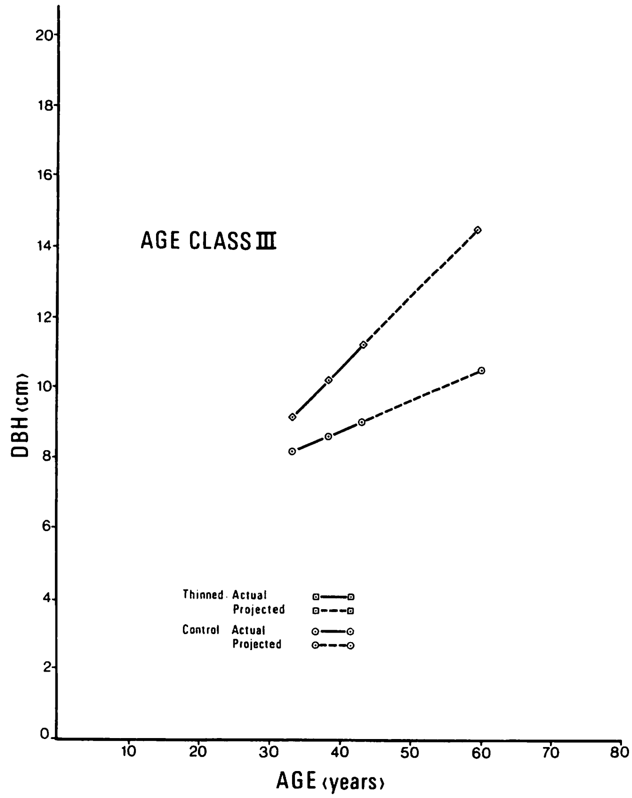

Figure 4. Simple projection of 10-year DBH growth response of sample trees.

If we allow for initial differences in average DBH, it appears that thinning may result in a net gain of approximately 3.3 cm over the control at age 60 years (Fig. 4). A significant reduction in rotation age is evidently possible.

The average DBH of sample stems on the thinned area at age 60 years will be approximately 14.4 cm (Fig. 4) in comparison with approximately 18.0 and 18.1 cm, respectively, for the Age Class I and II thinned stands (Fig. 2 and 3). As previously stated, comparisons between the different age classes are difficult. However, the magnitude of the differences between DBHs at age 60 years does serve to illustrate the result of thinning at a later age in stagnated stands, i.e., there may be a positive response to thinning as previously indicated but the opportunity to avoid a period of reduced, unproductive growth as a result of overcrowding may be lost.

In summary, therefore, it is apparent that all three age classes responded positively to thinning in terms of diameter growth. Results from studies in the Prairie Provinces and the Lake States have generally shown favorable responses in diameter increment of individually spaced trees over a wide range of age classes (Wilson 1952; Cayford 1961, 1964; Buckman 1964; Steneker 1969). Generally, the heavier the thinning the greater the response (Cayford 1961, 1964; Buckman 1964; Bella and de Franceschi 1974a). Although there was a positive response to thinning in the higher age classes in this study, poor responses have been noted in older stands (Wilson 1951). As Cayford (1961) suggests, in closed jack pine stands, crowns recede very rapidly, and thinnings, if they are to be effective, must be made while the crowns are large enough to utilize additional space effectively.

Volume

As stated previously, stand volume estimates have not been made in this study. In general, long-term results in this area are lacking. However, 32- and 40-year results from thinnings in jack pine at age 18 and 10 years, respectively (Cayford 1961, 1964), indicate that thinning did not result in increased total volume production and that the heavier the thinning, the poorer the response. In contrast, 37-year results from thinnings in jack pine at age 5 years show greater total volume production in stands thinned from 4- to 8-ft (1.2 to 2.4 m) spacings than in the unthinned stand (Benzie 1983). However, since volume generally becomes distributed on fewer trees as a result of thinning, merchantable volume is the better indicator. Cayford (1961) reports that, in the above-mentioned stand thinned at age 10 years, thinning to a 6-ft (1.8 m) spacing increased sawtimber volume by 1,200 board ft per acre (7.00 m^3/ha) or pole production by 80 poles per acre (203 per ha). In the stand thinned at 18 years, sawtimber volumes were increased by 435 to 1,337 board feet per acre (2.54 to 7.80 m^3/ha) at age 50 years, with the greatest increases from thinning to 5- and 6-ft (1.5 and 1.8 m) spacings (Cayford 1964).

Form

Buckman (1964) provides 22-year results of thinning of jack pine at spacings from 4 to 8 ft (1.2 to 2.4 m) at age 5 years. The live crown receded most with the close spacings. The height to the first live branch and to full crown was greater with closer spacings. Although neither was statistically significant, there was a slight tendency for tree taper at 20 ft (6.1 m) and butt flare at 0.5 ft (15.2 cm) to be greater with the wider spacings. Branch diameters increased with wider spacings. There was no statistical difference between spacings in the number of branches persisting in the 6- to 12-ft (1.8 to 3.7 m) section of the stem.

Bella and de Franceschi (1974b) state that jack pine has a tendency to develop irregular crowns if grown in open stands. Heavy branches and wide, bushy crowns with multiple leaders and stems are characteristic of this condition. It was noted that, for planted jack pine, there was a highly significant positive correlation between the percentage of irregular crowns and spacing distance, i.e., 10 to 20% for spacing from 1.2 to 3.0 m. Since artificially spaced stems are subjected to crown competition prior to release, it is expected that these latter figures would be somewhat reduced where, as previously mentioned, crowns may not respond to thinning.

Row Thinning

The discussion in this paper has been concerned with the spacing of individual trees. Mechanical strip thinning is a relatively low-cost method of reducing stand density (Bella 1974). However, a number of studies have shown only poor to moderate success in terms of growth response from row thinning (Steneker 1969, Bella 1974, Alm et al. 1979). Also, trees along the edges of the residual strips may be damaged and may exhibit an increased susceptibility to disease. Skilling (1957) shows that reducing the width of the leave strips from 6 to 3 ft (1.8 to 0.9 m) improves growth response but that the main disadvantage of row thinning is the lack of selectivity. Row thinning combined with within-row selective thinning may be the most desirable solution.

Summary and Conclusions

Precommercial thinning in jack pine stands aged 9 and 22 years on Site Class II (Plonski 1960) sites in northeastern Ontario did not result in increased height growth over a 10-year period. Similarly, it would be consistent with findings from studies outside Ontario not to expect a positive height growth response in the stand thinned at age 33 years.

All three age classes responded positively to thinning in terms of diameter growth, and consequently there will be significant reductions in rotation age. Although thinning at a more advanced age may be beneficial, it will not optimize growth within the stand since the opportunity to avoid a period of reduced, unproductive growth that is due to competition may be lost. Since thinning costs are lowest in the youngest stands (Riley 1973) it is, therefore, apparent that an early thinning, at perhaps 10 to 15 years, will yield the best biological and economic results.

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INSECT PESTS OF JACK PINE: BIOLOGY, DAMAGE AND CONTROL

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Abstract.--Although at least 58 insect species or groups are known to attack jack pine (Pinus banksiana *Lamb.) in Ontario, only 25 of these are considered important. The jack pine budworm* (Choristoneura pinus pinus *Free.), Swaine jack pine sawfly* (Neodiprion swainei *Midd.) and adult feeding by sawyer beetles* (Monochamus *spp.) are the most serious problems. The recent history, biology, life cycle and type of damage caused by these three pests are described and control measures are discussed. In addition, the effects of insects on plantations and seed and cone production are described briefly.*

Résumé.--Même si on connaît au moins 58 espèces ou groupes d'insectes qui attaquent le pin gris (Pinus banksiana *Lamb.) en Ontario, seulement 25 sont considérés commes importants. La tordeuse du pin gris* (Choristoneura pinus pinus *Free.), le diprion de Swaine* (Neodiprion swainei *Midd.) et des longicornes* (Monochamus *spp.) adultes suscitent les problèmes les plus graves. L'évolution récente, la biologie, le cycle évolutif et le type de dommages causés par ces trois déprédateurs sont décrits, et les mesures de répression sont examinées. Une brève description des effets des insectes sur les plantations et sur la production de graines et de cônes est également présentée.*

In Canada, jack pine *(Pinus banksiana* Lamb.) grows from the Atlantic Ocean west to the McKenzie River Valley. It is considered to be a tree of the boreal forest region and characteristically grows in pure stands or in mixture with black spruce *(Picea mariana* [Mill.] B.S.P.). It is also found in mixed conifer-hardwood stands with white spruce *(Picea glauca* [Moench] Voss), black spruce, balsam fir *(Abies balsamea* [L.] Mill.), trembling aspen *(Populus tremuloides* Michx.), balsam poplar *(Populus balsamifera* L.) and white birch *(Betula papyrifera* Marsh.).

Jack pine is one of the major species in Ontario's forests, ranking third after black spruce and poplar. In the boreal forest region of Ontario, which is roughly approximate to the Northwestern, North Central and Northern regions of the Ontario Ministry of Natural Resources (OMNR), black spruce comprises about 50% of the total volume of wood, poplar about 18% and jack pine about 15%. However, on a commercial basis, jack pine is considered to be the second most important tree species in northern Ontario. Jack pine is most abundant in northwestern Ontario where it reaches its best development on the sandy soils in a wide area north and west of Lake Superior. In general, volumes tend to decline towards the east and south although several districts in northeastern Ontario, namely, Kirkland Lake, Timmins, Gogama and Chapleau, have proportions of jack pine higher than the boreal regional average.

The volume of jack pine harvested in recent years from Crown lands has ranged from 5 to 5.7 million cubic metres annually. This represents about 31-32% of the total volume of wood harvested annually from Crown lands. About 77% of the allowable annual cut for jack pine was utilized in 1977-1978 and this figure is probably more than 80% today. While data on the overall picture for jack pine regeneration are difficult to obtain, approximately 55,000-60,000 ha are planted or seeded directly each year. Undoubtedly a much larger area of variable but unknown size is regenerated naturally each year as the result of fires or harvesting. Whether or not natural regeneration is satisfactory in terms of stocking may be a factor but the important point is that there is a large amount of immature jack pine in plantations or natural stands throughout northern Ontario.

Examination of selected references and of the records of the Great Lakes Forest Research Centre's (GLFRC) Forest Insect and Disease Survey Unit (FIDS) indicates that there are at least 58 insect species or groups that have been found attacking jack pine in natural stands or plantations in Ontario. However, only 25 species are considered important because they are known to have caused significant damage. The other 33 species or groups are considered to be of minor importance although all are recorded as causing injury in some form.

The complete list of 58 species or groups follows. Such a list is developed primarily from the data base accumulated since 1936 in Ontario by the Forest Insect and Disease Survey, an operational unit of the Canadian Forestry Service. Much of the information in the handbook "Insects of Eastern Pines" by Rose and Lindquist (1973) was generated from the records and experience of the FIDS staff. This handbook served as a major reference in the preparation of this paper. The insects have been found on jack pine in Ontario, although jack pine is not the preferred host in all cases. These insects are known to have caused damage in some form to jack pine or else they appear to have the potential for causing damage in natural or man-established forests. The insects are listed in alphabetical order by scientific name with the common name following.

INSECTS

***Acantholyda erythrocephala* (Linn.), Pine false webworm - introduced defoliator, potentially serious pest of jack pine plantations.

Aphrophora cribrata (Walker), Pine spittlebug - occasionally a problem in plantations.

Aphrophora saratogensis (Fitch), Saratoga spittlebug - minor problem in jack pine in Ontario.

Argyrotaenia tabulana Free., Jack pine tube moth - needleminer, not a serious pest in Ontario.

Caripeta spp. (2 species), Pine loopers - defoliators, not known to have caused serious injury in Ontario.

***Cecidomyia piniinopis* O.S. and *C. resinicoloides* Will., Jack pine midges, and *C. resinicola* (O.S.), Jack pine resin midge - capable of causing twig mortality and killing small trees.

***Cephalcia fulviceps* Roh., Pine webspinning sawfly - defoliator, occasional problem on jack pine.

Chionaspis pinifoliae (Fitch), Pine needle scale - minor problem on jack pine.

**Choristoneura pinus pinus* Free., Jack pine budworm - defoliator, most serious insect pest of jack pine in Ontario, also feeds on male flowers.

C. rosaceana (Harr.), Obliquebanded leafroller - defoliator, occasionally causes serious damage to young plantation trees.

Chrysobothris sp. (5 species), Flatheaded wood borers - secondary insects, larval boring damages or degrades wood.

Cinara spp. (8 species), Jack pine aphids - feed on sap from all parts of the tree, occasionally a serious problem.

Conophthorus banksianae McPherson, Jack pine tip beetle - adult beetles bore into tips of twigs, larvae feed in shoots, serious injury seldom occurs.

***Dioryctria disclusa* Heinr., Webbing coneworm - this cone insect was the most important factor in a 1982 survey of jack pine seed and cone losses in Ontario. *D. abietivorella* (Grote), Fir coneworm, also feeds in jack pine cones.

Dioryctria zimmermani (Grote), Zimmerman pine moth - stem borer, not a serious pest of jack pine in Ontario.

***Diprion similis* (Htg.), Introduced pine sawfly - introduced defoliator, occasionally causes severe damage.

Eucordylea canusella Free., Banded jack pine needleminer - needleminer, not a serious pest.

***Eucosma gloriola* Heinr., Eastern pine shoot borer - this shoot borer can be a particularly severe problem in poorly managed or thinly stocked plantations.

Eupithecia palpata Pack., Small pine looper - defoliator, not known to have caused serious injury.

***Exoteleia dodecella* (Linn.), Pine bud moth - introduced bud miner, jack pine not preferred but will be attacked in heavily infested areas.

***Exoteleia pinifoliella* (Cham.), Pine needleminer - needleminer that occasionally becomes very abundant on jack pine.

***Hylobius pales* (Hbst.), Pales weevil - adults feed on twigs and can kill small trees.

***Hylobius radicis* Buch., Pine root collar weevil and *H. warreni* Wood, Warren's collar weevil - larvae feed under the bark at the root collar, have caused serious damage in plantations.

Ips pini (Say), Bark beetles, and three other *Ips* species - secondary insects; however, young drought-affected trees may be killed.

Lapara bombycoides Wlk., Pine sphinx moth - defoliator, severe injury not recorded.

Laspeyresia toreuta (Grt.), Eastern pine seedworm - larvae feed in second-year cones.

**Monochamus scutellatus* (Say), Whitespotted sawyer beetle - maturation feeding by adults on cambium of twigs or branches kills trees or girdles main stem in the crown; black spruce and jack pine on edge of clearcuts or stands left as seed trees are most heavily affected.

***Monochamus notatus* (Drury) and *M. scutellatus* (Say), Roundheaded wood borers - secondary insects, larval boring damages or degrades wood; serious problem if logs left in woods or at mill site.

Neodiprion abbotii (Leach), Pine sawfly - defoliator, not a serious pest, relatively rare.

Neodiprion compar (Leach), Pine sawfly - defoliator, not a serious pest, relatively rare.

***Neodiprion lecontei* (Fitch), Redheaded pine sawfly - defoliator, serious pest of young plantations.

Neodiprion maurus Roh., Pine sawfly - defoliator, not a serious pest.

***Neodiprion nanulus nanulus* Schedl., Red pine sawfly - defoliator, serious problem occasionally.

Neodiprion nigroscutum (Midd.), Pine sawfly - defoliator, not a serious pest, relatively rare.

***Neodiprion pratti banksianae* Roh., Jack pine sawfly - defoliator, serious problem occasionally.

***Neodiprion pratti paradoxicus* Ross, Jack pine sawfly - defoliator, serious problem occasionally.

***Neodiprion sertifer* (Geoff.), European pine sawfly - introduced defoliator, potentially a serious problem in natural stands and plantations.

**Neodiprion swainei* Midd., Swaine jack pine sawfly - defoliator, serious pest of plantations, natural stands and mature timber.

***Neodiprion virginianus* complex, Redheaded jack pine sawfly - defoliator, planted trees 1 to 7 metres may be killed.

***Petrova albicapitana* (Busck.), Northern pitch twig moth - larvae mine twigs or branches, serious pest of young plantations.

***Phyllophaga* sp., June beetle (White grubs) - larvae feed on roots of seedlings.

***Pissodes approximatus* Hopk., Northern pine weevil - adults feed on twigs and can kill small trees.

***Pissodes strobi* (Peck.), White pine weevil - this shoot borer is a problem in plantations and regeneration where it damages or kills leaders.

Rhyacionia adana Heinr., Pine tip moth - larvae bore shoots of trees usually less than 1 metre in height.

Rhyacionia buoliana (Schiff.), European pine shoot moth - introduced insect, larvae mine buds and new shoots, not a serious problem in jack pine.

Rhyacionia busckana Heinr., Red jack pine shoot borer - larvae mine shoots of trees more than 1 metre in height.

Rhyacionia sonia Miller, Yellow jack pine shoot borer - larvae mine the tips of new shoots; serious injury has not been recorded.

Schizolachnus piniradiatae (Davidson), Woolly pine needle aphid - these insects suck sap from needles; not a serious problem in jack pine.

Semiothisa spp. (3 species), Striped pine loopers - defoliators, solitary larvae that feed on jack pine but have not been known to cause serious damage.

Sparganothis sulfureana Clem. and *S. tristriata* Kft., Needletier - shoot tiers, larvae feed on new shoots, have caused serious injury occasionally to young plantation trees.

Tetralopha robustella Zell., Pine webworm - defoliator, frequently a problem in plantations with trees up to 1 metre in height killed.

***Toumeyella parvicornis* (Ckll.) (= *numismaticum* [P & M], Pine tortoise scale - sucks sap from shoots and twigs, severe infestations occur occasionally, young trees suffer greatest damage.

Trisetacus ehamanni Keifer, Jack pine needlesheath mite - little known but probably not an important pest.

Xyela minor Norton, Pine flower sawfly - larvae feed on male flowers of jack pine.

Zale spp., Pine false loopers - defoliators, perhaps as many as 8 species of this genus may feed on jack pine, not a serious problem.

Zelleria haimbachi Busck., Pine needle sheathminer - common pest of jack pine but of minor importance.

* Major importance
** Moderate importance
Those not marked are of minor importance

Such rankings (or ratings) reflect the history of the insect in Ontario in terms of damage that has been caused and, to some degree, in terms of the potential for causing damage in the future.

In addition, significant damage may be caused by pine grosbeaks to buds of plantation trees; by red squirrels to the twigs of cone-bearing trees; by rabbits, porcupines and sapsuckers to stems and trunks; and by mice to the root collars or stems of young, planted trees.

The most important insect problems of jack pine in Ontario are jack pine budworm, Swaine jack pine sawfly and adult feeding by sawyer beetles. These will be discussed in some detail in this paper. For further information on any of the insect pests listed, please refer to the references and suggested additional reading at the end of the paper or contact the Forest Insect and Disease Survey Unit, Great Lakes Forest Research Centre.

The jack pine budworm, a close relative of the spruce budworm (*Choristoneura fumiferana* [Clem.], is considered one of the most important defoliators of jack pine in central Canada and the Lake States and occurs throughout the southern range of jack pine in Canada from the Atlantic provinces to Alberta. Sizeable infestations have occurred frequently in one part of Ontario or another since the early 1930s. Interspersed among the short-lived infestations were two particularly destructive outbreaks that occurred over much of northwestern Ontario between 1936 and 1943 and around Midhurst and St. Williams in southern Ontario between 1940 and 1942. Another severe outbreak occurred between 1966 and 1973 when heavy infestations damaged jack pine stands in northwestern and central Ontario. A maximum area of about 2.3 million ha was moderately to severely defoliated in 1967. Considerable tree mortality occurred in Kenora, Dryden, Sudbury, North Bay, Parry Sound, Pembroke and Algonquin districts. Spraying operations totalling almost 6,000 ha were conducted by OMNR in 1968, 1969 and 1972 for the purpose of protecting high-value areas such as provincial parks, plantations and stands of high-quality timber. The Canadian Forces Base at Petawawa and pine plantations at the Petawawa National Forestry Institute were sprayed by the Canadian Forestry Service in cooperation with OMNR in 1969. Fenitrothion was used in 1968 and 1969 and Zectran in 1972. The 1968-1972 Ontario control projects are described by Sippell and Howse in Prebble (1975).

Jack pine budworm populations were generally low from 1974 to 1981 except for an upsurge in the Kenora area in 1979 which subsided quickly. In 1982 population increases became evident in the Georgian Bay area where several infestations totalling 1,000 ha were mapped in the Owen Sound, Huronia and Parry Sound districts. In 1983, moderate-to-severe defoliation totalling 67,000 ha was mapped in Atikokan, Blind River, Espanola, and Parry Sound districts. In addition, population buildups were reported from Terrace Bay, Wawa, Hearst, Chapleau, Kirkland Lake, Temagami, Timmins, Maple and Lindsay districts.

Jack pine is the principal host tree but red pine (*Pinus resinosa* Ait.), Scots pine (*P. sylvestris* L.) and eastern white pine (*P. strobus* L.) are also damaged. This univoltine insect overwinters as a small second-instar larva under bark scales or in other protected locations on twigs and branches and becomes active, usually in the latter part of May, feeding in male flowers if these are available or on the developing foliage of the new shoot. Larvae feed for about 6 weeks and, in early or mid-July when they are fully grown, they pupate in the feeding sites. Moths emerge in a week or so, in late July or early August, and after mating they deposit eggs on needles in clusters of about 40. Hatching occurs in about 10 days. A few days later the tiny larvae, without feeding, spin overwintering silken shelters (hibernaculae) under bark scales, moult to second instar and prepare to overwinter.

The larvae feed mainly on new growth. They prefer male flower clusters but consume new foliage readily. Often new shoot development is well advanced before substantial feeding occurs. The larvae are wasteful feeders in that they sever needles from the shoot but seldom consume them entirely. They form feeding shelters along the axis of the shoots within a loose webbing, tying needles and adjacent shoots together. The feeding debris and frass remain caught in the webbing and, as this material accumulates, it imparts a distinctive reddish appearance to attacked trees that is detected readily by aerial surveys. If severe attack is repeated for two consecutive years or more, trees will die; however, top-killing, crooked or multiple leaders, and reduction in increment are more common. In 1971, fully stocked stands of pole-sized jack pine, on generally good sites near Lake Traverse, Algonquin Park District, suffered 25% mortality and 30% top kill following light defoliation in 1967 and moderate-to-severe defoliation in 1968 and 1969. The infestation collapsed in 1970. Some 115,000 cubic metres of timber were salvaged in 1971-1972. More severe damage can occur in low-density stands of large-crowned, flowering trees or in intermediate or suppressed trees of low vigor.

The population dynamics of jack pine budworm are not well understood. Outbreaks usually last only two to four years. Population buildups can occur on a widespread or local basis rather suddenly and appear to be related to the occurrence and abundance of male flowers on mature trees. The removal of old "orchard-type" heavily flowering trees as well as susceptible intermediate or suppressed trees has been recommended as a preventive measure to inhibit population buildup and improve the quality of residual stands. How practicable this is in terms of the vast areas of jack pine in Ontario is questionable. During outbreaks, new infestations have appeared 80 km or more from the nearest known infestation source, probably as a result of mass flights of moths. Outbreaks usually collapse suddenly. Population declines have been attributed to parasites, a virus disease and decreases in male flower production.

If it becomes necessary to prevent tree mortality or to minimize defoliation the only practicable means of direct control is the application of insecticides. However, choice of material is limited in that fenitrothion appears to be the only registered insecticide that can be applied aerially against jack pine budworm. Undoubtedly, materials such as *Bacillus thuringiensis (B.t.)*, acephate (Orthene), aminocarb (Matacil), dimethoate (Cygon) and carbaryl (Sevin-4-oil) would be effective but such materials can be used only under experimental permit.

The Swaine jack pine sawfly is one of many sawflies attacking and damaging jack pine in Ontario. It is probably the most economically important sawfly threatening jack pine in eastern Canada and during the past 30 years has killed large areas of merchantable timber between the 46th and 49th parallels, mostly in Quebec but also in northeastern Ontario. In Ontario, infestations of the sawfly have occurred periodically and have been centred in a number of apparently highly susceptible stands which, in many cases, are on rocky lakeshores and islands. This insect also represents a threat to plantations, particularly those in close proximity to infested mature stands.

The insect is present throughout the range of jack pine in Ontario but, over the years, the most persistent infestations have occurred in two widely separated areas: 1) the adjoining forest districts of Temagami, Kirkland Lake, Gogama, Chapleau, Sudbury, North Bay and Parry Sound, and 2) in northwestern Ontario, east of Lake of the Woods in Fort Frances, Kenora, Dryden and Atikokan districts. Over the years, infestations have been more widespread, persistent and damaging in northeastern Ontario then in the northwest. Outbreaks of this sawfly were not well documented prior to the 1940s; however, it is believed that an outbreak occurred in the vicinity of Biscotasing, Chapleau and Gogama districts in the late 1920s, collapsing in 1931. Sporadic infestations have been recorded in the Lady Evelyn Lake area, Temagami District since the early 1940s. Limited salvage cutting was carried out in accessible semimature and mature stands from time to time during the 1970s. In recent years, infestations have centred around Banks and Makobe lakes in Banks and Wallis townships and around Big Boot Lake in Van Nostrand and Klock townships. These infestations, which totalled about 775 ha in 1980, expanded to nearly 5,700 ha in 1981 and declined to 4,650 ha in 1982. Harvest or salvage operations have continued for the past four years. Recently completed surveys show that approximately 518 ha were infested in 1983 as populations declined throughout the area. In any event, this situation has been of concern to OMNR because of the threat posed to some 23,500 ha of jack pine working group to the north of the Banks-Makobe lakes infestation, which represents the future wood supply for the Elk Lake Management Unit, Kirkland Lake District, and to some 3,000 ha of jack pine plantations in the vicinity of the infestation.

This sawfly has a one-year life cycle. The adult sawflies emerge in late June and early July. Eggs are deposited in dense clusters, usually one egg per needle, occasionally two or three. Jack pine is the only tree species known to be suitable for oviposition by *N. swainei*. Each female deposits her total complement of about 60-65 eggs in the needles of a single new jack pine shoot. Eggs hatch in about a month and the young larvae feed in colonies on old foliage. Older larvae may move out to and feed on the foliage of the current year. Larvae may be found feeding from July to October but generally in September larvae moult to the last non-feeding larval stage and drop to the ground and spin cocoons in the soil beneath the tree, wherein they pass the winter. Development within the cocoon is resumed in mid-May, pupation occurs in June, following which the adults emerge, and the cycle is repeated.

Young larvae feed only on the outside edges of needles of foliage other than that of the current year. Older larvae consume needles completely. Since the adults prefer to oviposit on foliage exposed to direct sunlight, feeding injury is more prevalent in the upper crown. This results in top killing in stands where moderate-to-light infestations persist for several years. However, when populations are high enough to consume the available food supply, the larvae will feed on new as well as old foliage, and completely defoliated trees will die within a year or so. More typically, however, tree mortality occurs after 3 or 4 years of partial (moderate-to-severe) defoliation. Trees that survive the immediate period of defoliation may die in the 3 or 4 years following collapse of the infestation or may remain stagheaded for several years.

Important natural control factors are parasites, predators including insects, birds and small mammals, low temperatures during larval development and a polyhedrosis virus disease. Control of this insect, at least in northeastern Ontario, may be accomplished (to some extent) by cutting highly susceptible stands that support chronic infestations. Unfortunately, the most susceptible stands seem to involve shoreline reserves where cutting is restricted. Salvaging damaged timber is another option that should be practised whenever possible. Severe outbreaks in Quebec in the 1960s prompted experimental trials in 1960 and 1964 with a nuclear polyhedrosis virus. Because of doubts about the efficacy of virus applications over large areas, operational chemical control projects with phosphamidon and fenitrothion were conducted in 1965 (60,700 ha sprayed), 1967 (36,420 ha) and 1972 (7,120 ha) to prevent serious defoliation or timber mortality in selected areas. The chemical control operations were considered quite successful and produced a recommendation that fenitrothion be used at 153 g or less per ha for future operations against this insect. Any currently acceptable stomach or contact insecticide which includes fenitrothion, acephate, aminocarb, dimethoate, malathion or carbaryl should prove effective; however, fenitrothion is the only material registered for use against this pest.

Sawyer beetles are generally considered secondary insects in the forest in that they attack dying or recently dead trees, although fresh-cut logs left in the bush or in storage for a year can be seriously damaged or degraded if not protected. However, in recent years, an unusual but primary type of damage became evident across northern Ontario. High populations of the whitespotted sawyer beetle, *Monochamus scutellatus* (Say), caused severe tree mortality as the result of maturation feeding by adult beetles on the bark of twigs and branches of jack pine and black spruce. This damage was first noticed in 1977 at a number of locations in the Northwestern, North Central and Northern regions. It continued to worsen until 1981 when the severity and extent of damage started to decline. About 200 ha of forest were affected in 1980. This figure declined to 135 ha in 1981 and to about 25 ha in 1982.

Adults are usually in flight by late June and through July and August. Eggs are deposited in slits cut in the bark of dying, recently dead or cut trees. The young larvae, on hatching, proceed to the wood surface where feeding takes place in shallow tunnels. Normally, two years are required for development from egg to adult stage in northern Ontario; however, recent evidence obtained by FIDS staff indicates that development can be completed in 14 months or less if the host is fire-killed jack pine timber. Otherwise, late in the first summer, the larvae tunnel deep into the wood where they overwinter. Larvae continue tunnelling in the wood the following spring, then pupate and emerge. Some larvae are delayed and do not emerge for another year. Hence, life cycles of one, two and three years are possible.

High populations of beetles may be due to one or more of the following causes of tree mortality: fire, drought, spruce budworm or poor timber-harvesting practices. If one or more of the preceding factors is present to a greater degree than usual, then the increased host material could result in increased beetle populations. It is probably not a coincidence that tree mortality resulting from fires and spruce budworm has increased greatly throughout northern Ontario in the last 10 years but this is not the entire explanation. Generally, adult feeding is associated with cutting operations. Slash and cutting residue, stumps and decked logs are sources of attraction to flying adults. The adults first feed on healthy fringe or open residual trees and then breed on recently cut material. Hence, the heaviest damage has been observed along the edges of recent clearcuts, in groups of seed trees left in clearcuts, or in residual blocks of timber left in checkerboard-pattern harvested areas.

Preventing this type of damage would seem virtually impossible. On the one hand, it cannot be predicted which stands will be attacked, and those that are attacked and damaged heavily are only a small proportion of the trees susceptible to damage. On the other hand, removing all sources of attraction does not seem feasible in view of the extent of tree harvesting and the lack of incentive for companies to sanitize their operations after cutting. If we could predict which stands would be attacked or could react quickly enough to the presence of high populations of adult beetles in a particular location, trees could perhaps be protected by thorough ground spraying of tree crowns with an insecticide such as lindane. Aerial application would not likely be effective unless a drenching device could be attached to a helicopter. Alternative control methods might be developed by utilizing the beetle pheromone or the attractive odors (pinenes) emitted from fresh-cut trees.

In recent years, the FIDS field program has included surveys to obtain baseline data on various insect pests and diseases affecting plantations or young natural stands of the major tree species under regeneration in Ontario. Jack pine plantations throughout northern Ontario were examined in 1979 and 1982; 55 and 54 plantations, respectively, were examined each year. The eastern pine shoot borer was the most frequently detected insect in 1982, occurring in 39% of the stands examined (in comparison with 36% in 1979). Overall damage was minor, with an average of 1.0% of leaders infested (2% in 1979). The highest incidence was 9% in Timmins District. Trees under 6 m seem to be preferred. White pine weevil was found affecting 35% of the plantations, but only .7% of the leaders were killed. The highest incidence of weevilling was 11% in Gogama District. Most of the damage occurred on trees less than 6 m in height. Again, this is very similar to the situation in 1979. Jack pine tip beetle was found in 28% of the plantations; the average incidence of damaged leaders was .6% (.2% in 1979), and the highest incidence was 11% in a Thunder Bay District plantation. The insect prefers trees under 2 m in height although it will attack trees between 2 and 6 m. The northern pitch twig moth was found in 22% of the plantations but damage was not significant. Other insects found were jack pine sawfly *(Neodiprion pratti banksianae* Roh.) and jack pine budworm. Populations were low and damage was negligible. A number of diseases were detected during the course of the survey; however, on the basis of the levels of disease detected, it was concluded that most jack pine plantations in northern Ontario are healthy and do not have serious disease problems at the present time. In conclusion, a variety of damaging insects and diseases were active in the jack pine stands examined in 1982 but damage and pest levels were generally low and comparable to those of 1979.

In a continuing program to assess pest problems associated with seed production, a special survey of jack pine cones was made by the FIDS Unit in 1982 to determine the extent and causes of damage. One hundred cones were collected from nine locations in northern Ontario: two in each of the Northwestern, North Central and Northeastern regions and three in the Northern Region. Green succulent cones close to full size in the second year of development were obtained. Where possible, the collections came from seed production areas or tree seed orchards. The proportion of damaged cones averaged 26% for the nine locations and ranged from 6 to 41%. Seed losses within damaged cones ranged from 9 to 90%. Over all, seed losses were only 6%. The highest losses occurred in the Northern Region where a high proportion of damaged cones was coupled with a highly significant reduction in seed numbers. For various reasons, many of the causes of cone damage could not be identified; however, the webbing coneworm *(Dioryctria disclusa* Heinr.) and other, undetermined, species of lepidoptera were the major causes of seed reduction and cone damage. Generally, however, jack pine seed production in northern Ontario was not seriously affected by pest problems in 1982.

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JACK PINE DISEASES IN ONTARIO

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Abstract.--*Jack pine* (Pinus banksiana *Lamb.) is a relatively hardy species and although it has many disease enemies, none alone has been widespread or serious. The pathology of jack pine in Ontario is characterized by local damage and losses due primarily to decay caused by* Phellinus pini *(Thore ex Fr.) Pilat (=* Fomes pini *[Fr.] Karst.) and cankers caused by Scleroderris canker* (Gremmeniella abietina *[Lagerb.] Morelet) and the sweetfern blister rust* (Cronartium comptoniae *Arth.). Life cycle, symptoms, damage and controls for the latter two diseases are presented as well as a brief account of other diseases on jack pine in Ontario.*

Résumé.--*Le pin gris* (Pinus banksiana *Lamb.) est une espèce relativement rustique, et si elle est sujette à de nombreuses maladies, aucune n'a été particulièrement répandue ou grave. Du point de vue des maladies, le pin gris en Ontario se caractérise par des dommages et des pertes localisés attribuables principalement à la carie causée par* Phellinus pini *(Thore ex Fr.) Pilat (=* Fomes pini *[Fr.] Karst.) et à des chancres causés par* Gremmeniella abietina *(Lagerb.) Morelet (chancre scléroderrien) et* Cronartium comptoniae *Arth. (rouille-tumeur). Le cycle évolutif, les symptômes, les dommages et les mesures curatives pour les deux dernières maladies sont présentées, ainsi qu'une brève description d'autres maladies frappant ce pin en Ontario.*

Introduction

Jack pine (*Pinus banksiana* Lamb.), a species widely distributed throughout northern Ontario, thrives on light sandy soils. The species is almost transcontinental and it extends the farthest north of all the North American pines. Jack pine, in comparison with other coniferous forest tree species, is rather short-lived, and of small-to-medium size. Its importance in Ontario can be appreciated by comparing jack pine harvest data with those for white spruce (*Picea glauca* [Moench] Voss) and black spruce (*Picea mariana* [Mill.] B.S.P.) (Table 1). These three species typically make up about 85% of the Ontario harvest, and in 1981, the stumpage revenue generated by jack pine alone was $14.1 million. Jack pine is also one of the more important tree species planted in Ontario (Table 2).

Table 1. Timber harvested on Crown land by species (m^3) (Anon. 1982).

Species	1980	1981	1982
Spruce	8,222,273	8,029,356	7,724,772
Jack pine	5,733,806	5,475,573	5,362,713

Table 2. Tree production by species ('000,000 seedlings) (Anon. 1982).

Species	1980	1981	1982
White spruce	16.7	14.4	16.4
Black spruce	11.8	17.4	17.2
Jack pine	18.8	19.1	25.8

Jack pine is a hardy species that resists the impact of weather and, although it has many enemies, none alone has been widespread or serious. The pathology of jack pine is characterized by local damage and losses due to seedling damping-off, gall rusts, needle rust and needle cast, cankers and root rots.

In Ontario, losses have been noted most frequently from wood decay caused by *Phellinus pini* [Thore ex Fr.] Pilat (= *Fomes pini* [Fr.] Karst.), Scleroderris canker *(Gremmeniella abietina* [Lagerb.] Morelet), and sweetfern blister rust *(Cronartium comptoniae* Arth.). Wood-decay fungi have caused approximately 1 million m^3 of cull loss annually and most of this was white pocket rot caused principally by *F. pini* (Basham and Morowski 1964). The percentage cull caused by wood decay fungi was greatest in overmature stands. Stands less than 60 years of age had less than 1.0% rot defect (Basham 1967). Consequently, increased utilization of jack pine managed on a rotation age of less than 60 years will result in considerably less impact by decay fungi.

Sweetfern Blister Rust *(Cronartium comptoniae* Arth.)

The large, resinous basal cankers commonly found on jack pine are symptoms of the sweetfern blister rust disease. The disease is characterized by two herbaceous hosts, sweetfern *(Comptoniae peregrina* [L.] Coult.) and sweet gale *(Myrica gale* L.). Ecological studies (Gross 1976) indicate that the abundance of sweetfern and the rust is favored by coarse-textured soils and low levels of phosphorus in the soil. Sweetfern is highly adapted to dry sites and both jack pine and sweetfern regenerate well after fires. Survey data (Sippell et al. 1976) indicate that, geographically, sweetfern is not common west of 85°W latitude to a latitude of 91°W, but it occurs thereafter in Rainy River and Fort Frances districts. About half of the jack pine stands within the geographical range of sweetfern do not contain sweetfern. Many of these stands show an ecological trend to increased spruce *(Picea* spp.) and fir *(Abies* spp.) content based on the presence of spruce and fir regeneration. Sweet gale, on the other hand, occurs throughout the range of jack pine in Ontario on wet sites, and does not seem to be as important in spreading the rust (Gross 1976).

The fungus that causes sweetfern blister rust is a typical heteroecious rust with five spore stages. Cankers on jack pine are most prominent in June and July when orange spore-producing fructifications called aecia are present on the blisterlike growths on the cankers. Aeciospores infect sweetfern or sweet gale foliage and soon the uredial and telial spore stages appear on the undersurface of infected leaves. Teliospores produced by the telia germinate to produce the basidiospores that infect pines in July and August. Urediospores infect sweetfern and sweet gale, increasing the potential for teliospore production. A pycnidial stage occurs on pines in the spring just before the production of aecia.

Infection of pine by the rust stimulates blisterlike overgrowths of the wood and bark, and deep fissures often form in the wood, where cankered tissue dies or is eaten by rodents. Cankered tree portions are commercially unacceptable because they are distorted, have a high resin content, and are often decayed. This type of cull loss averages about 11% of the merchantable cubic volume per cankered tree (Gross et al. 1978). Cankered trees also experience a reduction of about 20% in cubic volume growth (ibid.). Seedling and juvenile pines are often killed by the disease but, as trees age, a tolerance to the presence of cankers seems to develop, and mortality then is largely a function of suppression.

A survey (Sippell et al. 1976) showed that 6.5% of the jack pine were cankered within the geographical range of sweetfern. Elsewhere, where only sweet gale occurs, 1.0% were cankered. This translates to about 0.7% cull loss and 1.3% growth loss for all jack pine within the range of sweetfern, and negligible losses elsewhere. For all of Ontario a loss of 30,000 m^3 seems a conservative estimate. This loss, however, is concentrated in the Northeastern and Northern regions, and in heavily infected stands, losses can be severe.

Most pines are infected by the rust in the first years of growth. Anderson et al. (1967) showed that first-year seedlings (9 weeks old) were much more susceptible to infection than pines in the second and third years of growth. In Macklen Township near Timmins, Ontario, the impact of sweetfern blister rust in a young jack pine stand was followed from tree age 4 to 15 years (Gross, unpublished). No new infections were observed during the study, and if cankered parts were carefully dissected, the pattern of distorted wood usually indicated that trees were infected near the ground line in the initial year of growth.

The impact of sweetfern blister rust as a killer of young trees is probably more important than growth losses and cull defect in older trees. Anderson et al. (1967) outplanted infected 2-year-old jack pines. After 6 years, 68% were dead and most of the mortality occurred in the third and fourth years of growth. In the Macklen Township study (Gross, unpublished) pines affected by sweetfern blister rust averaged 5.6% mortality annually from the start of the study in the fourth year through the tenth year of growth, after which mortality averaged 1.5% and most trees that died were suppressed. The mortality rate for unaffected pines was consistently about one-fifth the rate for affected pine. Armillaria root rot was present on over 90% of the pines that died and were not affected by the rust. Armillaria root rot was also present on about 12% of the rust-affected trees that died. This percentage was significantly higher than expected, and indicates that the rust favors pines and makes them vulnerable to root rot attack.

These studies show that about 70-80% of jack pine infected by rust die within 10 years. Interpreting the impact of this mortality is difficult. Certainly, poorly stocked stands have suffered mortality caused by rust if more than 20% of the remaining trees are cankered. Many of these situations have been encountered but accurate impact analysis of disease-caused mortality requires information about desired tree density, rotation age, and other management considerations. Plantations are established to desired density standards, and in these, mortality caused by disease reduces density and therefore has an impact. Also, the stand openings occupied by sweetfern that are common in many jack pine stands are at least partly the result of mortality caused by sweetfern blister rust. In young stands, cankered pines are concentrated in and near patches of sweetfern, and in older stands, patches of sweetfern consistently have a lower jack pine density than surrounding areas devoid of sweetfern (Gross et al. 1980). Hence, disease-caused mortality has an obvious impact.

Complete control of the sweetfern blister rust disease does not seem practicable; however, there are several control measures that can be employed and programs for the breeding of disease resistance provide some hope for the future. First, trees appear to have some resistance to infection after the first year. High-hazard sites with dense sweetfern populations should be planted with stock at least 2 years old. The currently produced container stock does not meet this criterion. Second, where natural regeneration is expected, managers should consider planting additional trees in and near patches of sweetfern as there is a good chance that these areas will be poorly stocked. Beyond a distance of 12 m from sweetfern patches, infection hazard seems to be low (Gross et al. 1980). Third, infection-free nursery stock is desirable. Sweetfern and cankered jack pine are common adjacent to several Ontario nurseries. For several years routine inspections of jack pine seedlings were made at Swastika nursery and no evidence of rust infection was found. Nursery personnel are continuing the inspections. The reasons for the negligible amount of rust infection are not clear; however, vigilance should be maintained in nurseries. Finally, discrimination against sweetfern vegetation, especially around nurseries, should be enforced. Skid roads and landings are rapidly colonized by sweetfern and alternative vegetation should be encouraged in such areas.

Scleroderris canker (*Gremmeniella abietina* [Lagerb.] Morelet)

The fungus now commonly referred to in North America as *Gremmeniella abietina* was discovered and first described in Europe by Karsten in 1884. Working with the imperfect or conidial stage, Karsten proposed the name *Septoria (Rhabdopora) pinea*. Brunchorst described the same fungal stage more fully in 1888 (Roll-Hansen 1973). Although plantations throughout the Great Lakes area of Ontario had been exhibiting symptoms throughout the 1950s, the causal fungus was not identified in North America until 1962 (Skilling and Cordell 1966). The fungus was named *Scleroderris lagerbergii* Gremmen. Although several scientific names have been proposed and adopted for varying lengths of time, *Gremmeniella abietina* (Lagerb.) Morelet is the most widely accepted name at present. The accepted common name in North America is Scleroderris canker; however, there are still frequent literature references to *Brunchorstia pinea* in Europe and to *Scleroderris lagerbergii* in Europe and North America.

More recently, three physiological races of *G. abietina* have been recognized--the European, North American and Asian (Dorworth and Krywienczyk 1975). The Asian race has not yet been reported in North America but the European race has been found in several states in the United States including New York, New Hampshire and Vermont. However, it has not been found in plantations or natural stands in Ontario and is therefore not discussed further in this paper.

The North American race of Scleroderris canker first appeared in the Great Lakes region some 40-45 years ago (Skilling 1978). By 1967, Scleroderris canker was widely spread in Ontario, largely as a result of shipping and planting infected nursery stock (Punter 1967). In some cases, mortality in exposed red pine (*Pinus resinosa* Ait.) plantations reached 92% (Dorworth 1971). The fungus (*G. abietina*) now appears to cause an indigenous disease in Ontario (Dorworth 1972, 1976).

The Canadian range of the North American race of Scleroderris canker now includes Alberta, British Columbia, Ontario, Quebec, New Brunswick, Nova Scotia and Newfoundland. Infestations in the United States occur in Maine, New York, Michigan, Wisconsin and Minnesota.

The first disease symptom, a red discoloration at the needle bases, usually appears in the spring of the year following infection of pine meristems. During the summer, all the infected needles turn yellow-brown and are usually shed by autumn. Throughout the balance of the second year after infection and into the third, the fungus can develop in the branches and into the mainstem; a canker then begins to form.

The cankers are characterized by a greenish stain in the sapwood and cambial region. Seedlings are often killed as the canker develops and girdles the stem. The fungus usually advances in older trees at a rate of one internode a year and cankers 0.5 m or more in length are common. Infection rarely occurs more than 2 m above the ground so that trees greater than 2 m in height usually survive the disease.

Two fruiting stages are produced by the North American race of *G. abietina:* the sexual or apothecial stage and the asexual or pycnidial stage. The apothecia are common on dead branches in the spring and the pycnidia can be found throughout the year.

Scleroderris canker is commonly found in "infection pockets". Individual infected trees harbor the disease, which spreads radially to adjacent trees. In naturally regenerated areas, Scleroderris canker has very little effect and need not be considered as an economically important pathogen on jack pine (Dorworth and Davis 1982). Although infection occurs over a wide geographic area, extensive mortality is evident only in the infection centres. However, as with red pine, the effect of Scleroderris canker is often more serious in topographic depressions than on well drained uplands. In forest plantations, the trees are not seriously affected by Scleroderris canker regardless of the number infected once they reach a height of 4 to 5 m (Dorworth and Davis 1982). However, the disease can cause mortality and damage to young jack pine stock, particularly if large numbers of infected seedlings are shipped from the nursery.

Silvicultural practices are probably the best means of Scleroderris control. *G. abietina* is generally considered a weak fungal parasite and, as such, successfully attacks trees of low vigor. Although jack pine is more resistant to infection than red pine, care should be taken to ensure that it is planted on good sites. Jack pine should not be planted outside of its natural range. Frost pockets and large flat areas with poor air drainage should be avoided. On susceptible sites, pruning of the lower branches of red pine has been practised, but once the trees have reached a height of 2 m, there is little need to continue this practice (Dorworth 1976). There is no evidence to suggest that pruning of the lower branches in jack pine is beneficial.

In the nursery, seedlings should be handled with care to prevent damage that may predispose them to infection. Diseased stock must be identified and destroyed before it leaves the nursery. One infected seedling in a bundle of 25 can result in 100% of the trees being infected at the planting site. Low branches on susceptible trees in and around the nursery should be pruned and destroyed to help reduce the potential for disease spread. Fungicides should be used regularly to prevent outbreaks of the disease in the nursery. Chlorothalonil, the active ingredient in Daconil 2787 and Bravo 500, is currently recommended in Ontario.

Jack pine has some genetic variability and Scleroderris-resistant provenances have been identified (Teich 1967). However, the transfer of genetic disease resistance to other jack pine populations requires further study to determine if it is possible (Teich and Smerlis 1969).

Other Common Diseases of Jack Pine

Armillaria root rot *(Armillaria mellea* [Vahl. ex Fr.] Kumm.) frequently kills jack pine in seedling and juvenile stands. Data from several surveys of plantations indicate that Armillaria is frequently present in young stands but usually less than 1.0% of the trees are affected. When mortality greater than this is encountered, other factors such as poor planting procedure, adverse site conditions, or unfavorable climate are usually implicated.

Fomes root rot *(Heterobasidion annosum* [Fr.] Bref.) (= *Fomes annosus* [Fr.] Karst.) also affects jack pine, but this problem is confined to southern Ontario where jack pine is less common. Cankers are caused mainly by Scleroderris and several stem rusts including sweetfern blister rust, comandra rust *(Cronartium comandrae* Pk.) and stalactiform rust *(Cronartium coleosporioides* Arth.). All influence the tree by causing reduced growth and volume, but sweetfern blister rust is much more common than the others.

Globose gall rust *(Endocronartium harknessii* [J.P. Moore] Y. Hirat.) and oak gall rust *(Cronartium quercuum* [Berk.] Miy. ex Shirai) cause round stem galls on young pines and branch galls on pines of all ages. Data from western Ontario (Gross 1983) indicate that there is no growth loss or cull defect associated with the presence of galls caused by *E. harknessii* even in instances in which trees have galls on virtually every branch. However, the gall rusts and stem rusts all cause mortality of seedling-sized pines, and instances of 5% mortality have occurred in Ontario (Howse et al. 1981).

The most common foliar diseases are needle rust *(Coleosporium asterum* [Diet.] Syd.), needle cast *(Davisomycella ampla* [Davis] Darker) and Diplodia tip blight *(Sphaeropsis sapines* [Fr.] Dyko and Sutt.). Infected needles are shed in the year following infection for both needle rust and needle cast; hence, some foliage is always present and these problems do not appear to cause tree mortality. Growth loss may also be negligible as data (Gross, unpublished) obtained over a 3-year period for one juvenile stand showed no observable growth loss over a range in intensity of defoliation caused by needle rust. Diplodia tip blight can be an important disease of jack pine, but in Ontario, generally only scattered shoot mortality is observed.

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VARIABLE-DENSITY GROWTH AND YIELD OF MANAGED JACK PINE PLANTATIONS

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Abstract.--Permanent sample plots and stem analysis information have been used to compare jack pine (Pinus banksiana *Lamb.) in plantations and natural stands.*

The growth and yield potential for northern plantations is indicated.

Basic data for managed and unmanaged plantations are presented in the form of variable-density growth and yield tables.

Résumé.--Des parcelles permanentes d'échantillonnage et des analyses de la tige ont servi à comparer le pin gris (Pinus banksiana *Lamb.) en plantations et en peuplements naturels.*

Le potentiel d'accroissement et de production pour les plantations du Nord est indiqué.

Des données élémentaires concernant les plantations aménagées et non aménagées sont présentées sous forme de tables d'accroissement et de production à densité variable.

Introduction

Jack pine *(Pinus banksiana* Lamb.) is known to reproduce quite readily under natural conditions. The last 20 years of management experience have shown that jack pine is also responsive to a variety of artificial regeneration techniques. The most extensive method used operationally so far in Ontario is planting of bare-root stock. In the last 4 years jack pine has been the most planted species in Ontario.[1]

Nevertheless, the data base for the growth and yield characteristics of plantation jack pine is still relatively small (Shea 1981). Mervart (1982) concluded that "[v]ery little data can be found which would help in comparing plantation yields to the yield from Ontario's natural forests".

To assist in filling this void, we will compare height growth and volume data from natural stands with permanent sample plot information from a 54-year-old jack pine plantation growing in Vespra Township. The plantation information was gathered over the years by the combined efforts of the Ontario Ministry of Natural Resources (OMNR) management and research staff. It is unique in Ontario primarily because it was collected over a 33-year period of tending. The plantation is now past the critical site index age of 50 years; consequently, the yield figures can be compared with those from natural stands of a similar site class. Since stem analysis data are also available, the early growth figures can be used as a basis of comparison

[1]Tiemann, H. 1983. Ont. Min. Nat. Resour., For. Resour. Br., Toronto, Ont. (pers. comm.)

for younger plantation performance in northern Ontario.

We also include yield response resulting from manipulation of stand density in the Vespra Township plantation. Although a degree of trepidation may be experienced when considering thinning in jack pine management, it is well to know what effect changes in density have upon stand growth. Since the efforts of site preparation and planting have already been proven acceptable, perhaps clearing, spacing or even thinning may become feasible in the future. Eventually, we might even need to use the thinning biomass which is at present lost as mortality. As we shall see, this is no small amount.

Growth of Natural Stands

In the context of the question of how to estimate yields for our new forests, let us briefly look at the available approaches. Although intended for natural stand application, the usual attempt is to use Plonski's (1974) normal yield tables. Average height/age is measured to obtain the appropriate site class. An estimate of stocking, usually in terms of basal area, is required to adjust the tabular yield figure.

Another approach is the use of variable-density growth and yield tables. Evert (1976) recognized the effect of initial stocking upon yield. On the basis of natural stand data from two pulp companies he presented yields for stands which had variable numbers of trees at age 30 years. While Evert's tables are given by production class, his height/age curves are very similar to Plonski's from 30 to 60 years.

The drawback in applying either of these approaches to our young northern plantations is that Evert's tables start at 30 years while Plonski's start at 20 years but, as with all tables, the number of observations at this age is small. We are left with the problem: "Where will the younger plantations fit into the available yield tables?"

A few years ago, forestry students at their fall camp tried an alternative method--stem analysis--to obtain early stand growth records. As Shea (1981) advocated, the growth potential of plantation jack pine may be indicated using stem analysis techniques to construct site-specific height/age curves for natural stands. Figure 1 gives two examples of such height/age curves for natural jack pine, one from each of Gross Township and Holmes Township, growing on deep sands near Swastika nursery in Kirkland Lake District. These are compared to Plonski's height/age

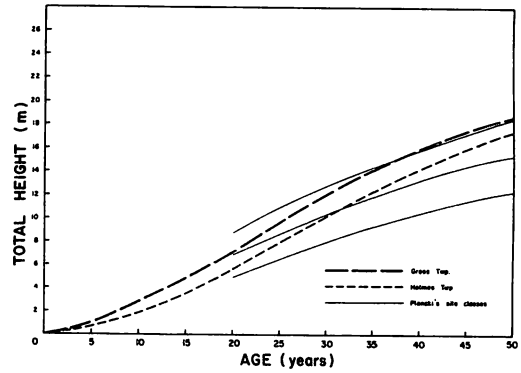

Figure 1. Comparison of natural jack pine height/age curves for Gross Twp and Holmes Twp with Plonski's (1974) curves.

relationship and show that, at 50 years, the Gross Township stand is an example of Site Class I while the Holmes Township stand falls between site classes I and II. At 20 years of age, however, both the curves are almost one site class lower in relation to Plonski's heights. This may indicate an over-estimation of heights of younger trees by Plonski.

A better appreciation of this difference in height at an early age can be gained when we plot annual height increment, rather than total height, over age. In Figure 2 the current annual increment (CAI) and mean annual increment (MAI) for the Gross Township stand are compared with Plonski's Site Class I values. The MAI curve for Gross Township rises more slowly and peaks about 10 years later than Plonski's (22-23 years). This indicates that Plonski's CAI has to be extremely rapid before this age. And, if the growth patterns were similar, the Gross Township stand should end up in Site Class II. However, since both height/age curves reach the same height at 50 years, it may be inferred that Plonski's start too high, at least in comparison with stands on this kind of site.

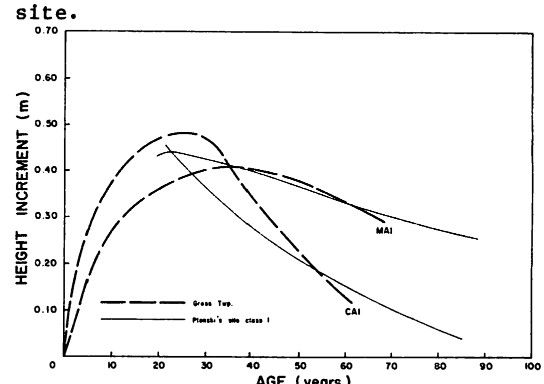

Figure 2. Comparison of Gross Twp annual height increment with Plonski's (1974) Site Class I values.

A more accurate comparison of the effect of early growth upon later site classification should be made between stands having similar growth patterns. Figure 3 represents two such stands which differ, as we have seen, by about half a site class. The Holmes Township stand curves peak lower and about 5-7 years later than those in Gross Township. It is clear that the rate of CAI in early years is most important in the determination of site class. This consequence of early growth rate must be emphasized because it is at this time in the life of a stand that management can have the most influence. In order to allow jack pine plantations to achieve the full potential of the site we must make sure that they are free to grow in the very early years after establishment.

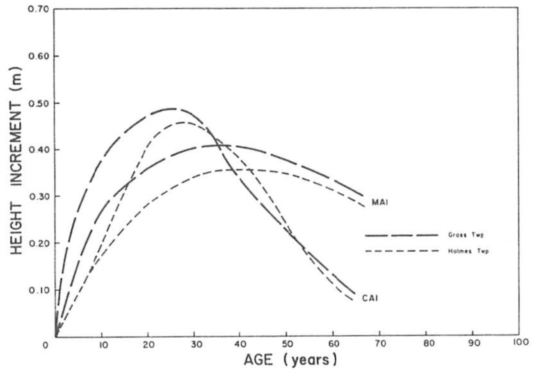

Figure 3. Comparison of annual height increments for Gross and Holmes townships.

Growth of Plantations

Using the same criterion, annual growth rates, let us look at plantation performance. Some of the oldest plantations in the Northern Region are provenance tests planted in 1955 by Carmichael (1962) in Cane Township, east of Elk Lake, on land which had been cleared for agriculture. We have height measurements at 16 (Skeates 1979) and 26 years of age, so MAIs are available at those points but no CAIs have been taken. On the other hand, a cooperative study of growth and yield in younger jack pine was started in 1979-1980 with the Kirkland Lake District. Twenty-seven permanent sample plots (PSPs) were established in Burt Township on another deep sand site. A stem analysis sample was completed after the 17th growing season in 1981, and the annual increments were plotted in Figure 4. The growth rates are considerably greater than those for the natural stands shown in Figure 3; however, the plantation is not old enough yet that we can be sure it will follow the same growth pattern. Therefore, Figure 4 also includes the only other available data of an older plantation from Hendrie Forest, Vespra Township in Huronia District. These height growth data came from a stem analysis which was carried out in the fall of 1981 and checked against total stand heights measured on PSPs periodically since 1947. Figure 5 illustrates this stand which is growing well although it was planted south of the normal range for jack pine. It has few diseases, except typical stem and branch galls, and few pests besides the occasional porcupine. The CAI and MAI curves in Figure 4 show very similar rates of growth in Vespra and Burt townships. The northern plantation peaked slightly later and at a slightly lower point than the southern one. This encourages the prediction that the northern jack pine will perform very much the same as the Vespra Township stand.

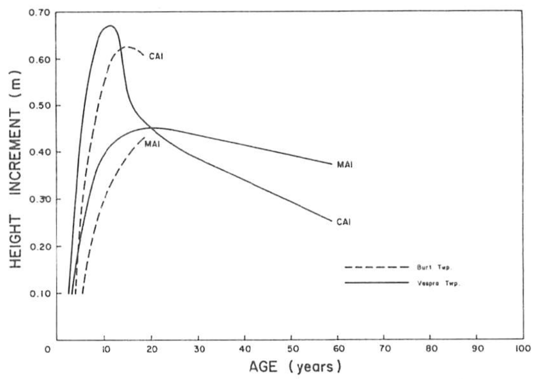

Figure 4. Annual height increment/age for plantation jack pine in Burt and Vespra townships.

Figure 5. General view of jack pine plantation at Vespra Twp. (Photograph taken in 1979 by G. Stroempl.)

If this is so, we can compare the plantation height/age curves with those of natural stands as in Figure 6. While the curves are a little different in shape, it is apparent that the Vespra Township plantation has developed into a stand at least half a site class better than the typical Site Class I stand in Gross Township. Therefore, we could expect the Burt Township plantation to do better than Site Class I by 50 years of age. The significance of this possibility lies in the fact that the original jack pine stand where the Burt Township plantation is now growing was classified as Site Class II. There appears to be potential for northern plantations to do better than natural stands by a whole site class.

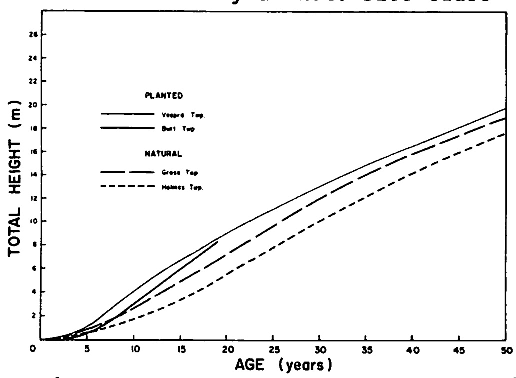

Figure 6. Comparison of total height/age curves for planted and natural jack pine.

Future Yield of Plantation

Thus far we have considered height mainly as an indicator of potential volume yield. While height is a primary component of volume, density of stocking is the most important variable affecting yield. We can, therefore, compare the number of trees/ha standing in the two plantations under consideration. At 16 years from planting the Burt Township plots averaged 2,586 live stems/ha while at 23 years from planting the Vespra Township plots contained a very similar 2,785 stems/ha.

Survival was more uniform at Vespra Township with little mortality between establishment and 23 years of age. Spacing was not as regular in the northern plantation following barrel scarification and there has been natural ingrowth as well as considerable girdling of smaller stems by hares. The range in number of trees/ha was 1,860-3,280 at Burt Township and 2,420-3,180 at Vespra Township. These differences in initial density should not affect the total volume production but, if the stands are left untouched, they will affect the amount of mortality and average stand diameter.

Since the 12 Vespra plots were thinned to different levels, additional information on the results of density control has been obtained which should be applicable to northern plantations. The first thinnings, in 1948 at 23 years from planting, were to a range of residual basal areas from 13.8 m^2 to 25.3 m^2/ha. Remeasurements and thinnings have been made at 5-year intervals since then. The resulting growth and yield information has been summarized in equation form in Table 1, one equation each for stand height (HT), basal area (BA) and gross total volume (GTV). Since the estimates of basal area were from an integrated form of the regression equation, no R^2 and SEE values are given, but Freese's test of accuracy (Rennie and Wiant 1978) has been applied and the results are shown. This test states that unless a 1-in-20 chance has occurred, the estimated values of basal area will be within 5.1% of the true value. The volume estimates are biased higher than observed data for unthinned situations and lower for thinned stands but since the standard errors were reasonable, the data from all levels of thinning, including control plots, were used.

The tables in the Appendix relate to stands of only one site class. The site index is given at the top left corner of the tables (20.7 m at 50 years). Stand age at 5-year intervals and stand height information are given at the top of each table. A range of present BA and corresponding GTV is listed on the left of the table and a range of thinning percentages is listed across the top. The body of the table gives 5-year growth and yield (either BA or GTV) following thinning, if any.

One example of how the tables might be used is outlined in Table 2. Starting with a 20-year-old jack pine plantation, two management options and the resulting changes in stand yield are given. In the first case, no thinning is done while the second option is to thin every 4th row at 20 years and to remove the middle row of the remaining three at 30 years. Three results should be noted:

1) The GTV produced by age 35 years is very much the same in both cases and would probably become identical if the simulation procedure were followed for one or two more growth periods.

2) The two thinnings in option 2 would be commercially productive (55 m^3/ha) and would return some revenue earlier than with option 1.

Table 1. Height, basal area and volume equations developed from jack pine plantation data in Vespra Twp.

Height Equation:

$$HT = B_1 (S) ((A/50) - (A^2/50^2)) + (S) (A)/50$$

(a) Metric $B_1 = 0.1010$ $R^2 = 0.9870$ SEE = 0.1374

(b) English $B_1 = 0.3313$ $R^2 = 0.9870$ SEE = 0.4507

where HT = dominant stand height (m or ft)

A = stand age (years)

S = site index (m or ft at 50 years)

B_1 = coefficient

Basal Area Equation:

$$BA_f = \sqrt{B_1(A_f-A_n) - B_2(A_f^4-A_n^4) - B_3(\ln(A_f)-\ln(A_n)) + BA_n^2}$$

(a) Metric $B_1 = 70.9972$ $B_2 = 0.00006204$ $B_3 = 1025.36$
% Error = 5.1[a]

(b) English $B_1 = 1347.1824$ $B_2 = 0.001177$ $B_3 = 19457.52$
% Error = 5.1[a]

where BA_f = future stand basal area (m^2/ha or ft^2/ac)

BA_n = present stand basal area (m^2/ha or ft^2/ac)

A_f = future stand age (years)

A_n = present stand age (years)

B_1, B_2, B_3 = coefficients

Volume Equation:

$$V = B_o + B_1 (BA) (HT)$$

(a) Metric $B_o = 0.5458$ $B_1 = 0.4116$ $R^2 = 0.9966$ SEE = 0.1598
% Error = 12.7[a]

(b) English $B_o = 7.8029$ $B_1 = 0.4116$ $R^2 = 0.9960$ SEE = 2.2840
% Error = 12.7[a]

where V = stand volume (m^3/ha or ft^3/ac)

BA = stand basal area (m^2/ha or ft^2/ac)

HT = dominant stand height (m or ft)

B_o, B_1 = coefficients

[a]Using a modification of Freese's test of accuracy (Rennie and Wiant 1978) at p = 0.05.

Table 2. Example of the use of jack pine growth and yield tables[a].

Enter table with present stand conditions:

Age	Basal area (BA)	Gross total volume (GTV)
20 years	19 m^2/ha	70 m^3/ha

Option 1	Option 2
No thinning at 20 years	Thin every 4th row - remove 17.5 m^3/ha
AT AGE 25:	AT AGE 25:
BA = 21 m^2/ha	BA = 17 m^2/ha
GTV = 98 m^3/ha	GTV = 80 m^3/ha
No thinning	No thinning
AT AGE 30:	AT AGE 30:
BA = 24 m^2/ha	BA = 21 m^2/ha
GTV = 130 m^3/ha	GTV = 114 m^3/ha
No thinning	Thin every 3rd row - remove 38.0 m^2/ha
AT AGE 35:	AT AGE 35:
BA = 28 m^2/ha	BA = 19 m^2/ha
GTV = 168 m^3/ha	GTV = 116 m^3/ha
Total volume removed = 0	Total volume removed = 55 m^3/ha
Total production = 168 m^3/ha	Total production = 171 m^3/ha

[a]Found in Appendix.

3) Though not shown in the growth tables, the average DBH of residual trees in option 2 would be much greater than for the unthinned stand as we shall see in the next section.

Comparison of Natural Stand and Plantation Yields

At the outset, the height growth of the Vespra Township plantation was compared with that of the natural stands with similar development patterns. We can now compare their yields, given similar densities of stocking. Table 3 gives stand statistics from the unthinned control plot 1 at Vespra Township and a plot in Gross Township with similar stocking. The figures are almost identical except for stand age.

Two observations may be made regarding this "no management" situation. First, it took the Site Class I natural stand about a decade longer to reach the development attained by the plantation that was half a site index better at 50 years of age. This can have a direct bearing upon the length of rotation to be expected from the new forest. Second, the standing volume of the Site Class I natural stand at 50 years, obtained from stem analysis, was 193 m^3/ha--about 51 m^3/ha less than the plantation at the same age.

The difference in yield is almost identical to the difference between Plonski's Site Class 1 and Site Class 2 (52 m^3/ha) at 50 years. On the basis of the height/age comparison, approximately half of this figure may be ascribed to the influence of site class.

Table 3. Comparison of stand characteristics between an unthinned plantation and a normally stocked natural stand.

Stand parameter	Plantation Vespra Twp (Plot 1)	Natural stand Gross Twp type 251 (Plot 1)
Age (yr)	50	61
No. of stems/ha	1135	1100
Basal area (m^2/ha)	28.2	27.6
Avg diam (cm)	17.8	17.9
Dominant ht (m)	20.7	20.3
Standing vol (m^3/ha)	244	233
AT 50 YEARS:		
Dominant ht (m)	20.7	18.5
Standing vol (m^3/ha)	244	193

The remaining volume may reflect the influence of more uniform spacing or some other attribute of plantations. In this instance the new forest has shown the potential to produce 10-15% more volume per unit area than the natural forest.

Table 4 compares a "heavily" thinned stand in Vespra Township (Plot 4) with a "widely" spaced natural stand in Gross Township. The standing volume of the natural stand at age 50 years (158 m^3/ha) was 26 m^3/ha less than that of the plantation. The trend is the same as above, although the actual difference is smaller than between the unthinned stands.

The advantages to be gained by thinning a plantation are readily seen by contrasting the thinned and unthinned plots at Vespra Township (Table 5). Thinning in Plot 4 has resulted in a significantly greater average diameter, 21.3 cm vs 17.8 cm on the control plot. In addition, most of the volume lost through mortality is retrieved. Useable GTV to age 50 years on Plot 4 totalled 320 m^3/ha (standing plus thinned volume) against 244 m^3/ha on the control plot. The thinnings in this case amounted to 42% of the commercial volume.

Two less productive but perhaps more practicable methods of affecting density than commercial thinning are wider planting to begin with, and early spacing in already established stands. With the degree of planting success usually attained with jack pine the former is feasible. The latter allows for a greater margin of error in obtaining adequate and uniform stocking. In either case, the potential development can be projected using the natural stands which have already been considered. Table 6 repeats the statistics for the Gross Township plots, one in a normally stocked (Type 251) stand and the other in a widely spaced (Type 258) stand. While the site index is almost identical, the standing volume for the widely spaced stand is only 82% of the former at 50 years of age. Even so, the wide spacing might be the more desirable logging prescription considering that the average diameter is 7 cm greater (25.1 cm vs 17.9 cm). Stand statistics for Evert's (1976) initial Site I table (620 trees/ha at 30 years) are given for comparison with the widely spaced example. With appropriate estimates for mortality Evert's tables may be used as a guide to determine early spacing levels.

Conclusions

1) Jack pine plantations have the potential to produce 10-15% more GTV than natural stands on the same site.

2) Rapid early growth is necessary for plantations to capitalize on the full potential of the site. Therefore, management inputs such as early spacings, cleanings, or precommercial thinnings are advisable. These will result in the greatest benefit in terms of shorter rotations and more efficient harvesting.

Table 4. Comparison of stand characteristics between a heavily thinned plantation and a widely spaced natural stand.

Stand parameter	Plantation Vespra Twp (Plot 4)	Natural stand Gross Twp type 251 (Plot 1)
Age (yr)	50	67
No. of stems/ha	593	440
Basal area (m^2/ha)	21.4	22.1
Avg diam (cm)	21.3	25.1
Dominant ht (m)	20.5	21.1
Standing vol (m^3/ha)	184	210
AT 50 YEARS:		
Dominant ht (m)	20.5	19.4
Standing vol (m^3/ha)	184	158

Table 5. Comparison of unthinned (control) and thinned jack pine plantation, Vespra Twp.

Stand parameter	Plot 1 Control	Plot 4 heavily thinned
Age (yr)	50	50
Avg diam (cm)	17.8	21.3
Gross total vol		
standing (m^3/ha)	244	184
thinned (m^3/ha)	-	136
mortality (m^3/ha)	92	7
Total production (m^3/ha)	336	327

Table 6. Comparison of natural jack pine stand characteristics.

Stand parameter	Normal spacing Gross Twp Type 251	Wide spacing Gross Twp Type 258	250 trees at 30 years Evert Site 1
Age (yr)	61	67	65
No. of stems/ha	1100	440	420
Basal area (m^2/ha)	27.6	22.1	21.1
Avg diam (cm)	17.9	25.1	25.3
Dominant ht (m)	20.3	21.1	21.8
Standing vol (m^3/ha)	233	210	190
AT 50 YEARS:			
Dominant ht (m)	18.5	19.4	18.6
Standing vol (m^3/ha)	193	158	150

3) Commercial thinnings have shown a significant increase in stand diameter while retaining the same total GTV production. The larger diameters will allow utilization for higher-quality products.

4) Total useable biomass can also be increased significantly (up to 40% of GTV) simply by reducing potential mortality through thinning.

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APPENDIX

Projected 5-year growth and yield for plantation jack pine in S.I. units

	Stand before thinning	0: 5-yr growth	0: 5-yr yield	10: 5-yr growth	10: 5-yr yield	20: 5-yr growth	20: 5-yr yield	25: 5-yr growth	25: 5-yr yield	33: 5-yr growth	33: 5-yr yield	40: 5-yr growth	40: 5-yr yield	50: 5-yr growth	50: 5-yr yield
		Percent thinning													
Site index 20.7		Present age 20				Present height 8.8 m						Height in 5 years 10.9 m			
Vol (m^3/ha)	35	29	64	29	61	30	58	31	57	32	55	33	54	34	52
BA (m^2/ha)	9	4.7	14	5.0	13	5.4	13	5.6	12	6.0	12	6.3	12	6.8	11
Vol (m^3/ha)	70	28	98	28	91	27	84	27	80	28	75	28	70	29	64
BA (m^2/ha)	19	2.7	21	3.0	20	3.3	18	3.5	17	3.8	16	4.1	15	4.7	14
Site index 20.7		Present age 25				Present height 10.9 m						Height in 5 years 12.9 m			
Vol (m^3/ha)	35	41	76	42	73	43	71	44	70	45	69	47	68	49	67
BA (m^2/ha)	7	6.5	14	6.9	13	7.3	13	7.5	13	7.8	12	8.2	12	8.7	12
Vol (m^3/ha)	70	34	104	35	98	35	92	36	89	37	84	38	80	40	76
BA (m^2/ha)	15	4.0	19	4.4	18	4.8	17	5.0	16	5.4	15	5.8	15	6.5	14
Vol (m^3/ha)	105	34	139	34	128	34	118	34	113	34	105	35	98	36	89
BA (m^2/ha)	23	2.9	26	3.1	24	3.5	22	3.7	21	4.0	19	4.4	18	5.0	16
Site index 20.7		Present age 30				Present height 12.9 m						Height in 5 years 14.9 m			
Vol (m^3/ha)	70	41	111	42	105	44	100	45	97	46	93	48	90	51	86
BA (m^2/ha)	13	5.0	18	5.3	17	5.8	16	6.0	15	6.4	15	6.8	14	7.5	14
Vol (m^3/ha)	105	38	143	38	133	39	123	40	118	41	111	42	105	45	97
BA (m^2/ha)	19	3.6	23	3.9	21	4.3	20	4.5	19	4.9	18	5.3	17	6.0	15
Vol (m^3/ha)	140	38	178	38	164	38	150	38	143	38	132	39	123	41	111
BA (m^2/ha)	26	2.8	29	3.1	26	3.4	24	3.6	23	3.9	21	4.3	20	4.9	18

(continued)

Projected 5-year growth and yield for plantation jack pine in S.I. units (cont'd.)

		Percent thinning													
		0		10		20		25		33		40		50	
	Stand before thinning	5-yr growth	5-yr yield	5-yr growth	5-yr yield	5-yr growth	5-yr yield	5-yr growth	5-yr yield	5-yr growth	5-yr yield	5-yr growth	5-yr yield	5-yr growth	5-yr yield
Site index 20.7			Present age 35				Present height 14.9 m					Height in 5 years 16.9 m			
Vol (m^3/ha)	70	46	116	48	111	50	106	52	104	54	101	56	98	59	94
BA (m^2/ha)	11	5.4	16	5.8	15	6.3	15	6.5	14	6.9	14	7.3	14	7.9	13
Vol (m^3/ha)	105	41	146	42	137	44	128	45	123	46	117	48	111	51	104
BA (m^2/ha)	16	4.0	21	4.4	19	4.8	18	5.0	17	5.4	16	5.8	16	6.5	14
Vol (m^3/ha)	140	40	180	40	166	41	153	41	146	42	136	44	128	46	117
BA (m^2/ha)	22	3.1	25	3.4	23	3.8	21	4.0	21	4.4	19	4.8	18	5.4	16
Vol (m^3/ha)	175	40	215	40	197	40	180	40	171	40	158	41	146	43	131
BA (m^2/ha)	28	2.6	30	2.8	28	3.1	25	3.3	24	3.7	22	4.0	21	4.6	18
Site index 20.7			Present age 40				Present height 16.9 m					Height in 5 years 18.8 m			
Vol (m^3/ha)	105	43	148	44	139	46	130	47	126	49	120	52	115	55	108
BA (m^2/ha)	15	4.1	19	4.4	17	4.8	16	5.0	16	5.4	15	5.8	14	6.5	13
Vol (m^3/ha)	140	40	180	41	167	42	154	43	148	44	138	46	130	50	120
BA (m^2/ha)	20	3.2	23	3.5	21	3.9	19	4.1	19	4.4	17	4.8	16	5.4	15
Vol (m^3/ha)	175	40	215	40	197	40	180	41	172	42	159	43	148	46	133
BA (m^2/ha)	25	2.6	27	2.9	25	3.2	23	3.4	22	3.7	20	4.1	19	4.7	17
Vol (m^3/ha)	210	41	251	40	229	40	208	40	197	40	181	41	167	43	148
BA (m^2/ha)	30	2.2	32	2.4	29	2.7	26	2.9	25	3.2	23	3.5	21	4.1	19
Site index 20.7			Present age 45				Present height 18.8 m					Height in 5 years 20.7 m			
Vol (m^3/ha)	140	38	178	39	165	41	153	41	147	43	137	45	129	49	119
BA (m^2/ha)	18	2.9	20	3.2	19	3.5	17	3.7	17	4.0	16	4.4	15	4.9	13
Vol (m^3/ha)	175	37	212	38	195	38	178	39	170	40	157	41	147	44	132
BA (m^2/ha)	22	2.4	24	2.6	22	2.9	20	3.1	19	3.4	18	3.7	17	4.2	15
Vol (m^3/ha)	210	38	248	37	226	37	206	38	195	38	169	39	165	41	147
BA (m^2/ha)	27	2.0	29	2.2	26	2.5	24	2.6	22	2.9	21	3.2	19	3.7	17
Vol (m^3/ha)	245	39	284	38	259	37	234	37	221	37	202	38	185	40	162
BA (m^2/ha)	31	1.8	33	1.9	30	2.2	27	2.3	25	2.5	23	2.8	21	3.3	19
Vol (m^3/ha)	280	41	321	39	291	38	262	38	248	37	225	37	206	38	179
BA (m^2/ha)	36	1.5	37	1.7	34	1.9	30	2.0	29	2.2	26	2.5	24	2.9	20

(continued)

Projected 5-year growth and yield for plantation jack pine in S.I. units (concl.)

	Stand before thinning	Percent thinning 0		10		20		25		33		40		50	
		5-yr growth	5-yr yield	5-yr growth	5-yr yield	5-yr growth	5-yr yield	5-yr growth	5-yr yield	5-yr growth	5-yr yield	5-yr growth	5-yr yield	5-yr growth	5-yr yield
Site index 20.7			Present age 50				Present height 20.7 m					Height in 5 years 22.5 m			
Vol (m^3/ha)	140	32	172	33	159	34	146	35	140	36	130	38	122	41	111
BA (m^2/ha)	16	2.2	18	2.4	17	2.7	15	2.8	15	3.1	14	3.4	13	3.8	12
Vol (m^3/ha)	175	32	207	32	189	32	173	33	164	34	151	35	140	37	125
BA (m^2/ha)	20	1.8	22	2.0	20	2.2	18	2.3	17	2.6	16	2.8	15	3.3	13
Vol (m^3/ha)	210	32	242	32	221	32	200	32	190	32	173	33	159	35	140
BA (m^2/ha)	24	1.5	26	1.7	23	1.9	21	2.0	20	2.2	18	2.4	17	2.8	15
Vol (m^3/ha)	245	33	278	33	253	32	228	32	216	32	196	32	179	33	156
BA (m^2/ha)	28	1.3	30	1.5	27	1.6	24	1.7	23	1.9	21	2.1	19	2.5	16
Vol (m^3/ha)	280	35	315	34	286	33	257	32	242	32	220	32	200	32	173
BA (m^2/ha)	32	1.2	33	1.3	30	1.4	27	1.5	26	1.7	23	1.9	21	2.2	18
Site index 20.7			Present age 55				Present height 22.5 m					Height in 5 years 24.3 m			
Vol (m^3/ha)	175	21	196	21	178	20	160	20	151	20	137	20	125	21	109
BA (m^2/ha)	18	0.8	19	0.8	17	0.9	15	1.0	15	1.1	13	1.2	12	1.5	10
Vol (m^3/ha)	210	23	233	22	211	21	189	21	178	20	161	20	146	20	126
BA (m^2/ha)	22	0.6	23	0.7	21	0.8	18	0.8	17	0.9	16	1.0	14	1.2	12
Vol (m^3/ha)	245	25	270	23	244	22	218	21	205	21	185	20	167	20	143
BA (m^2/ha)	26	0.6	26	0.6	24	0.7	21	0.7	20	0.8	18	0.9	16	1.1	14
Vol (m^3/ha)	280	27	307	25	277	23	247	23	233	22	209	21	189	20	160
BA (m^2/ha)	30	0.5	30	0.5	27	0.6	24	0.6	23	0.7	20	0.8	18	0.9	16
Vol (m^3/ha)	315	29	344	27	310	25	277	24	260	23	234	22	211	21	178
BA (m^2/ha)	33	0.4	34	0.5	30	0.5	27	0.6	25	0.6	23	0.7	21	0.8	17
Vol (m^3/ha)	350	31	381	29	344	27	307	26	288	24	259	23	233	21	196
BA (m^2/ha)	37	0.4	38	0.4	34	0.5	30	0.5	28	0.6	25	0.6	23	0.8	19

NORTHERN REGION JACK PINE TREE IMPROVEMENT PROGRAM

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Abstract.--The major aspects of the jack pine (Pinus banksiana *Lamb.) tree improvement program in the Northern Region are described. The program is designed to replace seed gradually from local stands with genetically improved seed from orchards. Breeding zones, site location, plus-tree selection, orchard establishment, progeny testing, and advanced generations are discussed.*

Résumé.--Les principaux aspects du programme d'amélioration du pin gris (Pinus banksiana *Lamb.) dans la région du Nord sont décrits. Le programme vise à remplacer graduellement les graines provenant des peuplements locaux par des graines génétiquement supérieures produites dans des vergers. Les zones de reproduction, le choix des emplacements, la sélection d'arbres plus, l'établissement de vergers, le contrôle des descendances et les générations évoluées sont examinés.*

Introduction

A fast-growing tree of the boreal region, jack pine (*Pinus banksiana* Lamb.) has risen to major importance in the Northern Region, where it accounts for 38% of all conifers harvested from Crown lands (1.2 million m^3/year). It is highly variable, and important traits are under a moderate degree of genetic control (Yeatman 1974). Jack pine can be and is being planted on a wide variety of sites, and performs well in even-aged plantation culture. With this blend of genetic attributes and high demand, an intensive tree improvement program should be most productive.

The objectives of the Northern Region jack pine tree improvement program are as follows:

1) by 1985, to meet all seed requirements from local, identified seed sources;
2) by 2000, to meet seed requirements for bare-root and container stock from rogued, first-generation seed orchards.

Coupled with good forest management, the use of genetically improved planting stock should result in greater plantation success, shorter rotations, greater volume per unit time, and improved product uniformity. Future generations of improved trees should mean even larger gains.

Elements of the Improvement Program

Control of Seed Source

One of the prerequisites of any tree improvement program is control of seed source. The results of provenance tests of many different forest trees are so consistent that a general rule emerges. With few exceptions, the local seed source is the best. Rarely, outstanding provenances that perform better than the local source are tentatively identified. However, the extent and duration of testing required to determine the utility of non-local sources suggests that evaluation of individual tree variation within a predefined local source is a more efficient means of long-term genetic improvement.

Before seed orchards reach full production, regular supplies of seed can be obtained from seed collection areas (SCA) and seed production areas (SPA). Seed collection areas are located in stands of above-average quality at or near rotation age. Cones are collected from tops during the logging operation. SPAs are established in good-quality young stands (15-30 years), and are actively managed to encourage abundant cone production, including thinning to remove poor phenotypes and open crowns to full sunlight. Cone collection is from standing trees, such that the SPA can produce repeated seed crops.

There is little, if any, genetic gain from either type of area, but the guarantee of a ready supply of locally adapted seed more than justifies the establishment of these areas. Both SCAs and SPAs are temporary, and are phased out when seed orchards reach maturity.

At the present time, there are four SPAs and eight SCAs in the jack pine area of the Northern Region. New areas will be developed as needed. It is expected that SPAs and SCAs will produce all seed needed for the artificial regeneration program until the mid-1990s. At that time, the first seed orchards will be producing some seed. By 2000, the majority of seed for planting stock will come from seed orchards, with SPAs and SCAs supplying the needs of direct seeding.

Establishment of Seed Orchards

The establishment and development of seed orchards constitutes a more advanced stage of forest tree improvement. Careful management of seed orchards supported by judicious selection, breeding, and progeny testing will result in appreciable genetic gains. First-generation genetic improvement of jack pine in the Northern Region relies heavily on the establishment of seed orchards.

Breeding Populations

Before embarking on an ambitious seed orchard program, it was necessary to determine the geographic area that would be represented by a given orchard. In the past, seed orchards of other species in Ontario were established according to the site region concept (Hills 1960), i.e., an entire site region was considered a single breeding population. The substantial area of a single site region suggests that this is not a sound approach. On the contrary, in the absence of detailed provenance data, it is much wiser to start with small breeding zones, expanding these zones if and when the data warrant.

In recognition of the need for small breeding zones, four zones were arbitrarily delineated. These zones are shown in Figure 1 and the accompanying demand for seed and stock

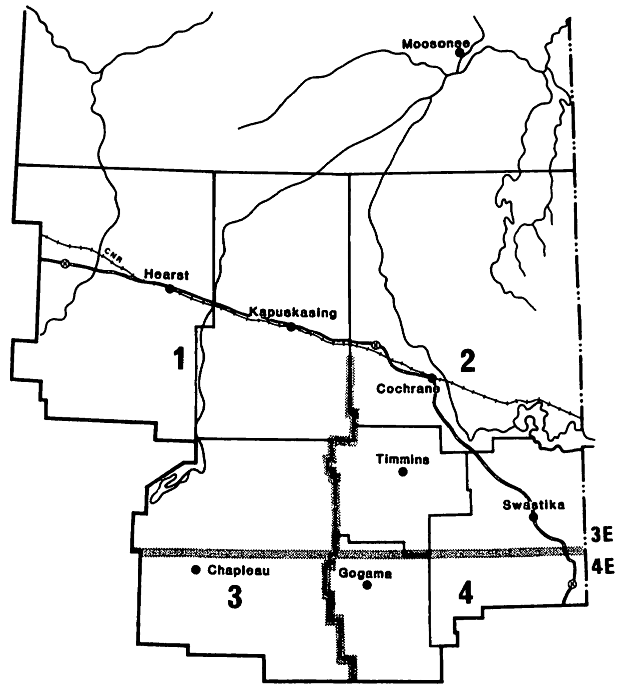

Figure 1. Jack pine breeding zones.

is given in Table 1. It is not claimed that these breeding zones in fact represent true breeding populations; rather, the zones are only a starting point from which four first-generation populations will be artificially created. As progeny test information becomes available, it may very well be possible to combine certain breeding zones into larger areas, thereby simplifying advanced-generation selection and breeding. If fewer and larger breeding zones had been defined at the outset and data had shown that smaller zones were required, it would have been impossible to separate new populations. Therefore, this portion of the Northern Region strategy is purposely conservative, retaining flexibility when the data are available.

Table 1. Anticipated demand for jack pine seed and planting stock by breeding zone.

Breeding zone[a]	Stock demand[b] ('000)	Seed demand[c] ('000)
1	7,322	25,100
2	5,335	15,000
3	2,230	7,500
4	5,745	17,600

[a]See Figure 1

[b]Bare-root and container stock combined to 1986

[c]5 seeds/seedling bare-root, 2 seeds/seedling container

Orchard Type

The two orchard approaches (clonal and seedling) will be used in the first generation. There are advantages and disadvantages to both approaches, but either will result in appreciable genetic gain. In general, clonal seed orchards have the potential for more genetic gain than seedling orchards, but can be more difficult and expensive to establish. On the other hand, progeny testing in seedling seed orchards is more expensive because of the much greater numbers of trees involved.

Seed orchards established for breeding zones 1, 2, and 4 will be of seedling origin. Breeding zone 3 will be represented by a seedling and by a clonal orchard.

Seed Orchard Site Selection

Once the breeding zones were delineated, the next step was to find suitable seed orchard sites within each area. Because of the lead time required for orchard site preparation, it is necessary to locate sites well in advance of plus-tree selection. Consider the predicament of having no place to plant seedlings or grafts when the stock is ready. Therefore, the schedule of seed orchard establishment starts with orchard location at least 2 years before the first orchard planting. To date, four orchard sites have been located using the following selection criteria.

- sandy to silty loam soils
- average fertility and pH
- 2% organic matter content
- level topography
- weather history
- pest incidence
- fire history
- pollen isolation
- water supply
- labor supply

A fifth site will be located soon with similar scrutiny. It is unlikely that any one site will have all the aforementioned attributes; consequently, the risks of compromising one factor must be weighed against the advantages of another. The drawbacks of the seed orchard sites selected to date are either not severe enough to warrant rejection of the site or manageable by known techniques.

The orchard sites selected also take into account expected seed demand and seed production. Although an academic exercise at best, Table 2 was constructed to provide a rough estimate of seed orchard area requirements. To bolster the admitted weakness of these estimates, conservative assumptions were used.

Table 2. Orchard area requirement for each breeding zone.

Breeding zone[a]	Container seed requirements ('000)[b]	Nursery stock seed requirements ('000)[c]	Orchard area requirements ('000)[d]
1	7,650	17,500	17.0
2	8,200	7,125	11.0
3	2,450	5,025	6.0
4	7,400	10,175	12.0

[a]See Figure 1

[b]Seeds per shippable container

[c]5 seeds per shippable seedling

[d]2.0 million seeds per ha at age 15 years; crops of this size will probably occur every other year, but collectible crops will be available every year.

Seed Orchard Site Preparation

Depending on original site conditions, site preparation treatments have ranged from simple plowing, disking, and harrowing to more severe felling, rootraking, plowing, and disking. Properly prepared sites take on the appearance of agricultural fields ready for planting. To protect against erosion, cover crops of perennial grasses are being established.

Plus-tree Selection

In each of the four breeding zones, 400 trees will be selected, for an overall total of 1,600. To date, 750 trees have been selected. For the most part, selection is by a rapid ocular procedure. Good-quality stands are located on Forest Resource Inventory (FRI) maps, and cruised systematically. Plus-trees are selected along cruise lines with a minimum distance of 120 m between trees. One hundred trees from breeding zone 3 will be selected by the check-tree method. These trees will be used in both seedling and clonal seed orchards. All trees selected will be chosen according to the following criteria:

- freedom from insects and diseases
- straightness
- flat branch angle
- uniform multinodal development
- above-average volume production
- straight and serotinous cones (Yeatman 1975)

One hundred cones and 10 scions are collected from each plus-tree intended for a seedling seed orchard. From each tree selected by the check-tree method, 100 cones and 90 scions are taken. A disk is cut at breast height from all trees for wood quality determinations.

Seed Orchard Establishment

Seedling seed orchards: Usually, a first-generation seedling seed orchard is established with open-pollinated families derived from each plus-tree. Based on progeny test data, the poorest families are removed (rogued), leaving the best families to mate randomly and produce genetically improved seed. However, to achieve this goal, several steps along the way must be carefully planned and executed.

Seed orchard design: The planting design utilized for jack pine seedling seed orchards in the Northern Region is somewhat complex, but might be called a replicated random block. This type of design is required in seedling seed orchards to 1) minimize related matings, 2) achieve significant selection differential at roguing, and 3) reduce spatial problems often associated with roguing.

Within any given block, there are 25 planting positions spaced at 4 m x 4 m. Around each planting position four trees are planted, each of a different family and always randomly situated. The result of this design is 100 trees per block, each of a different family, and planted in a 5 x 5 matrix with four trees per planting position. Four hundred families, then, would make four blocks of 100 trees each. This configuration is replicated as necessary over the orchard.

The orchard will be rogued in two stages. The first roguing will take place about year 7, and will remove the three poorest trees from each group of four. Assuming random distribution of families, the most likely outcome is that the best families will be present in high frequencies and the poorest families will be present in low frequencies or eliminated entirely. Families of intermediate performance will be present in varying frequencies depending upon rank.

As progeny test data become more reliable (about year 10 to 12), a second roguing will be carried out further to eliminate substandard families. Ideally, every other tree would be removed, resulting in 8 m x 8 m spacing. However, this situation is unlikely, so that roguing decisions must necessarily include consideration of final spacing.

Orchard phase-in: The schedule for orchard establishment calls for planting half the seed orchard in one year and half the second year. Because of the design characteristics, the orchard will be planted in alternating strips. The first seed orchard in the Region was planted this past spring, and all four seedling seed orchards should be established by 1986.

Clonal seed orchard: A clonal orchard is usually established by grafting scions from mature plus-trees onto rootstock. In this way, each plus-tree is replicated exactly many times, i.e., each graft is genetically identical to the plus-tree from which it came. Based on progeny test data, the best clones are retained in the orchard and the poor clones are rogued.

Seed orchard design: The design for the first-generation clonal orchard is known as a permutated neighborhood, and can be generated by the computer program COOL (Computer Organized Orchard Layouts) (Bell and Fletcher 1978). Basically, this design creates interlinked "neighborhoods" of variable composition, and provides required separation of ramets of the same clone. Repeated neighborhoods are avoided and panmixis is thereby encouraged.

The clonal orchard will be rogued in two stages. Using 7-year progeny test data, approximately the poorest 25% of the clones will be rogued. By the 12th year, the orchard will be rogued to the best 20-25 clones. These remaining clones will be the best general combiners, i.e., when mated to many other trees they produce good offspring.

Orchard establishment: In the spring of 1983, heavy-grade jack pine 408 containers were planted at the clonal orchard site, two per planting location at 4 m x 4 m spacing. This stock will serve as rootstock for field grafting the orchard during 1984 and 1985. Scions collected from plus-trees will be double grafted to ensure equal representation of clones. Where both grafts survive, one can be moved to another position in which both grafts have failed.

Field grafting has consistently proven to be a preferred method of pine grafting, giving higher survival, better growth, and earlier cone production[1] (Koenig 1968, Wheeler 1978). These advantages most probably stem from the use of unrestricted, high-quality rootstock. Relatively untried in jack pine until

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[1]B.J. Zobel, Professor Emeritus, North Carolina State University, Raleigh, N.C. (pers. comm.)

recently, field grafting has been tested in the Northern Region with favorable results. Grafts made in the spring of 1981 produced female flowers in the spring of 1982. Prince Albert Pulpwood in Saskatchewan has established an 8.0-ha production clonal orchard by field grafting.[2]

The procedure is fairly simple, involving the creation of mini-greenhouse environment around the graft to nurse it along until a union is established. Approximately 6 weeks after grafting, the first scions will start to flush. At the pinfeather stage, scions are established and can be slowly released. Throughout the summer, grafts will continue to flush, at least into early August. Some grafts may die back over the winter, but adventitious buds often flush the following spring. As the grafts develop, branches on the rootstock are gradually pruned back until only the grafted portion remains.

Orchard phase-in: As with the seedling seed orchards, the clonal orchard will be established over a 2-year period. Fifty plus-trees selected over the winter of 1983-1984 will be grafted in May, 1984 with the remaining 50 trees completed in May, 1985 according to a similar schedule.

Breeding Orchards

A small number of scions from each plus-tree are being grafted exclusively for use in breeding orchards. A breeding orchard is usually created on a site distinct from the production orchard and consists of several copies of each plus-tree in the program. This orchard serves two purposes. First, it separates the breeding function from the seed-production function, such that there is no conflict that would reduce annual seed production. Second, it serves an an insurance policy of sorts, providing source material should a disaster such as fire strike the production orchard. Grafts are planted out in clonal rows to facilitate searching during the pollination season.

Once the grafts in the breeding orchard start to flower on a regular basis (about 5 years after grafting), controlled pollinations will be started according to a predetermined mating design. At this writing, an interconnected partial diallel is being considered. This design requires only a modest amount of crossing yet yields reliable estimates of both general and specific combining ability.

[2]D. Roddy. Prince Albert Pulpwood, Prince Albert, Sask. (pers. comm.)

Progeny Testing

At the present time, progeny testing is the only way to determine the breeding value, or genetic worth, of trees in the seed orchard. Selection of *phenotypically* superior plus-trees in no way guarantees superior genetic quality. The objective is to identify accurately, and as soon as possible, those clones or families that consistently produce good offspring. Those trees that do not produce above-average progeny are rogued from the seed orchard production population.

Most of the progeny tests in the first generation will be open-pollinated trials. In the case of seedling seed orchards, the best *families* will be identified. The best general combiners will be identified in the clonal orchard. In either case, a high proportion of second-generation selections will come from the best families, thereby capitalizing on both family and within-family selection.

The field design must necessarily be an incomplete block design. The large number of families in each breeding zone precludes any type of complete design. Progeny tests are scheduled to be planted in the second year of establishment for any given orchard.

Supplementary tests will also be planted utilizing full-sib crosses produced in the breeding orchards. These tests will augment the information obtained from the open-pollinated trials. Because fewer families are involved, a complete block design will be used.

Seed Orchard Management

Seed orchard management can be separated into two stages: the establishment phase and the production phase. The goals of each stage are different and therefore require different management practices.

Management during the establishment phase is directed toward achieving high survival and vigorous growth. High survival translates into higher seed and cone production, and makes roguing decisions easier. Vigorous growth helps produce well developed crowns, and therefore more cone-bearing surface. Management practices during this phase include irrigation, fertilization, weed control, and fire control.

The production phase shifts emphasis to stimulation of regular, large seed and cone crops. This is the money-making end of the operation. Genetic gain for any given orchard is fixed at a point in time; therefore, the only way to increase value is to increase seed production (Porterfield 1974). Several management practices have been shown to increase cone and seed crops in southern pine seed orchards, and there is every reason to believe that these practices will work in jack pine. These management practices include fertilization, subsoiling, selective irrigation, and strict pest control. These and other cultural methods will be tested and employed as required.

Advanced Generations

The process of genetic improvement is never-ending: selection and breeding are continuous processes leading to better genetic material. Because forest trees are relatively unselected, they contain tremendous amounts of genetic variation. Coupled with the relatively long generation interval (at present 10-15 years), this program should realize significant genetic improvements for many years.

As time passes, the progeny tests will yield selections for second-generation orchards. The combination of family and within-family selection should result in increased gains equal to those achieved in the first generation. Several new selections from natural stands will also be included in second-generation source material to keep the base broad. Wide crosses over breeding zones will also produce new genetic combinations. As always, this new material will be thoroughly tested to determine genetic worth. Second-generation selection should begin by the late 1990s with the first second-generation seed orchards being established early in the 21st century.

Summary

The long-term goal of the Northern Region jack pine tree improvement program is to produce a forest of better quality and in a shorter period of time than is produced at present. To accomplish this goal, an integrated program of genetic tree improvement and good silviculture is necessary. The most heroic efforts of tree breeders can be foiled by poor forest management, while maximum gains will not be achieved through good management without genetic improvement. The foregoing statement is incontrovertible, and is the key to success.

Initially, better than average seed can be supplied from SCAs and SPAs. These sources will provide the necessary seed until seed orchards start producing appreciable quantities. As seed orchards continue to produce, SCA and SPA seed will be gradually phased out. First-generation orchards will also become obsolete, giving way to advanced-generation orchards and even better-quality seed.

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JACK PINE REGENERATION IN THE NORTHWESTERN REGION

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*Abstract.--The economic importance and regeneration of jack pine (*Pinus banksiana *Lamb.) in the Northwestern Region are discussed. Site regions and types are reviewed in relation to the abundance of jack pine. Levels and types of silvicultural treatment are presented, including cutover classification results and site preparation equipment used.*

Résumé.--L'auteur discute l'importance économique et la régénération du pin gris (Pinus banksiana *Lamb.) dans la région du Nord-Ouest. Il examine les régions et types de sites du point de vue de l'abondance du pin gris, et passe en revue divers niveaux et types of traitements sylvicoles, y compris les résultats de la classification des terrains déboisés et l'équipement employé pour la préparation du sol.*

Introduction

Jack pine (*Pinus banksiana* Lamb.) is the most important commercial species in the Northwestern Region (Fig. 1) of the Ontario Ministry of Natural Resources (OMNR). The species represents 50% of the volume harvested and 95% of the area regenerated annually. This paper summarizes the status of the jack pine regeneration program in the region, including types of sites treated, equipment used and treatments.

Economic Importance

The average volume of jack pine harvested annually in the Northwestern Region is 1,469,976 m^3. The relationship of the volume of jack pine harvested annually to the total harvest for the period 1974-1982 is shown in Table 1.

Within the region, jack pine is processed into a variety of products including pulp, paper, lumber, studs and ties. In 1981, licensed mills reported receiving a roundwood (all species) volume of 2,255,134 m^3 of pulpwood and 286,154 m^3 of sawlogs (Anon. 1982). In addition, 119,982 bone dry tonnes of pulp chips were produced, 45% of which were consumed within the region. Of the 20,993 bone dry tonnes of shavings produced, 18% are used in pulp mills, 25% in energy production and 56% are waste.

Figure 1. The northern regions of Ontario.

Table 1. Relationship of annual jack pine harvest to the total harvest in the Northwestern Region.

Year	Jack pine (m^3)	Total, all species (m^3)	Jack pine (%)
1974-1975	1,188,003	2,274,155	52
1975-1976	843,535	1,822,563	46
1976-1977	985,649	2,028,428	49
1977-1978	1,402,165	2,882,454	49
1978-1979	1,492,774	3,045,600	49
1979-1980	1,965,503	3,692,459	53
1980-1981	1,903,891	3,709,725	51
1981-1982	1,917,755	3,759,309	51
1982-1983	1,530,512	2,965,308	52
Avg	1,469,976	2,908,889	50

Sawdust production amounts to 20,998 bone dry tonnes of which 26% are used and 74% are waste. As indicated previously jack pine represents 50% of the total harvest and is utilized in the pulp mills and sawmills in the region.

Site Regions and Types

Zoltai (1965) reported a humid to subhumid macroclimate in northwestern Ontario. Site regions 2w, 3w, 4w, 3s, 4s, and 5s are represented in the Northwestern Region. In site regions 4s and 5s jack pine was reported as the most abundant species (Zoltai 1965). Jack pine dominance is attributed to its ability to regenerate after fire disturbance and withstand drought.

The Great Lakes-St. Lawrence and the Boreal Forest regions as described by Rowe (1972) are both represented in the Northwestern Region. Red pine *(Pinus resinosa* Ait.) and white pine *(Pinus strobus* L.) forest communities are prevalent throughout the Quetico and Rainy River forest sections of the Great Lakes-St. Lawrence Region. Logging and fire disturbance have led to an increase in boreal species, particularly jack pine, trembling aspen *(Populus tremuloides* Michx.), largetooth aspen *(Populus grandidentata* Michx.), white birch *(Betula papyrifera* Marsh.) and balsam fir *(Abies balsamea* [L.] Mill.) (Rowe 1972).

The Central Plateau and the Upper and Lower English River forest sections of the Boreal Forest Region support jack pine as the most prevalent species which occurs in both pure and mixed stands. In the Northern Coniferous section, black spruce *(Picea mariana* [Mill.] B.S.P.) is the predominant species. Upland sites support mixed stands of black spruce and jack pine; however, frequent fires favor the spread of jack pine.

Jack pine is found growing on a wide variety of soil types across the region. Shallow till over bedrock, rolling clay plains with rock outcrops, and deep outwash and deltaic sand plains associated with moraines all support stands of jack pine. Pockets of clay and sand are found interspersed throughout the aforementioned areas.

Silvicultural System

Clearcutting followed by site preparation and planting or seeding is the most common silvicultural system in the Northwestern Region.

The average annual area regenerated artificially to jack pine is 22,400 ha, which is 94% of the regional regeneration program.

Site Preparation

Mechanical site preparation is carried out on 87% of the areas treated in the Region. Table 2 relates type of site preparation equipment to the average area completed annually for planting and seeding.

Site preparation for direct seeding accounts for 83% of the total program. Barrels and chains pulled by both tractors and skidders constitute the principal site preparation technique, accounting for 49% of the program.

Annually since 1971, unit foresters in the Northwestern Region have prepared reports in which the cutover areas are classified according to their suitability for mechanical site preparation treatments. Classifications for the periods 1971 to 1975 and 1976 to 1981 are included in the Appendix. Table 3 provides a summary of this information, indicating that 67% of the jack pine working group is treated mechanically in comparison with 57% for all other working groups.

Regeneration

Sixty-seven percent of the jack pine working group is treated mechanically in comparison with 57% for all working groups combined. Table 4 indicates the relationship between the average area of species regenerated annually and treatment types for the Northwestern Region.

Table 2. Average area treated annually for planting and seeding by site preparation equipment type.

Equipment	For container planting (ha)	For bare-root planting (ha)	For direct seeding (ha)	Total	Area planted and seeded, by equipment type, as % of total area
T.T.S. Disc	311	388	1,209	1,908	14
Barrels and chains	625	474	5,807	6,906	49
Straight blade	10	342	95	447	3
Bräcke	124	45	2,534	2,703	19
Brush cut plow	6	23	242	271	2
Prescribed burn	5	3	165	173	1
No mechanical site preparation	12	44	1,628	1,684	12
Total	1,093	1,319	11,680	14,092	
%	8	9	83		
Other[a]	208	544		8,268	

[a]includes wildfire, root rake, rome disc, pads and chains, mechanical site preparation not coded (Anon. 1983).

Table 3. Summary of the cutover classification for mechanical treatment for the periods 1971-1975 and 1976-1981 expressed as a percentage for the jack pine and total working groups in the Northwestern Region.

	1971-1975		1976-1981	
Classification[a]	Jack pine (%)	Total (%)	Jack pine (%)	Total (%)
Too wet	8	10	6	14
Too rocky	15	14	5	4
Too rough	10	10	5	5
Too small	nil	nil	1	1
Residuals	12	19	8	11
Inaccessible	6	7	5	5
Withdrawn	nil	nil	2	2
Regenerated naturally	4	4	1	1
Regenerated artificially	45	36	67	57

[a]Classification by area is shown in the Appendix.

Table 4. Average area of species regenerated annually by treatment.

Treatment	Jack pine (ha)	Black spruce (ha)	White spruce (ha)	Total (ha)	%
Bare-root planting	669	672	357	1,698	7
Container planting	1,298	11	nil	1,309	6
Direct seeding	20,474	210	nil	20,684	87
Total	22,441	893	357	23,691	
%	95	4	1		

Site preparation followed by direct seeding is the most common regeneration treatment in the Region. It has proven to be a satisfactory treatment on the shallow, stony soils that comprise the bulk of the area. It is equally suited to sand plains and outwash deposits. Jack pine is seeded aerially in late winter at the rate of 50,000 viable seeds/ha.

The success of direct seeding is variable. Stocking surveys conducted in the Dryden District for the period 1972 to 1978 are representative of the Region and are summarized in Table 5.

Planting of bare-root 2-0 jack pine is carried out primarily on deep and/or heavier soils in conjunction with the more severe site preparation equipment. The 5-year planting stock forecast for the Region shows a projected demand of 1.5 million bare-root jack pine annually.

Spencer-Lemaire "Rootrainer" containers are used in the container planting program. Container planting allows for an extension of the planting season, and many stony sites not suited to bare-root planting can be successfully planted with containers. Projected demand for jack pine containers is 6 million annually.

Insects and Diseases

At present there are no serious widespread problems with insects or diseases on jack pine regeneration in the Northwestern Region. Eastern pine shoot borer (*Eucosma gloriola* Heinr.) has been reported to have destroyed on the average 5.1% of the terminal shoots on jack pine (Thomson and Jones 1982). Adult sawyer beetles (*Monochamus* spp.) are causing severe damage and tree mortality on jack pine and black spruce in isolated locations in the Kenora District. White pine weevil (*Pissodes strobi* Peck) populations are reported to be low, with damage to jack pine leaders ranging from 0 to 2%.

Armillaria root rot (*Armillaria mellea* [Vahl ex Fr.] Kumm.) is present in the Region, with damage levels ranging from 0.6% to 1.3% of the trees examined in 37.5% of the areas sampled (Thompson and Jones 1982). Low levels of mortality are attributed to this root rot, with weakened trees being more susceptible to attack.

Globose gall rust (*Endocronartium harknessii* [J.P. Moore] Y. Hiratsuka) was also reported, with infection incidence ranging from 3.2 to 28.0% and averaging 14.5%.

Table 5. Stocking percentages for direct seeding 3 and 5 years after treatment in comparison with those for untreated cutover.

Treatment	3rd-year stocking		5th-year stocking	
	Jack pine (%)	Jack pine and spruce (%)	Jack pine (%)	Jack pine and spruce (%)
Direct seeding	45	53	47	55
Natural regeneration (untreated)	N/A	N/A	12	29

In 1982, a special survey was conducted throughout northern Ontario to determine the incidence and impact of insects and diseases in high-value regenerated jack pine stands (Thomson and Jones 1982). Twelve areas in the Region were sampled and no serious problems were identified.

Regeneration Concerns

Forestry staff within the Region have expressed concern about the variable results obtained from direct seeding. It is thought that the lack of adequate moisture may be a problem during germination and early establishment. Late summer droughts common to this Region may also cause poor results. Both of these areas require research.

Competition is a problem on sites having heavier soils. Applications of 2,4-D currently provide some control. There is a need for approved herbicides that will control weed species not affected by 2,4-D.

A high regional demand for seed has increased the awareness of the need to use seed efficiently. Operational research trials of existing technology that makes efficient use of seed are needed.

The need for jack pine tree improvement work in the Region has been recognized and a program description is in the final stages of preparation.

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APPENDIX

a) Summary of the cutover classification of the Northwestern Region by working groups, 1971-1975

	Area (ha)										
	Working group										
Site class	Red and pine	Jack pine	Black spruce	Balsam fir	Other conifers	Poplar	White birch	Other hard-woods	Non-productive forest lands	Total	%
Too wet		3,285	4,688	66	31	659		48	305	9,082	10
Too rocky	32	6,336	4,129	2	72	1,855		75	562	13,063	14
Too rough		4,270	2,320	19	19	1,635	31	60	668	9,022	10
Too small	6	34	33			289	45		41	448	-
Residuals	30	5,243	9,306	635	38	2,482		288	163	18,185	19
Inaccessible	91	2,606	2,997	41	9	1,129		49	83	7,005	7
Regenerated naturally	5	1,804	942	151	-	567	26	-	392	3,887	4
Regenerated artificially	10	19,957	7,879	135	105	5,466	70	85	433	34,140	36
Total	174	43,535	32,294	1,049	274	14,082	172	605	2,647	94,832	100
%		46	34	1		15		1	3		

Prepared by G. Brown from Management Unit cutover classification reports on file in the Northwestern Regional Office, Kenora, Ont.

b) Summary of the cutover classification of the Northwestern Region by working groups, 1976-1981.

	Area (ha)											
	Working group											
Site class	Red and white pine	Jack pine	White spruce	Black spruce	Balsam fir	Other conifers	Poplar	White birch	Other hardwoods	Non-productive forest lands	Total	%
Too wet	2	2,495	7	7,992	124	15	282	6	2	1,191	12,116	14
Too rocky	54	1,888	5	1,143	17	-	218	15	-	233	3,573	4
Too rough	22	2,224	-	1,840	57	10	247	21	-	55	4,476	5
Too small	11	416	-	406	24	8	104	4	-	54	1,027	1
Residuals	81	3,240	15	4,334	273	6	1,571	195	4	171	9,890	11
Inaccessible	11	1,857	-	1,793	60	9	588	46	1	90	4,455	5
Withdrawn	2	1,013	11	301	9	-	112	6	6	36	1,496	2
Regenerated naturally	29	371	0	676	4	2	66	9	-	27	1,184	1
Regenerated artificially	162	27,546	140	17,927	255	11	3,078	282	86	375	49,862	57
Total	374	41,050	178	36,412	823	61	6,266	584	99	2,232	88,079	
%	-	47	-	41	1		7	1		3		100

Source: Management Unit cutover classification reports on file in the Northwestern regional office, Kenora, Ontario.

JACK PINE MANAGEMENT IN THE BOREAL FOREST OF ONTARIO: NORTH CENTRAL REGION

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Abstract.--Current management practices in the boreal jack pine (Pinus backsiana *Lamb.) forest of the North Central Region are discussed in terms of management planning and silvicultural treatments. The success rates of silvicultural treatments are given and problems within the Region are discussed. Recommendations based on a survey of foresters from each district in the Region are made for regeneration treatments.*

Résumé--On se penche sur les pratiques actuelles d'aménagement de la forêt boréale de pin gris (Pinus banksiana *Lamb.) du point de vue de la planificaiton et des traitements sylvicoles. On indique les taux de succès de ces traitements et on examine des problèmes existant dans la région. Enfin, on présente des recommandations au sujet des traitements de régénération en s'appuyant sur un sondage réalisé auprès de forestiers de tous les districts de la région.*

Introduction

The jack pine *(Pinus banksiana* Lamb.) species ranks third in area among the Crown production forests of the North Central Region, behind spruce *(Picea* spp.) and poplar *(Populus* spp.). The species represents 31% of the annual volume harvested and 40% of the annual area regenerated. At present, 80% of the jack pine working group harvested annually receives regeneration treatment. Current practices in the boreal jack pine forest of the North Central Region are discussed in terms of management planning and silvicultural treatments. Jack pine management problems are summarized for the Region.

Management

All boreal jack pine working groups are managed under the even-aged management system. Some form of clearcut silvicultural system is applied to all stands.

The North Central Region's management strategies are aimed at maintaining the permanent coniferous working groups and the upper half of the poplar site class. The permanent coniferous working groups on which management emphasis is placed are the spruce working group and the pine working group (i.e., jack pine).

Markets for jack pine have grown steadily over the past 20 years. Currently the total allowable cut in the Region for the jack pine working group is committed to supplying the existing wood-using industries. Pulpwood and sawlog markets are evenly distributed throughout the Region. Jack pine now accounts for 31% of all wood harvested in the Region, of which 70% is produced for pulpwood and 30% for sawlogs. Table 1 compares the volume of jack pine harvested with that of all species harvested, since 1976.

Present utilization of the jack pine working group in the pure pine or pine-spruce

Table 1. Relationship of annual jack pine harvest to total harvest in the North Central Region.

Year	Volume: Jack pine (m^3)	Volume: Total all species (m^3)	Jack pine (% of total)
1982-1983	1,232,238	4,855,829	39
1981-1982	1,648,236	5,387,979	32
1980-1981	1,806,060	5,988,038	33
1979-1980	2,145,383	6,235,533	29
1978-1979	2,043,648	6,090,193	30
1977-1978	2,104,483	6,003,670	28
1976-1977	1,694,161	5,178,294	30
Total	12,674,209	39,739,536	221
Average	1,810,601	5,677,076	31

(Source: Ontario Ministry of Natural Resources regional scaling returns).

stands is good. Stands with a large percentage of poplar, balsam fir (*Abies balsamea* [L.] Mill.), or white birch (*Betula papyrifera* Marsh.) are poorly utilized as a result of partial cutting practices. It has been rare in the past to have markets for all species and products available from these mixed stands. Incomplete utilization of the trees in a cutover hinders subsequent regeneration treatments and the establishment of a new stand.

Silviculture

The silviculture system used by the North Central Region to regenerate jack pine consists of clearcutting, site preparation for natural regeneration, planting or seeding, and tending as required. The following is a broad description of the three common types of jack pine stands:

"1) Pure or almost pure stands of jack pine generally occur on dry sites i.e., ridges, upper slopes or sandy flats. The soil texture commonly varies from coarse to medium sand and the soil depth ranges from shallow over bedrock to moderately deep to deep. In general, the degree of shrub competition on dry sites is slight.

2) The mixedwood stands of jack pine, white spruce, black spruce, balsam fir, aspen and white birch generally occur on fresh upper and middle slopes. The soil texture commonly varies from moderately deep to deep, medium to fine sands or loamy tills. Considerable shrub competition is usually encountered in these stands, particularly after either a part or all of the stand has been removed.

3) The mixed jack pine and black spruce stands are found on the fresh to moist lower slopes or flats having deep loamy tills or clays of moderate structure and also on sand flats where the sand is finely textured or has a silt component. The presence of shrubs on these sites before cutting and the shrub competition which develops after logging is of a less serious nature than in the mixedwood stands of jack pine, aspen, white birch and balsam fir." (Eyre and Le Barron 1944)

The methods of securing jack pine regeneration on recent cutovers are determined by the original stand composition, site conditions, competing shrub growth and logging methods.

Clearcutting is the harvesting method used in jack pine stands and results have demonstrated that cutting with no further silvicultural treatment results in an inadequate level of regeneration (Table 2). Silviculture is discussed under three headings: *Site Preparation, Regeneration Treatments,* and *Tending*.

Site Preparation

Most of the site preparation in the Region is mechanical although prescribed burns are used very effectively on jack pine-mixedwood sites (stand type 2 under **Silviculture**) to reduce the quantity of slash and to remove part of the humus layer. At present, greater emphasis is being placed on prescribed burns in the Region.

Where jack pine is to be established by planting (stand types 2 and 3 under **Silviculture**) the basic objective is to remove the slash for ease of planting and to skim off the duff layer to expose the mineral soil. The site preparation standard for planting is 2,500 plantable spots per ha.

Table 2. Annual average regeneration treatments and success rates from 1976 to 1981 for the North Central Region.

Treatment	No. of trees (000,000)	Area (ha)	Fifth-yr stocking, jack pine (%)	Fifth-yr stocking, jack pine + white spruce (%)
Planting				
Bare-root	1.734	1,250	62	69
Container (Spencer-Lemaire)	.298	210	55	65
Seeding	-	3,350	56	65
Scarification for natural regeneration	-	2,490	41	52
No treatment			14	29

(Source: Ontario Ministry of Natural Resources district records)

Areas designated for aerial seeding with site preparation (stand types 1 and 3 under **Silviculture)** require 20% of the gross area to be a mineral soil-humus mixture.

The TTS Disc Trencher and barrel drags are used for scarification, prior to planting or seeding, on areas with heavy slash and a shallower humus layer. Sites containing a deep humus layer (15 cm+) and deep mineral soil (25 cm+) require scarification with Young's Teeth subsequent to planting or seeding. Bräcke cultivators and Leno scarifiers are suited to shallow sites that are to be regenerated by spot seeding.

Regeneration Treatments

The site must be considered carefully in planning a jack pine regeneration program. As a rule the better the jack pine site, the more difficult the regeneration problem becomes because of competition from other tree species and ground vegetation.

Regeneration treatments on jack pine sites in the North Central Region do not vary a great deal from district to district. The three most common treatments are seeding, scarification for natural regeneration and planting.

The average annual harvest in the jack pine working group between 1977 and 1981 in the Region was 9,500 ha; during the same period 7,300 ha were regenerated annually. Over all in the Region 46% of the regenerated jack pine sites are seeded, 34% are scarified for natural regeneration and 20% are planted. In most districts, regeneration treatments are carried out soon after the harvest.

Table 2 shows the average number of hectares seeded and planted with jack pine or scarified for natural regeneration to jack pine, as well as the stocking percentages after 5 years.

Table 3 shows the quantity of jack pine bare-root and container stock planted in the Region between 1976 and 1982.

Table 3. Jack pine bare-root and container stock planted between 1976 and 1982 in the North Central Region.

Year	Bare-root stock (000,000)	Container stock (000,000)	Total
1982	1.608	.149	1.757
1981	1.880	.692	2.572
1980	1.253	.165	1.418
1979	1.842	.183	2.025
1978	2.056	.499	2.555
1977	1.556	.384	1.940
1976	1.943	.013	1.956
Total	12.138	2.085	14.223
Average	1.734	.298	2.032

(Source: Ontario Ministry of Natural Resources district records)

Jack pine seed is generally applied from a fixed-wing aircraft at a rate of 50,000 seeds per ha. In addition, hand seeding and seeding with site preparation (e.g., Bräcke or barrel seeders) have been widely used in the Region. General observations indicate that sites that received good site preparation and were relatively free from other competing vegetation were successfully regenerated, averaging over 60% stocking to jack pine 5 years after treatment. Planting is often the easiest and most reliable method of establishing jack pine, particularly in areas with rough topography, an inadequate seed supply or an expected competition problem. The North Central Region plants 2+0 bare-root and Spencer-Lemaire containerized jack pine seedlings. Field observations indicate that container-grown seedlings perform as well as bare-root stock. The average survival rate in the Region for both types of stock five years after planting is between 65% and 75%. Generally, container stock is planted on rougher sites with shallow soils. The most common reasons for planting failures are: 1) poor planting quality, 2) improper site preparation, and 3) severe competition from undesirable vegetation.

Scarification for natural jack pine regeneration is prescribed on areas where there is an abundant seed supply and where competing vegetation is not expected. The most common method uses crawler tractors to pull shark-finned barrels and spiked anchor chains to break up the jack pine slash, producing a suitable seedbed and dispersing slash over the prepared seedbeds. The method has had a variable success rate since it is highly dependent on the quality of the seedbed preparation. It has produced, on the average, stocking levels of 41% for jack pine 5 years after treatment.

In conjunction with the three main treatments described above, various clearcut cutover patterns are used to protect the productive capacity of the forest site. For example, block cutting is employed on large areas with very fine sand or blow sand soil textures.

Tending

There are two basic methods of plantation release in the North Central Region: herbicide aerial spraying and hand release.

The hand release method gives complete control over which species and individuals are removed from the plantation. Depending on the amount of competition in the plantation, the cost can range from $150 to $370 per ha, which is more than the cost of the original regeneration treatment in some cases. Another tending problem is the frequent need to repeat the release treatment at 2- or 3-year intervals, because of the rapid re-establishment of the original competing vegetation. The method is used only where small sections of a plantation need release or where the plantation is less than 10 ha in size.

Most release operations in the Region are carried out by aerially spraying 2,4-D herbicide at a rate of 1.7 kg a.i. per ha. Since jack pine is more susceptible to herbicide damage, the rate is lower than that used on spruce plantations. The aerial application of 2,4-D at the recommended rate does not produce an adequate level of competition control.

At present, the forest manager in the North Central Region lacks the means required to do an adequate release job. An assortment of herbicides must be made available in order to have effective competition control on all vegetation (e.g., raspberry, *Rubus strigosus* Michx.). The Region is currently attempting to examine and identify all silvicultural treatments which require tending.

Management Problems

The following concerns are based on a survey of each district in the North Central Region:

1) poor utilization of hardwood species
2) inadequate control of competing vegetation by 2,4-D herbicide
3) selection of forest sites suitable for jack pine management
4) growth and yield information as it relates to site type preparation
5) shortage of bare-root and container stock for planting
6) soil texture and moisture regime as they relate to seeding success

These concerns require attention in order to have an effective jack pine management program in the North Central Region.

Damage to jack pine by insects and diseases is not a serious problem in the Region since it is scattered and infrequent.

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JACK PINE REGENERATION IN THE NORTHERN REGION

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Abstract.--The economic importance and regeneration of jack pine (Pinus banksiana *Lamb.) in the Northern Region, as well as site types and the silviculture system, are discussed. Summaries of the type, quantity and success rates of silviculture treatments and problems within the Region are given.*

Résumé.--Il est question de l'importance économique et de la régénération du pin gris (Pinus banksiana *Lamb.) dans la région du Nord. Les types de sites et le système sylvicole sont examinés. Les traitements sylvicoles (type, quantité et taux de réussite) et les problèmes sont décrits brièvement.*

Introduction

Jack pine *(Pinus banksiana* Lamb.) is the second most important commercial species in the Northern Region (Fig. 1). It represents 27% of the annual volume harvested and 29% of the annual area regenerated. Within the next 2 years it is anticipated that 19 million jack pine seedlings will be planted annually in the Region.

This paper summarizes the economic importance of jack pine and the management tools being used at present to regenerate areas to jack pine. An effort is made to anticipate future problems and requirements.

Economic Importance

Table 1 indicates the volumes of jack pine harvested annually since 1973 in relation to the total harvest.

Figure 1. The Northern regions of Ontario.

Table 1. Relation of annual jack pine harvest to total harvest in the Northern Region.

Year	Jack pine vol (m^3)	Total vol all species (m^3)	Jack pine (%)
1981-1982	1,393,779	5,334,458	26
1980-1981	1,495,820	5,547,752	27
1979-1980	1,531,324	5,568,547	27
1978-1979	1,522,521	5,456,913	28
1977-1978	1,429,324	5,262,629	27
1976-1977	1,081,155	4,443,223	24
1975-1976	725,995	2,725,324	27
1974-1975	587,293	5,493,334	11
1973-1974	1,024,516	4,910,470	21
Avg	1,199,081	4,971,405	24

The average annual harvest represents direct Crown charges of approximately $7 million, and a value added of $103/$m^3$ has been suggested. At this rate, the Northern Region jack pine represents $123.5 million to the province of Ontario.

Of the jack pine harvested, 90% goes to a sawmill as the first processing step. This means that jack pine is especially important to the sawmill-dependent towns of the Northern Region.

Site Types

The Northern Region is covered by three main forest sections of the boreal region (Rowe 1972). The Northern Clay Belt covers most of Cochrane and Kapuskasing districts, and half of Hearst and Timmins. The Missinaibi-Cabonga section occupies the height of land through Kirkland Lake, Timmins, Gogama and Chapleau, while the Central Plateau section occupies the northwestern part of the Region in Hearst District.

For practical purposes the Northern Region is usually divided into two sections, the black spruce (*Picea mariana* [Mill.] B.S.P.) Clay Belt and the Missinaibi-Cabonga Central Plateau jack pine.

For operational purposes there are four main site types for jack pine silviculture. These are the stereotype sand plains, coarse loamy tills, shallow sand and tills over bedrock, and the heavier silt or clay loams. Each of these main sites has different treatment requirements and success rates. These factors create a need for diverse equipment and silvicultural practices within the same basic silvicultural system in the Region.

Silviculture System

Clearcutting, site preparation, planting or seeding and tending as required constitute the silvicultural system for jack pine in the Northern Region. The annual harvest in the jack pine working group is 8,403 ha, and the average area regenerated annually to jack pine is 7,779 ha. In most districts, the regeneration is right behind the harvest. Jack pine silviculture is a definite success story in this Region.

Site Preparation

Mechanical site preparation is used on 90% of the areas and prescribed fire on 10%.

Table 2 lists the type of site preparation equipment used and the average area completed annually for planting and seeding.

Table 2. Site preparation equipment used for planting and seeding treatments in the Northern Region.

Equipment	Area treated annually			Prime mover
	Total (ha)	For planting (ha)	For seeding (ha)	
Young's teeth	3,640	1,590	2,050	tractor
Bräcke	1,902	1,123	779	skidder
Barrels and chains	1,167	900	267	tractor
Straight blade	542	472	70	tractor
TTS and Leno	106	25	81	skidder
Other	101	58	43	tractor
Prescribed fire	617	595	22	

The site preparation standards are 2,500 plantable spots/ha or 20% mineral-soil exposure for aerial seeding at 50,000 seeds/ha. Individual site prescriptions may alter these goals.

In general the more severe site preparation using tractors is done on the coarse, loamy tills and high-competition sites. The increased severity of preparation gives an increase in vegetation control. The skidder-powered equipment is used on the sand plains and shallow soils where competition problems are not anticipated. These areas can be done for half the price of the other areas.

Regeneration

Planting and seeding are the two regeneration treatments carried out in this Region for jack pine. Table 3 shows the area of seeding and bare-root and container planting of jack pine. The stocking percentages at 5 years and the retreatment percentages are also given.

There is a trend away from seeding on the better sites. The better spacing control and higher guarantee of success make planting a better option if the stock is available. The most common reasons for failure of planting and seeding are listed below. This Region has had no success at all with natural regeneration.

Planting - improper site preparation for site
- competition outcompetes planted trees
- weather (in occasional years)
- planting quality problems
- stock quality

Seeding - insufficient mineral-soil exposure
- weather (much more of a factor with seeding than with planting)
    - spring drought
    - frost
- birds and animals

Tending

The only practical tending method at present is the use of 2,4-D by aerial or ground application. Areas are inspected and sprayed as required after the jack pine has hardened off. Research work is being done on other chemicals that will control the grasses and raspberries that 2,4-D does not affect.

Insects and Diseases

Jack pine regeneration appears to have no serious problems with insects or disease. A special jack pine plantation survey carried out by the Great Lakes Forest Research Centre (MacLeod et al. 1982) detected a variety of insects and diseases, but no problem areas. The major insects and diseases of jack pine are as shown in Table 4.

Management Problems

The following problems are based on a survey of the forest management staff in the Northern Region. Concerns are listed in order of the frequency with which they are mentioned in the various districts.

1) Growth and field information:
    - vs plantation management
    - vs soil texture and moisture regime
    - vs site-preparation techniques
2) Soil texture-moisture regime vs aerial seeding success
3) Competition control of species not affected by 2,4-D
4) Tree improvement--improved stock

These topics require some research and transfer of knowledge to the field forestry staff. We don't have problems establishing jack pine, but we need to know what results we are achieving in the long run.

Summary

Jack pine is of major importance to the forest economy of the Northern Region. We have a number of successful tools for regeneration and we are very close behind the cut with our regeneration program.

Insects and diseases are not major problems in either the mature stands or the plantations.

Table 3. Average annual regeneration treatments and success rates up to 1982.

Regeneration type	No. of trees ('000,000)	Trees/ha	5th-year stocking jack pine (%)	5th-year stocking jack pine, spruce (%)	Retreatment (%)
Bare-root	6.1	3,299	68	75	4
Container (paperpot)	3.9	1,587	76	76	4
Seeding		3,273	59	65	36

Table 4. Major insects and diseases of jack pine in the Northern Region.[a]

Disease or insect	Area affected (ha)	Trees affected (%)	Districts affected
Eastern pine shoot borer (*Eucosma gloriola* Heinr.)	885	0-9.3 leaders killed	Kirkland Lake, Timmins, Gogama, Chapleau
Jack pine sawflies (*Neodiprion* spp.)	severe defoliation in certain areas	30	Kirkland Lake, Timmins, Gogama, Chapleau
Swaine jack pine sawfly (*Neodiprion swainei* Midd.)	4,651	moderate defoliation	Kirkland Lake, Elk Lake Unit
White pine weevil (*Pissodes strobi* Peck.)	1,048	leader mortality	all
Armillaria root rot (*Armillaria mellea* (Vahl. ex Fr.) Kummer)	906	2.7 (mortality)	Kirkland Lake, Gogama, Timmins, Chapleau

[a]As noted in MacLeod et al. (1982).

As the plantations reach the age of possible thinning we require better growth and yield data than we now have to determine if thinning is going to be biologically and economically feasible in the future.

Jack pine regeneration is very successful in the Northern Region, as thousands of hectares of plantations have been established. Now we have to take the next step--plantation management.

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REVIEW OF THE JACK PINE REGENERATION PROGRAM IN THE NORTHEASTERN REGION

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Abstract.--Jack pine (Pinus banksiana *Lamb.), which is economically the most important boreal species in the Northeastern Region, accounts for 19% of the total annual cut, 77% of which is in the boreal transition forest. Major changes in regeneration systems, begun in 1977, have increased the level of planting from 1.4 million to 2.1 million seedlings annually with substantial improvements in survival rates. Site preparation methods, equipment and standards are described briefly. Past and current problems, with suggested improvements, are discussed.*

Résumé.--Le pin gris (Pinus banksiana *Lamb.), qui du point de vue économique est l'espèce boréale la plus importante de la région du Nord-Est, constitue 19% de la récolte annuelle totale, réalisée à 77% dans la forêt boréale de transition. Les changements importants observés au niveau des modes de régénération depuis 1977 ont eu pour effet d'augmenter le nombre de semis plantés annuellement, de 1.4 à 2.1 millions, et d'améliorer de façon substantielle les taux de survie. Les méthodes, l'équipement et les normes de préparation du sol sont décrits brièvement. Des problèmes actuels et passés sont examinés, et des améliorations sont suggérées.*

Introduction

Jack pine (*Pinus banksiana* Lamb.), though primarily a boreal species, constitutes a major portion of the mixedwood, transitional forests of the Northeastern Region (Fig. 1). This member of the pine species supplies the bulk of the feed stock for the three major sawmills and a pulpmill located in the Region.

A successful jack pine regeneration program is therefore of vital importance to the health and well-being of the Region's forests.

Regional Statistics

The regional average annual harvest of jack pine is 286,795 m^3 which is 19% of the total regional cut of 1,495,603 m^3 (Table 1). Approximately 59% of this cut goes to feed sawmills, 30% is in the form of roundwood pulp and the remaining 11% is wood chips. The

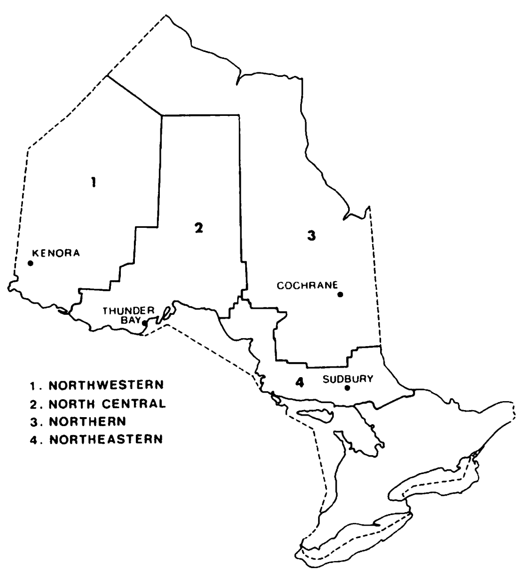

Figure 1. The northern regions of Ontario.

average area cut in the jack pine working group is 1,353 ha per year, representing a volume of 234,767 m^3 per year or an average yield of approximately 173.5 m^3/ha. Of the area cut, 77% is in the boreal and the boreal transition forest regions, yielding 90% of the volume. The remaining 23% is in the Great Lakes-St. Lawrence forest region, yielding only 10% of the volume.

Based on the above statistics, about 82% of the total jack pine cut is harvested from the jack pine working group, with 18% of the volume taken from mixedwood stands in other working groups.

Table 1. Annual cut (scaled volume), Northeastern Region.

Year	Jack pine (m^3)	Total, all species (m^3)	Jack pine (%)
1981-1982	398,378	2,081,268	19.1
1980-1981	457,312	1,733,823	24.6
1979-1980	289,501	1,764,098	16.4
1978-1979	212,769	1,455,582	14.6
1977-1978	260,271	1,422,598	18.3
1976-1977	197,423	1,171,381	16.9
1975-1976	182,802	1,015,957	18.0
1974-1975	243,924	1,339,241	18.2
1973-1974	338,804	1,476,483	22.9
Total	2,581,184	13,460,431	19.1
Average	286,798	1,495,603	

Regeneration Statistics

The regional silviculture program dealing with the regeneration of jack pine changed drastically with the advent of the new paperpot container seedling in 1977. The 10-year average level of jack pine planting (bare-root and container), prior to 1977, was in the order of 1.4 million seedlings per year, with peaks of 2.9 million seedlings occurring in 1969 and 1971. In contrast, the 5-year average planting level for the period 1978-1982 was 2.1 million seedlings, an increase of 50% over the previous 10-year period. This trend is expected to continue until 1988, at which time the level of jack pine planting will be approximately 13 million seedlings.

The major change in the approach to jack pine regeneration is in the increasing emphasis on the use of containerized seedlings as planting stock. In the 10 years preceding 1977, 73% of planted jack pine was bare-root stock and 27% was in containers. In the peak year 1971, the ratio of bare-root to container stock was 50:50. Since 1978, the ratio of bare-root to container stock has been 29:71. By 1988, it is expected that 90% of the planting stock used will be in containers. The increase in the use of container seedlings is primarily due to the relatively high survival rates achieved through a wide spectrum of sites. In Figures 2a and 2b, we see the sudden rise in survival rates achieved for both bare-root and container jack pine, well ahead of the general average.

Figure 3 indicates the relative levels of treatment for the four silvicultural techniques used in the artificial regeneration of jack pine. The data represent the means for 2 years--1979 and 1980. On average, we treat 2,085 ha per year. Of this area, 45% is container stock planting, 15% is bare-root planting and the remaining 40% is seeded both with and without accompanying site preparation. The success of these projects has been measured in terms of stocking for the seeding projects and 2nd-year survival for the planting projects. The container seedling system of regeneration obviously enjoys the highest success rates at 94% survival, with bare-root planting following at 80% survival. Seeding with site preparation is the least successful method at 49% stocking, and direct seeding--done mostly by hand--has an average stocking level of 60%. It should also be noted that the container planting results are far more consistently achieved than those of the other treatments. Results of seeding with site preparation are the least consistent.

The reason for the sudden increase in the demand for container seedlings is very clear, i.e., better results, making the overall silvicultural system more reliable. Furthermore, we have found that the container seedling is easier to handle (i.e., it can be field-stored), and it is more flexible in terms of planning and the extended planting season it affords the forester.

Site Preparation Equipment

The site preparation techniques used to regenerate jack pine all attempt to remove the insulating layers of organic matter (duff) from the mineral soil surface. The most common machine used in the boreal forest region is the TTS disc trencher, due to its ability to work in extremely rough terrain. Some areas are site-prepared using the Bräcke. Both hand planting and seeding are follow-up treatments to the site preparation. Wherever possible, prescribed burns are used prior to mechanical treatment. Seeding is normally

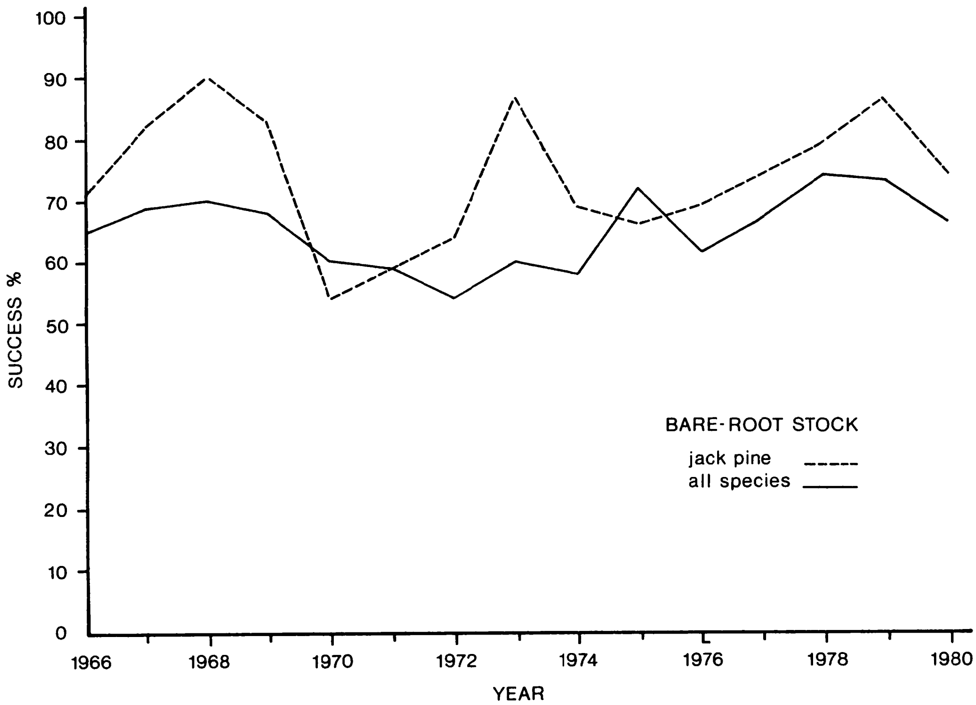

Figure 2a. Survival by year for bare-root stock - second-year assessment.

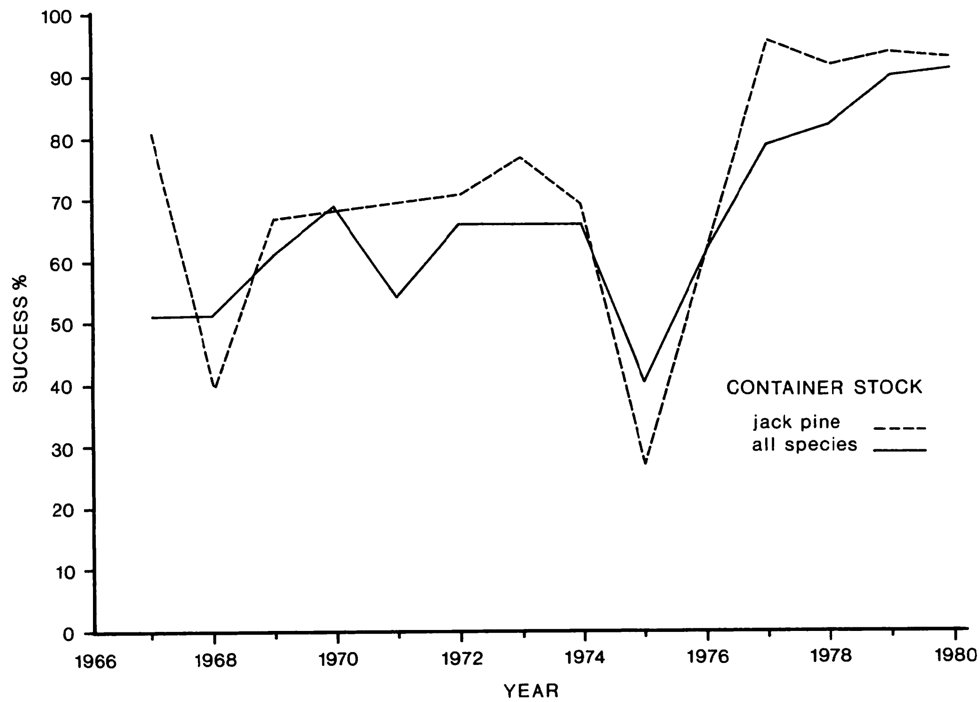

Figure 2b. Survival by year for container stock - second-year assessment.

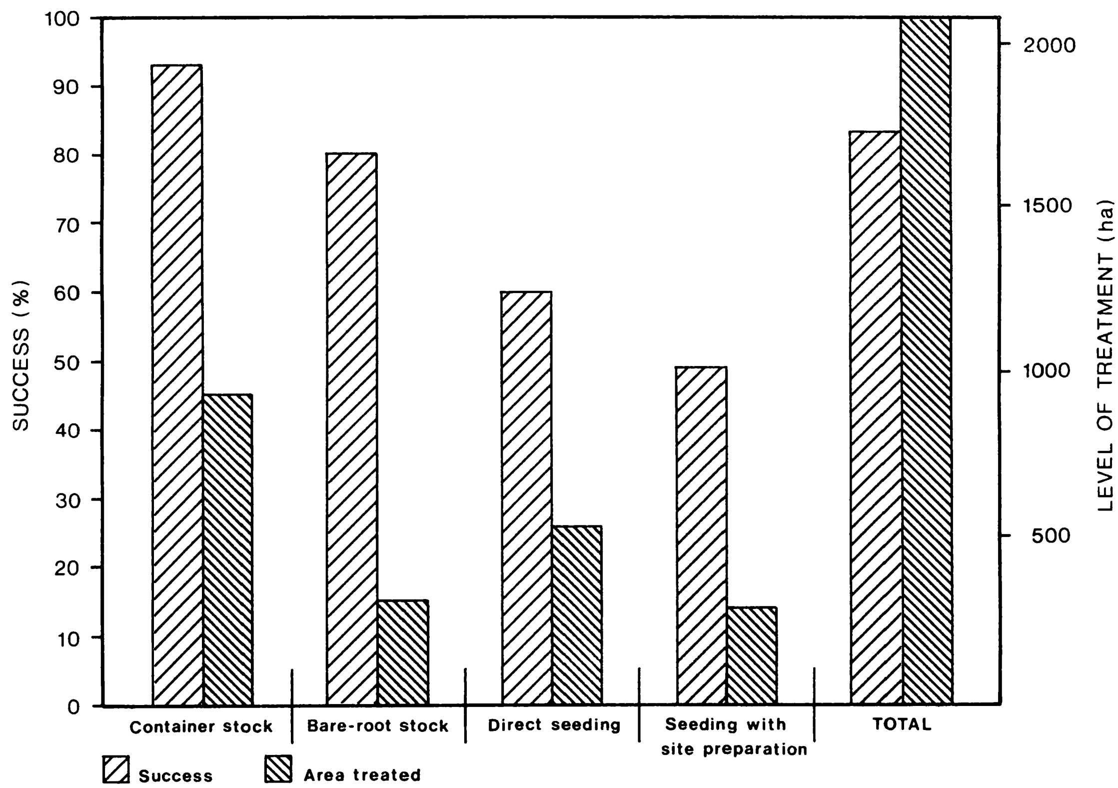

Figure 3. Regeneration treatments and results.

carried out by hand or, on occasion, from the air. Generally, it is accepted that neither machine produces sufficient, suitable seedbed for aerial seeding purposes in a single-pass application.

In the more southern mixedwood forests, where utilization and competing vegetation pose greater problems than in the boreal portions of the Region, straight blades, blade rakes, Young's teeth and the Marttiini plow are all tools that are used to "corridor" the slash-ridden sites. All treatment techniques, when used properly, tend to be successful. Unit costs vary with the equipment used.

The most common reason for failure of projects in this working group is the lack of proper site preparation treatment. The only known failures in the jack pine container system of regeneration are on projects where no site preparation treatments were carried out. Table 2 illustrates the importance of good site preparation. These data were obtained from quality-control plots established at the time of planting and on sites typically site prepared.

The seeding treatments, with site preparation, are done with the Bräcke or by the "rake and shake" method which utilizes hand tools for site preparation. The results of these treatments are extremely variable with resultant stocking ratings ranging from 20% to 83%, the average being 49%.

Equipment Evaluation

The Northeastern Region uses a system of site preparation assessment which evaluates a given sample area and determines its suitability for a given species and treatment. Three categories of acceptable, marginal and unacceptable are first defined by the field staff. For jack pine planting we require, for acceptable performance, a minimum 30-cm x 60-cm scalp per 4-m^2 plot in which the mineral soil is totally exposed or has a maximum 25% organic content in the top 20 cm of the soil profile. This organic content may be mixed with the mineral soil or may be on the surface as a duff layer no deeper than 2.5 cm. A marginal plot would be one with a scalp down

Table 2. Jack pine container stock[a] summary, Northeastern Region: quality-control data.

District	Size	Dry wt (g)	Ht (cm)	Root-collar diam	Site prep.	Growing season	Survival[b] (%) Fall	1	2	3	Avg ht increment[b] (cm/yr) Fall	1	2	3
Sudbury Parkin Twp					yes	over-wintered	100	100	100	-	-	20.5	28.8	-
Sudbury Parkin Twp					yes	over-wintered	99	93	92	-	-	19.8	26.8	-
Sudbury Cascaden Twp					yes	over-wintered	95	84	84	-	-	16.3	25.0	-
Wawa	408	.518	14.33	1.85	yes	spring	99	94	-	-	-	-	-	-
Wawa	408	.518	14.33	1.85	yes	spring	100	99	96	-	-	-	-	-
Blind River	408	.518	14.33	1.85	yes	spring (planted 3rd wk in June)	-	-	-	-	-	-	-	-
Sudbury Hutton Twp					no	spring-grown	70	62	57	-	-	16.0	18.6	-
Sudbury Hutton Twp					no	spring-grown	52	48	44	-	-	28.5	22.8	-
Sudbury Hutton Twp					no	spring-grown	69	73	57	-	-	21.5	12.3	-

[a]planted 1976 and 1977.
[b]1,2, and 3 refer to first-year, second-year and third-year assessments.

to a minimum size of 30 cm x 30 cm and/or with mineral soil organic content between 25 and 50%, with the duff layer not exceeding 5 cm in depth. For seeding, we require a maximum of 15% exposed mineral soil per quadrat, provided that the soil organic content is 25% or less. If the soil organic content is between 25 and 50%, then 30% exposed mineral soil is required. The organic content must be mixed with the mineral soil. If the quadrat has between 16 and 30% exposed mineral soil and 25 and 30% organic matter, or between 7 and 14% exposed mineral soil with less than 25% organic content, then the plot is deemed marginal. All other plots are deemed unacceptable.

For a given area, the acceptable and marginal plots are tallied, giving a weight of 1 to acceptable and a weight of ½ to the marginal. In this manner, we calculate the percentage of area suitable for a specific treatment. Table 3 illustrates typical results obtainable, using the above-mentioned equipment.

Table 3. Typical results of site preparation assessment for jack pine seeding and planting on stone-free sites.

Equipment	Area suitable (%) Plant jack pine	Seed jack pine
TTS	71.9	78.0
Bräcke	75.1	82.5
Straight blade	87.0	
Young's teeth	75.0	
Blade rake	74.0	
Marttiini plow (modified)	87.8	

Reasons For Failure

Planting

Jack pine survival rates are the highest of all species planted in the Northeastern Region. Under the current container system, failure rates are very low and are either the result of poor or nonexistent site preparation or are caused by outside agencies such as fire, rabbits, birds, etc. Even the poorest grades of stock have had acceptable survival rates (Fig. 4a and 4b) and good growth performances.

We have found that the performance of bare-root stock has not been as consistent as the performance of container stock. Flushed stock, particularly from the southern nurseries, almost invariably performs poorly. Best results have been obtained with stock received from those nurseries, e.g., Gogama, located near or north of the plantation. We suspect that the early flushing, along with the normal handling and storage practices, creates a moisture stress situation within the plant, such that even the hardy jack pine cannot overcome.

Direct Seeding

Direct seeding results are marginal but vary widely. Aerial seeding carried out in the 1970s has more often than not resulted in failure, yet those areas treated in the 1960s have been successful. Several recent hand seeding projects carried out in well site-prepared areas have been successful. In an analysis of regeneration projects on the Franz Management Unit, Thomson (1978) suggested that performance seemed to be correlated to weather and quality of site preparation. The years 1965, 1969, 1971 and 1972 were poor years for treatment and also years with low levels of rainfall. However, there was sufficient variability in site quality between projects treated in different years that firm conclusions could not be drawn.

It is the author's opinion that one of the major factors influencing seeding success is the degree of frost action on the seedbed. It is very common to find numerous 1-year-old seedlings in the early fall but in subsequent inspections, the following spring, very few rising 2-year-old seedlings can be found. On the fresher and finer-textured soils, one can often find frost-heaved seedlings, particularly on microsites devoid of organic matter. For seeding to be successful, it is very important to get early germination and adequate height growth prior to overwintering in the first year after germination. For this reason, we now recommend that all seeding be carried out in the fall or very early in the spring, just after the snow melts. This timing of treatment will ensure adequate moisture for germination and initial early establishment of the seedling, and will, it is hoped, reduce losses from frost heaving.

Seeding with Site Preparation

The failure rate on projects attempting to combine seeding with site preparation is very high; consequently, this treatment is used as a last resort on rough sites impossible to treat mechanically or on better sites inaccessible to planting crews. Both the Bräcke and the hand scalping tend to leave scalps that are depressed below the general soil surface. Though germination rates are often acceptable, survival of seedlings is hampered by accumulation of debris and soil in the depressed scalps. We estimate that most of the mortality is a result of the seedlings being buried. The smaller the scalp, the poorer the results. We estimate that a scalp with 30 cm x 30 cm minimum dimensions is necessary if hand seeding is to be done without mechanical site preparation.

Insect and Disease Problems

Diseases and insects have posed no severe problems in the Northeastern Region in jack pine. Light damage by insects such as the eastern pine shoot borer (*Eucosma gloriola* Heinr.) and the white pine weevil (*Pissodes strobi* Peck) is evident throughout the Region. Armillaria root rot (*Armillaria mellea* [Vahl. ex Fr.] Kumm.) is present in younger plantations under 10 years of age, particularly on the poorer sites. None of the above is considered to affect plantation success significantly.

On occasion, birds have been known to pluck up containerized seedings, and rabbits have destroyed several plantations by devouring the succulent leaders in local areas.

Management Problems

One of the more serious problems facing the forester in managing mixedwood jack pine stands is the utilization of other species such as poplar (*Populus* spp.) which are commonly found growing in association with the jack pine. The markets for poplar are limited in most areas and the wood tends to be of marginal quality, particularly in the older stands. What does one do with residual standing timber? If the timber is left standing,

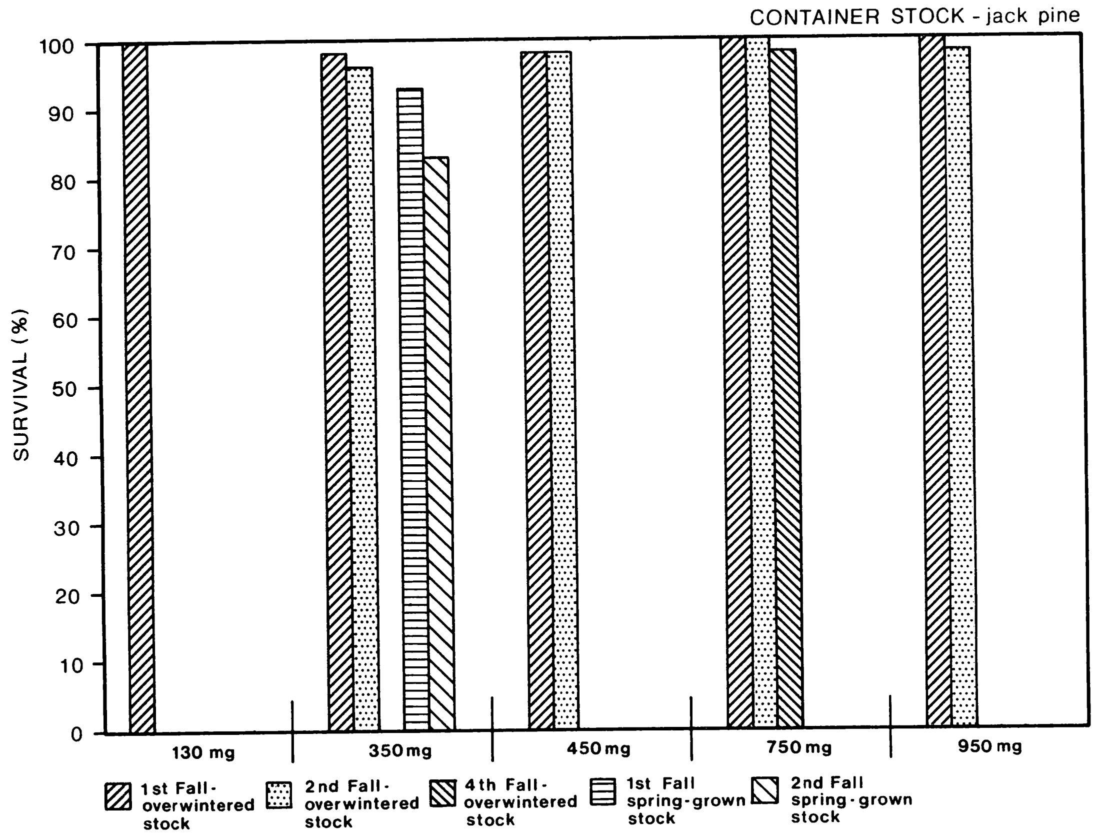

Figure 4a. Survival and oven-dry weight at shipping.

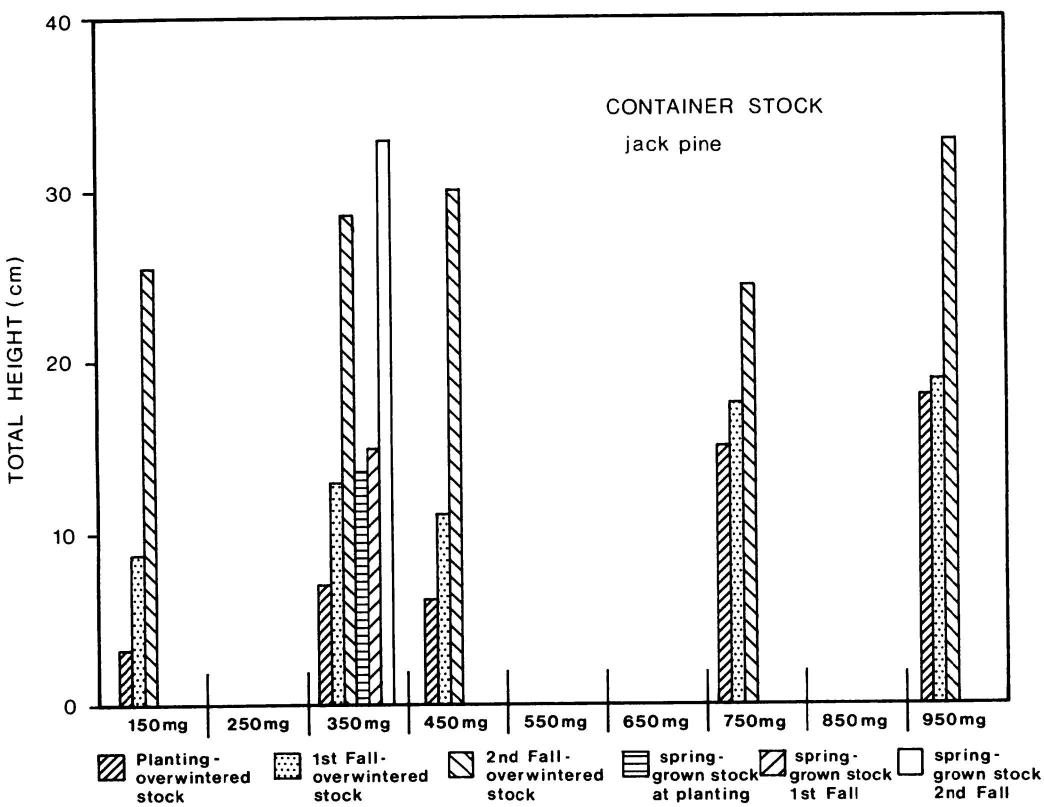

Figure 4b. Total height and oven-dry weight at shipping.

it is difficult and expensive to eradicate. If the timber is knocked down, it impedes subsequent treatments and will sucker profusely and compete with the jack pine.

Management of competing vegetation is difficult with current technology. Use of 2,4-D in release programs is limited to areas where competition is already severe or damage to the crop tree is likely. On fresher, fine-textured sands, loams and silts, although the use of 2,4-D may alleviate our brush and tree competition problem, dense grass and raspberry patches often take over, and are equally destructive of young tree seedlings. New and better control methods are required for vegetation control.

Summary

Jack pine is among the most important tree species in the Northeastern Region. The bulk of the artificial regeneration program, particularly seeding and container planting, is centred around this species.

If recommended practices are followed, successful plantation establishment is not a problem. Site preparation using mechanical tools, often in conjunction with herbicides and fire, is deemed essential. Tending treatments pose a problem but are required on the fresher, fertile mixedwood sites. Due to its inherent flexibility and good success rates, the container system of regeneration is expected to replace all other artificial regeneration techniques, wherever feasible.

Further work is necessary to improve tending practices. Better utilization of subcomponent species is essential for efficient management of the jack pine working group.

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OVERVIEW OF MANAGEMENT OPTIONS FOR JACK PINE IN ONTARIO

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Ladies and gentlemen, during the past three days we had an opportunity to assess and evaluate the prominent position that jack pine (*Pinus banksiana* Lamb.) holds not only in the economic life of Ontario but also in that of the other provinces and the Lake States in which it grows. We are indebted to the forest scientists of the Lake States and those of the Canadian Forestry Service for providing us with early literature on the genetics and silvical characteristics of jack pine, which we used as a benchmark in developing our own management and regeneration guidelines reviewed at this symposium.

We have discovered that jack pine is the most adaptable conifer, and that it will outperform almost all of our native species on most sites, from bare rock to deep organic soils. Jack pine is the second fastest-growing conifer after larch (*Larix laricina* [Du Roi] K. Koch); therefore, it can be a good competitor and one that offers a great potential for tree improvement.

Jack pine is very easy to regenerate. It responds well to planting, seeding and natural regeneration by fire. It is the only species that holds its own as far as the maintenance of the working group is concerned. The problems of the management of jack pine may be diverse across its growing range, yet they are similar even though they are not very serious. If jack pine is such a wonderful species, what then are the managment options left to us?

The requirement is the fine tuning of our regeneration techniques which would enable us to increase the stocking and spacing of our plantations through the concept of better area coverage. The potential of increasing the yield per hectare through the application of this concept is fantastic when you consider that the average stocking of the natural forests is only 60%. Good site preparation can also shorten the rotation of artificially seeded and planted stands because it results in better height growth than in natural stands.

Jack pine is not loblolly (*Pinus taeda* L.), lodgepole (*P. contorta* Dougl.) or Scots pine (*P. sylvestris* L.). Jack pine must grow in dense stands to overcome its competitors by crown closure. Crown closure is also required by jack pine for self-pruning and the maintenance of its height growth.

Jack pine will not tolerate juvenile spacing above 1.8 x 2.1 m (2,500 trees/ha). As you have seen on your field trip, the wider the spacing, the limbier the tree becomes, until at a spacing of 3.0 x 3.0 m it resembles an orchard tree with 50% of its volume in a short bole. The remaining 50% of its volume is in heavy branches that were developed by the tree in an effort to attain crown closure. As pointed out by one of the speakers, spacing will enhance the diameter but not the height growth of jack pine.

So much for the advocates of wide spacing who, a few years ago, were saying "Why plant a thousand trees per acre when we harvest only 400 or less?"

Remember the horrors and the laughs that reverberated through the ivory towers a few years ago, when the Premier of Ontario announced his policy of planting two trees for every one that was harvested? Well, the laugh is on the pundits because that is exactly what we must do, unless we intend to plant jack pine in alternate rows with aspen *Populus* spp.), aspen (*Populus* spp.), white birch (*Betula papyrifera* Marsh.) or balsam fir *Abies balsamea* [L.] Mill.), to prune it and to keep it growing straight up.

"Intensive management" is another catchy phrase that is often bandied about by forestry experts. As pointed out by two speakers, commercial thinning of jack pine can be economically feasible on site class 1 and possibly on the upper half of site class 2 stands where sawlogs are to be the end product. These areas, however, amount to only 10% and 15% of the forested land base of Ontario. The remaining 75% of the jack pine stands growing on the lower half of site class 2 and all of site classes 3 and 4 must be managed extensively for pulpwood by the most economical methods (e.g., seeding), just as a prairie farmer manages his wheat fields.

Intensive management to some people means spending $860 to $1,100 per ha to establish a stand of site class 1 capacity by planting after site preparation and tending the same plantation at least twice before it attains apical dominance over its competitors. This system of regeneration is much more glamorous than spending $86 to $110 per ha on row or spot seeding a stand of site class 2 or 3 capacity without a follow-up treatment by the extensive method. Some people have difficulty in accepting the fact that five times the volume from 10 times the area is a better bargain for the same amount of money. I don't think we can afford to leave out of production one out of every 10 ha of site class 2 or 3 jack pine we cut in Ontario. On the other hand, I do not see anything wrong with letting one out of every 10 ha go through the succession stage from site class 1 jack pine to site class 1 aspen. Remember that "just as you sow, so shall you reap", and you cannot harvest what you have not sown.

Another concept that keeps rearing its ugly head is the 80-km radius around each pulp and paper mill as a source of supply of raw material. This is "the near versus the distant land management theory". From the economic point of view, it sounds good. In fact, it is too good to be true, because it is not. The scenario in real life is quite different. Have you ever noticed, for instance, that the good land around each pulp mill is always patented, and that the reason some land around the mills is not patented is that it is just as poor as the distant land? Just how the proponents of this theory expect to practise intensive forestry on a pile of rocks surrounding most mills is beyond me.

Some of our people are not satisfied with Plonski's system of forest classification by species, stand, working group and site capacity. These people genuinely believe that a system based on the classification of the lower vegetation of a stand at rotation age will solve all of their management and regeneration problems. I have news for you! Cajander in Finland came up with a similar classification system based on indicator plants some 70 years ago. His system did not turn out to be a panacea for the forest management problems of Finland. It did, however, teach the Finns how to recognize the moisture regimes of their various sites by the indicator plants that occupied them. Did not Eyre do the same for jack pine? Neither Eyre nor Cajander, however, is able to provide you with a volume estimate based on his moisture regimes as Plonski can with his site capacities, even if the latter are not always accurate. Keep in mind, too, that any system based on the moisture regime of the various soils with their indicator plants at rotation age cannot tell you the successional changes that will be initiated on these sites by harvesting alone, or by the site preparation which follows, let alone by the chemical tending of the new crop. In short, the indicator plants are destroyed and the ecologist does not know the new ones that will replace the old ones by each successive human disturbance. Only your expertise based on your knowledge gained through personal experience can predict these outcomes. Therefore, you should use any aid, old or new, that will enhance your knowledge and enable you to do a better job both biologically and economically. Do not become a slave to any system that will bankrupt you morally and economically.

Tree improvement was high on the list of all status reports, and it should be so. Tree improvement can provide us with a better stem, one that is free of crooks and sweeps and other defects. It can provide us with rust-resistant trees and possibly with trees that are insect tolerant. Ultimately, tree improvement may even come up with modest volume gains. For short-term volume gains start with a fully stocked stand if you wish to harvest a fully stocked stand grown from a seed source collected, extracted and controlled like that of the Northwestern Region.

The management of our forest by site capacities instead of age classes, regardless of site capacity, is a concept that is beyond the comprehension of most people right now. Reducing the rotation age of jack pine from 80 to 70 years and breaking up the large age classes to control and prevent the outbreak of Swaine's sawfly is just plain heresy. How else would we be able to project into the future the large areas of single age-class burns and plantations you saw on your field trip?

Tending is a very serious problem both here in Ontario and in the other provinces. The greatest losses of jack pine, and indeed of any conifer plantation in Ontario, have been through the succession stage to aspen on most of our best sites. A temporary permit from the federal government allowing us to use forestry chemicals approved in the United States to stop this erosion until the chemicals are registered in Canada is urgently required. Do you not find it strange that the largest contributor to both the federal and the provincial economies of this land is unable to obtain permission to enhance that contribution through better forest tending? A farmer faced with a loss of $860 to $1,100 worth of grain per ha would simply hop on a tractor along with a few of his neighbors and bring the federal government to its knees on the nearest highway and keep it there until he got his chemical permit to save his crop. I wonder what our skidders, forwarders and harvesters could do about these staggering monetary losses that the provinces and their forest industries sustain every year.

Finally, don't be an instant expert and reinvent the wheel just because you did not invent it in the first place. Don't get the idea that forestry was not practised until you came along. If your ego is getting the best of you, just stop for a minute, look over your shoulder and see just who has the most successfully regenerated area to his credit, you or your predecessor. And after you have had a chance to assess the situation, keep your own counsel even if you outperformed him, for your deeds will speak much louder than your voice.

Right now, to you the Alumni of the Boreal Campus of George Brown College, I wish you well! I don't have to tell you to keep up the good work because I know you will.

To the rest of you that had a chance to hear us and to look us over, I hope you learned as much from us as we have from you, in order that together we may meet the forest management challenges of the future.

So until we meet again--if ever--God bless you all!

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