BLACK SPRUCE SYMPOSIUM

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and
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FOREWORD

The Black Spruce Symposium held at the Red Oak Inn, Thunder Bay, Ontario, September 23 to 25, 1975, was cosponsored by the Ontario Ministry of Natural Resources and the Canadian Forestry Service. Its purpose was to review recent developments in black spruce silviculture, to disseminate information to provincial forest managers, and to attempt to stimulate interest in and improve the management of black spruce. More than 140 delegates from provincial and federal forestry services, the United States Department of Agriculture, forest industries, universities, colleges of technology and equipment manufacturers attended the symposium.

The proceedings include 20 papers presented in three formal sessions. Abstracts in English and French are included with each paper, and measurements are given in both English and International units.

Discussions recorded during the symposium follow the relevant papers and groups of papers in the proceedings. Where paraphrasing was necessary for brevity or clarity the editors tried to retain the essence of questions, answers and related discussion.

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.

The second day of the symposium consisted of a successful field tour of clear cutting and strip-cutting operations and plantations on the license of Domtar Woodlands Limited, in the Nipigon forest district.

The program committee acknowledges its appreciation of those who presented papers, chaired the formal sessions, conducted the field tour and contributed in other ways to the success of this symposium.

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SESSION A

BLACK SPRUCE--THE CINDERELLA SPECIES AND THE STORY OF CANADIAN FORESTRY

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The perpetuation of black spruce (**Picea mariana** *[Mill.] B.S.P.*) *as an ecologically and economically important species in our northern forests poses a major challenge for forest scientists and managers. There is an urgent need for inexpensive, nonlabor-intensive silvicultural techniques appropriate to the range of site conditions on which merchantable volumes can be grown.*

La perpétuation de l'Epinette noire (**Picea mariana** *[Mill.] B.S.P.*), *essence écologiquement et biologiquement importante dans nos forêts nordiques, constitue un défi important pour les gérants et scientifiques forestiers. On devra de toute urgence mettre au point des techniques économiques et nécessitant peu de main d'oeuvre, appropriées aux stations dans lesquelles arbres marchands peuvent croître.*

INTRODUCTION

It is the expectation of the sponsors of this symposium, the Ontario Ministry of Natural Resources and the Great Lakes Forest Research Centre of the Canadian Forestry Service, that, through a review of recent developments in black spruce (*Picea mariana* [Mill.] B.S.P.) silviculture, information of potential value to provincial forest managers will be disseminated. The gathering here of forest scientists, experts, decision makers, and practitioners should stimulate interest in the subject and facilitate useful exchanges of opinions, ideas, and information.

Although my opening remarks were of a somewhat cynical cast, I expect that at least three distinct benefits will be realized from this symposium. First, the preparation of formal papers reporting on the results of research and investigation, together with the literature reviews, and consolidation of reference sources will be beneficial. A second benefit will be afforded through the opportunities for informal exchanges of observations, opinions and insights. The third and perhaps greatest benefit will arise from the field trip to be led by Messrs. Marek and Jeglum, when we shall be able to see and learn about the consequences of nearly 20 years of continuous, dedicated effort by a forester to manage his unit effectively.

Although black spruce silviculture is the major topic of this symposium, it is assumed that the overriding concern and ultimate objective of all assembled here is to expand our understanding and knowledge of the current situation, techniques and prospects for optimizing the material and environmental potential of black spruce as a principal component of the boreal forest in the future. Although such a suggestion may be deemed unnecessary, it is made because many foresters regard this species as one which should, wherever possible, be replaced by species that will yield higher volumes of wood fiber per unit area in shorter periods of time.

Sixteen years ago, "Spruce Management for the Future" was the theme of the annual meeting of the Canadian Institute of Forestry (see Fellows 1959). At that time, apart from a few small-scale experimental operations and reforestation projects, the planned management of the boreal forest, together with significant attempts to influence the new forest, both quantitatively and qualitatively through silviculture, were but faint expectations in Canada. Since that time, there have been significant improvements in the support provided for silviculture as a public enterprise. In Ontario, for example, the allocation of funds to silviculture by the provincial government has risen from about $1,000,000 in 1959 to about $9,000,000 in 1972. Although the latter figure must be discounted somewhat to allow for the inflation rates of the past few years, it is clear, nevertheless, that opportunities for silviculture have greatly improved. At the same time, the responsibility of those entrusted with the effective expenditure of those funds for the attainment of satisfactory long-term benefits has risen proportionately.

It has been my opinion for many years that the most serious obstacle to the improvement of Canadian forestry practice in general, and the management of our northern spruce forests in particular, has been socio-political rather than technical. Whether or not we have, or shall have at some future time, all of the necessary technical knowledge and expertise, we may find that other factors beyond our control will continue to obtrude to frustrate us, as they have thus far in the history of Canadian forest exploitation. For this reason, I decided to attempt to sketch a brief historical review of Canadian forest exploitation, and of policies, public attitudes, and technological developments in the past 75 years which have affected our northern black spruce forests. Such a review may provide a basis for an understanding of the past actions, attitudes, and difficulties which have confronted the forester and forest scientist in attempts to implement measures in practice for optimizing the regeneration, growth, and yield of black spruce on cut-over areas.

THE SPECIES

As is well known, black spruce is one of the most widely distributed species in Canada. Together with trembling aspen (*Populus tremuloides* Michx.) and white birch (*Betula papyrifera* Marsh.), it occurs in the ten provinces and the two northern territories. If the designers of our national flag had been concerned with representing thereon a tree of national significance, both in occurrence and in economic importance, they surely would have chosen the distinctive black spruce crown.

The wide geographic distribution of the species, through more than 100 degrees of longitude and 25 degrees of latitude, is paralleled by the exceedingly wide range of soils and site conditions on which it can grow. Thus, merchantable-sized stems and operable volumes per acre can occur on virtually all media from deep humus through clays, loams, sands, coarse tills, and boulder pavements to decidedly shallow soil mantles over bedrock. The stereotypic view of the species places it almost exclusively on swamp and muskeg sites and adjacent lower slopes. Observation suggests that, in fact, a significant proportion of the sites encountered in the boreal region can be utilized effectively only by black spruce.

Inventory Data

Several years ago, a review of the national inventory position (Manning and Grinnell 1971) indicated that spruce was the dominant tree species in Canada. It represented 40% of the coniferous volume and one third of the total volume for all species in the country.

A report summarizing the data from forest inventory surveys in Ontario (Dixon 1963) revealed that the principal species in the province was black spruce. Of the total volume of coniferous species growing in the province, black spruce represented 48%, and of the total inventoried volume of all species it represented 29%.

The first general report on the forest resources of Ontario (Sharpe and Brodie 1930) was published nearly 45 years ago. It is interesting to note that, in the summary of the inventory data, spruce represented 60% of the total volume of all species recorded, and 63% of the estimated total volume of conifers. In 1930, the volume of spruce growing stock was estimated at 154 million cunits, an estimated volume which, through improved data sources and techniques, more than three decades later, increased to 520 million cunits.

Utilization

In Table 1, data are provided which indicate the significance of spruce as a component in total provincial timber production in the past 20 years. Unfortunately, black spruce and white spruce (*Picea glauca* [Moench] Voss) volumes are not reported separately in the annual reports of the Ontario Department of Lands and Forests/Ministry of Natural Resources. It is assumed, however, that not more than 10% of the total volume of spruce indicated is represented by white spruce. It may be sufficient to observe here that black spruce represents nearly half of the total annual provincial timber production.

Table 1. Timber production data from annual reports of Department of Lands and Forests/Ministry of Natural Resources (Ontario Crown lands)

Total cut all species (cunits)	Total value of stumpage ($)	Total production of spruce (cunits)	Total prod. of spruce as % of total cut, all species	Total value of spruce stumpage ($)	Total value of spruce stumpage as % of total value of stumpage
1953 (1951-1952 season)					
4,900,000	----------	2,481,000	51	---------	--
1963 (1961-1962 season)					
3,256,000	11,297,000	1,559,000	48	5,743,000	51
1973 (1971-1972 season)					
4,438,000	13,900,000	2,163,000	48	7,313,000	53
1966 (1964-1965)	Data for selected northern administrative districts				
Port Arthur District					
367,900	----------	265,200	72	---------	--
Geraldton District					
584,000	----------	384,200	66	---------	--
Sioux Lookout District					
235,000	----------	441,000	88	---------	--
Kapuskasing District					
502,000	----------	441,000	88	---------	--

Ontario pulpwood production: 1923 - 573,000 cunits; 1937 - 609,000 cunits; 1954 - 3,740,000 cunits

The significance of spruce as a component of annual production for several of the northern administrative districts of the former Ontario Department of Lands and Forests is indicated in the lower section of Table 1. These data, for the 1964-1965 operating year, reveal again the importance of spruce and, more particularly, of black spruce in the timber economy of the province.

The volumes of pulpwood to be produced in the boreal forest region in the 1975-1976 operating year by eight major pulp and paper companies are recorded in Table 2. Of the total volume that will be produced by these companies, spruce will comprise 60%, and of the spruce volume, black spruce will represent 90%. On the basis of the data provided, it would appear that 52% of the total volume of black spruce to be produced will be obtained from upland sites.

Black spruce continues to maintain its preeminent position in pulpwood production operations, and it is apparent that it will do so in the future, at least until the remaining growing stock reserves recorded by our forest inventory surveys have been utilized.

History

The exploitation of eastern white pine (*Pinus strobus* L.) and red pine (*Pinus resinosa* Ait.) was a significant factor in the development of the economy of the new province of Ontario, immediately following Confederation. The phenomenal growth of a saw-milling industry based, essentially, on the liquidation of the best and most accessible stands of those species has been well described by Lower (1938). The rapid decline of that industry, beginning about 1908, after little more than a half century of unregulated, unrestrained cutting in the Great Lakes—St. Lawrence watershed, coincided fortuitously with the rise of the pulp and paper industry beginning at the turn of the present century. The industry found that the lowly black spruce which had, for so long, been spurned as of negligible value for forest products, provided, with the least difficulty, the highest yields per unit volume of high-quality fiber for pulp and newsprint manufacturing.

The rate of growth of the pulp and paper industry in Ontario, based primarily on black spruce, paralleled that of the lumber industry based on white pine and red pine in the previous century. Although there were only two or three wood fiber-based mills in Ontario in 1900, there were established within 20 years 16 paper mills, 9 pulp mills, and 13 combined pulp and paper mills, a total of 38 establishments (Beck 1921). An important factor in this growth, of course, was the action by the United States government of repealing the tariff on Canadian newsprint in 1913. The continuing economic importance to our province, and indeed to Canada, of this industry based, to a significant degree, on black spruce, is well known and documented (Anon. 1969).

The rise in the rate of exploitation of black spruce from a minimal volume in 1900 to the current level of approximately 2 million

Table 2. 1975-1976 pulpwood production data for Crown lands in Ontario and Manitoba (provided by pulp and paper companies - boreal forest region)

Company	Total production, all species (cunits)	Total volume of spruce in total production	Spruce vol. as % of total production	Black spruce vol. as % of total spruce vol.	% black spruce to be cut on upland sites
A	323,000	287,000	89	92	9
B	408,000	210,000	51	95	45
C	278,000	205,000	74	75	40
D	126,000	95,000	75	96	75
E	907,000	605,000	67	91	36
F	750,000	375,000	50	95	60
G	348,000	200,000	57	98	87
H	276,000	135,000	49	78	72

cunits per annum prompts questions as to the techniques used in the harvesting of those volumes, and the extent to which the productivity of the areas from which they have been removed has been maintained or improved. To date, what has been the impact upon the forest environment of the exploitation of black spruce?

During the past 75 years, developments in timber harvesting technology have led to the application of a considerable number of systems for removing the merchantable portions of tree stems from cutting areas to a delivery system such as a river, lake, or road. Our major concern with the systems, however, is not the systems or techniques themselves, but rather the environmental and silvicultural consequences following the application of each of them. On the basis of the aforementioned criteria, I have divided the systems into three major groups.

The first group includes all those systems that were applied up to about 1950 and can be characterized as having the least direct impact upon the soil (or tree-rooting medium), vegetation, and advance growth in the cut-over areas, in comparison with those assigned to groups two and three. The group includes such systems as the hand cutting and piling or bunching of 4-ft (121.92-cm) and 8-ft (243.84-cm) wood for winter forwarding by horse and sleigh, and for all-season forwarding by cable yarder. At the end of the period, tractor and articulated-frame wheeled forwarders were developed to transport hand-piled wood from the cutting area to road systems.

In general, it can be said of the systems in group one that the maximum impact upon forest sites and vegetation caused by the forwarding of the wood was restricted to a maximum of 15% to 20% of the cut-over area. A common characteristic of all of these systems was the assignment of portions of the uncut timber to individual cutters in the form of strips 66 ft (20.07 m) wide and frequently 1/4 mile (0.40 km) or more in length.

In group two are included systems involving the hand cutting and wheeled skidder forwarding of tree lengths, or full trees, to processing sites on roadsides. The progressive development of larger, more powerful, and heavier skidding machines together with the nature of the system, involving the assignment of large blocks of timber to cutting crews, has tended to increase the proportion of a cutting area subjected to the direct impact of the application of these systems. Soil compaction, the creation of deep ruts and trenches, and the more extensive destruction of residual trees and advance growth appear to be associated with them. This system has been applied extensively for approximately 20 years.

Beginning about a decade ago determined efforts by the forest industry to mitigate woodlands labor problems and to improve wood delivery costs led to the creation of mechanized timber harvesting systems, which are included in group three. These systems differ significantly from those in groups one and two in that they involve the felling and removal of timber by decidedly large, heavy, wheeled or tracked machines. When compared with those in groups one and two, it would appear that they have a maximum adverse impact upon soil, site conditions, vegetation, and advance growth, over a decidedly high percentage of the cut-over area.

What have been the silvicultural consequences of the application of these systems in the boreal forest? Opinions, and supporting data for them, will doubtless be presented during the next several days. The question is of interest when considered in relation to the declarations, statements, and contentions which have emanated from the three major entities having a direct interest in the question, i.e., the forest industry, the forestry profession, and the government/public sector of the province.

In the past two decades, public information messages from the pulp and paper industry have conveyed positive statements supporting the general theme that industry forests are "the best managed in Canada". A sampling of such messages is included in Appendix A. They suggest that the silvicultural consequences of logging have been decidedly beneficial.

Appendix B contains excerpts from letters I have received in recent weeks from foresters employed by several of the major pulp and paper companies in northern and northwestern Ontario. The forthright "all's well in the woodlands" institutional messages in Appendix A seem not to be supported so unanimously and unreservedly by the individual opinions in Appendix B.

At the request of the Ontario Ministry of Natural Resources, modified cutting procedures have been undertaken over the past several years by a number of the companies on a progressively increasing scale. Several of the industry spokesmen referred to above expressed concern about the impact of the imposition of these methods on operating costs and, further, questioned the silvicultural value of an apparent trend toward universal application of alternate strip, block and patch cutting.

The professional tendency, as manifested at national and provincial professional gatherings, on the question of the silvicultural consequences of forest exploitation operations has, with but few exceptions, been to rationalize, equivocate, and avoid debate. In the period 1954-1960, particularly, the Ontario forest industry was concerned that the government of the day might wish to implement Section 23 of the Crown and Timber Act. That section stipulated, in part, that a licensee could be required by the Minister of Lands and Forests to undertake such measures as he might deem necessary to establish and maintain productivity of cut-over areas. Accordingly, industry foresters could often be heard at meetings of the profession justifying the failure or refusal of the industry to take initiatives in accord with the intent of this statutory measure. The principal reasons most frequently heard are recorded in Appendix C.

In that same period, foresters in the employ of the provincial government were significantly restrained in their efforts to achieve some silvicultural progress by a number of factors among which were government policy, inadequate budgets, professional and technical staffing, inertia and, above all, the hard economic line taken by the industry.

In considering the consequences of the exploitation of black spruce in particular, it is my opinion that, in general, the second forests of this species will be of much poorer quality and lower yield than those which they have replaced. Logic suggests that this must be anticipated when the logging of the original stands was planned and controlled only for the objective of minimum wood extraction cost. With but a few minor exceptions, silvicultural factors have never been seriously considered in operations planning, nor have they influenced in the slightest the logging systems employed in the past 75 years in Ontario.

It is my belief that, in all probability, Canadian forest history will reflect faithfully that of other countries. The mostly unregulated, uncontrolled, mechanized assault upon our northern forests, governed only by the consideration of minimum current wood extraction cost, will continue. The conversion of our northern forests to hard currency, with a minimal commitment of effort to the establishing of a high-quality second forest for the benefit of future generations, must be anticipated. Such is and has been the nature of our treatment (which some foresters persist in describing as "sustained yield management") of the northern forests for more than 75 years. The process has converted vast areas to a condition of reduced productivity, or from black spruce to stands of shorter-lived species and less stable forest ecosystems.

There is a general assumption at the present time that the conversion of extensive areas from black spruce to other species should not be regarded as a problem. It is contended that modern wood technology obviates the need for the perpetuation of black spruce and that, given sufficient time, almost all, if not all, cutovers will restock naturally to black spruce or to some other usable species. Unfortunately, a significant proportion of the total area of the boreal forest region, which is classified as productive by forest inventory surveys, is composed of sites on the extreme ends of the range of productive site conditions. At one end of this range can be found the merchantable muskegs, and at the other shallow soils on bedrock. These sites supported excellent virgin stands of black spruce, and are capable of supporting effectively *only* that species. The large aggregate area which they encompass in the boreal region is included in the allowable annual cut data upon which "designs for development" in the "province of opportunity" have been based.

The viewpoints of the forest industry and the forestry profession on the question of the consequences of our forest exploitation practices have been reviewed thus far. Other expressions of concern, from what could be deemed the public sector, might be of interest. A number are recorded in Appendix D.

Memories of the serious decline of the lumber industry because of the over-rapid depletion of white pine and red pine may have prompted the creation of a federal Royal Commission on Pulpwood a half century ago. In the report of the Commission (Anon. 1924), the pulpwood timber supply situation was reviewed for each province. An objective of the Commission was "to study the methods under which the timber is produced, managed and used with a view to the recommendation of measures which would more adequately ensure the maintenance of the forest resources in a state of continuous productivity". Repeated reference is made in the report to the failure of governments, both federal and provincial, to maintain the productivity of "what is over vast areas a sadly depleted and deteriorated forest estate".

Sentiments similar to those recorded by the federal Royal Commission on Pulpwood were expressed one year later by the Dean of the Faculty of Forestry at the University of Toronto (Howe 1925).

An Ontario Royal Commission on forestry two decades later (Kennedy 1947) observed that good reproduction in cut-over areas "has been the child of chance rather than of design".

In 1965, a White Paper of the Ontario Department of Lands and Forests outlined proposals for a program of renewable resources development in the province. The paper included a declaration that a number of measures would be taken, including the following:

> "All forest operators on Crown Lands will be required to follow silvicultural practices which will quickly assure full stocking of the medium and better sites of all cut-over lands."

The legislative basis for the implementation of the aforementioned declaration was provided by an amendment, in 1954, to the Crown Timber Act. Section 23 of the Act was expanded to include a provision previously referred to under which the [Ontario] Minister of Lands and Forests could require a licensee of Crown land to undertake such measures as the Minister deemed desirable to establish and maintain the productivity of the cut-over areas. The implications of this amendment for the forest industries were a major influence, I think, in the remarkable level of forestry projects and programs undertaken in that period.

The decade of the "fabulous fifties", as it was hailed, initially was one which appeared to carry great promise for the advancement of scientific forestry in Ontario. Company forestry departments were being expanded to undertake increased responsibilities in forest inventory surveys, the preparation of forest management plans, the establishment and measurement of permanent sample plots for growth and yield data, the conduct of regeneration surveys, and the initiation of silvicultural experiments both in areas formally established for the purpose and elsewhere. It was a decade of high professional hopes and expectations.

In spite of the above-mentioned provision of the Crown Timber Act, Crown timber licensees were able to avoid any major commitment of funds to modifications of cutting methods or to the rehabilitation of cut-over areas. Some of the arguments advanced by company foresters in support of inaction have been mentioned previously.

Early in the decade of the "soaring sixties", Professor R. C. Hosie, who was then president of the Ontario Professional Foresters Association, suggested in an address to the Association that:

> "We are blind if we don't see that slowly but surely our forest is being reduced in quality species. Anybody who doesn't believe that has only to take a trip through our cut-over forests. That is a very good place for anyone to go who would like to see what happends when exploitation disregards silviculture. There you will see a young forest remarkable mainly for the absence of quality. It is my confirmed opinion that this is a very serious happening with us and that is the crux of our forest problem."

In 1962, the silvicultural sword of Damocles implicit in Section 23 of the Crown Timber Act, which had been suspended over the forest industry for 8 years, was removed by a further amendment to the Act. The amendment transferred the responsibility for establishing and maintaining the productivity of cut-over areas from the industry. That duty was accepted by the Crown. Thus ended the "fabulous fifties" for forestry, and thus was wrought the de facto death of active and responsible participation in forest management and silviculture by the industry in Ontario.

The problem of provincial forestry came under review, once again, by a Forestry Study Unit composed of members of the staff of the Ontario Department of Lands and Forests. In the report of the Unit (Brodie 1967) a rapid expansion of the silviculture program on Crown lands was recommended. As a means of achieving this objective, the implementation of widely hailed Crown-industry cooperative regeneration agreements was begun at that time. Although the agreements appeared to be functioning well for 5 or 6 years, there were clear indications from the beginning of the present decade that they were destined to die a natural death.

In 1970, the Ontario Economic Council released a report on a review of past and present forest policies in Ontario (Butters 1970). The report encompassed a wide range of critical observations and recommendations relating to the forest industries and forest management. Particularly criticized was the lack of effort by the forest industry to ensure the regeneration of the second forest of a quality at least equal to that of the natural forest.

Finally, to complete this brief historical review of positions and statements taken on the issue of forest renewal during the past 50 years, mention might be made of the renewed effort by the Ontario Ministry of Natural Resources staff to develop government support and provide increased funding for an expanded program of silviculture. The instrument through which this has been achieved, in some measure, was a study entitled, "Forest production policy options in Ontario" (Anon. 1972). Because of the remarkable increase in the demand for wood in the past several years, it is understood that a further expansion of the silviculture program is being contemplated. There would appear to be a strong justification for such action because, in any case, the current silviculture program is restoring to productivity, according to statements from Ministry officials, only one third of the areas cut over annually.

OBSTACLES TO EFFECTIVE SILVICULTURE AND MANAGEMENT

Although I have strayed rather far from my assignment of addressing myself to "black spruce problems, regeneration, environment, industrial use", it has long been my belief that the most serious obstacles to the improved silvicultural treatment and more effective management of our boreal forests have been socio-political rather than technical in nature. Indeed, it is doubtful that wider opportunities for the application of the discoveries of the forest scientist, and the knowledge of the practising forester, can be expected until a number of obstacles have been eliminated. Some of these are listed below.

1. The current policy of maintaining as "two solitudes", logging operations, and the silvicultural measures undertaken to restore the cut-over areas to productivity. On previous occasions I have described this as a policy of "you liquidate, we regenerate", the "we", of course, being the people of Ontario.

2. A major obstacle to acceptable qualitative and quantitative standards of regeneration of the second forest on cut-over areas has been the total preoccupation of the forest industries with a sole objective, the annual production of the volumes of wood required by mills at minimum cost. Pious protestations and propaganda to the contrary, the forest products industries, with but few exceptions, have never been genuinely and fully committed to the implementation of the basic measures required for assured sustained yield management.

3. The third responsible entity in this list of obstacles to effective management is, of course, the forestry profession. Too many foresters in the past 30 years have been content to rest in the comfortable pew of standard duties assigned to them by employers. Too many foresters have served as silent, compliant employees of industry and government. Too many professional foresters have forgotten, or perhaps never recognized, a primary responsibility to the public interest. Too many have justified all that has gone under the guise of sustained yield management.

Many other obstacles which have been discussed ad nauseam in professional circles during the past two decades could be listed. Among these have been the problems of excessively large management units, lack of adequate professional and technical staffing in those units, lack of continuity in directing the operation of the units, lack of suitable regeneration stocking standards, lack of an adequate access road system coupled with lack of maintenance and the disintegration of existing road systems, and many others.

Beyond the aforementioned obstacles, however, is one which, in my opinion, transcends them and, in fact, is the basis for them. The major obstacle which forest scientists and managers have faced for many years, and which will confront them for yet a little while, is psychological. Only in the past few years has it become apparent to a small minority of concerned persons that the great Canadian myth of a limitless forest resource is just that--a myth. Nevertheless, we appear to be a number of years, or perhaps a decade or two, removed from feeling the pinch of timber shortages in the boreal forest region. Unless and until we do feel that pinch, the major impetus for a serious, substantial, and sustained commitment of government, the profession, and the forest industries to black spruce silviculture cannot be expected.

CONCLUSIONS

There are two challenges now confronting the forest scientist and the forest manager. The first is implicit in projections of potential demand for timber from Ontario's forests in the next 30-40 years. If those demands are to be met, it is clear that the current "you liquidate—we regenerate" approach to the growing of the second forest must be abandoned. Logging and silviculture must be reunited, and planned and implemented to achieve optimum, balanced efficiency, both in the extraction of wood and in the creation of conditions which will foster the rapid establishment of fully stocked new forests.

The second major challenge is and will be the limitation imposed upon forestry programs by the availability of funds. It is doubtful, to say the least, that forest industrialists or political decision makers will ever accord to forestry a high priority in their spending plans. We must accept that there will never be available to us all the funds we should like to have.

I conclude, then, that the perpetuation of black spruce as an important, if not indispensable species, both ecologically and economically, in our northern forests poses a major challenge for forest scientists and managers. That challenge is implicit in the need for effective, inexpensive, nonlabor-intensive silvicultural techniques appropriate to the range of site conditions on which merchantable volumes can be grown. In undertaking this challenge, we might do well to bear in mind the observations made 16 years ago by another forester (Fellows 1959), who said:

> "Could it be that we might find the solution to this vexing problem (spruce regeneration) sooner if we took time out from our hectic experimenting to study nature's own method with an approach a little more philosophical and a little less scientific than usual? Nature may not yield up a solution to the problem of regenerating cut-over areas, but it may well provide the essential key to the situation. Perhaps the patient application of logic to a close scrutiny of nature's working will bring results faster than expensive hit and miss experimentation based on incomplete knowledge."

It is my hope this symposium will serve to stimulate a wide interest in and positive action on the problems of establishing and growing black spruce as a vital component of our northern forests. The years are passing rapidly, and it is apparent that the farthest extremities of the boreal forest, in this province, at least, will be subjected to harvesting within the next decade or two. Black spruce may no longer be the Cinderella species, the lowly weed species of the genus *Populus* having assumed that role in the minds of some foresters in recent years. If black spruce is to be assured an appropriate position in the new forests following logging, however, rather more intelligence, logic, professional ability and concern must be demonstrated than have been apparent to date.

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APPENDIX A

Quotations from Public Information Publications of the Canadian Pulp and Paper Industry

"Spurred by self interest and its responsibilities, the industry employs hundreds of professional foresters whose aim is the scientific cutting of the forests and their conservation for use. Selective and other cutting methods are used to encourage natural regrowth. Pulp and paper spends more than all the provinces combined on managing and protecting the forests. The industry operates the best managed forests in Canada."

"Pulp and paper foresters have given new life and meaning to forest conservation. They manage the forests on a sustained yield basis. They harvest trees at the stage of their greatest value and utility. They encourage regrowth. They nurture young trees. And the modern operating methods they employ permit the more rapid growth of future harvests. Through forest management, they have assured wood harvests for the continuing and increasing needs of tomorrow."

"The pulp and paper mills lease their woodlands from the owners, namely, the people of Canada. The mills are responsible tenants. Their forest operations are modern. With surveys, nurseries, roads, communications, and scientific harvesting, they conserve the woodlands. They cut less wood than they grow. So their woods operations will continue to produce Canada's most important crop in perpetuity."

"Clear cutting is used primarily in the northern coniferous or Boreal forest to harvest natural, even-aged stands that have reached or are beyond maturity. In these stands, this is a highly satisfactory harvesting system both biologically and economically. Losses of residual trees from wind fall are very high when any system of partial harvesting is done in such mature forests. The clear cutting system, moreover, results in a new forest with the same natural and desirable even-aged characteristic as the parent forest."

The following quotation appeared a few years ago in a booklet published for educational purposes and widely distributed by a major pulp and paper company:

> "Except when fires and insect infestations occur, the results of planned cutting is a satisfactory new and natural forest 85 per cent of the time."

In the same booklet appeared this statement:

> "Professional foresters of today produce more wood more quickly than anyone could have dreamed possible even a few years ago.
> We are also going to show how cutting areas are planned so that companies can return again and again to cut the new trees that spring up as their cutters move from block to block of forested land."

APPENDIX B

Quotations from Letters Received from Foresters Engaged in Industrial Woodlands Operations

The following quotations are taken from letters received by the writer in recent weeks from employees of several of the major pulp and paper companies in northern and northwestern Ontario.

> "With black spruce, on both high land and lowland sites, a good proportion of the regeneration consists of advance growth. As mechanization of the logging process has occurred, with the use of ever larger machines, more of the advance growth is destroyed. While mechanized logging normally, during the summer months, produces more site disturbance, I do not think this compensates for the extra destruction of the advance growth."

> "In many of the stands the abundance of advance growth is a function of the age of the stand - most of those in which we are operating are over-mature. As we use up these over-mature stands and start operating in stands that are just reaching maturity, I think we will find much less spruce advance growth and a correspondingly poor regeneration situation for this species."

Another respondent from one of the above-mentioned companies made the following remarks:

> "In my opinion there has not been enough black spruce regeneration work done in the last 25 years. By and large, the class 2 and 3 sites have regenerated to about the same stocking as the existing mature forest. However, the really good black spruce swamp forests do not seem to be coming back to the same level as the original stands. I have no knowledge of the exact proportion of black spruce versus other species for the periods which you mention, except to say that no large scale planting or other regeneration work has taken place in black spruce swamps. Winter cut areas have been almost totally ignored either because of the wet sites or because of the lack of accessibility brought on by wet conditions. This means that perhaps one third of the annual cut-over is not being treated or even considered. A scarification contractor hired by the government refused to work in rocky terrain with bulldozers, so this effectively eliminates most of the

regeneration of the thin soiled upland black spruce areas as well. In addition, very little is being done on upland mixed sites having residual hardwood.

I should hasten to add that the logging industry in Ontario is probably at least as guilty as the Ministry in not having developed really effective scarification equipment. Through the regeneration agreements of a few years ago, industry had an opportunity to remain fully involved but opted to stay out instead. Not only did we lose a good deal of mechanical expertise, we also lost the service of the industry foresters, superintendents, and foremen, all of whom should be fully involved in the second forest."

A forester employed by another company in the region commented:

"Mechanical logging and large clear cuts in conjunction with scarification may have been good for jack pine, on the deep coarse textured soils, but black spruce regeneration was poor. The wet sites were churned up resulting in very severe competition problems. Shallow upland sites were prone to desiccation from exposure. After ten years, 30 per cent stocking.

Without the establishment of viable management techniques and their implementation, we will never obtain the same volumes as the original stands produced."

Finally, the following comments from another forest industry spokesman may be of interest. He reported that the results of the regeneration surveys conducted by his company on harvested black spruce areas indicated stocking ranging between 75% and 95%.

"The values shown are based on 15 years of regeneration surveys... . The surveys indicate a high success rate for black spruce on swamps. Regeneration on upland sites is also successful but the regenerated species includes balsam fir and jack pine as well as black spruce."

APPENDIX C

The State of Management of the Boreal Forest: Views from the Forestry Profession

"Our regeneration surveys reveal that we are obtaining adequate stocking on all but a very small portion of our cut-overs."

"Pulp and paper manufacturing technology developments will enable us to use any species which grow on the areas cut-over. Therefore, we should not be concerned if our operations tend to convert sites from the spruces and pine to balsam fir, poplar and birch."

"Our wood production costs are too high now. We can't afford to practise intensive silviculture."

"The forest lands are owned by the Crown, and we are simply a tenant. Therefore, we cannot be expected to invest the money of our shareholders in trees which we shall not own. The responsibility for the new forest is not ours."

"Given sufficient time, an acceptable new forest will become established naturally."

"Although there may be a need for silviculture in some areas, we don't have sufficient knowledge or data to warrant our attempting costly modifications at this time."

APPENDIX D

The Condition of Forest Management in Canada: Views from the Public Sector

> "We have been talking about forestry for 40 years in this country, and as yet we have no definitely stated or legislatively enacted forest policy on the part of the dominion government or that of any province, based on the fundamental essential of continuous production. We still regard the forest as something that must necessarily be destroyed in the process of utilization - as a mine and not as a restorable resource, capable under intelligent care of yielding successive crops to supply the needs of our sawmills and our pulp and paper mills. (C. D. Howe 1925).

Twenty-three years later a provincial Royal Commission on Forestry (1947) commented on the condition of reproduction of cut-over Crown lands as follows:

> "Up to the present, cutting practices on Crown lands in Ontario, as elsewhere in eastern Canada, have been governed by considerations of current operating costs, rather than by the needs of a future crop of timber from the same areas. Good reproduction, when it has occurred, has always created satisfaction, but it has been a child of chance rather than of design. (Ontario Royal Commission on Forestry 1947)."

Other views are expressed below:

> "After cutting, the valuable soft woods are being replaced by inferior species, principally poplar. This condition will continue until improved forestry practices have advanced so as to assure regeneration and tending of the growth of the valuable soft wood species through their stages of development to maturity. (Suggestions for Program of Renewable Resources Development, 1914, Ontario Department of Lands and Forests)."

> "Nevertheless, if we are convinced that future generations should be ensured the use of adequate stands of timber in their times, we must undertake more intense management practices while there are yet sufficient mature forests to aid materially in the cost of establishing the second crop. If money for this purpose is not provided from the operation of the present stands,

we will eventually be in the position of having to rely on funds made available from the consolidated revenue of the province to promote a business that should be self-supporting. (A Forest Policy for Ontario, Economic Council, 1970)."

ONTARIO STOCKING STANDARDS FOR BLACK SPRUCE

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The importance and purpose of stocking standards are discussed. Different methods of measuring stocking are noted. The Ontario stocking standards are described with particular reference to black spruce (**Picea mariana** *[Mill.] B.S.P.*). *Different standards and different quadrat sizes are considered, and a change in the Ontario stocking standards for black spruce is suggested.*

L'importance et le but des normes de densité sont discutés. Différentes méthodes de mesure de la densité sont signalées. Les normes ontariennes de densité sont décrites en ce qui a trait particulièrement à l'Epinette noire (**Picea mariana** *[Mill.] B.S.P.*). *Différentes normes de densité et différentes dimensions de quadrat sont débattues, et une modification des normes ontariennes de densité pour l'Epinette noire est suggérée.*

INTRODUCTION

A major purpose of the silviculture part of forest management is to produce a useful crop of trees at some time in the future. A critical stage of crop production is, of course, the establishment. At this time, along with decisions as to technique, site and species, comes the question of how many trees we need to establish to give us a suitable crop at the end of the rotation. This decision must be influenced by the stand tending that is expected and the product that is desired.

We are in the process of converting our forest from natural stands to managed stands, or at least to stands that have not been regenerated by the processes of nature. We know quite a lot about the natural stands, as they are now, through the Normal Yield Tables (Plonski 1960, 1974), numerous inventory and operating cruises, and logging experience. We can only guess at the earlier history of the present stands. We do not know the stocking at the time of establishment or how the stocking changed over the rotation to reach the present level.

We do not know that the present forest, or even the normal forest, is the best. It is quite possible that lower stocking during part of the rotation would have given larger but fewer trees, perhaps even in a shorter time. At present, industry would like large trees, but trends indicate that in the future the desire may be for maximum volume regardless of size.

We are spending a lot of money establishing tree crops, and we must make the best judgment possible of the most suitable stocking to strive for. Too many trees mean unnecessary cost in establishment and perhaps slower growth. Too few trees mean waste of the soil's productive capacity and low yields.

Stocking standards are used to express our objectives in regeneration and to guide the forest manager in his decisions.

The Measurement of Stocking

The British Commonwealth Forest Terminology (Anon. 1953) recognizes stocking in relation to numbers of trees, basal area, or volume per unit area. The Forest Terminology of The Society of American Foresters (Anon. 1964) uses stocking only in relation to numbers of trees. In Ontario, foresters have used different measures under different conditions.

In older stands, stocking is expressed as the proportion of actual basal area to the normal basal area given in the Normal Yield Tables. A stocking factor of 1.0 means full stocking and 0.5 means half of normal stocking. These proportions can be applied directly to the yield tables to give volumes.

In young regenerating stands, stocking and success in establishing the stands have usually been expressed as the number of trees per unit area. This is acceptable in plantations where spacing is fairly uniform, there is little ingrowth of other trees, and success depends mostly on survival of the planted stock.

In stands regenerated by natural means or by broadcast seeding, spacing is usually uneven. There could be large gaps in the stand interspersed with overstocked sections, and the average number of trees could be quite misleading, and unsuited to the purpose of judging stocking.

Ontario now bases its assessment of regeneration on a stocked quadrat system. Stocking is expressed as the percentage of quadrats stocked with an acceptable tree. As long as the quadrats represent the area to be assessed, the system gives a measure of the distribution of regeneration. The quadrat size used is a milacre, or 1/1000 acre (4.05 m^2, or about 1/2500 ha). With this system a fully stocked stand would have at least one acceptable tree on each quadrat, and a minimum of 1,000 trees per acre (2,500 trees per ha).

Where the distribution of trees is not systematic, as it is in planting, density (the number of trees per unit area) increases rapidly as the stocking percent increases (Gill 1950). New seedlings are much more likely to become established on the better spots that are already stocked than on the unstocked and poorer seedbeds. High percent stocking frequently means overstocking in some areas.

Density tends to decrease, for the same percent stocking, as the quadrat size increases. There is more chance of having a good seedbed in a large quadrat and, therefore, fewer trees are needed to ensure a given level of stocking.

Density has commonly been estimated in Ontario by tallying the total number of trees on every fifth or even tenth quadrat. A study by Clarke (1972) showed that it took a much larger sample than this to give statistically sound results, and that the cost would be high. Under the present level of forest management in Ontario there is little precommercial thinning or spacing done, and therefore little need of measuring the density of regeneration. Therefore, the practice has been discontinued. Estimates can be made of density when the stocking is known (Gill 1950), although the estimates are not very accurate.

Assessment of regeneration must take into account the health and performance of young trees, and their chance of reaching maturity. This is just as important as their numbers.

Ontario regeneration survey instructions (Anon. 1973) require that, to be stocked, a quadrat must have a healthy tree that is at least 1 year old and likely to reach maturity. Unfortunately, few of us can judge the chance of survival of a 1-year-old tree.

Alberta requires at least one 3-year-old tree or two 2-year-old trees for a quadrat to be considered stocked.

Mullin and Howard (1973) suggest a method of using aggregate heights as a measure of survival and performance. They multiply the number of trees by the average height to give a cumulative tree length per unit area. Unfortunately, a large number of poor trees could equal a more suitable number of good trees, although the method has some attractive aspects.

Standards of performance can also be set indicating the height the trees should reach at a given time.

The simplest way to measure performance is to set a standard on the size and vigor of any tree to be tallied. The stocking standard should be high enough to allow for average mortality, and proper tending should maintain growth. No set of stocking standards can be expected to protect an area from poor establishment practices and improper follow-up treatment. Assessment systems can give information on what is there, but improvements in forest management are the only means of correcting problems.

Stocking Standards

The present Ontario stocking standards (see Appendix) are based mainly on judgment. Until much more experience is gained and more studies are done, they can be little else.

It is recognized that the stocking should vary with site class, and perhaps also with site region, but the standards are not refined enough to consider these differences. Even in the south where we have been planting red pine (*Pinus resinosa* Ait.) for more than 50 years, we are not unanimous on the best spacing.

The objective for a predominantly black spruce (*Picea mariana* [Mill.] B.S.P.) stand is to reach, after 5 to 7 years, a stocking of 70% to acceptable conifers, and 60% to black spruce. There are restrictions on the amount of balsam fir (*Abies balsamea* [L.] Mill.) and poplar (*Populus* spp.) that can be tolerated. The assumption is that a stand regenerated to this level will, at maturity, produce 0.8 of the normal as shown in the Normal Yield Tables.

In the Ontario standards, regeneration is considered a failure in a black spruce stand if the stocking to acceptable conifers is less than 50%, and the stocking to black spruce is less than 40%. The assumption in this situation is that the stand will not be able to produce a merchantable cut. Half the area will be open, trees will be limby, and yields will be low. These fail areas will go into the barren and scattered category unless more regeneration work is done. Given time, many of these areas will fill in and reach a more satisfactory level of stocking on their own, but this can add many years to the rotation. Future demand for wood products is expected to be too high to waste the productive capacity of the forest land with long rotations or poor yields.

There is a gray area between success and failure in regeneration that is classed as unsatisfactory. It is assumed that such an area will yield a merchantable cut but only at a much reduced volume. There will likely be large gaps in the stand covering 30–50% of the area. Though not a failure, land use is poor. Further treatment such as planting, site preparation and seeding may be used to improve the stocking if the site is suitable. The decision to improve the stand will depend on such factors as site, availability of funds, location, and marginal return on the dollar, but mostly on the judgment of the management forester.

The chosen standard of 70% stocking is a compromise between the additional cost of more intensive management and the lower yields of less intensive management.

A higher stocking standard may be justified under some conditions. On the best sites close to mills and markets, or where genetically superior stock is available, we should aim at using the full capacity of each acre. Precommercial thinning or spacing may be necessary.

Some biological factors must be considered, but they are not readily quantifiable. How much space do the crown and roots of a black spruce tree need on different sites and at different ages? Is it possible to choose a spacing that will allow a stand to give a good yield, without expensive thinning, on a reasonably short rotation? How long can crown closure be delayed without serious detrimental effects on water levels, nutrients or erosion? The stocking standards attempt to steer a middle course.

Black spruce is also recognized as a minor component in other working groups on suitable sites. Its importance is probably not properly recognized by the stocking standards where it is in mixture with jack pine (*Pinus banksiana* Lamb.) on sandy soils, or on the deep, well-drained upland sites in mixture with white spruce (*Picea glauca* [Moench] Voss), balsam fir and poplar.

The Ontario Ministry of Natural Resources plans to review and revise the stocking standards periodically as new information and experience are gained.

Proposals for Changes

The commonest criticism of the Ontario stocking standards is that they are too high. If this is so, they should be lowered. The money thus saved in many cases could be put to better use in areas more in need of regeneration. However, we must not sacrifice quality and future yield to too great an extent, just to make it easier for ourselves. Somebody will want that wood, even desperately need it, in the future, and it is up to the present forest managers to make it available.

The average survival of black spruce trees 5 years after planting is 61% (Anon. 1974). We should consider raising our survival rate so that we would have to plant fewer trees per unit area. This may be a far better way to save money and still meet the present standards. More attention to site preparation on strip cuts may be another alternative to reducing standards.

The Ontario stocking standards could be changed by changing the percent stocking or the size of quadrat, or by introducing a new system.

No new system has yet been proposed that seems to offer any improvement over the one in use. If such a system is developed, Ontario will consider it carefully.

Ontario should not consider lowering the limit for satisfactory stocking for black spruce below the present 70%, or lowering the failure level below the present 50%. Poorer distribution than this will lead to excessive waste of growing space or unnecessary extensions to the regeneration period.

The size of the quadrat used for assessing stocking percent can be changed. Quadrat size is a reflection of the area which theoretically should be occupied by a tree, and therefore it reflects ideal spacing. A 1/1000-acre (1/2500-ha) quadrat represents an ideal spacing of 6 1/2 ft (2 m). This spacing, and the quadrat size, could perhaps be increased.

Many foresters and companies prefer to use a larger quadrat. The commonest seems to be 1/600 acre (1/1500 ha) which represents an average spacing of about 8.5 ft (2.6 m). Another quadrat size to consider is 1/800 acre (1/2000 ha) which represents an average spacing of about 7.5 ft (2.25 m).

Three quadrat sizes, 1/1000 acre, 1/800 acre, and 1/600 acre (1/2500, 1/2000 and 1/1500 ha), are compared for stocking percent and density in Tables 1 and 2.

Table 1. Comparison of stocking and quadrat size

Quadrat size	1/1000 acre (1/2500 ha)	1/800 acre (1/2000 ha)	1/600 acre (1/1500 ha)
Tree spacing	6 1/2 ft (2 m)	7 1/2 ft (2 1/4 m)	8 1/2 ft (2 1/2 m)
Stocking percent (approximate)	90	94	98
	80	86	93
	70	78	86
	60	68	78
	50	58	69
	40	47	57
	30	37	46
	20	24	31

Note: Conversions according to formula by Grant (1951).

Table 2. Comparison of trees per acre and quadrat size.

Quadrat size	1/1000 acre (1/2500 ha)	1/800 acre (1/2000 ha)	1/600 acre (1/1500 ha)
Tree spacing	6 1/2 ft (2 m)	7 1/2 ft (2 1/4 m)	8 1/2 ft (2 1/2 m)
Minimum no. of trees per acre (ha) at 70% stocking	700 (1750)	560 (1400)	420 (1050)
Probable maximum no. of trees per acre (ha) at 70% stocking	3500 (8650)	2500 (6200)	2000 (5000)

Table 1 shows that 70% stocking using a quadrat size of 1/600 acre (1/1500 ha) would be equivalent to just over 50%, the failure level, at a quadrat size of 1/1000 acre (1/2500 ha). This seems to be an unacceptably low standard for stocking in view of future needs for wood in Ontario.

Table 2 indicates that a 70% stocking standard could be met using 1/600-acre (1/1500-ha) quadrats with as few as 420 trees per acre (1050/ha). The number would not likely exceed 2000 per acre (5000/ha). Except in the stands with the higher densities, unusually high mortality could have a serious effect on stocking. A standard using a 1/600-acre (1/1500-ha) quadrat size seems to be unacceptably low in terms of trees per unit area.

Tables 1 and 2 also show an intermediate quadrat size, 1/800 acre (1/2000 ha). If the 70% stocking standard were kept, this quadrat size would seem to be a reasonable compromise. If it were adopted, the following changes could be expected:

1. The standards could be met with somewhat fewer trees per unit area.

2. The spacing objective would be a little greater so that fewer trees need be planted. This applies only if mortality is reduced.

3. There should be no increase in the chance of large gaps in the stand.

4. If there were fewer trees at the time of regeneration, and they were well distributed, there should be less mortality, with the opportunity of at least the same yield, with either a shorter rotation or larger diameters.

5. Some areas which do not have acceptable regeneration under the present standard would become satisfactory. This would allow us to concentrate our scarce funds and manpower on those areas more in need of regeneration work.

6. A standard based on 1/800-acre quadrats could be converted to SI units in relatively round numbers. At full stocking there would be 2000 trees per ha, at an average spacing of about 2 1/4 m. The quadrat size would be 1/2000 ha or $5m^2$.

If we can lower our standard a little, why not a little more? Perhaps we can, but it may be some time yet before we have reliable data to support our decision. I would be afraid that wider spacing and fewer trees would lead to under-utilization of the site and eventually to lower yields.

In the end it is a matter of judgment, and I would much sooner err on the side of too high a standard.

CONCLUSION

In conclusion I must stress the fact that we are still guessing at the type of regeneration we need now to give us a suitable future harvest. We must, however, have some sort of standard by which to measure our degree of success in obtaining regeneration.

The present Ontario standards in the black spruce working group of 70% stocking on a milacre (1/2500-ha) quadrat basis may be too high. It may be possible to lower the standard somewhat without reducing our objective of a future stand that will give 0.8 of the normal yield.

The measure of the distribution of regeneration, 70% stocking, must be maintained. We cannot afford large gaps in future stands.

The size of the quadrat can be increased and I suggest that it be changed to 1/800 acre (1/2000 ha). This would enable us to reach the standard with fewer trees. The average spacing of an exactly stocked stand would also increase to 7 1/2 ft (2 1/4 m). It would be relatively easy, though, to run a regeneration survey using both standards on several stands to see how they compare.

Our long-term aim should surely be to reach a level of competence and quality in our regeneration such that we rarely need to use this type of standard.

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APPENDIX

Ontario Stocking Standards for the Black Spruce Working Group

1. Regeneration period -

   7 years (5 years if planted)

2. Acceptable species -

   primary - black spruce
   secondary - white spruce, jack pine

3. Desirable stocking -

   Each of the following conditions should be met:

   a) black spruce - more than 60%
   b) spruce plus jack pine - more than 70%
   c) balsam plus poplar - less than 20%

4. Desirable trees per acre -

   less than 5,000 spruce and jack pine

5. Failure -

   If either of the following conditions applies:

   a) black spruce - less than 40% stocking
   b) spruce plus jack pine - less than 50% stocking

6. Release -

   May be required if either of the following conditions applies:

   a) spruce plus jack pine - more than 10,000 trees per acre
   b) dominant poplar - more than 30% stocking

RESULTS OF 40 YEARS OF STOCKED QUADRAT SURVEYS IN THE CLAY BELT

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Since 1935, Spruce Falls Power and Paper Co. Ltd. has used the stocked quadrat system and a 1/600-acre (6.74-m^2) plot for regeneration surveys. It is suggested that statistical analysis of data collected by successive remeasurements of permanent sample plots may indicate progressive development between occurrence of major disturbances and maturity of the stand.

Depuis 1935, les études de regénération effectuées par la Spruce Falls Power and Paper Ltée utilisent le système de places d'essai plantées et contenant 1/600^e-d'acre (6.74-m^2). L'analyse statistique des résultats obtenus lors de remesurages successifs dans les places d'essai permanentes peut indiquer le développement progressif entre l'arrivée de perturbations importantes et la maturité du peuplement.

INTRODUCTION

At Spruce Falls the stocked quadrat method for regeneration surveys has been in use since 1935. Previously, a continuous strip survey was used, each plot being 3 ft wide by 1 chain long (0.91 m x 20.12 m). In 1935 the quadrat used was 8.52 ft^2 (2.59 m^2), i.e., 1/600 acre (6.74 m^2). Compass lines were run through the area to be sampled at 3-, 5- or 10-chain (60.35-, 100.58-, and 201.17-m) intervals according to the objective of the survey; quadrats were examined at regular intervals, generally one chain (20.1168 m). A quadrat was tallied as stocked to a particular species if one tree of any size was found in it. Since Spruce Falls was interested only in conifers at that time, the quadrat was tallied as stocked or not stocked for spruce (*Picea* spp.) and/or balsam fir (*Abies balsamea* [L.] Mill.). On every tenth quadrat, in addition to the stocking record, a complete tally of all trees and all sizes was recorded to make it possible to determine approximate stand per acre. The tally was also subdivided by site according to the following classifications:

SITE I: well-drained land over which surplus water runoff is good--scant moss cover, thin humus layer--hardwoods usually present. If possible, subclassify as:

IP: pure conifer--original stand 75% or more conifer

IM: mixed--original stand less than 75% conifer.

SITE II: areas over which the drainage is not free running and water is evident for some time after heavy precipitation. The water table is not high enough to stunt growth. The humus layer is thick, generally over 6 in. (15.24 cm). (Four subclasses to Site II have since been discontinued and are omitted here.)

SITE III: merchantable muskeg--drainage poor with water table reaching close to surface through sphagnum--diameter and height growth retarded--humus layer thick, often several feet--stunted spruce left in abundance.

Depth of humus, ground cover, height and species of brush, topography and site boundaries were marked on a map sheet.

In spite of the fact that a quadrat by definition is square in shape, Spruce Falls began using a circular plot of radius 4.8 ft (1.46 m) in 1948 as a result of a survey in which the quadrats were permanently marked with wooden pickets so that they could be remeasured. Ten years later many could not be found because the pickets had decayed and fallen over. Other plots could not be accurately established because only one or two pickets were found. Only the center needs to be marked for a circular plot. This saves time and money because it is not necessary to lay out the four corners, and only one picket is required. Aside from the change to a circular plot there has been little change in the procedure since 1935.

In addition to their use for regeneration studies on cut-over areas, stocked quadrat surveys were used both before and after logging to determine the need for planting and for a treatment such as herbicidal spraying to release the conifer reproduction from broadleafed competition, as well as to determine the effect on the site of a particular logging system, to assess the survival of planted trees and thereby the success of the planting project, and to realize a variety of special objectives.

PLOT SIZE

At Kapuskasing, the size of the plot, whether square or round, has from the outset been 1/600 acre (6.74 m^2). Hosie (1953 and unpublished report) commented as follows on the Spruce Falls method:

"The system differs in certain particulars from that used by the Ontario Department of Lands and Forests; the main difference being in the size of the quadrat, or plot and the amount of information recorded on each. There the plot is 1/20 acre (202.34 sq. m) in size as compared with 1/600 acre (6.74 m^2). The smaller quadrat is to be desired. It simplifies the field work and helps to maintain accuracy. In dense vegetation it is easy to miss small tree seedlings, particularly when the observer has to move about. If he can stand in one position and overlook the whole plot, there is a reasonably good chance that few will be missed."

The decision to adopt the 1/600-acre (6.74-m^2) plot, however, was not made for the purpose of simplifying the operation. A basic concept of the stocked quadrat system is that the size of the plot should be equal to the growing space occupied by a single tree at the rotation age. For regeneration to be adequate, sufficient numbers of trees must be planted and spacing should be such that each growing space is occupied by at least one well established tree.

At Kapuskasing, studies carried out up to 1935 led to the conclusion that the mature stands of pulpwood then being logged contained an average of 200 trees per acre (500 per ha). It was recognized that these stands were not fully stocked but there were no data available to indicate what "fully stocked" should be. However, it was reasoned that 600 trees per acre (1500 per ha) in fresh cutover with allowances for mortality would provide 200 trees per acre (500 per ha) at rotation age. Later studies, including investigations of the radius of the crowns of spruce trees and of numbers per acre in fully stocked fire stands carried out in conjunction with the field work required for the preparation of yield tables, served to confirm the 1/600-acre (6.74-m^2) plot as the proper size. Table 1 provides a summary of stocking data and a formula for arriving at 613 trees per acre (1530 per ha) as the average at 100 years for fully stocked stands on sites I and II. Data for Site III were insufficient at the time to include this site in the calculations and in fact it occupies a relatively insignificant proportion of the limits.

ADEQUATE STOCKING

In 1950 there was an exchange of letters between Ed Bonner, Chief Forester at Spruce Falls and J. B. Millar, Chief Forester for Kimberly—Clark Corporation, Neenah, Wisconsin with respect to regeneration surveys of cutover and the determination of what constitutes an adequate degree of stocking. According to Bonner, "A definition might be a degree of stocking sufficient to reproduce stands equal in quantity and quality to those now being operated; but I do not think anyone has ever determined what that degree of stocking is."

This new concern may have been prompted by the fact that Spruce Falls was now beginning to collect assessments of cutovers older than 20 years which indicated a downward trend in degree of stocking. One suggestion was that mortality begins at 20 years of age and somewhere between 40 and 60 years there would be a drastic reduction in numbers. The quadrat should then be increased in size to something like 1/400 acre

Table 1. Average number of trees per acre[a] in fully stocked 100-year-old spruce stands

	Site I	Site II
Total spruce and balsam fir	700	1,130
Spruce and balsam fir 4 in.[b] DBH and over	590	900
Spruce and balsam fir 5 in. DBH and over	490	680
Spruce only 5 in. DBH and over	418	678

[a] trees per acre x 2.5 = trees per ha

[b] 1 in. = 2.54 cm

NOTE: Weighted average for spruce only, 5 in. DBH and over, assuming proportion of Site II to Site I to be approximately 3 to 1 =
$\frac{(3 \times 678) + 418}{4}$ = 613 trees/acre[a]

(10.12 m^2) and subsequently to 1/200 acre (20.23 m^2) for mature stands. The opposing theory favored the use of the 1/600-acre (6.74-m^2) plot throughout. At maturity, the stocking in the average stand, containing 200 trees per acre (500 per ha), would be 33 1/3%. The yield from such a stand as shown by the Spruce Falls yield tables would be 13 to 14 cords per acre (116-125 m^3 per ha), roughly 32% of normal cordage. Therefore, the 1/600-acre (6.74-m^2) quadrat was retained and for several summers thereafter regeneration studies of cutover and mature bush were made to determine some criterion of satisfactory regeneration for use in preplanting surveys. As a result the following standard was written:

> Adequate regeneration on cutover: 50% stocked to spruce or 300 well-spaced and established spruce per acre (750 per ha).
>
> Adequate regeneration in mature timber: for planting surveys prior to cutting, increase the above standards by 25% and count only spruce from 12 in. (30.5 cm) to 4 1/2 ft (1.37 m) in height.
>
> Degree of stocking: 62 1/2% or 375 well-spaced and established spruce per acre (937 per ha).
>
> Well-spaced and established spruce: The decision as to what constitutes well-spaced and established spruce is left to the discretion of the examiner but generally these will be spruce not competing with each other, usually at least 2 ft (0.61 m) apart, reasonably healthy and probably forming part of the final crop.

It is not immediately obvious from the records just what reasoning prompted these standards. In 1954, the data available for a group of P.S.P.s (permanent sample plots) were used to compare the number of spruce per acre that were 18 in. (0.46 m) and over in height immediately after cutting with the number present 15 years after cutting. The results are shown in Table 2. The average number of spruce for all sites at 0 years is 103 per acre (257 per ha) and at 15 years is 317 per acre (792 per ha), a 300% increase. The first thought for purposes of planting surveys was that any fresh cutover having less than 200 spruce per acre (500 per ha) with a reasonable chance of surviving should be marked for planting. The final decision specified a minimum of 300 per acre (750 per ha), presumably on the expectation that there would be from 600 to 900 per acre (1500-2250 per ha) at 15 years. Stocking of 50% was judged to be the equivalent of 300 well-spaced and established trees per acre (750 per ha).

Table 2. Spruce per acre[a] over 18 in.[b] high related to age of cutover

Site[c]	Age of cutover (yr)	Spruce per acre[a] over 18 in.[b] high
I M	0	56
	15	131
I S	0	87
	15	266
II SF	0	88
	15	598
II Swp	0	180
	15	272

[a] Spruce per acre x 2.5 = spruce per ha

[b] 1 in. = 2.54 cm

[c] I M = upland, mixed conifers and hardwoods

I S = upland, pure conifer

II SF = lowland, spruce flat

II Swp = lowland, spruce swamp

These standards are still in use today by Spruce Falls on the freehold portion of the limits. Recently some regeneration cruising has been carried out on Crown lands in an effort to confirm the results of previous surveys and to prepare for the writing of a new management plan.

DISCUSSION

When it comes to considering the pros and cons of the stocked quadrat system one hardly knows where to begin. Although it is the simplest method available, yet it is acknowledged that much more information is needed than such surveys can supply. Spruce Falls feels the 1/600-acre (6.74-m^2) plot gives the most realistic picture for Clay Belt forests. A major problem is that of relating to surveys made with a different plot size. Usually comparisons are attempted on the basis of trees per acre. Table 3 is included only to show the wide spread between maximum and minimum stand per acre corresponding to a given degree of stocking.

Table 3. Relationship between degree of stocking and stand per acre[a]

Degree of stocking	Stand per acre[a]			Basis plots
	Minimum	Average	Maximum	
0	0	8	60	66
10	20	64	210	21
20	36	140	210	9
30	123	233	372	9
40	69	370	732	10
50	253	476	630	8
60	240	507	810	13
70	202	760	1594	14
80	510	830	1794	11
90	242	1120	1896	5
100	968	2522	3271	6

[a] Stand per acre x 2.5 = trees per ha.

A similar lack of precision occurs when the 1-milacre (4.05-m^2) plot is used. Attempts to compare results by coincident surveys in P.S.P.s suggest that the milacre plot gives a wider range of values than the 1/600-acre (6.74-m^2) plot but generally comparisons are meaningless.

Spruce Falls has been using the formula $Y = 1-(1-x)^{\frac{a}{b}}$ (Hosie 1950) to convert degree of stocking, but with some misgivings. Ghent (1969) describes a pattern of bias which occurs in conversions using this formula.

As the years passed and the surveys were extended to 10-, 15-, 20-, 25- and 30-year cutovers the results seemed to become increasingly erratic and the suspicion arose that the system might not be suitable for surveys of regeneration on older cutovers. Degree of stocking was expected to remain relatively constant in spite of lower stocking per acre for older age classes but, in fact, as previously stated, it showed a tendency to decrease. Table 4 illustrates this apparent trend.

Table 4. Degree of stocking on various ages of cutover[a]

		Degree of stocking				
Site[b]	Age of cut (yr)	spruce	balsam	spruce and balsam	spruce or balsam	Basis quadrats
I P	5	43	80	38	86	3900
	10	45	68	36	77	763
	15	48	85	44	90	1168
	20	55	77	46	86	305
	25	41	67	28	80	292
I M	5	33	84	30	86	3466
	10	34	82	29	87	668
	15	38	72	30	80	781
	20	34	70	24	80	1023
	25	20	75	15	80	320
II	5	79	53	42	89	4715
	10	83	57	48	92	2577
	15	67	66	44	89	562
	20	75	73	52	96	3193
	25	63	55	32	87	762

[a] Includes all trees of any size.

[b] I M = upland, mixed conifers and hardwoods
I P = upland, pure conifer
II = lowland

The stocked quadrat system is designed for sampling a homogeneous population of random distribution. The planting method used by Spruce Falls tends to group the planted trees on available openings, piles of slash and dense underbrush being avoided. The distribution is no longer random. Is the stocked quadrat system of regeneration survey valid for these conditions?

Although Spruce Falls has clung to this system for some 40 years, it has not been with unwavering confidence. As an approximation of the average growing space required by a mature spruce, the 1/600-acre (6.74-m^2) plot seems appropriate. The Company believes that the results led to the adoption of a policy for regeneration of cut-over areas that is still "the only safe way of getting spruce in greater distribution or in greater quantity for the next cut and the least expensive way" (Hosie 1953 and unpublished report).

To quote Ed Bonner once again, "We need to know why the regeneration is there or why it is not there and what will be there at maturity." This same thought has been among the conclusions arising from a long series of symposia such as this one. The answer most probably lies in the forests where the growth and characteristics of typical stands can be studied by means of successive, periodic measurements of permanent sample plots. At Spruce Falls we have about 250 such plots, the earliest having been established in 1930. If we include the fire stands, we now have data spanning the full 100 years of the spruce rotation. It may be possible through statistical analysis to learn enough about the characteristic growth of various species on the variety of sites represented to draft a specific silvicultural plan for each site. If the data collected by Spruce Falls are not adequate for this purpose we may hope that the agencies which now have the responsibility for silviculture might be persuaded to establish additional sample plots to fill the voids.

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DISCUSSION

STENEKER

What kind of establishment periods are you talking about when you discuss stocking standards?

F. C. ROBINSON

We wait between 5 and 7 years before we do an assessment.

SLEEP

We don't generally make our first assessment of cutovers until the fifth year after the cut but with more recent logging methods we have to wait about 7 years before the regeneration becomes apparent.

JEGLUM

Mr. Robinson, one of the Ministry criteria for desirable stocking level is less than 20% combined stocking for balsam fir plus trembling aspen. There are two parts to my question: 1) Why is this value so low, when many of the original stands would have had more than 20% cover of balsam fir and/or trembling aspen, and 2) Why haven't you included some of the other less desirable species in that combined total of 20%, such as white birch and tamarack? These species can often increase tremendously in a cut-over stand of black spruce. You may obtain 60% or 70% stocking of black spruce, but you may have that much stocking of birch and tamarack as well.

F. C. ROBINSON

We're trying to refine the standards. Poplar and balsam seem to be the major competitors causing difficulties. These requirements to reduce the amount of poplar or not to accept a large amount of it are an indication that release is necessary. Perhaps these requirements don't belong in stocking standards. Where poplar is acceptable either we're into a mixedwood stand or else we're into a stand that is grouped, or clumped, and part of it should be rated as poplar working group and part as spruce. It is difficult to handle these things neatly. The white birch, tamarack, and other minor species haven't been considered a problem so far; when and if they appear to be, we will look into it.

KETCHESON

Mr. Robinson, have you attempted to weight your stocking standard with cost of establishment?

F. C. ROBINSON

No. Just how do you mean?

KETCHESON

If you have a stand with less than desirable stocking at 45%, you may have to decide whether you scarify and destroy that 45% and plant at $150/acre, or accept the 45% at zero cost.

F. C. ROBINSON

We need an idea of how many extra cunits we get for a dollar spent. Rather than destroy regeneration and spend a lot of money to raise a future yield from 10 cunits to 15 cunits/acre we could take that same money and raise a failed stand from practically 0 to 15 cunits/acre. It would probably be better to spend money on the failure than on improving a stand that's unsatisfactory. I hope our field staff examine their spending in those terms.

JEGLUM

Mr. Sleep, how readily available to the public is your stocking information?

SLEEP

It has not been published, but it's easy to photocopy it as we are doing with our permanent sample plot records.

I want to make another point here. As you can see from this specimen it doesn't necessarily take 100 years to grow a spruce tree. This one was suppressed for about 62 years and in the following 40 years it grew to this size. I'm not saying they all grow that big. Some of them will never get beyond 8 in. DBH in 40 years.

UNIDENTIFIED SPEAKER

Mr. Sleep, has there been any consideration in either your figures or Robinson's to tie in potential fiber production with a much shorter rotation age and, therefore, probably much higher stocking?

SLEEP

We do a lot of fancy talking around Spruce Falls about being at a crossroads and that at some time in the not too distant future we will start utilizing a higher proportion of other species. The thermal-mechanical refining system that's now being installed is supposed to have greater capacity in that direction, so perhaps there is some hope for hanging our hats on increased fiber production from utilization of other species.

F. C. ROBINSON

We are certainly considering fiber production, but there is a lack of good information and it's one of the reasons we like to have a fairly high standard. A well-stocked stand gives us the option of being able to produce a lot of fiber, yet we realize if we have too many trees we may end up with a lot of small ones and lose out. We need to do more work as we don't know enough about stocking standards.

SLEEP

Another point is that we're getting a lot more balsam fir back. If we can cut it at the right age it has potential but we always tend to think about the budworm creeping in from the southwest corner of the limits and what might happen to that balsam growth. We're back to the question of more research. Also, I think a case could be made for more cooperation between industry and government agencies right now. We seem to be choosing sides and drawing swords and having at it all the time. I think we're going to have to start working together more.

STANEK

You have spoken of stocking standards at the age of 100, but in balsam fir we know that stands deteriorate at the age of 60 approximately. In that case your stocking standard would have to be higher to utilize the site properly. Instead of 1,000 trees/acre we should be working with 2,000 trees/acre. And the same would apply to spruce if you lower the rotation ages, because this spruce [specimen displayed by Sleep] might be 190 years old. If you cut at a younger age, then I imagine the number of trees that would have to become established on an area would be much higher than 1000/acre (2500/ha).

GRINNELL

About the points of age and stocking. I think what we have to face is that if we're going to be concerned with some of the things Jeglum mentioned we have to operate in different rotations. There are two separate packages--short rotations such as Stanek is talking about, and longer rotations, and they're not compatible. This brings me to what Sleep said about plowing under regeneration and planting something else. I don't think this should be done, and Robinson rightly commented that it should not be done. We are very much concerned that they can predict what the results should be after the cut and therefore plan the program by the ecosystem. This touches very strongly on the business of balsam versus spruce. If there's balsam there must be enough to make it operable on a short rotation, and a big enough area to be worthwhile. On this point industry and government should cooperate more.

Our keynote speaker has posed a lot of challenges and I'm sure there must be comments from the audience about some of them.

RAUTER

Mr. Hearnden, you stated that the future forests of black spruce will be of a lower quality because of the logging systems. Could you expound on that and give us the alternative?

HEARNDEN

When logging is planned only with the objective of removing wood and when there is no attempt whatever to adjust logging techniques to assist the establishment of the next forest, one must anticipate a rather wide range of reproduction conditions. The major method now is machine felling which involves machines visiting virtually all parts of the cutting area with the destruction of essentially all advance growth. Under these conditions, when no attempt is made to provide for the reservation of seed sources at appropriate intervals, one can expect interesting reproduction results on some of these areas. Extensive regeneration surveys on areas which had been logged by the cut-and-pile method, with winter extraction on sleighs, showed 60% stocking by milacre quadrats. Most of that reproduction was layerings established before logging. We seem to be moving towards methods of wood extraction which are progressively more destructive. There is now a need for very careful thought about how we can assist the reestablishment of these stands, at minimum cost and with minimum labor input.

SWAN

Mr. Hearnden, in your paper you mentioned that the only thing that would get us going on spending adequate amounts on silviculture and forestry was the pinch of shortage. I believe there's another factor that can be brought into play and that is the pressure of public opinion. If we tell the people of Ontario that 28% of the cutover is being left unregenerated at present simply because insufficient funds are allocated to forestry, I think that, given the current consciousness of the need to perpetuate renewable resources, we will get the money we need for forestry and we'll be able to do the whole job properly.

ESTABLISHMENT AND EARLY DEVELOPMENT OF BLACK SPRUCE

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*Black spruce (*Picea mariana *[Mill.] B.S.P.) can be grown from seed as bare-root or container stock, or reproduced vegetatively from cuttings. It is readily established on upland sites. Annual height increment appears greater in large than in small planting stock. Roots are shallow at first, but later elongation rates are such that root competition precedes crown competition among planted trees.*

*On peut semer l'Epinette noire (*Picea mariana *[Mill.] B.S.P.) en pleine terre ou dans des contenants, ou elle peut être reproduite végétativement par boutures. On peut l'établir facilement dans les hautes terres. La croissance annuelle semble plus grande dans les grandes plantations (plutôt que les petites). Les racines ne sont pas profondes au début, mais plus tard leurs taux de croissance sont tels que la concurrence des racines précède celle des couronnes parmi les arbres plantés.*

INTRODUCTION

Seeding habits and seedling establishment have been well documented for natural regeneration, as have growth and yield of older natural stands, but the intermediate period, especially for planted regeneration up to 20 years of age, has been inadequately covered. Indeed, in a recent management guide for black spruce (*Picea mariana* [Mill.] B.S.P.) the earliest age for which yield data are given is 60 years (Johnston 1971). A comprehensive review by Vincent (1965) provides little information on plantation growth, particularly on well-drained soils. I propose, therefore, to deal with this species in terms of its establishment by planting on such soils because it is under these conditions that the largest growth rates can be attained.

The most effective silvicultural practices are those which capitalize on the natural characteristics of a species. Too often in silviculture we emphasize the place of a species in the natural forest succession, together with its attendant ecological relationship, and ignore the autecology of the species in relation to definite management objectives.

Characteristics Important in Plantation Establishment

Black spruce grows rapidly in height in its early years if given full light and room for rapid root extension. Hence, it can be expected to grow well in clear-cut areas if competing vegetation is minimal or is reduced by management practices. Often the large clear-cut area is subject to higher than average frequency of late spring frosts which can cause growth distortion in early flushing species such as white spruce (*Picea glauca* [Moench] Voss) and balsam fir (*Abies balsamea* [L.] Mill.), but is less of a hazard for black spruce, which flushes 1-2 weeks later.

Root systems of black spruce in mineral soils have been described by many investigators (e.g., Pulling 1918, Millar 1936, Bannan 1940, Curry 1961, Horton and Lees 1961, Schultz 1969). The species is characterized by shallow roots. Schultz (ibid.) found that only half of the natural trees had persistent main tap roots, whereas two thirds of his plantation trees had tap roots. However, the depth of penetration of the tap roots and sinker roots of the natural trees extended to 90 cm (35 in.), whereas for planted trees, depths were no greater than 45 cm (18 in.); the overall mean depth of penetration was 24 cm (9 in.). In northern Ontario, Curry (1961) concluded that the majority of roots of planted black spruce were in the upper 10 cm (4 in.). The lateral extent of the root system is less well documented: Horton and Lees (1961) found lateral root lengths of natural trees up to about 10 m (33 ft) and also noted a considerable amount of root grafting. Millar (1936) noted that natural black spruce usually had four or five large lateral roots from which vertical sinker roots grew to depths of 30-60 cm (12-24 in.). The shallow nature of the root system therefore enhances the species' ability to exploit the upper, fertile, moist soil horizons and to use moisture from limited precipitation. Another feature of black spruce is that it readily produces adventitious roots. Hambly (1973) has documented the marked increases in root development, both in early spring and in midsummer, shown by transplanted nursery seedlings of both black spruce and white spruce. Thus, outplanting of these species can be undertaken successfully in spring and midsummer. Outplanting in midsummer is preferable because height growth the first season after outplanting is not reduced, as often happens after spring planting.

Characteristically, the crown form of black spruce is narrow and cylindrical, with short, slender, horizontal branches. Thus, even at close spacing each bole can maintain large amounts of foliage in the light. Normally, black spruce maintains up to 5- and 6-year-old foliage on branches; the total photosynthetic capacity is high in relation to new foliage added each year.

Production of seed for large-scale reforestation of black spruce is not normally a problem with heavy seed years occurring at intervals of 2-6 years. In plantations, precocious trees may bear moderate cone crops at 10 years of age. An important feature of black spruce is that it can be propagated vegetatively by rooted cuttings (Rauter 1971). Cuttings may be taken in the March–April or July–August period from young plantation trees. Succulent epicotyls of 1-year seedlings are also readily rooted (Armson et al. 1975). These characteristics allow for early selection and propagation of clones and are valuable in subsequent tree improvement.

Establishment

Experience suggests that for well-drained soils, bare-root transplants of ½ + 1½, 1½ + 1½ and 2 + 2 age classes, in good condition and well planted, will give maximum survival and growth. The sizes of these transplants should be in the following ranges: height, 20–30 cm (8–12 in.); diameter, 3–6 mm (1/8–1/4 in.); dry weight, 3–10 g (0.1–0.3 oz); root area indices, >30 cm^2 (>4.65 $in.^2$). Seedling (2+0 and 3+0) bare-root stock is less reliable; if it is used, much greater care in site selection and preparation is necessary. Seedling stock less than 15 cm (6 in.) in height, 2–3 mm (0.08–0.1 in.) in diameter and 20 cm^2 (3.1 $in.^2$) in root area indices should not be used. In seedling stock the relative amounts of fine and coarse roots (root texture) can be critical for both survival and height growth (Clarke 1975). Figure 1 shows typical examples of fine and coarse root systems for 3+0 black spruce. Fine root textures >3 were considered optimum by Clarke.

Black spruce has been grown in a variety of containers in the past 5 years. My remarks on this type of stock will be based entirely on personal observation since data on performance after field outplanting of trees grown in different types of container are not available. The species is not well suited to solid plastic containers such as the Ontario tube. Although some successful plantings have been made the plastic restricts rapid root egress. Paperpot containers and plug-type stock do not have this disadvantage. Whatever the container, the stock should have a minimum height of 10 cm (4 in.) and be in a vigorous state, with some branches developing and the terminal bud not well formed, if it is to be planted during the growing season.

The diversity of types of stock and age classes available for black spruce renders it flexible in large-scale regeneration programs on varying land conditions. Seedlings grown in nurseries can be stored over winter in a frozen state (Hocking 1972); early spring-lifted stock can be cool stored at temperatures of 1-2° C (34-36°F).

Some form of site preparation is essential, if only to facilitate planting on most cutovers. Surface organic layers are essential for high survival and initial growth of black spruce; therefore, any mechanical preparation which exposes the mineral soil and removes surface organic matter completely should never be undertaken. This is especially deleterious on moderately well-drained to imperfectly drained soils. The species has a great capacity for exploiting upper organic horizons for moisture and nutrients; hence, site preparation such as crushing or chopping enhances the rooting medium.

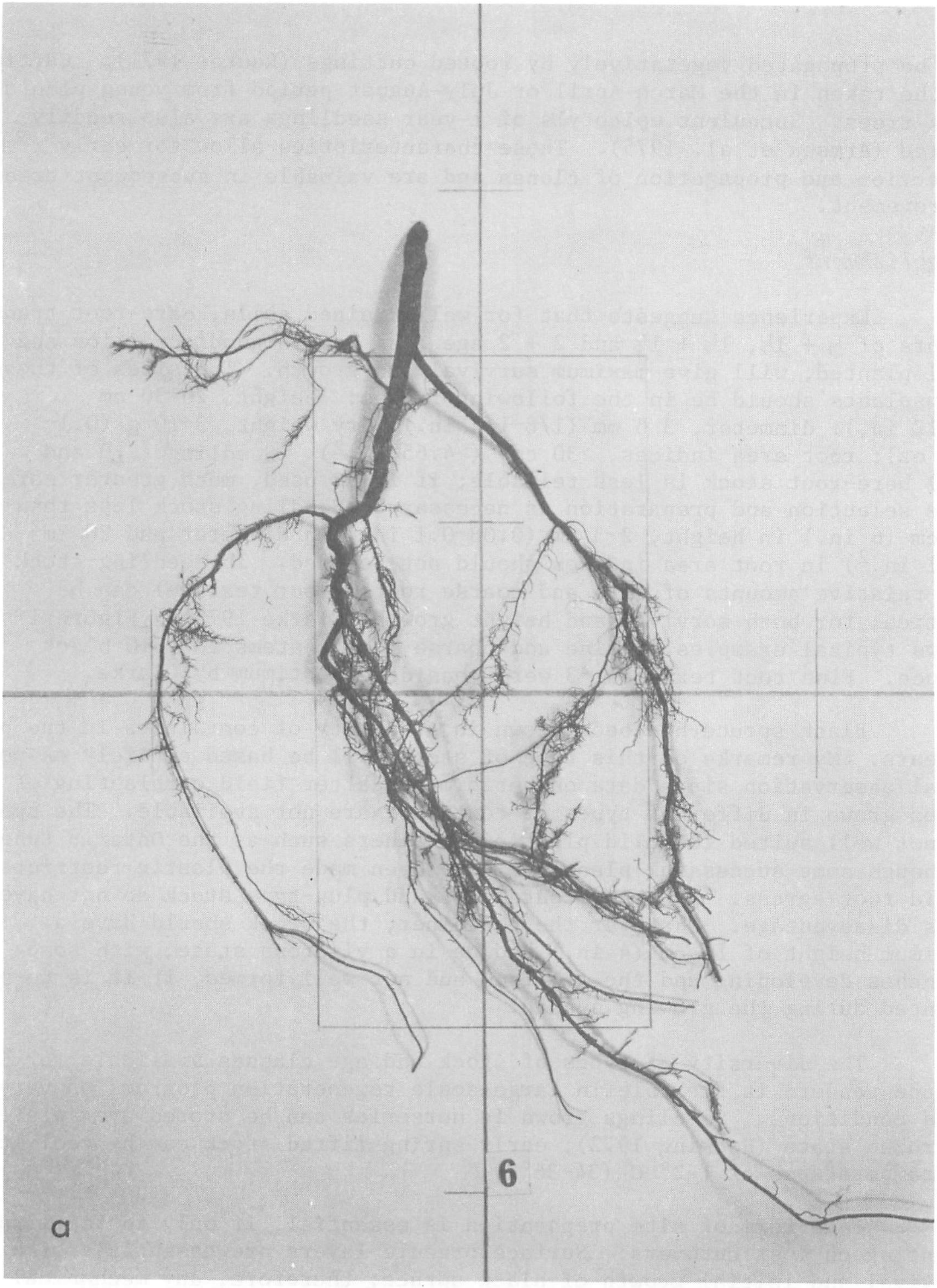

Fig. 1. Typical root systems of 3+0 black spruce.
(a) coarse-textured roots
total root area index - 43 cm^2 (6.67 $in.^2$)
ratio fine:coarse - 1·8

fine roots $\leq$ 1 mm ($\leq$ 0.039 in.) diameter,
coarse roots > 1 mm (> 0.039 in.)
(Photo courtesy of F. R. Clarke)

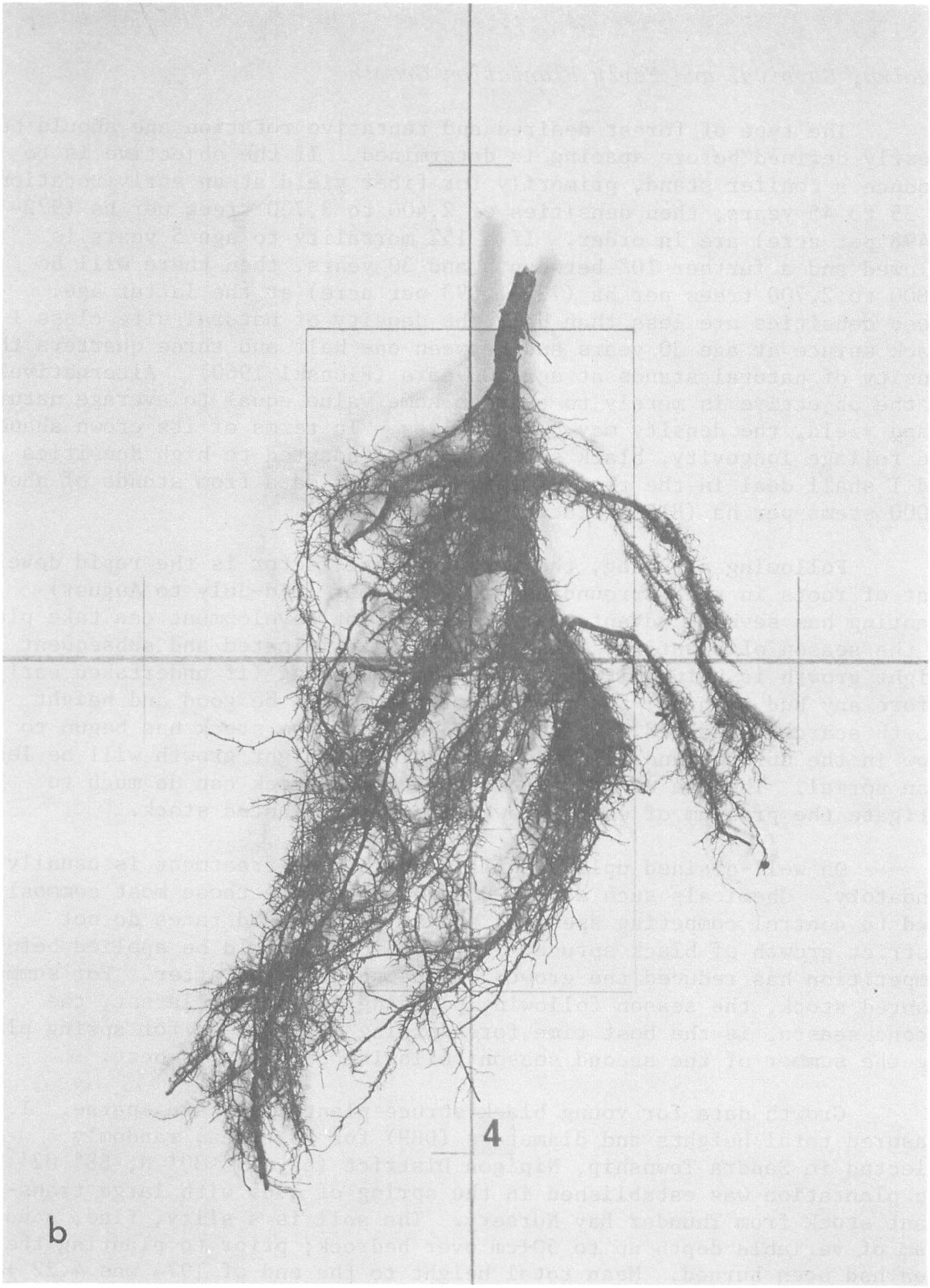

Fig. 1. Typical root systems of 3+0 black spruce.
(b) fine-textured roots
total root area index - 105 cm^2 (16.27 $in.^2$)
ratio fine:coarse - 3·0

fine roots $\leq$ 1 mm ($\leq$ 0.039 in.) diameter,
coarse roots > 1 mm (> 0.039 in.)
(Photo courtesy of F. R. Clarke)

Spacing, Survival and Early Plantation Growth

The type of forest desired and tentative rotation age should be clearly defined before spacing is determined. If the objective is to produce a conifer stand, primarily for fiber yield at an early rotation of 35 to 45 years, then densities of 2,400 to 3,700 trees per ha (972-1,498 per acre) are in order. If a 15% mortality to age 5 years is allowed and a further 10% between 5 and 30 years, then there will be 1,800 to 2,700 trees per ha (729-1,093 per acre) at the latter age. These densities are less than half the density of natural site class I black spruce at age 30 years and between one half and three quarters the density of natural stands at age 50 years (Plonski 1960). Alternatively, if the objective is merely to sustain some value equal to average natural stand yield, the density may be much less. In terms of its crown shape and foliage longevity, black spruce is well adapted to high densities and I shall deal in the rest of the paper with data from stands of about 2,000 stems per ha (810 per acre) at 5 years.

Following planting, the most critical factor is the rapid development of roots in the surrounding soil. Summer (mid-July to August) planting has several advantages: maximum root development can take place in the season of planting, frost heaving is eliminated and subsequent height growth is uninhibited. In spring planting (if undertaken early, before any bud opening) the root development will be good and height growth scarcely reduced. Frequently, however, the stock has begun to grow in the nursery and planting survival and height growth will be less than normal. The use of frozen or cool-stored stock can do much to mitigate the problem of early growth in spring-planted stock.

On well-drained upland soils, a herbicide treatment is usually mandatory. Chemicals such as 2,4-D and 2,4,5-T are those most commonly used to control competing species, and at recommended rates do not restrict growth of black spruce. The herbicide should be applied before competition has reduced the growth of the spruce, not after. For summer-planted stock, the season following planting or, at the latest, the second season, is the best time for applying herbicides; for spring planting the summer of the second season following planting is best.

Growth data for young black spruce plantations are sparse. I measured total heights and diameters (DBH) for 70 trees, randomly selected in Sandra Township, Nipigon District (ca. 49° 30' N, 88° 02' W). The plantation was established in the spring of 1965 with large transplant stock from Thunder Bay Nursery. The soil is a silty, fine, sandy loam of variable depth up to 50+cm over bedrock; prior to planting the area had been burned. Mean total height to the end of 1974 was 4.22 ± 0.09 m (13.8 ± 0.3 ft) and mean DBH 4.5 ± 0.1 cm (1.77 ± 0.04 in.). The pattern of annual height increments for nine trees selected at random from three height classes (large, medium and small) is shown in Figure 2. Several features are evident. Trees that are large or small at time of

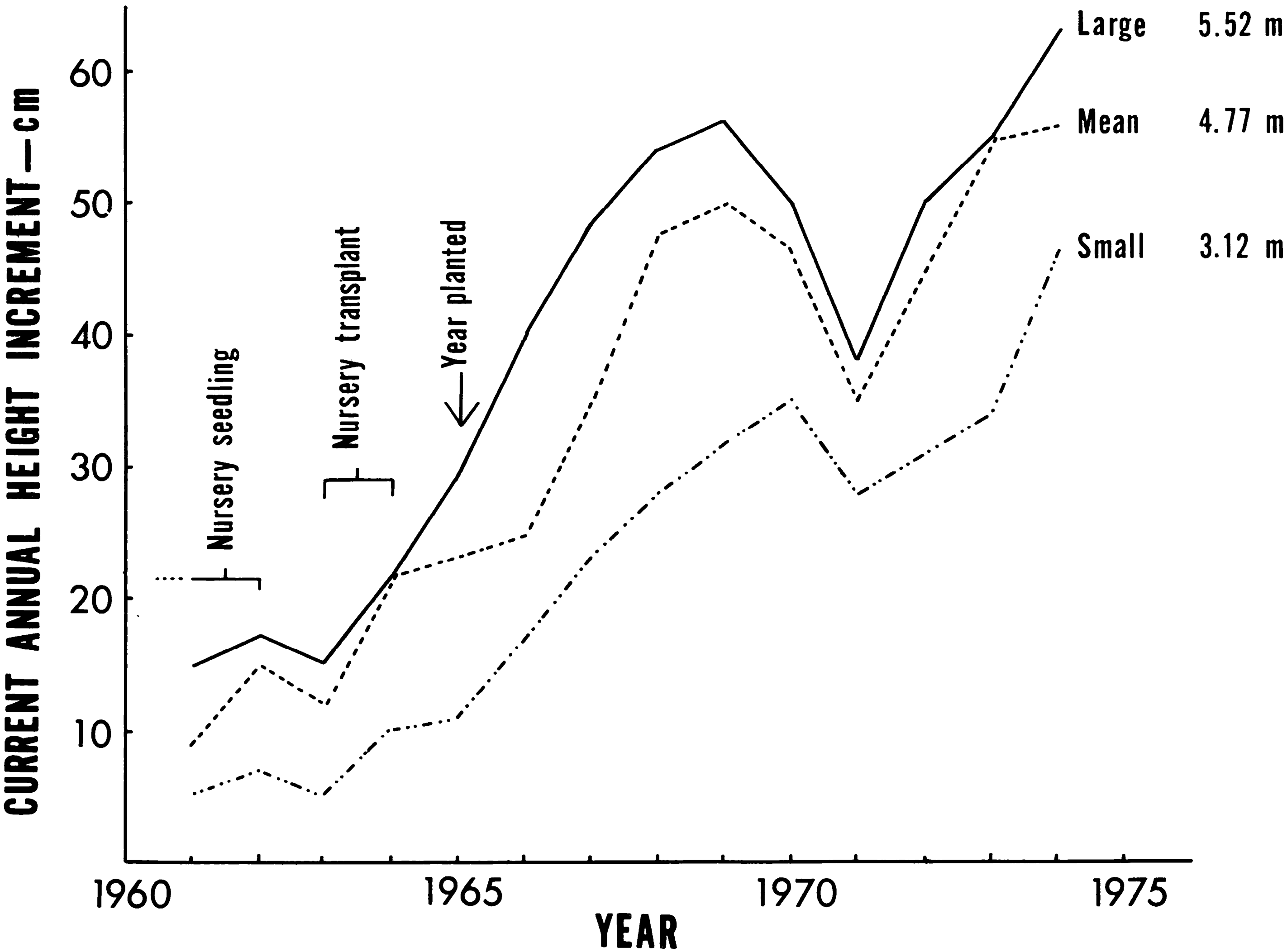

Fig. 2. Current annual height increments (cm) for large, medium and small trees in Sandra Township. Data are based on three trees selected at random for each size class.

planting remain large or small 10 seasons later. From this it follows that greater variation in stock size at time of planting will result in greater variation a decade later, and the use of more uniform planting stock should minimize later variation. Obviously, both genetic and environmental differences will also result in growth differences.

There is no evidence of planting 'check' the year of planting, but the large planting stock considerably increased its 1965 height over that of 1964 whereas the medium-sized and smaller trees showed only slight differences. All trees showed a consistent height reduction in 1970 and 1971. If we assume that this may be due to climatically induced moisture stress, we will see that the larger trees show greater height reduction than the smaller trees, presumably because their larger crowns would allow not only greater transpiration losses but also greater net photosynthate reduction resulting from moisture stress. A greater recovery is shown by large and medium trees than by small trees in 1972. The maximum crown diameter for the nine trees was 1.5 m (4.9 ft) and since the trees were planted at 1.8 by 1.8 m (6 x 6 ft) spacing, crown closure was barely beginning.

The form of root system of a medium-sized (4.5-m, or 14.8-ft) tree is illustrated in Figure 3. The original root system, though distorted, is still functioning, but the major upper laterals are roots that originated after planting. The lengths of these laterals far exceed crown widths. For example, one lateral grew 4.5 m (14.8 ft) in 8-9 years. Thus, intraspecific competition in the root zone begins well in advance of crown interference. It could be deduced that current annual height increments of 40-60 cm (1.3 - 2.0 ft) represent the maximum rates possible and that the rate will decrease as crown closure takes place. The disparity in height between large and small trees will likely be maintained, if not increased.

A comparison of height growth patterns associated with different topographic conditions is illustrated by Figure 4. These data are from a small sample of 12 trees growing in plantations of similar spacing in northwestern New Brunswick. Generally, the growth patterns are similar to those in Figure 2. The upland trees show greater increments than trees on the flat, yet the slopes of the curves are not too dissimilar. A feature of the flat is that cold air lies in it during the growing season; the reduced height in 1967 was due to late spring frost. There is an indication that, as the trees grow taller, a greater proportion of their foliage is at a higher level and may extend out of the zone of the cold air 'sink'. Thus, height growth of the trees in the flat after 10 to 15 years may be greater than anticipated if only the growth of the first 5 years is considered. The differential between the height of the upland and the trees in the flat may be reduced somewhat in the next 5 years.

The tree heights for these planted trees may be compared with data provided by MacLean and Bedell (1955). For their site A well-drained soil they found heights of 6.1 m (20 ft) at 12 years and 8.2 m (27 ft) at 20 years for natural black spruce.

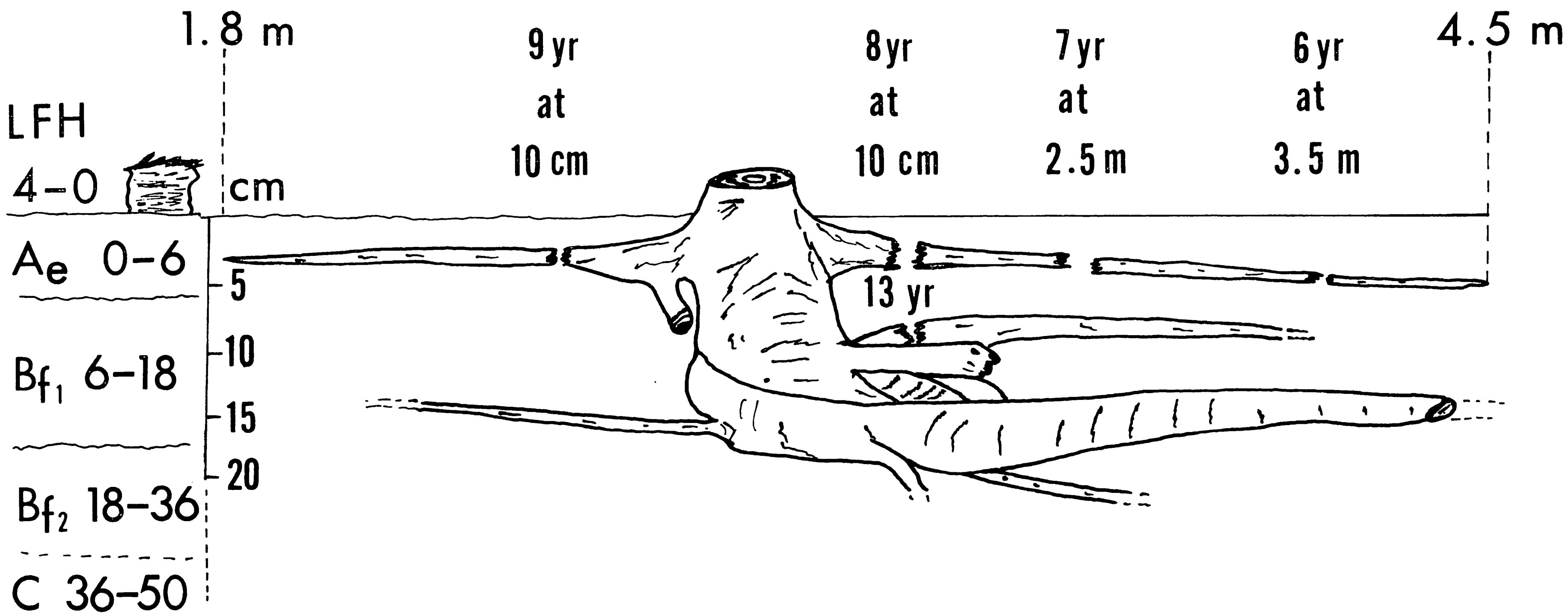

Fig. 3. Diagram of root system of black spruce. Ages of lateral roots at varying distances from stem and total lateral root extension are indicated as well as soil profile in which tree was growing.

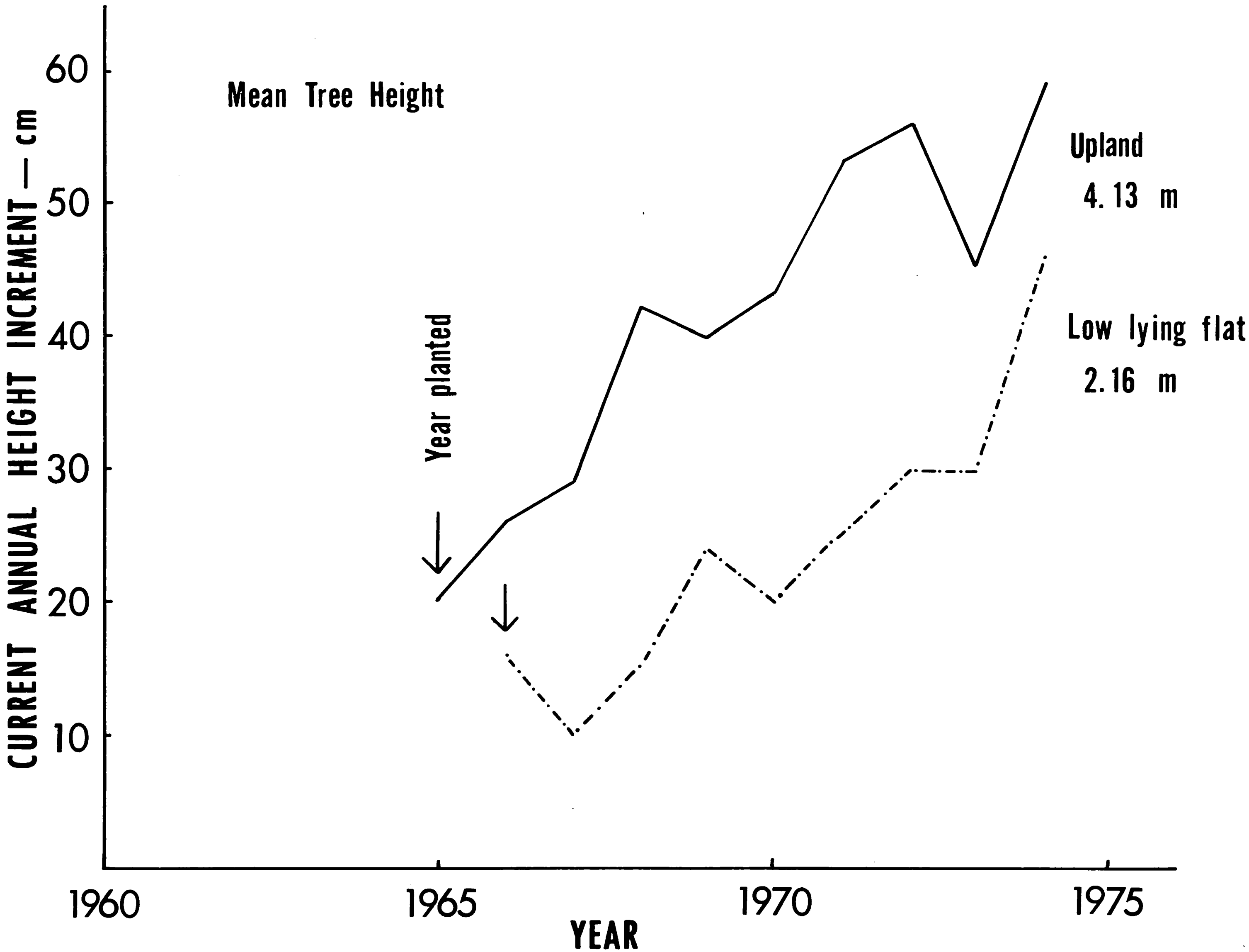

Fig. 4. Current annual height increments (cm) for black spruce in northwestern New Brunswick. Each curve is based on six randomly selected trees. Mean tree heights are given for trees on upland and low-lying flat.

SUMMARY AND CONCLUSIONS

Black spruce plantations can be readily established on upland soils, particularly where site preparation does not remove the forest floor completely. The species can be grown from seed as either bare-root or container stock and may be planted in spring and summer. It can be reproduced vegetatively from cuttings and this technique should prove useful in a program of tree improvement.

Patterns of annual height increment indicate that large planting stock retains its advantage over smaller stock and that maximum rates of 40-60 cm (1.3-1.9 ft) per year can be expected within 5 years of planting. Root development of natural and planted trees is shallow but rates of later root elongation are such that root competition occurs earlier than crown interference between planted trees.

ACKNOWLEDGMENTS

I wish to extend my sincere thanks to G. Marek and W. Nakamura who assisted me in obtaining data from plantations established by Mr. Marek for the Ontario Ministry of Natural Resources in the Nipigon District. I am also indebted to J. D. Irving Ltd. and N. H. Kreiberg for the opportunity to obtain data and experience on the artificial regeneration of black spruce during the past decade.

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DISCUSSION

STENEKER

Mr. Armson, in your graphs you showed height growth of planted and seeded material. Do I understand that after 50 years there will be no difference in the total height of the trees that were planted and those that were seeded?

ARMSON

No. The seeded trees are younger. Total height was established at a different time and I moved it over. I juxtaposed the annual growth of the seeded and planted trees. I was interested to see what kind of pattern of height growth a natural seedling had compared with a planted seedling and whether it succumbed in the same way to moisture stress.

HAAVISTO

In the previous two papers we heard about crown closures of 1,000 trees/acre which would give a crown diameter of roughly 6.5 ft. You've shown examples where the maximum diameter at considerably older ages is a matter of 1 to 1 1/2 m, roughly about half of what we're talking about. Would you consider that twice the stocking would be more appropriate, to achieve greater fiber production?

ARMSON

If we're establishing 1,200 to 1,400 trees/acre by planting, and if we assume a not unreasonable 15% mortality to age 5, and another 10% between 5 and 30 years (and that is a big question mark because we don't really know), we then wind up at 30 years with something in the order of 730 to 1,000 per acre, i.e., about one third of the actual density in Plonski's yield tables for site class I. When we are establishing trees as factories, with some kind of geometry, the significance of density and spacing is different than when we're talking about naturally regenerating an area. We get into a different kind of objective. We're talking about organizing the factories, organizing the root system, organizing the trees, and with black spruce at age 10 after planting, you do not have crown closure. If we judge by some of the natural trees we would probably get it at 15-20 years. But root competition has come into play by about age 10.

HAAVISTO

Is it true that you can have greater density and still retain your volume production?

ARMSON

I'm gambling on it. My observations and my thought processes lead me to say that the odds are about 70% in your favor. Fifteen years from now we'll have the answer.

HAAVISTO

Why can't we project a similar type of thing in natural stands?

ARMSON

I think we can come pretty close. There's something for somebody to get cracking on. I should also say that when we look at the patterns of growth--not just the current annual height increment--they tend to lend support to the conclusions that we can stack trees more closely.

DAY

Do you think that the current trend towards modified harvesting and natural reproduction will be advantageous in terms of productivity in black spruce unless measures are taken to ensure adequate spacing initially in those naturally reproduced stands?

ARMSON

If you intend to maximize current annual increment, you're probably going to space in many of those strips. I don't think there's any question about it, and you're well advised to do it by age 10, no later. If you're going to accept a "more natural development of the stands" and sacrifice growth with no further input, that's the other alternative. Here's where judgment comes in, the management decision as to what you are really trying to produce. What we're saying now is that we are trying to regenerate the forest, but the regeneration becomes a new forest. What we really ought to be asking ourselves is, "why are we regenerating the stands in the first place?"

STANEK

Most of the sites appear to be rather good upland sites. Did you have a reason for using black spruce? Obviously white spruce on these sites would have grown better than black spruce.

ARMSON

On many of these sites white spruce will grow as well as black spruce, but you do have this 5-year period, certainly at the beginning, where you get tremendous frost damage because of the exposure and the opening. If you wanted to grow white spruce you would do it in a different way. The owner in this particular case was attempting to establish a black spruce stand to yield fiber.

STANEK

I have a piece of land in a very sandy area which is rather poor in all nutrients. I have white spruce regenerating naturally and the leaders have grown 2 ft annually for the last 3 years. I don't think you find that in black spruce.

ARMSON

If we're talking fiber remember that white spruce branching habits are much different from those of black spruce and crown closure comes in much earlier than with black spruce. If you want to put all your wood on a single bole and not have it on a lot of branches so as to be able to stack trees more closely then I think the answer tends more to black than to white spruce. But I wouldn't want to argue with you about white.

WHITNEY

Mr. Armson, you mentioned root competition. You've looked at a lot of root systems. What, precisely, happens to roots when they become over-dense, when this competition starts? Are roots being killed? Have you seen pencil-sized roots killed, or is it only feeder roots?

ARMSON

I can't say much about black spruce in terms of your question. I think I can answer (I'll have to be cautious here) but my answer is based on a lot of measurement of jack pine. What seems to happen is that in the initial development, whether it be spruce or jack pine, you get this tremendous surge of roots and they define (there's a lot of data which confirms this) in the first decade of growth the root volume that is available to that particular individual. It doesn't matter whether you're talking red pine, jack pine, black spruce, or white spruce, since the documentation is in terms of root analysis and stem analysis. When that volume is exploited the tree is going to get more water, more nutrients. Anything which induces a stress, such as inadequate rainfall or nutrient supply, will tend to reduce growth. That means reduced photosynthate and the roots are going to get less. You get a backing up through the system of inadequate raw materials, water and nutrients, and stress operating to reduce photosynthetic capacity, back down the line to reduced photosynthates. We measure the reduced growth in the stem but the roots also are having a harder time, so you get a reduction in root development. This may mean mortality, too, of existing fine roots. Just what the relationships are for spruce or for jack pine we don't really know.

There's some excellent information on loblolly pine in Louisiana which tends to support this and they're dealing with beetles and some fungal organisms down there. I think we can take their studies as a model and use them here. Looking through some of these *Poria weirii* situations in Douglas fir, I suspect that we're into this sort of syndrome.

GROWTH AND ECONOMIC ANALYSES OF A FOREST DRAINAGE EXPERIMENT IN NORTHERN ONTARIO

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Results of growth and economic analyses of a 40-year drainage experiment in northern Ontario indicate that both individual tree and stand growth responded well to draining. On the basis of current drainage cost and projected stumpage prices, rate of return from draining similar sites will be up to 6%.

Les résultats des analyses de l'accroissement et du profit obtenus par suite d'un drainage expérimental effectué durant 40 années dans le nord de l'Ontario, montrent que tant la croissance de chaque arbre que celle d'un peuplement ont bien réagi au drainage. D'après le coût effectif du drainage et les frais de coupe anticipés, le drainage de stations similaires rapportera jusqu'à 6% de profit.

INTRODUCTION

Black spruce (*Picea mariana* [Mill.] B.S.P.) is the most important coniferous species in Ontario. It represents about 30% of the total growing stock of all pulpwood species (Dixon 1963) and, because of its high-quality pulping characteristics, constitutes more than 60% of the round wood utilized by the pulp and paper industry (Anon. 1969).

Most of northern Ontario's black spruce stands grow on peatland sites. Because of excess water, poor aeration, inadequate nutrient availability and adverse climatic conditions, the productivity of this species on organic soils is very low (LeBarron 1945, McEwen 1966). However, its productivity can be improved by drainage, fertilization, and thinning (Heinselman 1963, Stanek 1968, McEwen 1969).

Large peatland forest areas have been drained, fertilized and/or thinned successfully, particularly in Finland and Scandinavian countries (Huikari 1959, Heikurainen and Kuusela 1962, Heikurainen 1964, 1967, 1968, Huikari et al. 1968, Keltikangas and Sepälä 1968, Sepälä 1969, 1972). Most of these studies report on the hydrological and physiochemical characteristics of the Feno-Scandinavian peatland forestry amelioration. Few of the more recent studies, however, analyze the effect of drainage, fertilization and thinning on growth, yield and other stand characteristics.

Several small-scale forest drainage experiments have also been conducted in Canada and the United States (Day 1949; Satterland and Graham 1957; Walters et al. 1959; McEwen 1969; Stanek 1968, 1970). One of the earliest experiments conducted in Canada was established in 1929 near Iroquois Falls, Ontario by the Abitibi Paper Company Limited and the Ontario Department of Lands and Forests (now the Ontario Ministry of Natural Resources). The purpose of this experiment was to determine the effects of drainage on growth and yield and also to assess the economic feasibility of draining marginal and submarginal peatland black spruce stands. The objective of this paper is to summarize the growth and economic analyses of the above experiment. Detailed description of the experiment is given elsewhere (Day 1949, McEwen 1969); nevertheless, it is briefly outlined here.

THE EXPERIMENT

In 1929 a swamp drainage system was established on a 66-acre (26.7-ha) stand of typical, submarginal black spruce averaging 77 years of age, north of Iroquois Falls, Ontario. Based on a level survey of the area, 8,526 lineal ft (2,599 m) of drainage ditches were dug manually at an average cost of \$16.77 per acre (\$41.44 per ha). Following this operation, forty 1/160-acre (25.3-m^2) square growth plots were established at varying distances from the ditch system (Fig. 1) and three control plots were established in the adjacent undrained area. On each plot all trees $\geq$ .5 in. (1.27 cm) DBH were tagged and DBH and height were measured to the nearest 1/10 in. (2.5 cm) and 1 ft (30 cm), respectively. Other pertinent data regarding ground vegetation and peatland characteristics were also collected. Originally it was planned to remeasure the growth plots in 1940 and every 10 years thereafter. However, the first remeasurement was made in 1956 (Masterson 1957), the second in 1965 (McEwen 1969) and the third in 1969 (Payandeh 1973a).

GROWTH ANALYSES

Methods

<u>The 1969 growth remeasurement</u>: In the 1969 growth remeasurement DBH and height of all trees with DBH $\geq$ .5 in. (1.27 cm) within each growth plot were measured to the nearest 1/10 in. (2.5 mm) and 1 ft (30 cm), respectively. Tree ages were determined from increment cores taken at 1 ft (30 cm) stump height from two to three dominant and codominant trees per plot. Additional data such as form quotient, crown width, crown class, and crown condition were collected on these trees. For each plot, peat depth was

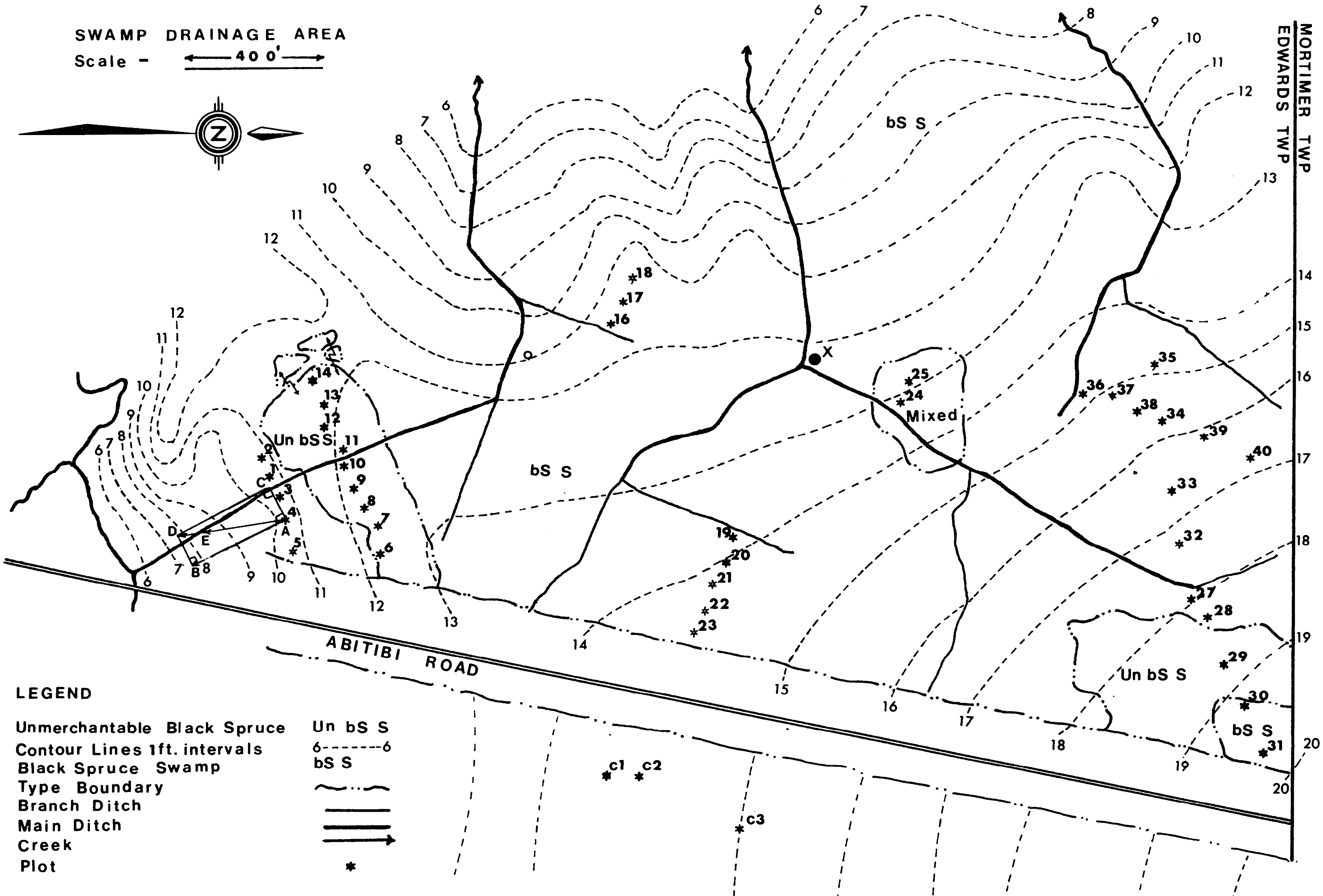

Fig. 1. Contour map of the experimental area showing the drainage ditches and plot locations.

estimated to the nearest foot (30 cm) and the degree of humification of peat was determined according to the Von Post scale (Von Post 1924). The peat moisture regime and peatland cover types were also determined for each plot.

Sixty trees were felled and sectioned for individual tree growth analysis. These trees were located near the growth plots at varying distances from the three main drainage ditches. For each tree, in addition to the above data, distance to the nearest tree, height to live crown and crown length were measured to the nearest foot (30 cm).

Analyses and Results

Individual tree growth analysis: Individual tree growth data from cores and disks were analyzed in detail. Data from one of the sectioned trees that showed exceptional growth response to drainage were also analyzed separately. Figure 2 shows a disk cut from this tree at ground level. The rate of diameter growth of this tree after draining almost tripled while its rate of height growth nearly quadrupled.

Increment core data from 40 trees were used to compare the rate of tree diameter growth for 30 years before and 40 years after draining. Results of Student's t tests indicated a significant (at the 1% level) increase in diameter growth after draining. Pre- and postdrainage tree diameter growth equations, given below, were derived by means of stepwise multiple linear regression (cf. Draper and Smith 1967):

$$\Delta d_b/\Delta t = .027 + .00015\ S\ M + .03\ S\ A^{-1}; \qquad R^2 = 0.64 \qquad (1)$$

$$\Delta d_a/\Delta t = .04 - 288\ d_2^{-2} + .01\ M - .006\ S + .31\ S\ d_2^{-1} + .33\ S\ A^{-1} - 4.1\ A^{-1} + .004\ C_w; \qquad R^2 = 0.51 \qquad (2)$$

Where: $\Delta d_b/\Delta t$ and $\Delta d_a/\Delta t$ denote annual tree diameter growth before and after draining, respectively, S = site index, M = moisture regime, A = tree age, d_2 = distance of water flow from plot centre to drainage ditch, and C_w = crown width.

The above equations indicate that predrainage annual tree diameter growth was significantly correlated with site index, moisture regime and age. In addition, the postdrainage diameter growth was significantly correlated with distance of water flow from the ditch and crown width.

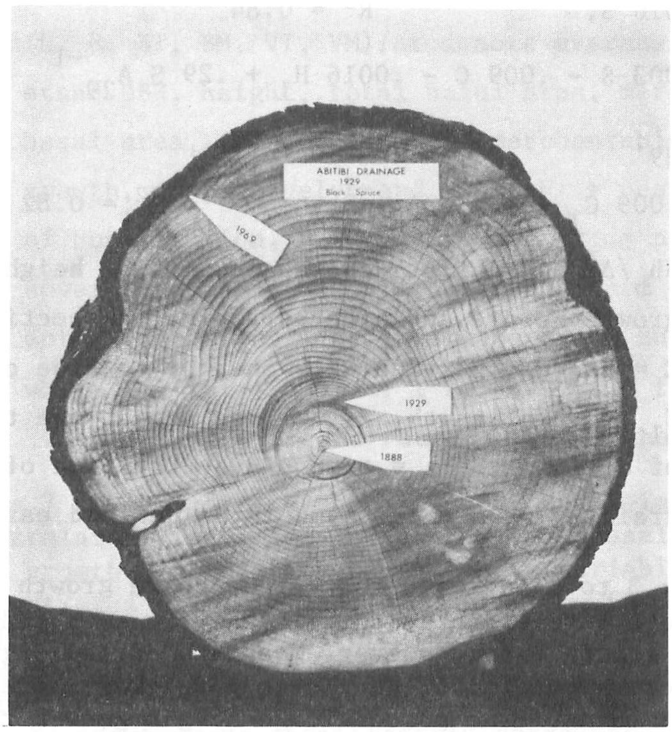

Fig. 2. A section cut from a tree at ground level showing the extent of diameter growth response to drainage.

wider crowns and larger initial diameter growing on better sites and located some distance away from the drainage ditch system. These equations also indicate that the height growth response to drainage was higher for younger trees with larger crowns growing on better sites.

2. Stand growth analysis (equations 7 to 12) indicates that: (a) younger stands with lower initial stocking produced greater DBH and height growth, (b) younger stands growing some distance away from the drainage ditch system had better growth response for both total and merchantable basal area, while the latter was also greater for smaller initial average stand DBH, and (c) both total and merchantable volume growth were greater for younger stands with lower initial stocking growing some distance away from the drainage ditch system.

ECONOMIC ANALYSES

Preliminary Analysis of the Data

Volume stratification: In the initial survey, the drainage area was stratified into several site types, based primarily on physiographic features. However, for practical reasons, in the present analysis growth plots were stratified into three volume classes based on their 1929 volumes. These three classes are referred to here as good, medium and poor sites. Those plots whose initial merchantable volumes were less than 6, between 6 and 12, and more than 12 cords/acre (35.7-71.4 m^3/ha) were considered to be on poor, medium and good sites, respectively. Table 1 summarizes the data on the number of plots, average stand age, estimated natural yield and drainage response by site strata for the drainage area and for the control site for the four measurement dates.

Physical yield data: The merchantable volumes calculated for various site strata in the drainage area consist of two yield components: (1) the expected natural yield and (2) the additional volume due to drainage response. These two yield components were differentiated based on the assumption that natural growth and yield of the three site strata in the drained area would have been directly proportional to those on the control site if the area had not been drained (Table 1). The effects of possible bias on the results from the above tenuous assumption were evaluated (Payandeh 1973b).

Table 1. Estimated natural yield (merchantable volume, cords per acre)[a] and growth response due to drainage for the Abitibi drainage area by site strata for the four measurement dates

Site stratum	No. of plots	Stand age in 1929	Year: 1929	1956			1965			1969		
			Natural yield only	Natural yield + drainage	Natural yield only	Drainage response	Natural yield + drainage	Natural yield only	Drainage response	Natural yield + drainage	Natural yield only	Drainage response
Good	10	85	29.10	39.10	36.31	2.79	42.80	29.48	13.32	44.90	24.98	19.92
Medium	11	85	8.76	14.96	10.93	4.03	17.31	8.88	8.43	20.62	7.52	13.10
Poor	17	71	2.43	8.38	3.03	5.35	10.89	2.46	8.43	13.22	2.09	11.13
All	38	79	11.28	18.36	14.28	4.28	21.15	11.43	9.72	23.70	9.69	14.02
Control	3	81	10.60	---	13.23	--	---	10.74	--	---	9.10	---

[a] 1 cord per acre = 5.95 m^3 per ha.

Table 2. Actual and projected stumpage charges ($ per cord)[a] on black spruce pulpwood in Cochrane District 1930-1970, 1972-2012

Year: 1930	1935	1940	1945	1950	1955	1960	1965	1970	1972	1982	1992	2002	2012
1.37	0.73	1.42	1.35	1.72	2.97	2.95	2.86	3.15	3.57[b]	4.50[b]	5.55[b]	6.72[b]	8.01[b]

[a] $1.00 per cord = $ .41 per m^3.

[b] Source: Payandeh (1972).

Price data: Data on the actual stumpage charge, i.e., price in dollars/cord charged to companies by the Ontario Ministry of Natural Resources for black spruce pulpwood in Cochrane District from 1930 to 1970, as well as projected future stumpage prices for 1972 to 2012 (Payandeh 1972), are given in Table 2. Stumpage value or gross revenue per acre for various site strata within the drainage area and the control site were calculated for each measurement date, based on Tables 1 and 2, and are given in Table 3.

Final Analysis and Results

Once the gross value ($ per acre) of the various site strata and measurement dates was calculated, the annual rates of return on the initial cost were determined for: (1) combined rate of return from natural yield plus drainage response, (2) rate of return from natural growth only, and (3) rate of return due to drainage response alone. Results of the foregoing calculation can be summarized as follows:

1. The rate of return from natural growth on the entire drainage area decreased from 3.8% to 1.7% from 1929 to 1969. This rate was falling off prior to drainage, a fact which suggests that, if the area had been drained earlier, the response to drainage might have been greater.

2. The rate of return from natural growth and drainage response varied for various site strata and different periods. It varied from 0.8% to 1.9% for the poor site and from 2.2% to 2.7% for the good site between 1929 and 1969. If future stumpage prices increase as projected (Table 2), this rate will continue to rise for several years to come.

3. The rate of return due to drainage response increased steadily over the 40-year period for all site strata. This rate will perhaps continue to increase for several years. For the good site, this rate varied from -2.7% to 3.4% for the periods 1929-1956 and 1965-1969, respectively. The negative rate of return means that, in the first interval, the additional value growth was not enough to cover the cost of drainage. Such results should not be surprising because most silvicultural investments have a considerable time lag before producing positive rates of return.

Table 3. Gross value ($ per acre)[a] of natural yield + drainage response, natural yield only, and drainage response of the Abitibi drainage area by site strata for the four measurement dates.

	Year									
	1929	1956			1965			1969		
Site	Natural yield only	Natural yield + drainage	Natural yield only	Drainage response	Natural yield + drainage	Natural yield only	Drainage response	Natural yield + drainage	Natural yield only	Drainage response
Good	39.86	116.13	107.84	8.29	122.41	84.31	38.10	141.44	78.69	62.75
Medium	12.00	44.43	32.46	11.97	49.51	25.40	24.11	64.95	23.69	41.26
Poor	6.07	24.89	9.00	15.89	31.15	7.04	24.11	41.96	6.58	35.38
All sites	15.45	54.53	41.82	12.71	60.49	32.69	27.80	74.66	30.49	44.16
Control	14.52	---	39.29	---	---	30.72	---	---	28.67	---

[a] $1.00 per acre = $2.47 per ha.

The foregoing results were based on actual costs and stumpage prices from 1929 to 1969. However, expected future rates of return from drainage will be higher mainly because of lower current drainage cost—stumpage price ratio. To demonstrate the effect of this factor, results of this experiment were projected into the future on the basis of current drainage cost estimates and projected future stumpage prices (Table 2). Recent drainage trials in Cochrane, Ontario (V. F. Haavisto, personal communication) indicate that, with suitable machinery, black spruce stands may be drained at 12.5¢ per lineal foot (0.3 m). Since the Abitibi experiment had on the average 129 ft of ditches per acre (97.1 m/ha), the current cost of draining a similar site would be 129 x 12.5¢ = $16.14 per acre ($39.88/ha). Analysis of this projection over the period 1972-2012, by 10-year intervals, was carried out, and the results can be summarized as follows:

1. Expected rates of return from projected natural growth will decrease from 3.1% to 1.7% over the next 40 years.

2. Projected combined rate of return on initial stumpage value plus current drainage cost will increase for all site strata over the 40-year period. However, these rates will increase much faster for the poor site than for the good site, and will vary from a low of -3.0% in the first decade to a high of 3.7% in the last decade for the poor site.

3. Expected future rates of return from drainage alone will be considerably higher than those previously calculated, because of lower current drainage cost—stumpage price ratio. These rates range from 4.4% for the poor site to 5.9% for the good site for the first and last decades, respectively. These rates will also continue to increase for several years beyond the projection period.

The above analyses are based on stumpage prices which provide estimates of expected future direct rate of return to the province. If the analysis is carried out on the basis of the price of wood delivered to the mill, higher rates of return will result mainly because of lower transportation costs and reduced felling and bucking costs.

CONCLUSIONS AND RECOMMENDATIONS

From the results of growth analysis of the present study, it may be concluded that both diameter and height growth and, therefore, volume and value growth of individual trees of submarginal peatland black spruce can be improved significantly by draining. Growth response to drainage will be higher for younger trees with larger crowns growing on better site and some distance away from the drainage ditch system.

Effects of draining on stand growth characteristics were not as significant and distinct as those on individual trees, mainly because of lack of predrainage data for comparison and the high and irregular mortality that occurred between 1929 and 1969. Nevertheless, results indicate that stand basal area and volume growth rates responded well to draining and that generally younger stands with lower initial stocking, growing on better sites and some distance away from the drainage ditch system, grew faster.

The above findings are somewhat inconclusive, since they are derived from the results of a single and poorly designed experiment. However, they do point out the effects of draining on individual tree and stand growth. Analysis of future remeasurements of this experiment as well as other growth and fertilization experiments established in 1970-1971 in the Cochrane District should strengthen the findings presented here. Such analyses, utilizing simulation modeling to evaluate the effects of various silvicultural treatments, particularly drainage and fertilization, on the growth and yield of peatland black spruce, are now under way.

From the results of the economic analysis of this study, it may be concluded that both physical and value growth of slow-growing unmerchantable black spruce in northern Ontario can be increased by forest drainage. On the average it took about 30 years for the additional value growth due to drainage to offset its cost. However, this interval is expected to be shorter (15 to 20 years) in the future because of lower current drainage cost—stumpage price ratio. The rate of return from natural growth culminated before drainage, suggesting that if the area had been drained earlier, the response would have been greater.

The rate of return from natural growth declined from 3.8% to 1.7% from 1929 to 1969. On the other hand, the average rate of return from drainage increased from -1.1% to 2.5% over the same period. The actual rate of return from drainage varied from 1.9% to 3.4% for various site strata. Expected future rates of return from draining forest stands similar to those drained in the present experiment should be between 4.4% and 5.9%. Such expected rates are based on the projected stumpage prices and do not include savings in harvesting and transportation costs that might result from drainage. If these savings are also attributed to drainage, the expected rate of return from the best drainable sites might be as high as 10%.

As stated earlier, this experiment was financed jointly by the Abitibi Paper Company Limited and the [then] Ontario Department of Lands and Forests. Expenditures for future experiments or operational-scale drainage, fertilization or other silvicultural investments may be borne by the company or the province alone, or may be shared by them. Returns from such silvicultural investments are realized by the province in the form of additional revenue per acre and by the company in the form of savings in harvesting and transportation costs. Therefore, if the company bears the total cost of treatment, it should receive some compensation or subsidy from the province, perhaps in the form of lower stumpage charges on the wood harvested from the treated areas. On the other hand, if the province bears the total cost of treatment, it should expect a higher rate of stumpage charge on the wood coming from the treated areas. However, a sharing of costs and benefits seems most appropriate.

The author would like to emphasize the limitations of the data used for this study. More intensive research is needed to determine the economic feasibility of various silvicultural treatments such as drainage, fertilization and/or thinning. In particular, properly designed experiments should be established to determine the sites most suitable for treatment in terms of stand age, site quality, stocking, peat depth and other characteristics. Studies should also be conducted to determine an optimum drainage system, i.e., ditch depth, slope and drainage intensity or ditch spacing, etc., for economically drainable sites. Finally, comprehensive economic analyses of such studies should be undertaken to determine the overall feasibility of intensive management of peatland black spruce resources in northern Ontario.

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DISCUSSION

UNIDENTIFIED SPEAKER

I don't understand the drainage process itself. Do you put ditches through the lowland area and does the water seep into the ditches or do the ditches go somewhere and drain somewhere in particular?

PAYANDEH

Yes. They change the slope pattern of the land, so the excess water will drain into them.

UNIDENTIFIED SPEAKER

So it's sort of a perched watertable in these plots and there's somewhere else lower in the immediate area. I don't quite understand a swamp such as the one you demonstrate, but I assume it is a low area. Where is the water headed in the ditches? It must go to some lower area.

PAYANDEH

Yes. You have to have some lower area such as a river or a ditch to be able to drain the water into it. If you have an absolutely flat area there is no use putting in drainage ditches.

SWAN

In this particular case where does the water go? Into a low-lying area?

F. N. ROBINSON

Didn't it go into a creek?

PAYANDEH

Yes.

WYNIA

I'm interested in the types of soil you're dealing with in this experiment. It seems to me that there are massive differences in the quality of organic soils. Some of them will have substantial quantities of nitrogen which are quite an incentive to tree growth, and drainage will make this nitrogen available. What kind of assurance have you that you are dealing with a reasonably productive soil in this test?

PAYANDEH

In some places in this area the peat depth is as much as 5 ft. Whether the availability of nitrogen will be sufficient for growth we really don't know, but previous investigations indicated that the lack of phosphorus is probably the main drawback in terms of nutrients. But as far as I know there hasn't been any indication of a lack of nitrogen. Assuming enough nitrogen, once you add phosphorus and other elements it might improve the growth response.

BURGER

About 10 years ago McEwen reported on a similar situation in Iroquois Falls; I wonder if it was the same stand. He concluded that there was no increase in growth after drainage and I wonder if that might be due to the fact that his measurements were made on an area basis and yours were made on growth of trees close to the ditches.

PAYANDEH

Yes. I have a summary here of discussions I presented in two other papers I published. I discussed in detail why McEwen and Masterson (1956) could not come up with definite conclusions in terms of growth. There were four possible reasons for this: first, they were trying to correlate the growth response with the distance from plot centers to drainage ditches, measured perpendicularly to the ditches--assuming such a distance represents the effective distance of water flow from the ditch. But as Figure 1 shows, most of the main ditches were dug parallel to the natural slope of the forest floor and perpendicularly to the contours of the land.

Such a distance does not represent the effective distance of water flow from the ditch. And in their analysis they were trying to correlate their measurements, through those distances, with growth response. Now, I calculated a modified distance to approximate effective distance of water flow from the ditch based on a product vector, as shown in Figure 1. In my regression analysis I used both measurements, i.e., the distance that they used and the distance that I derived. In every case the distance that I calculated was picked up. In other words, it was correlated with growth response; theirs, however, was not.

The second reason was that the drainage area was initially subdivided into several site types, based mainly on physiographic features, and they were trying to analyze their results in terms of those site types. Apparently, there is no significant relationship between the growth response in this case and the type of land they had.

The third reason was that they were seeking a direct inverse relationship between the growth response and the distance from the ditch (the way they measured the distances). My analyses show that such a simple inverse relationship does not exist. The only function for distance which was picked up was the sine function; in other words, the highest growth response was not that which was closest to the ditch; i.e., maximum growth response occurred some distance away from the ditch.

The fourth reason was that high and irregular mortality occurred among plots between 1929 and 1965, when McEwen did the remeasurement, and that caused another problem. Hence, he and Masterson could not analyze the data the way I did.

DE GRAND

What age do you suggest spruce should be before you drain a particular site?

PAYANDEH

I will not commit myself on the basis of this particular experiment. I assume it would vary with site, peat depth and other characteristics, and with the kind of slope. But what I could say on the basis of this experiment is that the average age of this stand when they drained it was 77 years and that was too late. Somewhere between 30 and 50 years would perhaps be a better age.

SESSION B

TREE PLANTING AND STOCK QUALITY--A VIEW FROM THE FOREST

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*Planting of black spruce (*Picea mariana *[Mill.] B.S.P.) in recent years has not yielded particularly impressive results. Several factors are responsible, but there is evidence that stock quality is one of the most important. If the quality of black spruce nursery stock can be improved sufficiently, higher survival rates should result.*

*La plantation de l'Epinette noire (*Picea mariana *[Mill.] B.S.P.) n'a pas produit des résultats particulièrement impressionnants ces dernières années. Cela est dû à plusieurs facteurs, mais il paraît que la qualité des plants en constitue le plus important. Si la qualité des semis d'Epinette noire peut être suffisamment améliorée, il devrait en résulter de plus forts taux de survie.*

My role in this symposium is to present the views of foresters in the field on planting stock. I hope to approach the subject from the viewpoint of a management forester, since many of us are responsible for timber management programs on units of several thousand square miles and with annual cuts of several thousand acres. I mention this because I sometimes feel that administrators and others who are somewhat removed from field operations don't always appreciate the geographical scope of a management forester's responsibilities and, consequently, the limitations on our operations.

Rightly or wrongly I don't intend to look too far into the future in my discussion of stock quality. I am taking this approach because I am always afraid that crystal-ball gazing may obscure immediate solutions to present problems.

To begin with I would like to review our experience in the recent past with black spruce (*Picea mariana* [Mill.] B.S.P.) nursery stock quality. During 1970, we carried out a survey on the survival of transplant and seedling nursery stock that had been planted in the former Geraldton District between 1956 and 1969. This survey was instituted because of numerous instances of generally poor survival in many of the more recent plantations. These results, we felt, could be traced in some cases at least to the generally poor quality of the seedling stock that we were receiving and to other related factors.

Table 1. Summary of survival of black spruce planting stock by year and season of planting and age class of stock

Year	Season	District 3+0	District 2+2	Sample unit 3+0	Sample unit 2+2	Northwest 2 yr	Northwest 5 yr	Northeast 2 yr	Northeast 5 yr
1957	spring	-	-	-	-				
	fall	-	50	-	-				
1958	spring	-	81	-	80				
	fall	-	-	-	-				
1959	spring	-	80	-	-				
	fall	-	55	-	-				
1960	spring	-	78	-	98				
	fall	-	81	-	-				
1961	spring	85	-	-	-				
	fall	-	80	-	88				
1962	spring	-	95	-	-				
	fall	-	75	-	96				
1963	spring	63	87	-	-				
	fall	-	80	-	80				
1964	spring	68	93	-	-				
	fall	86	80	-	80				
1965	spring	96	-	-	-				
	fall	47	72	-	-				
1966	spring	70	-	-	-	76	70	73	67
	fall	-	81	-	58				
1967	spring	66	-	52	-	73	63	76	54
	fall	-	75	-	65				
1968	spring	45	-	71	-	59		72	53
	fall	48	65	48	-				
1969	spring	-	88	-	91	63		57	
	fall	34	-	14	-				
1970	spring	65	89	38	61	61		71	
	fall	-	-	-	-				
1971	spring	-	-	63	-	60		60	
	fall	-	-	-	-				
1972	spring	-	-	72	-				
	fall	-	-	-	73				
1973	spring	-	-	83	-				
	fall	-	-	-	-				
Average	spring	64	90	60	81				
	fall	39	76	42	73				
	both	53	80	55	75		66		58
Range	spring	45-96	78-95	38-83	61-98				
	fall	34-86	50-81	14-48	58-96				

NOTE: Data for district based on figures compiled in fall, 1970
Data for sample unit based on figures compiled in summer, 1975
Data for regions from MacKinnon (1974)
All figures are latest available at time of compilation

Table 1 presents the results that were derived for black spruce nursery stock for the District during the course of that study. It also contains a more up-to-date summary for one management unit included in the original survey. Three trends were evident. First the survival rates for seedling stock were generally below those for transplant stock. These results are similar to those reported by Dr. Mullin from the RH-8 series of experiments (Mullin 1968). The second trend that was of interest was the extreme variation in the survival range for seedling stock when compared with transplant stock. We interpreted these results as indicating that the seedling stock was more fragile and, therefore, more susceptible to the rigors of outplanting than was the transplant stock. In the third place we noted the extremely poor survival results for fall-planted seedling stock.

For comparison purposes I have included in Table 1 the second and fifth year survival figures for black spruce planted between 1966 and 1971 as published in the Ontario Ministry of Natural Resources' most recent report (MacKinnon 1974). These figures are for the former Northwestern and Northeastern Regions. The average fifth year survival for black spruce planted in the Northwestern Region is 66% and in the province 61%. I doubt if anyone would deny that these are acceptable results. It is very easy for foresters, when faced with results like these, to place the blame directly on poor-quality stock. However, in my experience, it is seldom so clear-cut a picture. The ultimate survival of any plantation is the result of the interaction of a number of factors affecting stock survival. I would like to comment briefly now on some of these factors and make some observations on the impact of stock quality in relation to them.

Storage of Lifted Planting Stock

The increasing size and duration of planting projects--particularly in the spring--often resulted in longer storage periods than had been used in the past. Various types of cold storage, in which temperature and humidity can be more or less controlled, are currently used to store dormant stock in the spring. An obvious consequence of lifting and storage is the risk of stock deterioration while it is in storage. Although constant low temperatures and high relative humidities can delay deterioration, this must be considered as a delaying action only, particularly in ice-cooled field storages where temperatures are more difficult to control.

One cause of deterioration is the development of harmful molds on stored trees. We have observed that these molds are likely to develop sooner and spread more rapidly on smaller stock than on larger stock stored under the same conditions. It has been suggested (Navratil 1973) that compaction of the planting stock, both within the bundle and within the storage container, can affect mold development (i.e., the greater the compaction, the greater the risk of molding).

Perhaps larger trees, with their greater stem thicknesses, are able to resist compaction to a greater degree than smaller stock. Since molding has caused serious deterioration of stock on many occasions, this may be one advantage of the larger stock.

We have not, however, been able to determine any other obvious relationship between stock size and deterioration in cold storage. One study in Indiana (Williams and Rambo 1967) involving the overwinter storage of red pine (*Pinus resinosa* Ait.) and white pine (*Pinus strobus* L.) concluded that transplants of those species were a better risk for such storage than were seedlings. While one can hardly use that study to draw conclusions for black spruce, it is information of a type that would surely be of interest.

Planting Quality

Just as there is a tendency for field people to blame the nursery stock for poor survival, so too is there a tendency for nursery people to suspect inadequate planting quality as the cause of poor survival--and with good reason. Confronted with a shrinking labor force in the face of an increasing tree planting program, confronted with rapidly escalating costs in an endeavor in which it is almost impossible to economize without sacrificing quality, confronted with some pretty difficult planting sites (we are, of course, talking about the Precambrian Shield), it is not all that often that we in the field can point to a planting project and state, unequivocally, that this is a project in which the trees were planted as they should be planted.

If, then, we cannot expect the best quality planting, we must ensure that the stock we are using will be able to withstand the rigors of normal outplanting. It might be argued that larger stock (which, incidentally, most foresters equate with better quality) is more difficult for planters to handle owing to the increased volume, weight and root development. However, this is a tradeoff that most foresters I know are prepared to make. I have found that on most sites large trees are more likely to meet planting quality standards than are small trees.

Sites and Site Conditions

A discussion of black spruce planting sites is beyond the scope of this paper but there are several points in this regard that I would like to discuss briefly.

In some areas of the province the sites and site conditions may be relatively homogeneous, thereby greatly simplifying both the planning and the operational phases of a planting project. However, in other areas, sites are much more variable and one is confronted with a heterogeneous pattern of sites and site conditions. For these areas, the accurate, long-term forecasting of stock quality requirements is difficult. Moreover, the logistics of matching the stock to the site during the operational phases of planting may be quite difficult to accomplish given the normal level of intensity. For the near future we are obviously going to require higher proportions of the better grades of stock than would be indicated by an acre-to-acre assessment of stock quality requirements.

Although black spruce is probably being planted on a wide range of sites, I suspect that a lot of it is being planted on moderately deep, upland sites. On such sites, mechanical site preparation is often relatively simple, hand planting is usually easy and, of course, site quality is higher. Hence, yields are better. However, on such sites competition from a wide variety of plants can be expected. Aerial herbicide spraying has commonly been used to release conifers from competition on such areas. However, with the increasing awareness of both the biological and economic value of aspen (*Populus tremuloides* Michx.) and white birch (*Betula papyrifera* Marsh.) regeneration which occur in varying amounts both within and adjacent to black spruce plantations, aerial herbicide spraying for release is increasingly being questioned. Consequently we may find that many of our plantations will get little, if any, tending. In that case we will have to rely largely on the initial site preparation and the quality of the planting and planting stock to ensure successful establishment of the plantation.

The foregoing comments will, I hope, serve to illustrate the position in which many management foresters find themselves in their tree planting programs. Theoretically, tree planting offers many proven advantages: genetically superior stock produced to high standards in the nursery can be planted carefully at uniform spacing on the most productive sites, thereby ensuring high yields of valuable fiber in reduced rotations. In fact, the limitations I have just described, among others, require improvements in the current planting program wherever possible to produce better results than those presented in Table 1. One of these improvements is to ensure that stock quality meets near-maximum standards for the site to help maintain high survival and reduce the extreme variation in survival rates.

I have refrained from describing the standards that I feel are required since these will vary depending on the sites being planted. However, on the basis of results from past years, we believe that in Terrace Bay District we will require black spruce stock comparable to the 2+2 stock received in past years or the 1½+2½ black spruce received this fall. Although we have not as yet obtained the vital statistics for this stock, we presume that it will fall within the heavy size class. Our long-term forecasts for nursery stock reflect these thoughts.

Black spruce planting programs should aim at *minimum* acceptable survival rates of about 75% 5 years after planting. Of course, given this minimum, the *average* survival may well be in the order of 85%. The advantages of such an aim are obvious: the better the anticipated survival, the lower the initial planting density. By increasing average survival from 65% to 80% or 85%, we can realize substantial savings in terms of dollars per acre and these dollars could go a long way towards defraying the extra costs of producing better quality stock and, I might add, better site preparation, planting and so on. Moreover, we could likely expect better growth, the same number of trees could regenerate more acres and all those connected with our tree planting program would justifiably feel more satisfied.

In conclusion, I hope that I haven't portrayed stock quality as the single culprit responsible for the relatively poor past performance of our black spruce tree planting programs. There has been a general improvement in the quality of stock produced during the past several years at the Thunder Bay nursery. If this improvement can continue and if we can make refinements in the planting phases, I am sure we can expect far more acceptable results from our tree planting program.

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STANDARDS IN THE PRODUCTION AND PLANTING OF BLACK SPRUCE

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Describing stock by age class is no longer adequate in nursery management. More critical values related to demands of the planting site are required. A standard for plantation growth will facilitate development of specifications for new planting products. Some Ontario nurseries have developed monitoring procedures for production and shipping stages, but not for outplanting.

En aménagement des pépinières, la description des groupes de semis par classes d'âges n'est plus adéquate. Il faut fournir des chiffres plus critiques décrivant les propriétés de la station de plantation. Une norme de croissance en plantation facilitera le développement de ce qu'il faut pour de nouveaux produits de plantation. Quelques pépinières ontariennes ont mis au point des marches à suivre pour les stades de production et d'expédition, mais non pour celui de la plantation.

INTRODUCTION

Of the various regeneration packages available, planting of seedlings is one of the major methods used in Ontario. Table 1 gives a breakdown of the area of Crown land in the province regenerated by planting, direct seeding, and other methods in the years 1973 to 1975 inclusive.

Table 1. Area, in acres[a], of Crown land in Ontario regenerated by planting, direct seeding and other methods, 1973-1975.

Method	1973	1974	1975
Planting	75,500	65,200	61,300
Direct seeding	21,800	25,100	59,900
Other	52,700	41,300	42,700
Total	150,000	131,600	163,900

[a] 1 acre = 0.40 ha.

For the year 1974-1975, the cost of seed, nurseries and planting on Crown land and Woodland Improvement Agreements (excluding site preparation and tending) was approximately $1,042,000 for 11,600 acres (4,700 ha) of black spruce (Table 2).

Table 2. Approximate cost of regeneration on Crown land and Woodland Improvement Agreements in Ontario, 1974-1975.

Item	Cost, all species[a]	Approx. cost black spruce[b]
Seed	$150,000	
Nurseries and containers	$3,200,000	
Planting	$3,100,000	
Site preparation	not available	
Tending	not available	
Total	$6,450,000	$1,042,000

[a] Total area, all species: 72,500 acres (29,000 ha)

[b] Total area, black spruce: 11,600 acres (4,700 ha)

NOTE: Cost of regenerating black spruce was calculated as a % of cost of regenerating all species (based on area regenerated).

On the basis of planning projections, the volume of planted material will increase, but the percentage of area planted will decline in comparison with that regenerated by other methods.

Although this presentation is to deal mainly with the production of planting stock, I would also like to discuss briefly a few phases of the overall planting system. A nursery is a production-oriented, cost-controlled operation, as is the planting phase. Hence, the principles that apply to production management may also apply to our planting system. I speak of standards and specifications for our various levels of activity. We have remarkably few of these considering our level of expenditure and the volume of planting.

In a steel mill or a paper mill, a number of tests are made during the manufacturing process to ensure that the final product meets certain tolerances. These tolerances vary depending on the level of stresses to be met. What are the parallels in our planting system?

Although we may know what the total yields are to be for a large area of land, the yield per acre for a particular project has not been well defined. The expected rate of growth is therefore not prescribed, particularly in the juvenile stage of plantation development, which is what we are discussing now. The specifications for the planting stock that we ask the nurseryman to produce are equally ill defined.

To parallel the industrial production control or monitoring standards, the planter would have to know the level of performance required of planted seedlings. For each project area, a preplanting forecast of the basic factors in the growth process would be made and weighed together, so that within prescribed limits of probability, levels of input into site preparation and grades of planting stock could be set. The methods for monitoring the activities and for assessing the plantations have to be related to the prescribed standards of achievement.

The general terms, physical and physiological, that are now being used to describe factors within the planting system would have to be assigned values on a scale of relative importance. We want to be able to relate the factors used by the nurseryman to describe his products to the stresses measured in the outplanting phase.

This emphasis on standards has come about with a recent reevaluation of the types of nursery stock we produce. This reevaluation has been due partly to a gradual shift in fertility that makes some traditional products impossible to grow now.

At this point I would like to discuss four phases of the planting system and see what type of standards might be applied. These phases are pre- and post-assessment of planting, shipping and holding of stock, seed, and production of stock.

STANDARDS FOR PLANTING PHASE

In recent years the nurseries have been determining the types of seedlings that will be produced but this is clearly the responsibility of the planter. The problem is, however, that there is no meaningful measurement of those factors that make a tree grow and no precise data are available for prescribing stock dimensions.

In the preplanting phase, the knowledge of sites should be such that each area could be assigned to a difficulty class in which moisture and competition with a given degree of site preparation are taken into consideration. With a given level of stress, the specifications for a grade of seedling could be set (i.e., weight, root area, etc.). In the postplanting phase, a specified level of growth and survival should be achieved.

We have survival or stocking specifications, but not growth specifications. Data could be obtained for this purpose from some of the better plantings established by research staff or from the better field outplantings.

The actual planting operation could be guided by a Planting Hazard Index (Leech 1961) similar to the Fire Hazard Index. This hazard index would predict the success of the planting on the basis of soil moisture, weather, etc., and the condition of the planting stock.

For the planting phase, then, we are talking of three areas in which standards could be used: preplanting planning, during the planting operation, and postplanting performance.

DISTRIBUTION PHASE

The principal concerns in moving stock between the nursery and planting site are dormancy, vitality of roots, freshness and temperature.

Initial discussions with research staff indicate considerable difficulty in monitoring the physiological status of a seedling. Electrical impedance may be useful in measuring dormancy for late fall lifting but it is not useful in the spring. It does not seem possible to determine quickly whether a seedling's root has dried out to the point where its root regeneration capability has deteriorated. We think freshness is measurable using a pressure bomb. During transit or holding in the field, temperatures within the package are not easily recorded.

The working ranges or tolerances of the readings we can take are only generally known and variability for our major species is often largely unknown.

While most of our experience has been with white spruce (*Picea glauca* [Moench] Voss), we know that black spruce is amenable to storage, and lies in the middle range of species difficulty.

For more than five years some nurseries have been storing stock and are now ready to utilize storage facilities more fully. More overwinter storage and early spring storage are planned. It will be possible to ship only dormant stock since the spring lifting period will be shortened to about 3 weeks.

Considerable field storage capability already exists but problems are encountered in attempting to make use of this capability because stock is not dormant, temperatures are too high and holding periods are too long. Stan Navratil has been monitoring these storages in the North Central Region for two seasons now and has gathered a great deal of information.

SEED PRODUCTION PHASE

Black spruce seed in the bare-root production system is difficult to handle. It is one of our smallest conifer seeds and is not easily handled by our seeding equipment. The equipment is difficult to calibrate for accurate sowing rates and it is difficult to place seed at the correct depth in the soil. As a result, germination and early survival percentages are lower than for other major conifers, approximating 25%-40% at the end of the first summer.

Black spruce seed has several excellent qualities that lend it to container use. The seed contains very few culls, with tests showing 90%-95% of the total population capable of germination. It germinates rapidly and uniformly with a minimum of stratification. Actual germination often approaches the seed test limit.

Nurserymen as plant propagators are vitally interested in the availability of improved seed. Black spruce is generally behind white spruce in the volume of material available from the seed production area. No improved seed was available in 1973 to any nursery, but in 1974, 1,112,000 seeds of site region 3213 were used at Thunder Bay. This is less than 1% of our total annual consumption.

Future trends in seed improvement await an increased level of activity and, to some degree, new technology. In the cleaning of seed for container production, improvement in dirt removal for certain grades of seed is required. The Grade A seed is not being used by some container growers because of its high dirt content, despite its proven ability to produce larger seedlings.

In the distant future, when the tree improvement activity is at a higher level, Ontario could dedicate one of its nurseries to tree breeding and the propagation of this very select material, thereby following the lead taken by other countries. Orono is considered a possible site and has for the past three seasons been trying to perfect a system for rooting small spruce cuttings. Black spruce is generally less successful than white in striking a root.

STANDARDS FOR STOCK PRODUCTION PHASE

While preparing the Nursery Soil Manual recently, K. Armson and V. Sadreika spent considerable time reviewing the trends in nursery stock production over the past several years. In general the weight of seedlings has increased in response to increased fertility levels. The data for black spruce in Figure 1 are typical for other species as well. Within a nursery, however, numerous factors create a great deal of variation from year to year so that consistent trends may not be so evident (Fig. 2).

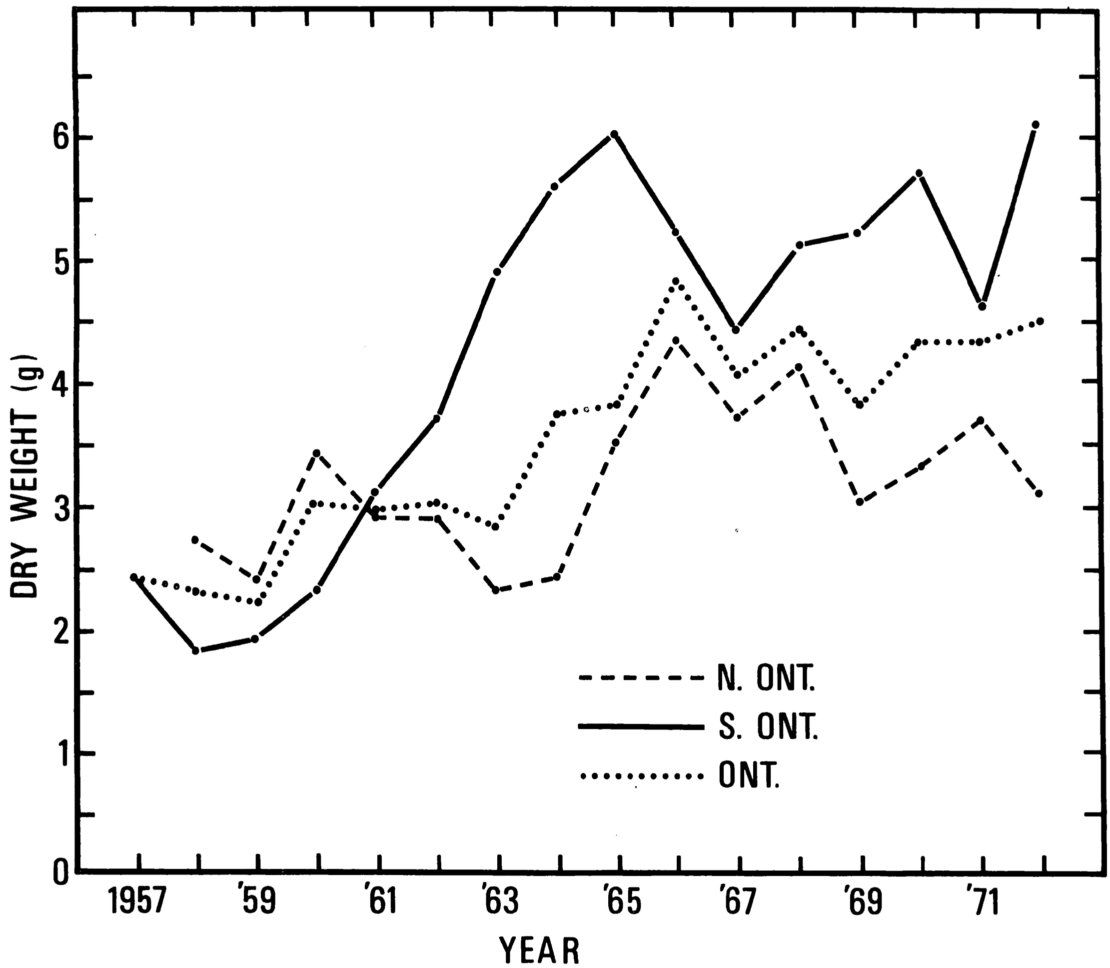

Fig. 1. Trends in dry weight production for 3+0 black spruce.

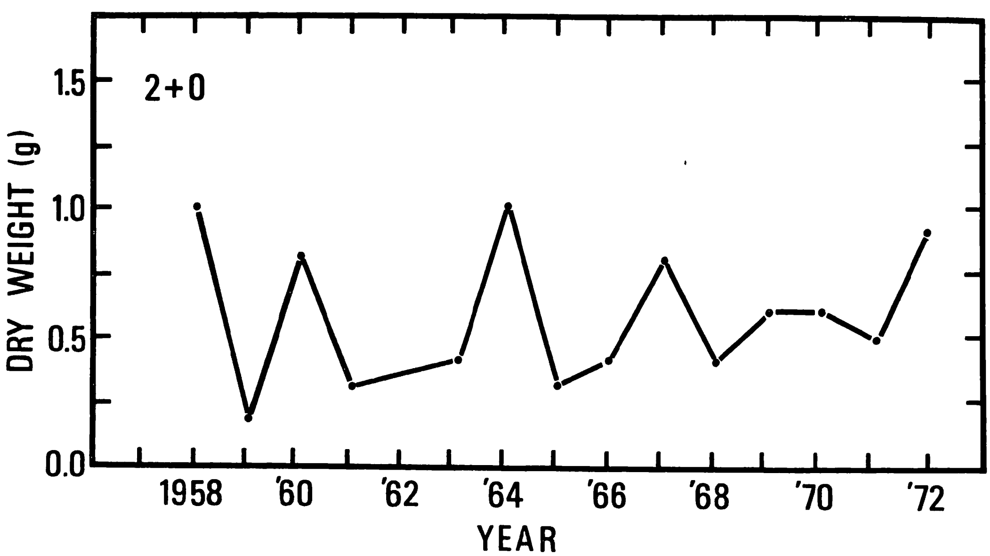

Fig. 2. Trends in dry weight production for 2+0 white spruce at Thunder Bay nursery.

Table 3. Size ranges by age class for black spruce at five Ontario nurseries

Age Class	Nursery	Weight (g)	Diam (mm)	Height (cm)	Root Area Index (cm^2)
2+2	Kemptville	12.9	-	-	-
	Midhurst	8.4	5.0	22	70
	Swastika	12.9	6.2	34	-
	Thunder Bay	11.5	5.6	30	94
	Dryden	8.9	5.1	31	62
3+0	Kemptville	5.8	3.3	30	66
	Midhurst	4.5	2.7	32	38
	Swastika	4.9	4.4	28	45
	Thunder Bay	2.6	2.6	24	21
	Dryden	3.5	2.8	30	36
1+2	Kemptville	10.8	8.0	38	96
	Swastika	6.4	4.5	25	45
	Dryden	7.2	4.8	25	-

Source: Sadreika, V. 1973. Averages for nine years of production (1964-1972) (unpublished material).

The range in size, over a 9-year period, for three age classes is given in Table 3. It can be seen that, owing to the wide variation in size from nursery to nursery, the age class may represent a rather vague image of a type of seedling. In presenting a standard to the nurseryman to indicate what was to be grown, age class was generally abandoned in favor of more specific dimensions (i.e., weight, diameter, root area). These are parameters the nurseryman can control by changing his cultural program (fertilizing, watering, undercutting, transplanting).

We thought it best to grow two or three grades of stock to try to satisfy the range in difficulty of planting sites. The heavy grade was designed to grow on the extreme sites, and the medium grade on the easier areas. It was hoped that the resulting performance would satisfy a standard for growth performance.

The heavy and medium sizes were set arbitrarily, partly on the basis of what seemed too large or too small, partly on the basis of what the nurseries could reasonably expect to grow. Heavy seedlings were to be 0.35 oz (10 g) in dry weight and have 50 sq. cm of root area. Medium seedlings were to be 0.18 oz (5 g) in dry weight and have 30 sq. cm of root area. In some cases nurseries will have to adjust their growing regimes to meet these standards. The planters will have to determine over time if the dimensions of the seedlings are adequate.

Table 4 shows the rotations that were set to achieve the grade standards for various species. Table 5 gives the grade and volume of black and white spruce stock.

Table 4. Nursery products--grade and age class

	Grade	Dryden Swastika	Thunder Bay	Kemptville St. Williams	Orono Midhurst
Black spruce	heavy	1½+1½	1½+1½	-	-
	medium	3+0	3+0	-	-
White spruce	heavy	2+2	2+2	1½+1½	1½+1½
	medium	1½+1½	1½+1½ 3+0	3+0	3+0
Jack pine	heavy	-	-	-	-
	medium	2+0	2+0	2+0	2+0
Red pine	heavy	-	-	-	-
	medium	3+0	3+0	3+0	3+0

Table 5. Grade and number of black spruce and white spruce seedlings, fall 1975-spring 1976, in OMNR nurseries

	Grade (%)		No. of seedlings
	heavy	medium	
Black spruce	61	39	18,200,000
White spruce	57	43	28,600,000

The volume of transplanting is greatly increased for northern nurseries in particular. The increase in area under cultivation is minimized by increasing the number of rows of transplants per bed from six to eleven for the 3-year transplants. This increased density should not affect the dry weights appreciably.

As the monitoring activity in nursery production develops, various standards will evolve. Some nurseries are well along in developing a standard growth curve for their various products. By sampling plants periodically during the growing season, they can determine if their actual growth corresponds to the standard and adjust their growing formula, thereby reducing much of the annual variation in growth. Some level of monitoring exists at all nurseries, the more advanced being equipped with pressure bombs, rhizometers, impedance meters, Delmhorst meters, ovens, scales, etc. As previously stated, standards or working ranges for some of the equipment are ill defined; consequently their use is often rudimentary.

Future developments in the production of black spruce will see greenhousing replace the conventional open field seedbed stage. This could mean container seedlings for direct outplanting or containers transplanted in the nursery. If containerized black spruce 8-10 in. (21-26 cm) tall could be produced, their performance should be equivalent to that of a medium grade. To date our containers are much smaller than 8-10 in. To replace the heavy grade of conventional bare-root stock, the containers will have to be transplanted as 1+1 or 1+2.

The Forest Research Branch of the Ontario Ministry of Natural Resources is also exploring the possibility of replacing the container in this 1+1 with the Dewa plug system, using equipment from the Dutch greenhousing industry. Between the nursery and the greenhouse, planting stock could be available for a planting season from May to August 15 in the north, and quality could be such that we are able to maintain our planting performance standards.

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PRODUCTION OF BLACK SPRUCE NURSERY STOCK IN THE BOREAL FOREST REGION

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*Nursery managers and foresters planning planting operations must agree on stock specifications. Changes in production processes are difficult and expensive. Black spruce (*Picea mariana *[Mill.] B.S.P.) has several characteristics that make it particularly suitable for container stock and transplanting. It is a difficult species to grow consistently well.*

*Les gérants de pépinières et les forestiers qui planifient les plantations doivent s'entendre à propos des spécifications concernant les plants. Les changements de procédés de production sont difficiles et coûteux. L'Epinette noire (*Picea mariana *[Mill.] B.S.P.) présente plusieurs caractères qui la rendent particulièrement propice à pousser dans des contenants et à être transplantée ainsi. C'est par ailleurs une essence à croissance inconstante.*

When the technical decision has been made to use nursery stock to regenerate certain areas with black spruce (*Picea mariana* [Mill.] B.S.P.), the nursery stock production process is set in motion. Depending on the nursery stock product desired, the actual production process takes from 1 to 5 years, assuming that seed is available and the capital investments for suitable production facilities have been made. Thus, if we define medium-term planning as having a 2- to 5-year range, planning for the use of planting stock becomes a long-term proposition.

Since most nurserymen were once management foresters, they appreciate the dilemma of the management forester who must predict quantity and size of nursery stock required for the ensuing year, and for 5 years hence. The development of techniques for natural regeneration of black spruce over the last 5 years cannot help changing the whole spectrum of black spruce nursery stock production needs. If a nurseryman appears somewhat skeptical when another "ultimate solution" to black spruce regeneration is announced, it is only because he has just finished building the facilities and developing the nursery techniques which were the "ultimate solution" two or three field forester generations back (say 5 years ago).

Thus far, the most workable solution to the planning dilemma is a high level of person-to-person communication. If the nurseryman knows what is happening, he can anticipate bottlenecks and test nursery techniques well before the product requirements are stated in long-term plans.

I hope to explain to you some of the silvicultural characteristics of black spruce as they have affected nursery stock production at the Thunder Bay Forest Station and to leave you with an appreciation of them.

As Ken Reese explained, we now produce both field-grown and container-grown black spruce. The container program is still at the pilot stage but I will return to it later. In the meantime, open field production of nursery stock that is shipped in bare-root condition is the main product of the Thunder Bay Forest Station. Our output in the last few years has varied from 3.2 million to 8.0 million. Certainly our production targets never varied that much.

Black spruce is the most difficult tree to grow in our nursery and, I believe, in all other northern nurseries.

There are major differences among the techniques for growing transplants and seedlings and I would like to dwell on these. The 3+0 seedling has been our major product during the last few years and the source of many of our problems.

Since the seed is so small and must be sown very near the soil surface, it tends to get lost, particularly in fall seeding. Wind erosion either buries the seeds or blows them right out into Lake Superior. It seems that, even without the wind moving the soil, seeds may move either up or down with frost action. Consequently, spring sowing (if possible during the last week in May), using stratified untreated seed, has been our most effective way of getting germination. Nevertheless, spring-seeded trees are not as able to withstand hazards of exposure during the first winter as are fall-seeded ones. I might mention that we use hydromulch rather than straw or sawdust after seeding.

In spite of our attempts to create uniform, favorable conditions, the influence of weather is all important. With improvements in irrigating capacity, hot dry weather is not as much of a problem as cold wet weather. It is hoped that tile drainage will alleviate the latter problem somewhat. Our best black spruce compartments tend to be slightly siltier than average and thus do not drain as easily. Submerged seedlings rarely last beyond 2 days except when dormant. Three inches of rain in 24 hours creates large puddles even on our sandiest soils.

Because we have not yet perfected our control over the environment of the germinating black spruce, we usually end up with a very wide range in population of trees per lineal foot of drill. Even though the average density may be quite acceptable, the bulk of the stock may and usually does occur in dense clumps, resulting in undersized stock with high top: root ratio.

The real problem in producing black spruce seedlings is that there seems to be a correlation between sowing density and germination rate: the more densely the seed is sown, the higher is the percentage of germination. If reasonably well-spaced trees are desired (our objective is 15 shippable trees per lineal foot [49 per m] of drill) the number of germinants required is sufficiently low that each of them must occupy its microsite independently of the others. This makes them very vulnerable to all adverse conditions, particularly frost heaving: the process of frost heaving eliminates the well-spaced seedlings, while clumps of trees survive.

Now let us turn to transplants. Our only recent product has been the 1½+1½ seedling (summer transplanted in its second growing season). During the first year and a half, these trees can be grown at very high densities, thus making it worthwhile to provide the most effective protection measures, even though they may be the most costly. At the time of transplanting, the trees are reduced to 25 per sq. ft (269 per m^2) for maximum root development. This procedure seems to result in the most generally acceptable type of bare-root planting stock. Land area requirement for 1½+1½ stock grown at 25 trees per sq. ft is only slightly higher than for 3+0 stock at 15 shippable trees per lineal foot of drill (six drills per 4-ft[1.22-m]-wide bed). Additional costs of transplanting result in a doubling of the production cost (excluding shipping costs).

A summary of the stock quality monitoring for the last 2 years at Thunder Bay is presented in Table 1. It is quite obvious that in 1974 we were dealing with an acceptable but variable crop of 3+0 black spruce, while in 1975 the quality was marginal for 3+0 and well above medium standards in the case of 1½+1½ transplants (Table 2). Unfortunately, no data are available for 1974 1½+1½ stock, but our experience certainly has been that this stock is much more reliable than 3+0 as far as quality is concerned.

At the Thunder Bay Forest Station, we have instituted a rather elaborate system of quality monitoring in which, apart from the parameters shown, samples of stock are measured for green weight, moisture content and stem moisture stress. In addition, some of the sampled stock is outplanted in the nursery to provide us with performance measurements. The data are made available to the field staff for inclusion in their plantation records.

Unfortunately, some of the parameters can be so variable that unreasonably large numbers of measurements are required to get statistically reliable data (Table 3). However, as our staff becomes more aware of the significant ranges of the nursery stock attributes, we will some day speak a common language.

Table 1. Averaged stock characteristics of black spruce shipped from the Thunder Bay Forest Station in the spring of 1974 and 1975

Year of shipping	Stock age	Total dry weight (g)	Top: root ratio	Root area (sq. cm)
1974	3E, 3+0	5.66	2.36	46
	3W, 3+0	3.88	2.80	43
	4W, 3+0	7.05	2.63	35
1975	3E, 3+0	6.47	4.71	28
	4W, 3+0	6.34	5.23	26
	3W, 1½+1½	8.53	2.49	57

Table 2. Standard characteristics of the three new nursery stock size classes

Size class	Weight (g)	Root area (sq. cm)
Small	2-3	15
Medium	5	30
Heavy	10	50

Table 3. Number of 3+0 black spruce seedlings required to compute seedling attributes with an allowable error of ± 10% at the 95% level of probability[a]

Attribute	Number of measurements needed
Top length (cm)	23
Root collar diameter (mm)	32
Root area index	280
Top dry weight (g)	178
Root dry weight (g)	279
Top:root ratio	47

[a] From H. Bax in course project, Lakehead University, 1972.

Last year, at a meeting, I asked a group of foresters and technicians to select for me from a large number of very variable 3+0 black spruce a sample of five trees that would best meet the most common requirements in one of their management units. The variation in their choice was a real shock to me. After years of trying to grow more uniform stock, I found that there was more variation in their requirements than there was in the stock. For example, the spread in selected top:root ratios (Fig. 1) was considerably broader than the spread in the 1974 shipping stock samples taken in the process of our quality monitoring, and this suggested to me that there was considerable inclination to sacrifice quality for size. In root area index (Fig. 2) again the trend was toward a much wider selection than our shipping stock provided. When looking at these histograms, please note that they are constructed on different numerical bases.

I should like to comment briefly on container stock production of black spruce. The species has a number of silvicultural characteristics that make it particularly suitable for container production:

1. seed generally has high viability
2. seedling growth is not particularly sensitive to photoperiodic and other climatic changes
3. variability between trees within a uniformly treated flat is usually minimal
4. there are black spruce planting sites where the smaller trees, normally produced in containers, are acceptable.

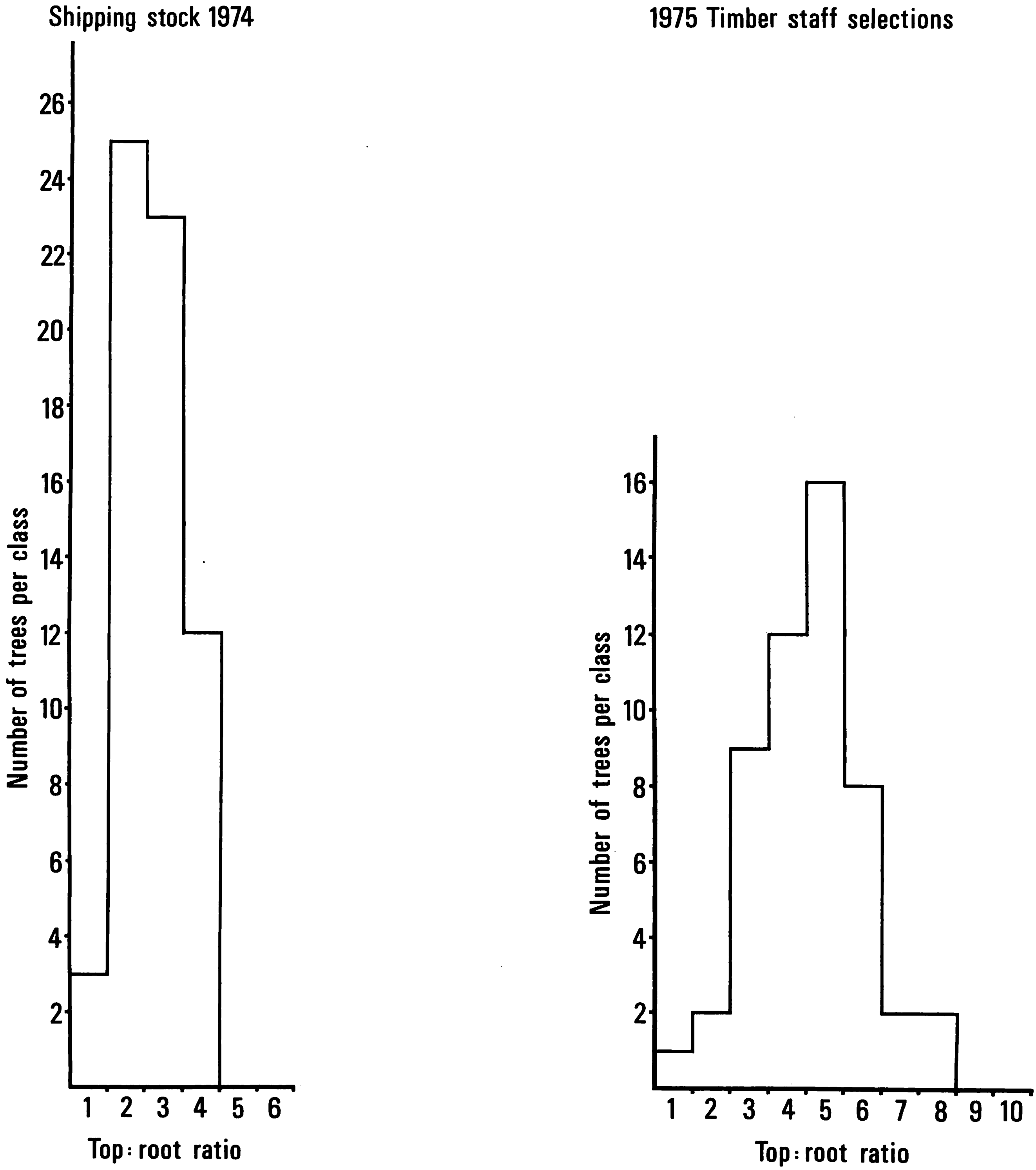

Fig. 1. Frequency distribution of integer classes of top:root ratios based on oven-dry weight of 3+0 black spruce planting stock.

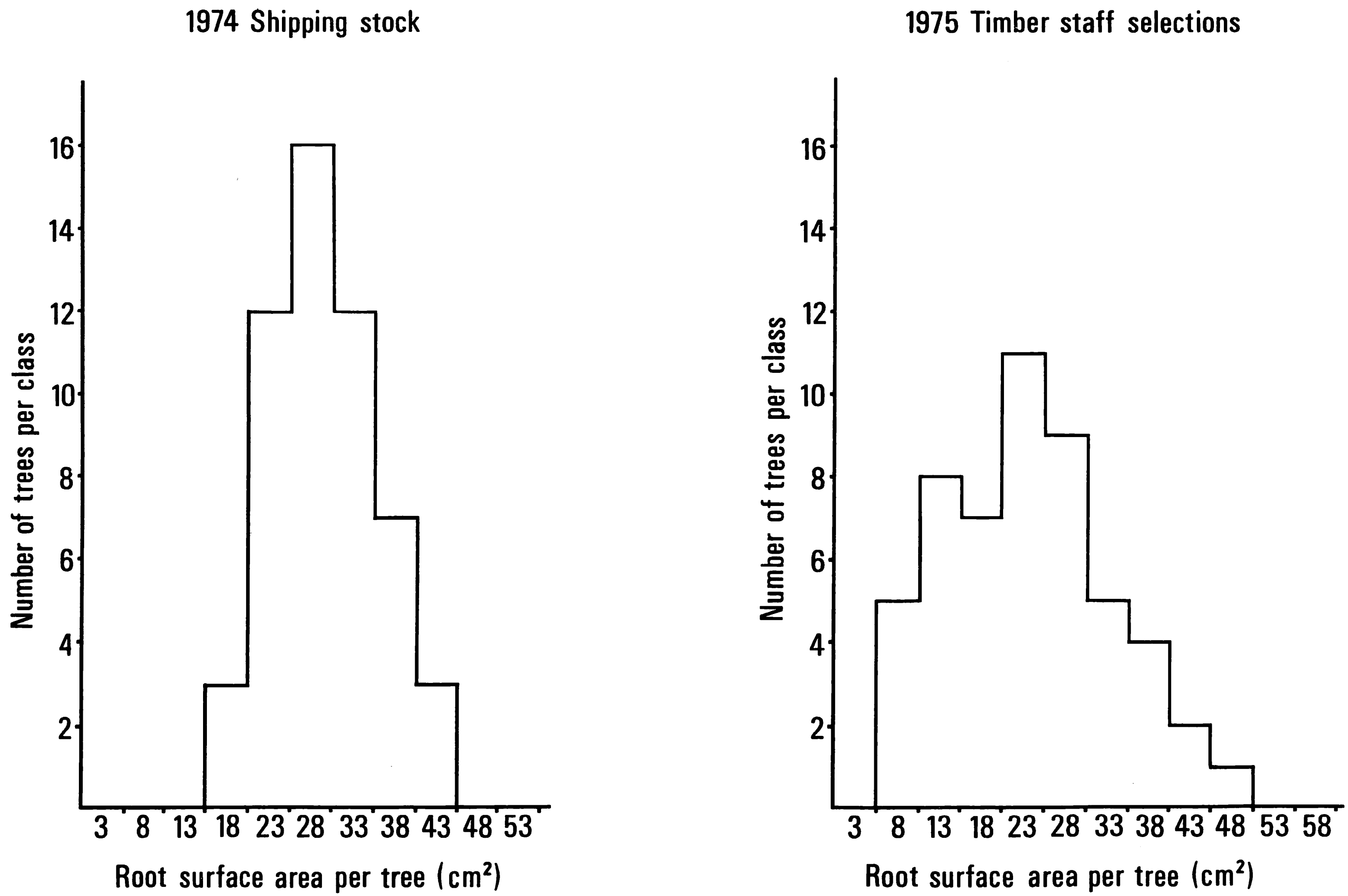

Fig. 2. Frequency distribution of 5 cm^2 interval classes of root surface area of 3+0 black spruce planting stock.

The production of black spruce container stock has been tried at Thunder Bay for about 10 years and we have progressed from the problems of the plastic Ontario tubes in flimsy, temporary, uncontrollable greenhouses to the problems of Spencer Lemaire root trainers (bookplanters if you like) in a large fiberglass greenhouse controlled by minicomputer.

In the meantime, during the last few years, we have distributed to all and sundry samples of our product in bookplanters, styroblocks and paperpots and my impression is that, provided we can guarantee certain minimum tree sizes at planting time, any of the systems will be acceptable in the field. So far, we have found the Spencer Lemaire bookplanters (Ferdinand model) best suited to our operations. I particularly like the "root trainer" effect of this "containerless container".

The production of container stock certainly does extend our workload into otherwise low activity periods and also provides an opportunity for an extended field planting season. This efficiency and the interest savings realized as a consequence of using container stock must be considered before a decision is made on the financial advantages of bare-root stock.

In closing, I should like to mention two investigations that have proceeded to the pilot-project stage and beyond:

1. Fall lifting of black spruce shipping stock for frozen overwinter storage and winter grading is now feasible, and under favorable conditions can result in improved first-year growth.

2. Summer shipping of black spruce, provided the stock is small and well balanced, is a possibility when there is adequate moisture on the planting site and a minimum delay between lifting and planting.

DISCUSSION

HAAVISTO

Mr. Reese, in your presentation, you showed that there's a considerable increase in the area of direct seeding and it's double or a little better. Are these figures the area treated or the area that has been successfully regenerated?

REESE

The areas treated, as reported by the districts for the Minister's report.

RAUTER

Mr. Reese, I'd like to emphasize a point you brought out--I think you're the first person in Ontario I've heard mention it. We haven't yet established the rates of growth we want with our outplanted stock, and I think in most instances in Ontario and right across North America, we rate our success on stocking (just the number of trees in a quadrat). Perhaps another thing we should look at is rate of growth. Perhaps success should be based on growth, not only on the number of trees per acre.

REESE

I think we're fairly close to achieving that objective. We now have a set of provincial targets for the amount of wood we're supposed to grow and a share of the targets has been allocated to management units. I think all we have to do now is pick out the patches of ground on which we're going to produce that wood, and then the yield curve would be the outfall of that, automatically.

PIERPOINT

Mr. Fry, in a general way you equated size with quality of stock--increasing size, increasing quality. But then you started to talk about stock quality requirement versus different site conditions, and I wonder whether you're saying you can get away with less than optimum quality on some sites but not on others. Or are you suggesting there are different optima for different site conditions? If so, could you give us one or two examples?

FRY

I think I sad there are different optimum sizes or qualities of stock for different types of site. In my district [Terrace Bay] we don't do very much planting on shallow upland sites. We don't do very much planting on lowland sites either. On both types of site, particularly the shallow sites, stock such as 2+0 might be suitable; certainly smaller stock would be, because of the limited rooting area that's available for putting the tree into the ground. I can't really comment on optimum stock size on lowland sites because we haven't planted very many.

AULD

When Armson was speaking he held up a tree that looked pretty good, with a thick, fibrous root system. One of the problems we've had is the lack of thick, fibrous root systems. Mr. Wynia, how are you coming with putting some roots on your trees?

WYNIA

I may have to pull that chart out again because we *have* been putting roots on the trees--surface areas of around 50 sq. cm per tree. That is a medium-sized tree. If you're going to put a large or heavy tree on that root area, then of course that's a different thing. You've got to have your tree balanced, but I don't think you're going to be able to get much more than that, and get it into the ground at all. I don't think the tree Ken Armson held up was over 60 sq. cm. But if he wants to bring it over to our rhizometer we'll measure it. Some soils will give you a better root surface area and in a very dry sand the roots are going to grow much farther away from the base of the tree so that when they are being pruned you're going to lose a fair number of them.

AULD

What methods are you using to put more roots on the trees?

WYNIA

Root pruning. At various times lateral and horizontal root pruning, lifting, irrigation patterns, schedules. All these things help. Feeding them well and having something in the ground that they want to feed on helps too. You have to grow a better tree and make sure that whatever roots you do grow are going to be shipped out, and not cut off in the root pruning. Transplanting is the ultimate, but it more than doubles the cost of your stock, and that's going to hurt someone.

GRINNELL

There's another question here. Rauter was asking what sort of parameter, beyond stocking standards, we are anticipating should be used to judge the quality of the regeneration.

Stage 1 is to send the stocking standards out, have the field staff look them over and come up with an average or something like that.

The next stage is to try to match stock specifications to site. The only individual doing work along this line is Kim, and we need more people doing that kind of work. If geneticists produce the uniform populations we're looking for, and ecologists design the parameters that are necessary for the ecosystem, and physiologists design a manipulation potential for these uniform stock lots, then we're starting to move ahead into the field that we are talking about. This is all coming up over the horizon in the next few years--we hope.

GORDON

Mr. Fry, I was interested in your comments on your future activities. One of the things you noted was that there would be some seeding, less tending, and more initial site preparation and attention to planting. I was concerned mainly about the "less tending" and, in view of Hearnden's remarks this morning concerning the distribution of black spruce sites where a lot of our high volumes are, at either end of the site spectrum, it is probable that we don't need less tending in plantings, but more.

FRY

I come from a district [Geraldton] where poplar has been a fairly important component of the cut. The mixedwood stands on the American Can licence cover roughly 50% of the productive forest area and a great proportion of the cutover. These mixedwood stands have yielded significant volumes of black spruce. A fair amount of our black spruce is being planted on mixedwood sites. These sites are mixed up. We may have 10 acres here and 5 acres there and they may be separated by black spruce stands. It's quite a heterogeneous pattern of sites. I'm afraid if we start spraying, which seems to me the only economically feasible tending at this stage, we're going to cause damage to the aspen component of that stand and to adjacent stands as well, and introduce pathogens that will come out some 30 years from now when wind breakage starts, or mortality from decay introduced by spraying. I don't know how many other districts feel this way, but since we have had to come to grips with aspen regeneration that occurs within and adjacent to black spruce plantations, this is my view. We did some spraying in 1969, and certainly, on the basis of the results I saw, I wouldn't want to do very much again. If we could get into some form of manual release, fine, but economically that's a long way off.

F.C. ROBINSON

I agree with both speakers--with Gordon who says we should be doing more tending and with Fry who says we should do less. Sure, we should do more, but with the way costs are going, and with labor difficulties, I don't think we're going to be able to. There are the situations Fry was talking about where we shouldn't tend if more spraying is the only thing we can do. If we could do intensive hand spraying or release, it would be very good silviculturally but I don't think Ontario could afford it. That's where the problem is and we'll likely have to direct our tending, a lot more specifically, to areas where we can get the best returns. On other areas we'll have to put up with a certain number of problems.

Aerial spraying can kill an overstory which provides useful cover and at the same time release harmful brush. Spraying from ground level, either manually or using sprayers mounted on skidders or small tractors, can leave the overstory intact and get rid of the brush underneath. You may then have grass or weed problems.

BURGER

Mr. Wynia, it seems to me that the nurserymen are concerned first with keeping costs down. Should the adequacy of their operations be based on low cost per unit, or on the quality of the product that goes out? Is there any way that money can move from the field back to the nurseries?

WYNIA

To the credit of our Ministry (and I have run a nursery for about 8 years now) I've never had the feeling that cost per se was the critical thing. It is whether it was money well spent. We always have to relate the money spent on growing trees in the nursery, possibly at exorbitant costs, to whether the field men are doing their planting right, and whether they could do it more cheaply if they took the proper precautions. This is a nurseryman speaking and I want to make that quite clear. The field men think we should be spending more money at the nursery. It's a lot easier for people to plant fewer trees, I realize. I don't feel that there is a constraint on spending. But it should be money well spent, because the money I spend on the nursery will be subtracted from the money spent out in the field planting those same trees. This is very important. We shouldn't overspend on the nursery to make up for inefficiency in the field. It's going to be a seesaw battle for a few years to come--otherwise it wouldn't be any fun running a nursery.

EFFECTS OF SEED ORIGIN AND THEIR UTILIZATION THROUGH SILVICULTURE AND TREE BREEDING

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*Seed-origin research in black spruce (*Picea mariana *[Mill.] B.S.P.) indicates sources of variation that can be utilized in providing high-quality seed to establish vigorous populations. Utilization of these differences should be integrated with seed collection and other silvicultural procedures. Seed orchards established from selected trees will eventually provide most seed.*

*La recherche sur l'origine des graines d'Epinette noire (*Picea mariana *[Mill.] B.S.P.) révèle des sources de variations qui peuvent servir à l'obtention de graines de qualité supérieure qui feront croître des peuplements vigoureux. L'utilisation de ces différences devrait être associée à la récolte des graines et autres activités sylvicoles. La plupart des graines proviendront éventuellement de vergers composés d'arbres choisis.*

INTRODUCTION

Two forms of silviculture are practised in Canada today: one based on natural regeneration and another based on artificial regeneration by sowing and planting. From the viewpoint of the geneticist they create fundamentally different problems and opportunities. In natural regeneration, local populations are always relied upon to restock cut-over or burnt sites, and as long as large and vigorous stands exist in the neighborhood, a new generation of wild trees will follow in the course of natural succession. Gene pools are perpetuated with very little change. However, when artificial regeneration is practised, the choice of seed presents a problem. Because of genetic variation among populations, methods of seed collection and distribution of seed and planting stock will influence the quality of the populations to be established, and difficult decisions will have to be made (Hawley and Smith 1954). The large investment in artificial regeneration makes it highly desirable to start with registered or improved seed as is common in other plant crops (Wang and Sziklai 1969). Since the cost of seed amounts to only a small percentage (1-2%) of total regeneration cost, forest managers all over the world have recognized that it pays to be careful in their choice of seed (Bouvarel 1966, Bergman 1970, Carlisle and Teich 1971). The advantages of artificial regeneration, e.g., the control of spacing with attendant reduction of the rotation period (Stiell and Berry 1973), can be fully utilized only if hardy, adaptable and fast-growing trees are established. The problem is not only to find populations equal to those that exist in the local area but also to increase the proportion of the best growers through selection and breeding. Tree selection is promising because the existing wild stands are very variable.

This paper gives examples of research findings that illustrate the need for good seed and reviews the methods currently available to maintain and improve genetic quality in black spruce (*Picea mariana* [Mill.] B.S.P.).

EFFECTS OF SEED ORIGIN

Seed origin influences the growth of black spruce in various ways: through site effects on seed development, by means of age, health and vigor of parent trees; and through geographic variation of genetic origin. Both environmental and genetic factors are involved, and very often their influence cannot be separated.

Cone Weight and Seed Weight

In one of our studies at Petawawa dealing with the variability of black spruce cones, we found that the size or weight of the cone influences the weight of the seed; this relationship is illustrated in Figure 1. The heavier and larger cones tended to have heavier seeds, as MacGillivray (1956) found in an earlier study. The correlation coefficient, r, was computed on the basis of stand means and was significant only at the 5% level. As is common in biological systems, several factors influence a certain response variable. For black spruce this has been discussed in detail elsewhere (Morgenstern 1969).

Site Effects on Seed Weight and Germination

The sites on which the parent trees grow influence the quality of seed produced (Youngberg 1952). For black spruce an important parameter of site is soil moisture because the species grows on sites ranging from dry to wet which differ in productivity. In a study initiated in 1963, five soil moisture regimes (M.R.) ranging from moderately dry (M.R. 1) to wet (M.R. 5) were recognized which correspond approximately to those used by Hills (1955). Six regions along a transect from Lake Erie to James Bay were sampled as described in detail in an earlier publication (Morgenstern 1969). The results from a total of 89 parent trees on five moisture regimes in Ontario Site Regions 3E, 4E and 5E (Hills 1961) are given in Table 1. Germination rate and survival of

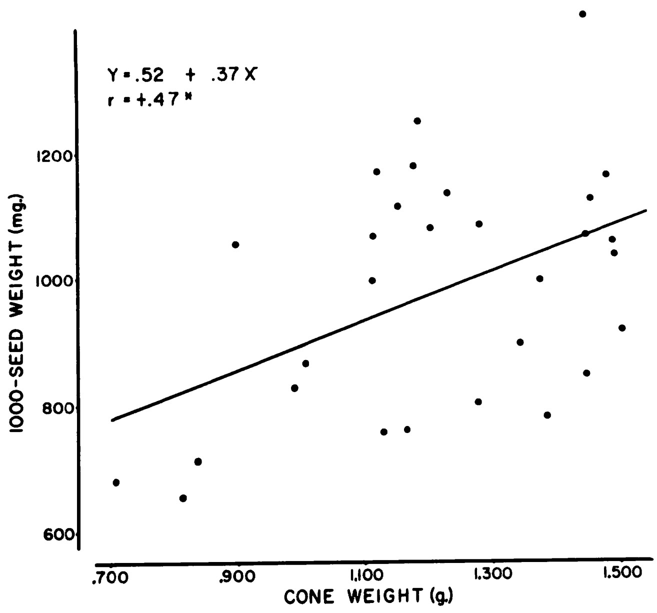

Fig. 1. The regression of seed weight on cone weight, based on means from 29 stands.

seedlings were related to moisture regime, being higher on the dry sites, and declining progressively on the wetter sites. It appears that these differences are related to the better nutrient conditions on the drier upland sites, where nitrogen and phosphorus are more easily available, than on the bog sites (Weetman 1962). Moisture regime had no influence on seed weight, but with increasing seed weight, germination was more rapid and the number of cotyledons also increased. Such effects of seed weight on germination and early development in black spruce have been observed by MacGillivray (1956), Skeates (1972), and Khalil (1975).

Region of Origin

Through natural selection, migration, isolation and other genetic processes, populations of our native species have differentiated and adapted to the regional climates in which they occur. In black spruce, this differentiation appears to have taken place largely in response to temperature and day length, which govern primarily the initiation of growth in spring and its cessation in autumn, respectively.

In the 1963 study mentioned earlier, greenhouse and nursery experiments were conducted from 1964 to 1967 and field experiments in 1968 at Petawawa and in the Kirkland Lake District of the Ontario Ministry of Natural Resources (then the Ontario Department of Lands and Forests).

Table 1. Correlation coefficients[a] among six variables in a germination experiment, based on 89 individual-tree progenies grown from seed collected on five soil moisture regimes each in regions 3E, 4E and 5E in Ontario.

Variable	X_1	X_2	X_3	X_4	X_5	X_6
X_1 Germination rate[b]	-	+0.59***	+0.52***	+0.05	+0.24*	-0.37***
X_2 Germination %[c]		-	+0.03	+0.07	+0.29**	-0.20
X_3 Survival %[c]			-	-0.18	-0.09	-0.27**
X_4 No. of cotyledons				-	+0.70***	-0.08
X_5 1000-seed weight					-	-0.16
X_6 Soil moisture regime						-

[a] Significance levels of R: *, 5%; **, 1%; ***, 0.1% (87 degrees of freedom)

[b] Germination counted every second day and calculated as described by Bartlett (1937)

[c] Transformed by arcsin (Steel and Torrie 1960) before analysis.

Table 2. Correlation coefficients among three variables at age 11 years (1974) in the experiment at Petawawa. The analysis was based on 16 populations (stands).

Variable	X_1	X_2	X_3
X_1 Survival %[a]	-	+0.55*[b]	-0.56*
X_2 Height		-	-0.94**
X_3 Latitude			-

[a] Transformed by Arcsin (Steel and Torrie 1960)

[b] Significance of correlation coefficients, R, denoted by *, 5%; and **, 1% (14 degrees of freedom).

Table 2 shows the correlations in the Petawawa experiment between survival, height and latitude of seed origin. Because the regions sampled were located in south—north sequence, latitude is a suitable geographic index for the climatic variables that determine plant responses. These responses are strongly correlated with climatic variables at the place of origin. For example, initiation of growth (flushing) in spring is highly correlated with spring temperature, and cessation of growth (bud formation) with decreasing day lengths in autumn, and with other factors. However, these physiological details have been described elsewhere (Morgenstern 1969) and will not be discussed here.

It is evident from Table 2 that survival is positively correlated with height; the populations that survived well also grew well. On the other hand, survival is negatively correlated with latitude; the populations of more northerly origin did not survive as well as southern populations. The causal agent of most of the mortality was the shoestring root rot (*Armillaria mellea* [Vahl ex Fr.] Kummer). Overall survival in the plantation was 87% with a range of 75-94% (means over all replications). Although the plantation was established very carefully with excellent planting stock on a site of at least average quality, the growth rhythm of the northern populations, when displaced to the south, was probably disturbed so that the fungus could spread. The northern populations also grew more slowly as is shown by the negative correlation with latitude.

Results from the experiment at Kirkland Lake are shown in Table 3. Here the local population (Kenogami Lake) survived and grew best and the southernmost population (Turkey Point) was poorest. The differences in height will probably increase, for at the time of planting the Turkey Point population (raised at Petawawa) was the tallest. At Kirkland Lake, growth rate began to decline, but the population was still taller than the Kenogami Lake and Turkey Point populations at age 7, i.e., 2 years after planting. It continued to fall back in comparison with these two populations, and was smallest at age 11 (Fig. 2). The survival differences have also increased with time (Fig. 3).

In the case of both experiments, it is clear that the local population is superior. Its growth rhythm is well adapted to the climate of the local area, and it will resist disease and compete strongly on its typical planting sites. Nevertheless, it is conceivable that an introduced population can do better than the native one, as is the case with a variety of species; however, for black spruce evidence of better performance on the part of an introduced population is not yet available for Ontario. In Newfoundland, Quebec and Ontario, populations grew more rapidly in nursery tests than did native populations, but long-term results from field experiments are required before changes can be made in seed policy (Khalil 1975).

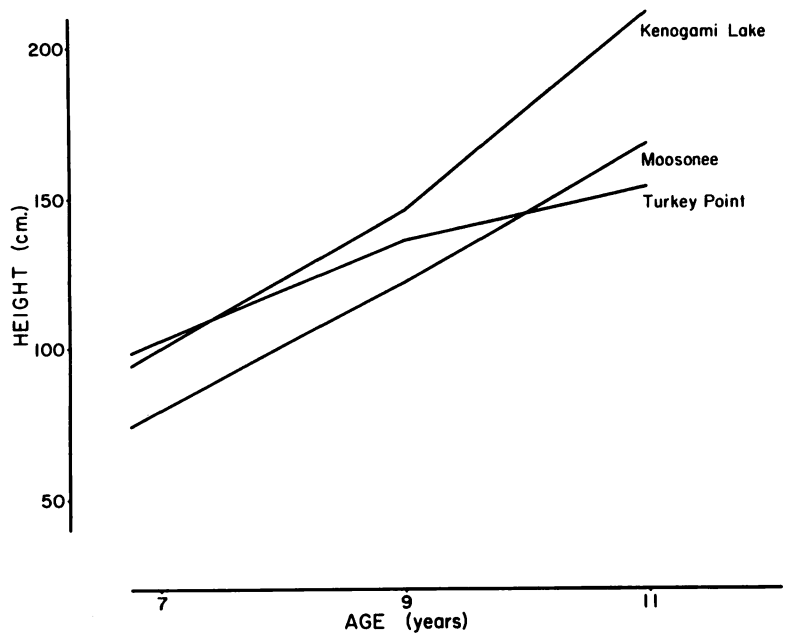

Fig. 2. Total height of three provenances in the experiment in Davidson Township, Kirkland Lake District.

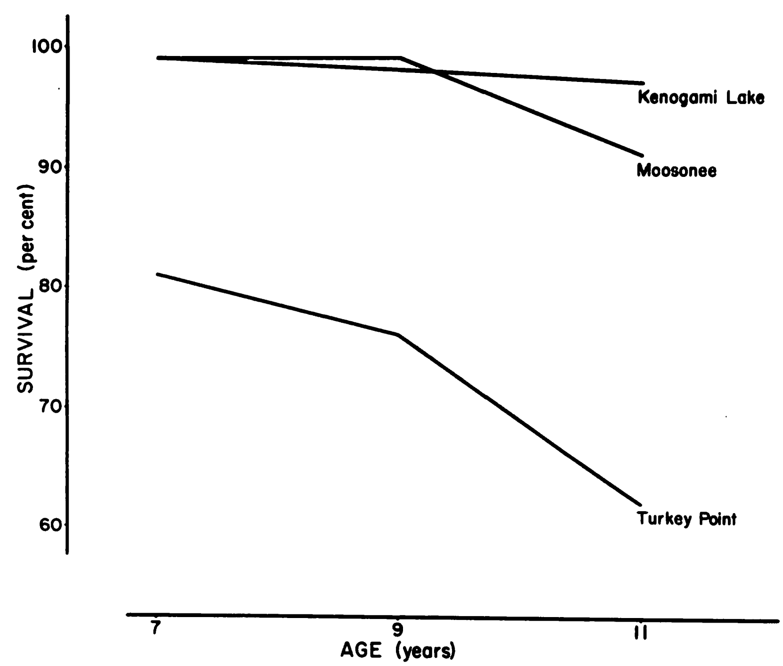

Fig. 3. Survival of three provenances in the experiment in Davidson Township, Kirkland Lake District.

Table 3. Survival and height of the six Ontario populations (arranged in north—south sequence) in the Kirkland Lake experiment at 11 years of age.

Origin	Survival (%)	Height (cm)[a]
Moosonee	91	168
Nellie Lake	91	192
Kenogami Lake	97	212
Chalk River	97	209
Lindsay	94	188
Turkey Point	62	154

[a] 1 cm = 0.4 in.

UTILIZING BENEFITS FROM DIFFERENCES DUE TO SEED ORIGIN

The utilization of differences due to seed origin should not be a separate acitivity but should be closely integrated with normal seed collection and other silvicultural operations. In this way such differences can be exploited immediately, and on a large scale.

Provenance Selection

As indicated in the preceding section, evidence is not yet available to show that introduced populations, e.g., populations from neighboring regions, can outperform native populations. The question remains unresolved until results are available from field experiments in the range-wide black spruce study initiated in 1967 (Morgenstern 1971). Most of the field experiments were established in the period 1973-1975 as cooperative ventures on the part of researchers in the United States and Canada.

Seed Zones

Displacement of populations over great distances from their origin is a very dangerous practice, and it has been shown that in species of *Picea* movements of 3 degrees in latitude and 300 m (984 ft) in elevation from the place of seed origin to the planting site can lead to losses of 6-17% in survival and height from the mean of all populations grown in a certain area (Morgenstern and Roche 1969). To avoid such losses, seed zones are delineated with the objective of setting limits to movement of seed and planting stock. Although genetic variation in many characters is continuous (clinal) so that abrupt boundaries really do not exist, it has been common silvicultural experience that seed zones are more practical and more easily applied than transfer rules stated in terms of degrees of latitude or meters in elevation (Stern 1962).

The seed zones used in the various Canadian provinces (Hills 1961, Fowler and MacGillivray 1967, Anon. 1970, Kennedy 1971, Calvert 1972, Dobbs et al. 1974) are based largely upon ecological regions, not genetic variation patterns, and have two weaknesses. One is that all species are treated alike. If species differ in distribution, frequency and variation within and between regions, a common seed zone is probably not justifiable. Thus in Sweden the seed zones used for Norway spruce (*Picea abies* L. Karst) and Scots pine (*Pinus sylvestris* L.) are not the same (Anon. 1963), those for spruce being wider. In white spruce (*Picea glauca* [Moench] Voss) there seems to be considerable variation within seed zones (Teich et al. 1975). This means that current seed zones do not adequately conserve populations and that individual, more specific zones may have to be devised. For black spruce, as indicated, results from comprehensive experiments are not yet available but in the absence of information, we should be conservative and avoid any movement beyond seed zone boundaries.

The second weakness of existing seed zones is that some of them are very large; consequently, any shifting of seed and plant material can result in wide displacement. For example, seed collected in the Sioux Lookout District of Ontario, which crosses the boundaries of two regions or seed zones[1], could be erroneously registered all in one zone, and be used in Region 3W as far east as Longlac, or in Region 4S as far west as the Manitoba boundary. Although we do not know exactly what the consequences might be, it is desirable to avoid such long-distance movements and keep track of all major collections within seed zones by recording the township of origin or other more detailed information.

Seed Collection Areas

Areas within seed zones that are stocked by mature stands of above-average quality may be designated as seed collection areas (Rauter 1973). "Quality" in this sense includes the types of cones and seeds produced, and preference should be given to stands with vigorous trees and large crowns, which tend to produce big cones and seeds that germinate rapidly. Such stands are likely found on the well-drained moist lowland sites and fresh-to-dry upland sites. Cone collections are concentrated in these areas and the stands are felled, preferably in good seed years (Morgenstern and Fowler 1969). The seed extracted should be labelled and kept identified from collection through the nursery to the field. The areas could be regenerated with the seed harvested from them, and in this way gene pool conservation can be achieved on a large scale and integrated with forestry practice without requiring extra efforts and special expenditures (Yeatman

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1 In Ontario, seed zones are referred to as site regions and are based on the regions delineated by Hills (1961).

1972). The Finnish standard stands for forestry research reflect a similar approach (Hagman 1973).

Seed collection areas allow individual districts to achieve a moderate degree of seed control and avoid losses from run-of-the-mill or widely displaced seed. Seed from stands on uplands that is of better quality and will produce seedlings with higher survival will be particularly suitable for direct seeding and tubeling production (Skeates 1972).

Seed Production Areas

Seed production areas make it possible to achieve a higher level of improvement. The stands selected should be on more or less level and accessible areas to facilitate collection by means of ladders and tractor-mounted equipment. They should be of less than half-rotation age to make thinning and fertilization possible without leading to excessive windfall. Thinning will improve the genetic quality of the population but only very slightly. More important will be environmental improvement for seed production, resulting in big crowns and well-developed cones and seeds. If and when the areas are eventually cut, the same measures for gene conservation as are used in seed collection areas can be instituted.

It has been suggested that seed collection costs in seed production areas will be higher than in normal cut-over areas by 50-100% (Rudolf 1959), but the increased per-acre cost for regeneration will likely be less than 1% because the cost of the seed is a very small proportion of total regeneration cost (Pitcher 1966). Using a safety factor of 2, Rudolf (1959) calculated that to produce an average of 1 million plantable seedlings per year, a seed production area of 9 ha (22 acres) would be required. The scale of operations indicated by these figures approximates present regeneration activities of one management unit in northern Ontario with a high percentage of black spruce cover types, and the figures could be used as a guide.

Seed Orchards

All of the preceding methods are designed to improve seed supply, seed quality and genetic composition of the seed and planting stock on an interim basis. Their value lies in the possibility of instituting some form of genetic control and making small genetic gains, but on a broad front. Once a selection program has been started, the ultimate goal is to produce all seed by means of selected trees in seed orchards. The genetic gains obtained through plus-tree selection and seed orchards are much greater than those gained through seed collection areas, seed production areas, etc.

Seed orchards have the objective of producing improved seed in quantity. This goal is sought by some or all of the following means (Matthews 1955, Zobel et al. 1958):

1. selection of a locality favorable with respect to climate, soil and application of management;

2. isolation from the surrounding wild population to avoid pollination from outside pollen;

3. avoidance of inbreeding by randomization of clones or genotypes;

4. maximization of seed yield and quality through cultural practices such as fertilization, maintaining wide spacing, bending, root pruning, irrigation, and control of weeds, animals and diseases.

Black spruce seed orchards can be developed in two ways: (1) as seedling seed orchards, or (2) as grafted clonal seed orchards. The former method could be started off by selecting promising seedlings in nursery beds and setting these out in plantations designed for seed production. Twenty-three years ago Spruce Falls Power and Paper Co. Ltd. pioneered this approach and developed their seed orchard at the Moonbeam Nursery near Kapuskasing, Ontario (Johnston 1963). The weakness of this method is that the origin of the selected seedlings is not well known (e.g., close relatives could be selected which would produce inbred seed in an orchard), and that nursery testing on one site is insufficient. The Ontario Ministry of Natural Resources applies this approach with the improvement of testing the superseedlings on several sites by means of rooted cuttings before establishing them in seed orchards (Rauter 1975).

Seedling orchards could also be developed in conjunction with an open-pollinated test program as described by Morgenstern et al. (1975). One of the tests is designed for seed production with close spacing initially, and then thinned on the basis of the results of the other tests. Alternatively, open-pollinated seed could be taken from the best individuals in the best single-tree progenies, and a new orchard could be planted. Tested trees are bound to be more suitable than those selected on the basis of their phenotype alone.

The second method is that of the more traditional grafted clonal seed orchard. Plus trees are selected and scions taken from them which are then grafted onto rootstocks and established according to certain designs in the orchard. Grafted clonal seed orchards of black spruce have now been established in many localities in eastern Canada and the United States.

From data provided by Spruce Falls Power and Paper Company Ltd. and Kimberly-Clark of Canada Ltd., it was calculated that approximately 4.4 ha (11 acres) of seed orchard are needed to produce 1 million plantable trees annually (Morgenstern et al. 1975). Even if the area requirements are doubled in conformity with the procedure used by Rudolf (1959), 240-

320 ha (600-800 acres) of seed orchards would suffice for the present planting program of 30-40 million seedlings and transplants used in Canada. It has been predicted that the area annually regenerated by artificial means will almost triple in the next two decades (Cayford and Bickerstaff 1968) and therefore all efforts should be made to accelerate selection programs.

ACKNOWLEDGMENTS

Mr. R. H. Armstrong, Spruce Falls Power and Paper Co. Ltd., and Mr. J. A. McPherson, Kimberly-Clark of Canada Ltd., have been most helpful in providing data on seed production in their orchards. The Ontario Ministry of Natural Resources, Kirkland Lake District, has made a test area available in Davidson Township. Mr. H. L. Gross and Dr. R. D. Whitney, Great Lakes Forest Research Centre, surveyed the plantation at Petawawa for presence of root rot and made suggestions regarding control. I wish to thank all of these individuals and organizations for their contributions.

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DISCUSSION

ARMSON

Dr. Morgenstern, in Table 2 you have a negative correlation between percentage survival and latitude. That is, survival decreased with an increase in latitude. Now in the graph, Figure 2, in fact, the lower latitude shows the lower survival. It seems to be reversed.

MORGENSTERN

No. Those two relationships in Petawawa and Kirkland Lake are not the same. The Turkey Point population survived very well at Petawawa but at Kirkland Lake it dipped down very substantially.

WHITNEY

The initial survival of the Turkey Point provenance at Kirkland Lake was good, but was the later mortality due to Armillaria?

MORGENSTERN

I visited the Kirkland Lake plantation about 3 weeks ago, and we pulled up some trees. We did not see any evidence of Armillaria, but it had been very dry. At this time of year we should have found some fruiting bodies if it was a problem. A few years ago when I visited that plantation I felt it suffered from late winter frost damage. There seemed to be something called "parch blight" and the needles were unable to withstand the drying wind late in March when the snow drops and the evaporation from the needles seems to be strong. This seems to be the case generally when one moves material from coastal or southern areas into drier continental areas.

HEENEY

If it takes 22 acres of seed orchard to give you enough seed to raise a million transplants, what age would that orchard have to be?

MORGENSTERN

We count on a productive period of 40 years.

HEENEY

What age would it have to be before you get that many seeds?

MORGENSTERN

According to experience in the Longlac orchard, seed production starts about 10 years after grafting, and increases year after year. I assume that about 20-30 years after grafting you would have maximum seed production.

STENEKER

When would you start taking the seed from the seedling orchard?

MORGENSTERN

The seedling seed orchard at Spruce Falls started producing substantial amounts of seed around 1960, about 8 years after establishment. There is a report on that seedling seed orchard in the Proceedings of the Pulp and Paper Association. In the early 1960s there was a CPPA meeting at Kapuskasing and Swan reported on the fertilization trials.

LANE

Why do you call the Moonbeam plantation a seedling seed orchard rather than a seed production area?

MORGENSTERN

First of all it is based on fairly highly selective material produced in nursery beds. Substantial amounts of stock were produced in the Moonbeam nursery and the total area established was about 5 acres.

LANE

On the basis of accepted definitions, though, wouldn't it be more correct to call it a seed production area?

MORGENSTERN

No. A seed production area in the normal terminology is selected from either a natural stand or a plantation that has been established in the normal manner, without seed production in mind. This plantation was established with seed production in mind from the beginning. I think this is the difference.

SWAN

Also the seedlings were selected on the basis of superior growth and when they were fertilized there was quite a large increase in seed production. There was extreme variability in seed production from one tree to another, and the orchard was thinned and the poor producers were removed.

STANEK

Can you relate the three tree tops with different-sized cones, which you showed in your slide, to trees of layering or seed origin?

MORGENSTERN

That is not impossible. These tree tops were collected near Pickle Lake in a stand that ranged from a bog to an upland.

STANEK

There's no information, then, about seed origin or layering?

MORGENSTERN

I don't remember having seen any layering in that particular stand, but I didn't look at the stand in detail.

REESE

The way we delineate our seed zones in Ontario is with Hills' site region map which is a pretty arbitrary breakdown of the province. What's the next stage in improving the delineation of our seed zones?

MORGENSTERN

I believe the next stage is to look at the distribution of the species and to analyze the more refined and larger provenance experiments that are coming up. On this basis we should find out how much variation there is within seed zones and what it means in silviculture practice. From these data we will be able to predict how much increased growth and survival we get within seed zones, and how this can be tied to silviculture. We will continue to have large areas regenerated naturally. But areas regenerated artificially by planting or seeding should be regenerated with selected stock, at least from seed production areas or, better, from seed orchards. This is our goal. This is where we can make real gains. We will not remain very long at the stage where we pay all our attention to seed zones, because we are shifting stock within those zones. I think we will move gradually to seed orchard seed production and then every large planting project will be tied to a particular orchard. This has been the practice adopted by agriculturists for over 2000 years in plant breeding and the production of crops so we are not quite up to date. We have to pull up our socks. We should be very broadminded. We should keep large areas in reserve as seed production areas in natural stands. We should practise gene conservation because we don't know what is going to happen in a few years' time. New diseases may be introduced. New products may be developed that require the tremendous diversity that we have in our natural forests and we should always keep an open mind.

RAUTER

As you said, our seed orchards are going to take 20 to 30 years to come into full production and it's going to take a few years for you to get some of the results from provenances. At present we are just collecting our seed on the basis of site regions, and obviously we have variation within the site regions. Until we get some of those results, do you think a good step would be to collect our seed on the basis of base map numbers or townships?

MORGENSTERN

Yes, I think that would be excellent. That's what we should aim for. If there is difficulty keeping things identified I think one man-year should be assigned to the problem. In fact, that person might be the most productive person in a forestry organization that has a large regeneration program.

BLACK SPRUCE SEEDING EXPERIMENTS IN THE CENTRAL PLATEAU SECTION B.8, MANITOUWADGE, ONTARIO

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*This paper summarizes field experiments to evaluate black spruce (***Picea mariana*** *[Mill.] B.S.P.) seed germination under different site and climatic conditions in northern Ontario. Despite mortality caused by flooding and clipping of newly germinated seedlings by cutworm, seeding appears to be a promising regeneration technique with more careful seed-bed preparation and seed placement.*

*L'auteur présente en résumé les expériences effectuées sur le terrain afin d'évaluer la germination des graines d'Epinette noire (*Picea mariana *[Mill.] B.S.P.) dans différentes stations et sous différents climats dans le nord de l'Ontario. Malgré la mortalité causée par les inondations et les ravages des vers gris sur les semis nouveaux-nés, l'ensemencement semble une technique prometteuse de régénération à condition de mieux préparer le sol et de mieux espacer les graines.*

INTRODUCTION

Although nature has successfully seeded thousands of acres of black spruce (*Picea mariana* [Mill.] B.S.P.), man has been unable to duplicate this feat in Canada (Waldron 1973). At the Direct Seeding Symposium held in Timmins, Ontario in 1973, Richardson (1973) not only indicated the potential benefits accruing from direct seeding as a regeneration technique, but also highlighted the many problems and hurdles that must be overcome to obtain seeding success.

Seed germination and seedling establishment is an extremely complex process that is affected by a great number of factors. Roe et al. (1970) described many factors influencing the regeneration of Engelmann spruce (*Picea engelmannii* [Parry] Engelm.) (Fig. 1). Arnott (1973) summarized the available literature and found many conflicting reports on factors affecting the establishment of direct-sown pine and spruce.

In comparison with other coniferous tree species, very little research has been done to assess factors affecting the seeding success of black spruce. Traditionally black spruce has been regarded as a swamp and peatland forest species, and in Ontario most research and silvicultural development have been undertaken in such areas. However, it also grows in extensive pure and mixed stands, with a shorter rotation period, on well-drained upland sites.

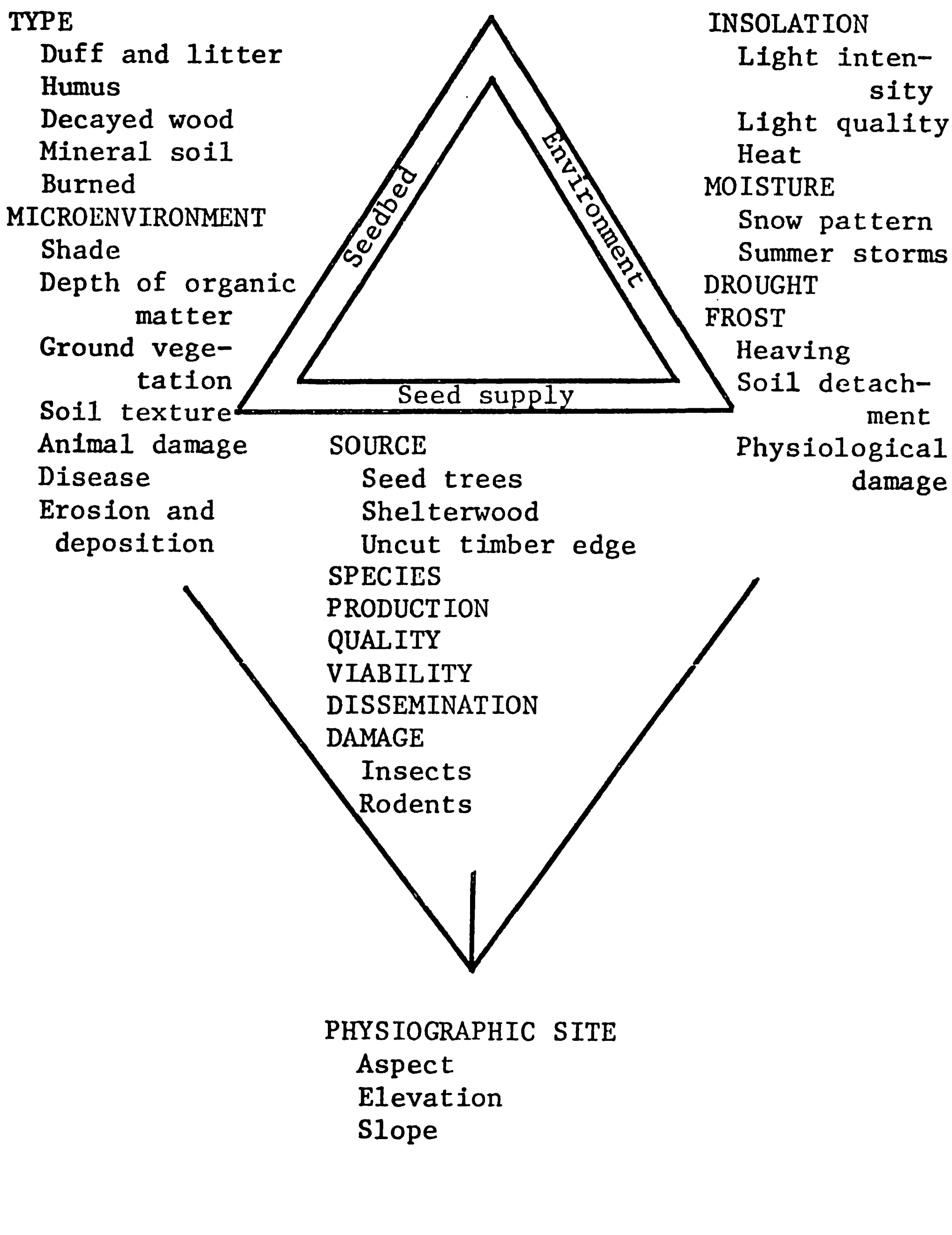

Fig. 1. Reproduction triangle illustrating the innumerable factors involved in seed germination and seedling survival (after Roe et al. 1970).

Linteau (1955) found in Quebec that black spruce grew best on a moist loam or sandy loam soil. It is commonly found growing on shallow or deep sands, or on gravel tills, and occasionally on moss caps over bedrock (Lafond 1958). While black spruce regeneration is sparse or absent after fire on very dry sites, it frequently succeeds jack pine (*Pinus banksiana* Lamb.) on these sites, if a black spruce seed source is available.

The degree of scarification desirable for black spruce seed germination has been open to question for years, as has the period of time that passes between scarification and sowing date (Richardson 1973). Similarly the season or date of seeding has been debated without resolution. Several researchers have examined the effects of seedbed condition on germination, and a seedbed's ability to retain moisture was generally considered most important (LeBarron 1944, Linteau 1955, Place 1955). Vincent (1965) rated seedbed receptivity to black spruce in order of quality as: (1) beds of slow-growing *Sphagnum* mosses; (2) moist rotten wood; (3) mineral soil with a light cover of *Polytrichum*; (4) moist bare mineral soil; (5) litter; (6) beds of fast-growing *Sphagnum;* (7) feather mosses, living and dead. He cautioned, however, that each may have disadvantages. For example, some *Sphagnum* moss growth engulfs seedlings, while litter and rotten wood often dry out, leaving roots without adequate moisture supply. LeBarron (1944) found that seedling mortality due to heat was lowest on mineral and scarified soil, and highest on burned duff. However, growth was better on the duff surface; this he attributed to a possible nitrogen deficiency resulting from the absence of organic matter in scarified soil. Place (1955) found that burned organic surfaces became very hot in sunlight, producing temperatures capable of causing a complete failure of germination.

Elsewhere, Noble (1974) recommended a thin organic matter seedbed for Engelmann spruce regeneration, while McMinn (1974) reported that organic matter and mineral-soil mixtures improved seed germination and seedling growth of white spruce (*Picea glauca* [Moench] Voss) and lodgepole pine (*Pinus contorta* var. *latifolia* Dougl.).

Although successful direct seeding of black spruce has rarely been achieved in Ontario, it has been achieved in other areas of North America where harvesting techniques differ. Johnston (1971) in Minnesota recommended burning slash within a year of harvesting, followed by seeding of 190,000 seeds per acre (469,300 per ha). On upland sites, he stressed that burning should be severe enough to expose mineral soil.

Richardson (1970) in Newfoundland obtained adequate stocking on burned, cut-over, moist-to-very-moist upland sites, but stocking was reduced on wet sites. He reported that the surface organic mantle was relatively thin (average depth 3.7 cm, or 1.5 in.) and provided a moist but not excessively wet seedbed with temperatures favorable to germination. He felt that seedling roots were able to penetrate the thin humus layer to the mineral soil before surface drought occurred. Furthermore, he stated that seeding must be done shortly after burning, as the humus material probably becomes dry and matted and unsuitable for retaining adequate moisture for germination. A cool and moist climate was considered more favorable for black spruce germination and survival than either a hot and dry one or a cold and moist one.

LeBarron (1944) found that shade cast by slash is beneficial to germination and survival in dry seasons. Logan (1969) found optimum seedling growth at light levels above 45% of available sunlight, and extremely reduced growth at 13% light, indicating that daily exposure to full sunlight for even a short period is desirable for young germinates, since healthier, well-developed seedlings are better able to withstand environmental stresses.

Fraser (1970), in studies of cardinal temperatures for the germination of black spruce seed, found that seed provenance had a significant effect on germination at different temperatures, and that optimum temperatures for maximum germination differed by provenance. Optimum temperatures for seed from Ontario site regions 3E, 4E and 5E (Anon. 1963) were 15.6 C (60 F) to 26.7 C (80 F), 15.6 C (60 F) to 21.1 C (70 F) and 10.0 C (50 F) to 26.7 C (80 F), respectively. Germination did not occur below 7.2 C (45 F) or above 35.0 C (95 F).

The application of present knowledge, climatic prediction, and additional research on site requirements for seed germination and survival are necessary to develop successful techniques for regenerating black spruce by direct seeding.

A series of autecological studies to evaluate factors affecting the germination, survival and growth of black spruce were established in 1971 by the Canadian Forestry Service at Manitouwadge, Ontario, in Section B.8 (Rowe 1972) of the Boreal Forest. Studies are still in progress but interim results are being reported at this time since they may influence future endeavors.

Concurrently, Fraser initiated a series of operational seeding trials in cooperation with the Ontario Ministry of Natural Resources at Manitouwadge, and an evaluation of seed coating and pelleting treatments (Fraser 1975). The combined research efforts will, we expect, be completed in 1977.

METHODS

In the autecology studies, climate, site and rodents were investigated in relation to their effect on the germination and survival of black spruce seed in northern Ontario. In addition to black spruce, three additional test species, jack pine, lodgepole pine and a natural hybrid pine (jack pine x lodgepole pine), were used to compare the germination and survival of black spruce in relation to these more tolerant conifer species. These investigations have continued over a 4-year period, 1971-1974, under a variety of climatic conditions. On the basis of a personal review of the available literature in 1970-1971, and a personal evaluation of past seeding trials, it was decided that, during the above studies, a seedbed composed of the Ah soil horizon or Ah mixed with Ae and Bf mineral soil horizons would be desirable and most likely to increase spruce seeding results.

Experimental Seeding Study 1971

In this first seeding trial, I selected two extreme sites, one a moist site cutover that had previously supported a black spruce stand, the other a dry site cutover that had previously supported a jack pine stand. Both sites were podzolic soils with variable depths of organic matter, a thicker depth being present on the moist site.

The experiment was designed as a randomized block with 400 seedspots on each site for the four test species (black spruce, jack pine, lodgepole pine and hybrid pine), 100 seedspots per species. The seedspots were prepared in early June by a Bracke scarifier-seeder (Parker 1972) pulled by a Timberjack wheeled skidder. The deep scalping teeth failed to expose the desired seedbed and instead prepared a steep-sloped furrow in the Ae or B horizon soils. Seeding was done by hand with a bottle shaker immediately after scalping, and seed was stepped on lightly to ensure seed—soil contact. Attempts to calibrate the seed shaker to release five to eight pine seeds or nine to twelve spruce seeds were not very successful and the actual number of seeds sown per scalp is not known.

Soil temperature was measured and recorded by means of recording thermographs with 12.7-cm (5-in.) chromium-plated sensors that were placed on the soil surface. One thermograph was placed on each site, and seedbed temperature was recorded for the duration of the 1971 growing season. Additional air temperature and rainfall information for the area was obtained from the Manitouwadge office of the Ontario Ministry of Natural Resources, approximately 24 km (15 miles) southwest of the experimental areas.

Germination, survival and stocking have been assessed periodically since sowing in 1971.

Experimental Seeding Study 1972

The desire to control seedbed conditions more carefully prompted a switch to seedspot preparation by hand in 1972 and succeeding years. The study initiated in 1972 was performed with four test species on sites similar to those of 1971 (moist and dry sites) and included a treatment to evaluate the effect of rodents on seed loss through the covering of selected seedspots with screening. A total of 400 seedspots per site were divided into 50 per species x screened or unscreened combination. Each seedspot was prepared by hand using fire rakes and mattocks to expose the Ah horizon and mix it lightly with the underlying Ae soil. A cone-shaped screen secured to the ground surface by wire pins was used for rodent protection.

Seeding was done by hand on June 25, 1972. Five seeds, of the species allocated to a scalp, were carefully placed in the scalp and stepped on lightly. Screens were then placed over those scalps assigned to receive rodent protection.

Germination, survival and stocking were assessed weekly during the first year and periodically thereafter. Colored toothpicks were used to mark individual seedlings as they germinated, with a different color being used for each weekly period.

Detailed environmental observations were recorded from mid-June to September, 1972 on both sites. Observation techniques and instruments used included: (1) continuous recordings of the seedbed temperature; (2) air temperature and relative humidity; (3) soil moisture content; (4) precipitation, and (5) solar radiation.

Experimental Seeding 1973 and 1974

In 1973 and 1974, new studies replicating that established in 1972 were installed north of Manitouwadge on similar, though not identical, sites. Seeding was performed in late May rather than late June as in 1972.

RESULTS

Since this symposium centers on black spruce, I will direct my presentation to that species and deal with the others on a limited basis. A more thorough examination of the other species will be presented elsewhere. Similarly, a detailed report of soils, microclimate, etc., will be issued later so that stocking, germination and mortality can be emphasized at the symposium.

Experimental Seeding 1971

In the 1971 seeding study, after 4 years of assessment, very little difference in stocking occurred between the two sites for any given species (Table 1). Despite the depth of the scalp produced by the Bracke, and the flooding and soil washing to which scalps are prone, stocking was surprisingly high for black spruce during the first year. Most mortality occurred during the year of sowing or in the spring of the following year. Very little mortality occurred in subsequent years.

Table 1. Experimental seeding, 1971; change in stocking by date of assessment

Site	Species	Assessment date: July 6 1971	Sept 28 1971	July 6 1972	July 7 1973	June 21 1974
		Mean stocking (%)				
Moist	black spruce	29	49	40	40	37
Moist	jack pine	75	77	66	62	62
Dry	black spruce	53	52	39	41	39
Dry	jack pine	81	82	74	74	74

Flooding in a portion of the 1971 moist site likely limited germination and caused mortality of those that did germinate in that zone. Despite the fact that all species were seeded on similarly prepared seedspots, and subjected to the same climatic conditions, it is quite apparent that black spruce seed was less able to germinate and survive than was that of the pines.

Vegetation was sparse on both sites at the time of seeding but the moist site was quickly reinvaded by grasses during the growing season. To date, competition from minor vegetation has not caused apparent mortality but may be affecting seedling development. Typically, vegetation first invaded disturbed and scarified seedspots and gradually became established on undisturbed duff.

Experimental Seeding 1972

Initially high stocking levels dropped over succeeding years (Table 2), but black spruce remained above 40% on both sites. The greatest drop in stocking and the correspondingly high Mortality Index[1] increase (Table 3) occurred during the first winter, then stabilized through the second season.

Jack pine seed began germination about 3 weeks after sowing, almost a week earlier than all other species (Table 4). Over all, germination levels tended to be slightly higher on the dry site regardless of species, and were generally higher when protected by the screens, particularly on the dry site. Jack pine was not as strongly influenced by

[1] Mortality Index is calculated as the ratio between the number of seedlings dead and the number of seeds germinated x 100.

protection as were the other species. This suggests some microclimatic modification rather than a rodent effect; however, spot temperature measurements with thermocouples indicated only a 1-2 C difference between protected and unprotected conditions. Soil moisture levels were not measured under screens and visual observations did not indicate any major differences in moisture outside the screens. Climate was generally moist and rainfall was above average, with only occasional extreme dryness in the surface soils. The moisture levels did not appear to drop below minimum values necessary for germination after the first week following sowing. Virtually all germination occurred in the first year of seeding for all species except hybrid pine. This species germinated in the second and third years; its lack of first-year germination is attributed to immature seed. With a mean germination level of 48% for black spruce seed, 48 seeds of every 100 sown were able to germinate. When combined with a Mortality Index of 75%, only 12 of those 48 seedlings can be expected to survive after 3 years. Thus about eight spruce seeds are required to be sown to obtain one survivor. For jack pine, with 60% germination over all and a Mortality Index of about 50%, approximately three seeds per survivor are required. Some flooding of seedspots occurred on the moist site and resulted in mortality in the fall and winter of the first year.

Experimental Seeding 1973

Heavy rainfall in June resulted in extremely wet soils on the moist site and flooding of 50% of the seedspot scalps on that site. Wet conditions continued throughout the summer as rain fell quite frequently. This resulted in extremely poor germination (Table 5) and low stocking (Table 6) of all species on the moist site. Even on the dry site, percent germination of all species was disappointing; however, stocking of jack pine, lodgepole pine and black spruce exceeded 50% at the end of the 1974 season. Although screening had no significant effect on germination on either site, a trend to increased germination under the screens was apparent.

The Mortality Index varied from a low of 8.6% for lodgepole pine on the dry site to a high of 72.3% for black spruce on the moist site. On the basis of the 1972 results, five spruce or four jack pine seed were required on the dry site to obtain one survivor, whereas 28 spruce or 20 jack pine were required on the moist site as a result of the extreme flooding conditions.

Experimental Seeding 1974

A dry season in 1974 resulted in poor germination on the dry site (Table 7), but very good germination of black spruce and jack pine on the moist site. Screening had a very significant effect on germination, particularly on the moist site. Despite the dryness of the season, soil moisture conditions on the moist site did not appear limiting to germination (Winston, unpublished data) even outside the protection of screens.

Table 2. Experimental seeding, 1972; change in stocking by date of assessment

Site	Species	July 18 1972	July 24 1972	Aug 3 1972	May 30 1973	June 18 1974
		Mean stocking (%)				
Moist	black spruce	9	38	70	45	41
Moist	jack pine	40	74	80	67	56
Dry	black spruce	6	50	77	50	44
Dry	jack pine	20	84	84	59	57

Table 3. Experimental seeding, 1972; change in Mortality Index[a] by date of assessment

Site	Species	July 18 1972	July 24 1972	Aug 3 1972	May 30 1973	June 18 1974
		Mortality Index (%)				
Moist	black spruce	0	1.5	4.2	63.0	75.2
Moist	jack pine	0	3.1	12.7	38.7	50.7
Dry	black spruce	0	0.0	12.3	54.8	64.8
Dry	jack pine	0	1.5	9.7	55.2	56.8

[a] Mortality Index = $\frac{\text{No. seedlings dead}}{\text{No. seeds germinated}} \times 100$

Table 4. Experimental seeding, 1972; change in germination as affected by screening for rodent protection

Assessment date	Species	Moist site: Screened	Moist site: Unscreened	Dry site: Screened	Dry site: Unscreened
		Mean germination (%)			
July 18 1972	black spruce	1.18	2.42	1.43	0.80
	jack pine	17.23	13.86	6.33	8.23
July 24 1972	black spruce	13.73	11.64	22.58	8.86
	jack pine	41.85	37.72	47.89	47.39
August 3 1972	black spruce	37.95	29.84	41.51	27.87
	jack pine	52.92	44.26	57.27	54.35
May 30 1972	black spruce	47.27	37.48	49.69	33.93
	jack pine	55.93	47.35	59.75	58.80
June 18 1974	black spruce	49.70	41.96	53.36	35.55
	jack pine	55.93	48.37	61.24	60.79

Thus there is a strong indication that rodents may have been an influential factor in reducing seed germination on that site, although a shading effect as well cannot be discounted. Conversely, on the dry site, moisture appears as the factor most limiting to germination, as screening failed to provide sufficient shade or microclimatic modification to permit increased germination.

Stocking was higher on the moist site than on the dry site for all species except black spruce at the end of 1974 (Table 8). However, these levels dropped over winter on the moist site, again because of flooding.

The Mortality Index was low for all species, but consistently higher on the moist site than on the dry site (Table 9). Approximately 30% of all seedlings killed were found to have been clipped at the stem just below the base of the cotyledons. This clipping was also observed in the previous years but was not tallied. Cutworms rather than rodents are suspected of having done the damage, since clipping occurred on both screen-protected and unprotected seedlings.

Table 5. Experimental seeding, 1973; change in germination as affected by screening for rodent protection

Assessment date		Moist site		Dry site	
		Screened	Unscreened	Screened	Unscreened
		Mean germination (%)			
July 2 1973	black spruce	8.87	6.05	24.08	14.46
	jack pine	7.64	2.45	25.18	22.72
July 9 1973	black spruce	11.64	6.86	33.43	21.18
	jack pine	8.06	3.90	30.06	27.09
August 14 1973	black spruce	15.13	8.06	38.74	27.80
	jack pine	9.51	4.43	32.02	28.11
July 19 1974	black spruce	16.40	8.50	40.77	28.19
	jack pine	10.11	4.43	32.53	28.11

Table 6. Experimental seeding, 1973; change in stocking by date of assessment

Site	Species	July 2 1973	July 9 1973	Aug 14 1973	July 19 1974
		Mean stocking (%)			
Moist	black spruce	23	21	17	11
Moist	jack pine	16	16	18	15
Dry	black spruce	54	59	54	53
Dry	jack pine	58	63	62	62

Table 7. Experimental seeding, 1974; change in germination as affected by screening for rodent protection

Assessment date	Species	Moist site		Dry site	
		Screened	Unscreened	Screened	Unscreened
		Mean germination (%)			
June 24 1974	black spruce	20.05	7.87	6.48	8.03
	jack pine	55.19	32.21	14.30	9.30
July 15 1974	black spruce	31.19	14.39	16.79	14.58
	jack pine	68.83	41.54	25.79	20.75
August 14 1974	black spruce	43.70	17.45	20.68	15.33
	jack pine	71.68	44.43	29.39	27.13
September 5 1974	black spruce	45.07	18.14	20.68	15.95
	jack pine	72.40	45.15	30.11	27.87

Table 8. Experimental seeding, 1974; change in stocking by date of assessment

Site	Species	Assessment date				
		June 25	July 15	Aug 14	Sept 5	July 16 1975
		Mean stocking (%)				
Moist	black spruce	48.25	50.00	51.75	50.00	18.2
Moist	jack pine	75.00	78.25	73.25	75.00	66.5
Dry	black spruce	31.50	50.25	50.25	50.00	40.0
Dry	jack pine	41.75	61.75	63.25	63.50	54.7

Table 9. Experimental seeding, 1974; change in Mortality Index[a] by date of assessment

Site	Species	Assessment date: June 25	July 15	Aug 14	Sept 5	July 16 1975
		Mortality Index (%)				
Moist	black spruce	2.4	24.6	29.3	30.5	86.4
Moist	jack pine	5.1	23.4	31.2	32.7	46.2
Dry	black spruce	0.0	17.5	25.5	27.1	48.3
Dry	jack pine	3.0	10.8	13.9	14.8	15.2

[a] Mortality Index = $\frac{\text{No. seedlings dead}}{\text{No. seeds germinated}} \times 100$

DISCUSSION

Hand scarification attempts to expose an Ah soil or mixed Ah and mineral soil have resulted in a modest increase in black spruce stocking beyond the 23% national stocking level reported by Waldron (1973). Except in cases of extreme flooding, stocking levels have exceeded 40% for black spruce, despite the extreme site conditions and the low seeding rate of five seeds per seedspot used in these studies. Calculations based on data collected indicate that one seedling can be expected to survive for approximately eight black spruce or four jack pine seeds sown under acceptable climatic conditions on a well-prepared seedspot. Riley (1974) reported that scarification to expose mineral soil on 25% of an area is required at a seeding rate of 20,000 jack pine seed per acre (49,400 per ha) to achieve full stocking for jack pine. If we assume similar scarification, the above data indicate that a seeding rate of 32,000 black spruce seed per acre (79,040 per ha) in a uniform pattern should provide nearly full stocking levels. This prescription at present assumes a mixed Ah and mineral soil or Ah horizon seedbed and favorable climatic conditions as prerequisites to spruce seed germination. Unfortunately, exposure by scarification as presently performed by the Ontario Ministry of Natural Resources rarely approaches the desired 25%[2] and corresponding increases in seeding rates must accompany lower scarification success.

Most seed germination occurred in the first year of sowing. Similarly, most mortality occurred during the first season and first

[2] L. F. Riley, Canadian Forestry Service, Great Lakes Forest Research Centre, Sault Ste. Marie, Ontario (personal communication).

winter. Unless major climatic extremes occur, it is reasonable to assume from the data presented that little mortality occurs after the second growing season and that stocking surveys performed after one complete year should provide a reasonable estimate of future stocking and the necessity of reseeding.

Studies to date to evaluate the effects of rodents on seed germination are inconclusive, since shading effects confound the results of the assessment. However, the data do suggest a high priority for further rodent population studies. These are being carried out by the Canadian Wildlife Service in both the Manitouwadge and the Nipigon areas.

Flooding reduced overall stocking by 30%. Clipping by cutworm or rodents was found to be an important factor, and requires consideration in future seeding studies. Encapsulation of seed and incorporation of pesticides might help to reduce clipping.

Site and soil conditions in themselves do not appear to be factors limiting spruce seed germination and seedling survival. Rather, climatic conditions appear to be the dominant factor in combination with the provision of shade, lack of flooding and favorable seedbed. It is also felt to be extremely important that seed be sown to take advantage of favorable climatic and soil moisture conditions as black spruce seed viability is negligible one year after it is sown. This fact has been verified by Fraser (1975) in seed viability studies.

Owing to the depth of the seedspots on the moist site where thick humus layers were removed, excessive flooding occurred not only during the summer but also during the fall and spring seasons. This subjected the seed and seedlings to flooding and ice conditions that would not likely be found on larger, machine-scarified seedspots. Consequently, it is reasonable to assume considerable increases of stocking by shallower scarification on very moist sites. In the studies, initial stocking levels above 60% of 70% were obtained, and might have been maintained if flooding had been avoided.

It is conceivable that stocking on sites intermediate between the very moist and very dry ones, with scarification to expose an Ah or Ah mixed with mineral soil seedbed, will be superior to those reported in this paper. The results of germination and stocking repeated over 4 years suggest that 40% stocking or better is not a fluke, but can be obtained over a wide range of sites by manipulating the seedbed more carefully and ensuring that sound seed is placed on the prepared ground.

Thus, by reducing flooding and cutworm loss and improving seedbed preparation and seed placement it appears that we can seed black spruce successfully on a wide range of sites in the Central Plateau Section of northern Ontario.

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DIRECT SEEDING BLACK SPRUCE--IS IT FEASIBLE?

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*Interim results are presented of direct-seeding trials with black spruce (*Picea mariana *[Mill.] B.S.P.) seed in the Central Plateau Section of the Boreal Forest. A combination of seed treatments is suggested for increasing direct seeding success. Seedbed preparation and seeding time are important.*

*L'auteur donne les résultats provisoires des essais d'ensemencement direct de graines d'Epinette noire (*Picea mariana *[Mill.] B.S.P.) dans la section du Plateau central de la région forestière Boréale. Il suggère un traitement complexe des graines afin d'augmenter le taux de germination. La préparation du sol et la date de l'ensemencement importent.*

INTRODUCTION

The direct seeding symposium held in Timmins, Ontario, in September 1973 (Cayford 1974) reviewed the state of direct seeding pines (*Pinus* spp.) and spruces (*Picea* spp.) in Canada. The subject matter of the 17 invited papers published in the symposium proceedings indicated the degree of interest in direct seeding as an alternative to planting for regenerating cutovers artificially. The related discussions revealed strong diametric views among foresters about the likelihood of successful direct seeding on an operational scale, particularly with black spruce (*Picea mariana* [Mill.] B.S.P.) seed.

In summarizing the symposium papers dealing specifically with black spruce, Richardson (1974) considered the silvicultural and economic aspects of seeding versus planting, the many operational aspects of direct seeding, and the problems related to each. He concluded, "What is most required, perhaps, [to increase the success of direct seeding] is improved site preparation, a definition of exactly what conditions are required to obtain optimum germination and establishment of spruces, and then the development of site preparation techniques to obtain these conditions. The development of effective repellents and seed encapsulation methods will also improve the efficiency and results of direct seeding."

In the previous paper (Winston 1975) and in later papers in this symposium (Haavisto 1975, and Virgo 1975) you heard and will hear about some of the more important seedbed requirements or conditions for good germination and establishment of black spruce on mineral soil and organic seedbeds, respectively. This paper deals primarily with some specific developments in rodent repellents and encapsulation, the two other aspects which Richardson (1974) concluded would influence the efficiency and results of direct seeding the spruces. The work reported here was preceded by extensive literature reviews and exploratory tests reported by Fraser (1974) and Radvanyi (1974).

Our procedure in testing repellents and seed pelleting has been to conduct laboratory and greenhouse experiments to determine whether particular seed treatments have any significantly adverse influence on germination and survival. If they do not, we begin research field trials to find out if the same responses to treatment occur in the more complex natural environments which are less amenable to manipulation and control. If they do, pilot-scale field trials using operational techniques are then required to demonstrate whether the treatments are effective enough to warrant including them in management practices.

The initial laboratory testing which has been completed for some treatments and will be reported in more comprehensive papers indicated that neither of the reputed repellent treatments, arasan and R-55, had any significantly adverse effect on germination of freshly coated black spruce seed. Radvanyi (1975) confirms this for R-55-coated black spruce seed germinated within the optimum temperature range. Likewise, two pelleting techniques appeared to have no significant effect on germination of black spruce seed although they delayed germination slightly, whereas germination from encapsulated seed was unsatisfactorily low. This paper deals with the second stage in the progression, the initial research field trials and some of the interim results of those trials that are still in progress.

REPELLENTS

The controversy about whether seed-eating small mammals are numerous enough on boreal forest cutovers to be hazardous to the direct seeding of black spruce is being resolved by Canadian Wildlife Service census studies. Initial results from these studies indicate at least five seed-eating small mammals per acre (12 per ha) on almost completely denuded 1-year-old clear-cut areas. According to Radvanyi (1974) the numbers of small mammals and their impact upon available seed should increase appreciably as vegetation becomes reestablished. If this is so, it will then be necessary to determine whether the species of small mammals known to be seed eaters do, in fact, consume black spruce seed.

Concurrently, cooperative 3-year field trials by the Ontario Ministry of Natural Resources, Great Lakes Forest Research Centre, and Canadian Wildlife Service began in September, 1973 to compare the effectiveness of operational hand seeding of untreated black spruce seed, and seed treated with arasan or with R-55. Seeding in September of one year and May of the following year provided comparisons of spring and fall seeding.

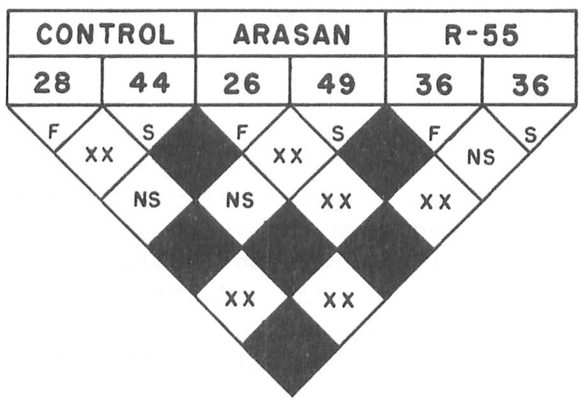
Methods

The trials were done on representative upland black spruce areas in the Terrace Bay forest district of the Central Plateau Forest Section, B.8 (Rowe 1972) near Manitouwadge (Fig. 1). The seeded areas were clear

Fig. 1. Direct seeding trials were done on clear-cut upland black spruce areas at Manitouwadge.

cut, by tree-length harvesting, in the summer or autumn of one year, scarified the following summer using mini-barrels and spiked anchor chains, and seeded the same autumn or the following spring.

The actual hand seeding was done by an OMNR seeding crew of three to five women. The sowers walked abreast along the scarified furrows depositing seed on the surface at about 6-ft (2-m) intervals. If the sowers judged the seedbed to be unreceptive, i.e., covered with bare rock, poorly scarified, etc., they selected a more favorable spot nearby in the furrow, or improved the seedbed by scuffing the surface by foot. Seeding by means of plastic bottles with perforated caps resulted in unreasonable variability in numbers of seeds per spot in the first seeding. Subsequently, modified R+S Einzelkorn hand seeders[1] were used to release five to eight seeds per spot. As each spot was seeded it was marked by a flagged wire pin and later tagged with a metal number for scheduled assessment.



F = fall, 1973 S = spring, 1974
** = highly significant: p = 0.01
NS = not significant

Fig. 2. Percent stocking, in October, 1974 on 1,000 seedspots, of untreated seed, arasan-treated seed and R-55-treated seed sown in September, 1973 and June, 1974.

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[1] R+S Einzelkorn Sa-Gerat seeders, available from Reid Collins and Associates Ltd., Vancouver, were calibrated to release the required number of seeds, and modified to facilitate placing of seeds on selected spots.

Percent stocking (Fig. 2) and mean numbers per seedspot analyzed by the chi-square method are interim results based on detailed examination (September/October, 1974) of 1,000 seed spots of each treatment (control, arasan and R-55) seeded in September, 1973 and May, 1974. The second phase of the trials, the sowing of seed in September, 1974 and May, 1975 will be assessed in September, 1975 and the previous sowings will be reassessed. Relationships between stocking and type of seedbed, slash cover, vegetation cover, etc., are beyond the scope of this paper and will be reported when the trials are completed.

Results

Twenty-eight-day laboratory tests with four 100-seed replicates of each treatement at 70 F (21 C) under low level illumination and at optimum moisture, indicated consistently high germinative energy[2] of the seed when it was sown in the field trials.

	1973	1974
Untreated control	99%	99%
Arasan	95%	97%
R-55	97%	98%

Stocking ranged from 26% from fall-sown, arasan-treated seed to 49% from arasan-treated seed sown the following spring (Fig. 1). Stocking differences among control (36%), arasan (38%), and R-55 (36%) were not significant when the results of fall and spring sowing were combined. However, for all treatments combined, stocking from spring sowing (43%) was significantly better than from fall sowing (30%). There was an average of two black spruce seedlings per stocked seedspot.

Sowing in September on seedbeds scarified in August resulted in significantly better stocking from R-55-treated seed than from either untreated or arasan-treated seed, between which there was no significant difference (Fig. 2). Sowing onto similar seedbeds the following May again resulted in almost identical stocking from untreated and arasan-treated seed but in this instance stocking from each was significantly better than from R-55-treated seed (Fig. 2).

Spring sowing of untreated and arasan-treated seed resulted in significantly better stocking than did fall sowing, but stocking from R-55-treated seed was identical from fall and spring sowing.

[2] Germinative energy = percent, by number, of seeds, spores or pollen grains in a given sample germinating within a given period (the energy period), i.e., 7 or 14 days [28 days], under optimum or stated conditions (Ford-Robertson 1971).

In Table 1 the numbers of stocked seedspots on the several categories of seedbeds are expressed as percentages of the total numbers of seedspots on those seedbeds. Although there was considerable variation within and between seed treatments and sowing dates, percent stocking in October, 1974 indicated that mineral soil was consistently the best seedbed.

Table 1. Percent stocking in October, 1974 on the major seedbed types (mineral soil, humus, mineral soil plus humus) by seed treatment and by time of sowing.

		Seedbed			
Sowing date	Seed treatment	Mineral soil	Humus	Mineral soil + humus	Others[a]
September 1973	Control	47	23	30	6
	Arasan	38	24	30	7
	R-55	48	28	46	2
	All	44	25	35	6
June 1974	Control	51	39	43	20
	Arasan	75	39	58	13
	R-55	61	19	38	11
	All	60	28	48	14
1973+1974	All	54	26	40	10

[a] Includes decayed wood, bark, dead moss, etc.

Discussion

Stocking in these trials appears disturbingly low until one realizes that even the lowest stocking (26%) (Fig. 2) is better than the average stocking (23%) from the 100 black spruce trials conducted between 1900 and 1972 and reported by Waldron (1974), while the best (49%) is more than twice as good.

That there was no significant difference in stocking between untreated and arasan-treated seed from either fall or spring sowing tends to support the laboratory-test results that arasan has no deleterious effect on germination and early establishment of black spruce (Fraser 1974).

The superiority of the R-55 treatment to the other two treatments in the September sowing suggests there was a fall problem of seed depredation by small mammals against which R-55 was an effective repellent but arasan was not. Conversely, if we assume this to be so, the reverse pattern of stocking from the May sowing suggests that small rodents were not hazardous to direct seeding in the spring. From the identical stocking from fall- and spring-sown R-55-treated seed one might infer that R-55 has some slightly adverse effect on germination and/or establishment of black spruce.

Until the Canadian Wildlife Service resolves whether and when small mammals are hazardous to direct seeding of black spruce in the boreal forest, the interim results of these trials suggest that it is advisable to use R-55 to coat black spruce seed to be sown in the fall. At this time, R-55 coating on black spruce seeds for spring sowing seems inadvisable.

The long-standing controversy about the effectiveness of arasan as a repellent treatment on tree seeds, and about its influence on germination (Fraser 1974), is now mainly academic insofar as black spruce in Ontario is concerned, as arasan 42 S and the particular Dow latex binder used in the Ontario arasan + latex + aluminum treatment are no longer available. However, these field trials do indicate that although arasan has no adverse effect on field germination of black spruce seed neither is it effective as a repellent.

When assessing seedbeds after scarification it is often extremely difficult to differentiate between a mineral-soil seedbed and a seedbed consisting of a mixture of mineral soil and humus, particularly when the classification is subjective. Hence, although mineral soil appears to have been a consistently better seedbed than the soil and humus mixture (Table 1), the only reliable indication from the data is that mineral soil and a mixture of mineral soil and humus are better seedbeds than humus for black spruce.

PELLETING

Before exploring the many potential advantages of pelleted seed for direct seeding it is necessary to determine whether pelleting materials or techniques have any adverse effect on laboratory and field germination, in that order. Results of exploratory tests indicating that the Moran Seeds Inc. (hereafter referred to as MSI) technique and material had no effect on germination of black spruce seed (Fraser 1974) were confirmed in later experiments to be reported shortly. The results reported here are from the subsequent field experiment to determine whether field germination from pelleted seed is as good as that from untreated seed.

Methods

The five seed treatments were: (1) Untreated control, (2) MSI spherical pellets 0.128 in. (3.3 mm) in diameter, (3) Asgrow coating (which enlarges the seed unit but does not alter the seed shape), (4) Asgrow spherical pellets 0.109 in. (2.8 mm) in diameter, and (5) FMC round tablet 0.77 in. in diameter x 0.26 in. thick (19.5 mm diam x 6.6 mm).

Two screening treatments (1) screened by conical wire-mesh screens, and (2) not screened, were introduced to get some measure of seed loss due to small mammals and birds.

Two seeding treatments (1) surface sown, and (2) surface sown and stepped on lightly, were added to indicate whether the additional seed/soil contact was advantageous. As the FMC tablet did not lend itself to this technique, the second treatment for FMC tablets was to bury them on edge to simulate the mechanical seeding practised with FMC-encapsulated vegetable seed.

The 10 combinations of five seed treatments x two screening treatments were replicated 10 times in a 10 x 10 latin square design, with one plot (latin square) for each of the two seeding treatments on each of four seeding dates, July 30, August 13 and 24, and September 10, 1973. The eight latin squares required for the complete layout were a minimum of 0.5 chains (10.1 m) apart and at least 3 chains (60.3 m) from the nearest standing trees. Plot selections for seeding date and seeding treatments were by random methods. Seed treatment x screening combinations within each latin square were according to Fisher and Yates (1967).

Within each plot 10 seeds were carefully sown, by hand, at the center of 18-in.-square (45.7-cm-square) seed spots scalped and scarified to obtain the uniform mixture of mineral soil and humus which Winston (1973) confirmed was desirable for black spruce seed. Seed spots were approximately 6 ft (1.8 m) apart in rows 6 ft (1.8 m) apart. Germinative energy[2] of FMC-encapsulated seed was less than 50% (Fraser 1974). For all other treatments it was $\geq$ 96%.

All seeded spots were assessed in September, 1973, in June and September, 1974, and in July and September, 1975. The entire experiment, deleting one Asgrow treatment and adding a second FMC treatment, was repeated in 1974. Reassessment of the first experiment and assessment of the second experiment were done this season. Following reassessment of the second experiment the results of both will be fully analyzed and reported. Only the results of the first three assessments of the first three seeding dates of the first experiment are reported here. The mean

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[2] Ibid.

percent germination and mean percent stocking values in Tables 2 and 3, respectively, are presented only as being strongly indicative of treatment effects which are subject to statistical corroboration when both experiments are complete.

Table 2. Percent germination by seed treatment, screening treatment, seeding treatment, and seeding date, for three assessment dates

Treatments		Assessment date: September 1973	June 1974	September 1974
Seed treatment	control	39	43	44
	Moran pellet	43	45	46
	Asgrow coating	43	46	47
	Asgrow pellet	34	37	39
	FMC tablet	16	28	33
Screen treatment	screened	40	46	48
	not screened	30	34	35
Seeding treatment	surface	34	39	41
	stepped on	36	41	42
Seeding date	July 30, 1973	40	40	41
	August 13, 1973	36	41	43
	August 24, 1973	30	38	40
	Sept. 10, 1973	[a]	[a]	[a]

[a] September-sowing results will be included in final analysis.

Germination Results

Field germination from MSI-pelleted seed and from Asgrow-coated seed was as good as that from untreated seed (Table 2). Germination from Asgrow-pelleted seed was not quite as good as it was from untreated seed; germination from FMC-encapsulated seed was quite poor in comparison with that from untreated seed. However, between the first and third assessments (approximately 1 year), germination from FMC-treated seed doubled--most of the increase occurring before the second assessment--whereas germination from other treatments increased less than 6% in the same 1-year period.

Germination was 10%-13% higher on the screened than on the unscreened seedspots, and it increased slightly more on the protected spots (8%) than on the unprotected ones (5%) (Table 2) from September, 1973 to September, 1974. Again, at least 75% of the increases occurred before the second assessment.

There was less than 3% difference in germination from surface-sown seed and from seed that was surface sown and then stepped on lightly (Table 2), and there was less than 2% difference in increased germination between the two treatments during the assessment period.

At the first assessment in September, 1973 there was 4% more germination from the earliest sowing than from the second one, and 6% more from the second than from the third. Germination from the earliest sowing (July 30, 1973) increased less than 1% in the 1-year interval between the first and third assessments, but during the same period germination from the second and third sowings (August 13 and 24) increased by 7% and 10%, respectively.

Discussion

That field germination from MSI-pelleted and Asgrow-coated seed was as good as or better than that from untreated seed indicates that either of these treatments is satisfactory for direct seeding black spruce. However, the more uniformly spherical MSI pellet undoubtedly has advantages for mechanized aerial and ground seeding over the Asgrow coating which does not change appreciably the size, shape, etc., of the seed. The physical advantages of the spherical, Asgrow-pelleted seed, similar to the MSI pellet, must be traded off against its slightly lower germination compared to that from untreated seed. Despite the reported advantage of FMC encapsulation for sowing vegetable seeds (Robinson and Johnston 1970), low field germination in this experiment indicates that it is not an acceptable treatment for direct seeding black spruce seed.

The somewhat better germination on screened spots suggests that screening was effective against seed-eating small mammals and/or birds that were active during the experiment. An alternative, equally valid indication is that screening provided sufficient shading to produce a more favorable environment for germination and early survival.

There was no realistic increase in germination from stepping on seeds to increase the area of contact with the seedbed, although actually covering seeds with soil might be preferable to surface sowing black spruce seeds as it has been shown to be for some other conifers (Horton and Wang 1969).

The apparent relationships between higher percent germination and earlier sowing did not occur beyond the first assessment, indicating that seeding between July 30 and August 30 was equally effective.

Stocking Results

Percent stocking from all except the FMC treatment was initially as good as or better than that from the untreated control (Table 3). By the third assessment stocking was best on the control treatment but had decreased on it and on the MSI, Asgrow-coating, and Asgrow-pelleting treatments by 18%, 30%, 32% and 33%, respectively. Conversely, stocking on the FMC treatment had increased by 19% in the same period. Most of the decrease in stocking, 75% on the control treatment, and 91% to 93% on the pelleted and coated treatments, as well as 84% of the increase in stocking on the FMC treatment, occurred between the first assessment in September, 1973 and the June assessment in 1974.

Table 3. Percent stocking by seed treatment, screening treatment, seeding treatment and seeding date, for three assessment dates

Treatments		Assessment date: September 1973	June 1974	September 1974
Seed treatment	control	86	72	68
	Moran pellet	90	62	60
	Asgrow coating	94	63	62
	Asgrow pellet	87	57	54
	FMC tablet	54	70	73
Screen treatment	screened	85	75	74
	not screened	80	54	53
Seeding treatment	surface	81	61	61
	stepped on	84	68	66
Seeding date	July 30, 1973	89	71	70
	August 13, 1973	88	70	62
	August 24, 1973	70	54	59
	Sept. 10, 1973	[a]	[a]	[a]

[a] September-sowing results will be included in final analysis.

For all treatments combined, the stocking results are rather promising, despite the fact that stocking decreased from 82% at the fall, 1973 assessment to 65% and 64%, respectively, at the 1974 spring and fall assessments. One would prefer to prevent the initial 15+% drop in stocking, due presumably to unseasonable early-fall or late-spring frost, winterkill, frost heaving, browsing or a combination of these, but even

60+% stocking one year after sowing is encouraging. Subsequent assessments will show whether stocking will remain static as it effectively has done since the overwinter mortality occurred.

Although percent stocking decreased by 11% and 27% on the screened and unscreened spots, respectively, from the first to third assessments, it was initially 5% better on the screened spots and became increasingly more so at the second (21%) and third (22%) assessments.

Percent stocking decreased by 18% with the stepped-on treatment and by 20% on the surface-sown treatment between September, 1973 and June, 1974 but only slightly (stepped-on) or not at all (surface-sown) thereafter. Stocking on the stepped-on treatment was never more than 7% better (second assessment) than that on the surface-sown treatment.

At the first assessment date in the fall of 1973 there was no difference in percent stocking between the first two sowing dates, July 30 and August 14, both of which were better stocked (18%, 19%) than the third sowing date, August 24 (Table 3). The same ranking held at the second assessment in the spring of 1974, but percent stocking was then 18% lower on the first two sowings and 16% lower on the third. At the third assessment in the fall of 1974 stocking had dropped only a further 1% on the first sowing, but worsened by 8% and 5% on the second and third sowings, respectively. At that time stocking was best on the first sowing (70%) and there was little, if any, real difference between the second sowing (62%) and the third (59%).

Discussion

For seed treatments, percent stocking at the first assessment suggests that neither pelleting nor coating has any adverse effect on initial stocking. One year later, stocking on the spots sown to pelleted and coated seeds is $\geq$ 60% and sufficiently close to stocking on the control spots (within 10%) to warrant serious consideration of the practicable advantages of pelleted and coated seed for direct seeding. The apparent slight advantage of the MSI-pelleted seed over the Asgrow-pelleted seed is subject to corroboration by further assessment and analyses of the complete results of both experiments.

Paradoxically, the FMC treatment which, according to the results of laboratory and field tests, has a somewhat adverse effect on germination and resulted in the poorest stocking (54%) at the 1973 fall assessment, resulted in even better stocking (73%) than the control (68%) one year later. If this indication is substantiated by subsequent assessments of both experiments the FMC treatment may warrant further consideration as a seed treatment for black spruce used in direct seeding.

The initially better stocking on the screened versus unscreened seedspots, which showed further improvement even as stocking worsened on protected as well as on unprotected spots, suggests that protection may be a prerequisite for seeding black spruce successfully. The 26% decrease in stocking on unscreened spots compared with only a 10% decrease on protected spots suggests that much of the decrease was probably due to browsing by small mammals or destruction by birds or insects against which it is extremely difficult to guard.

Stepping on surface-sown seeds to press them into the seedbed resulted in stocking only slight higher than that from surface-sown seed.

Allowing for the general over-winter reduction in stocking, the 2-week delay between the July 30 and August 13 sowings apparently had little, if any, influence on stocking up to and including the 1974 spring assessment. However, by September 1974, although there was only a 3% difference in stocking between the two August sowings, stocking appeared to be related to time of sowing, as the best stocking (70%) resulted from the earliest sowing (July 30).

CONCLUSIONS

"Conclusions" is a misnomer for this section which actually deals with surmises, as the statistical evidence to support definitive conclusions will not be complete until the field experiments with repellent-coated seed and pelleted seed are finished. Conclusions at that time, based on variance analyses and appropriate means tests, may or may not support these surmises, which seem quite logical from interim results.

Repellents

1. R-55 + acidified latex + graphite applied as a coating on black spruce seed discourages seed depredation by small mammals.

2. As a coating on black spruce seed, arasan + latex + aluminum flakes is not an effective rodent repellent.

3. Black spruce seed for fall seeding should be treated with R-55 to discourage depredation by small mammals.

4. Spring sowing of black spruce seed on upland cutovers is superior to fall sowing.

5. Mineral soil and a mixture of mineral soil and humus are probably equally receptive seedbeds for fall-sown black spruce seed but, relatively, mineral soil may be the better of the two for spring sowing.

Pelleting

1. MSI pelleting, Asgrow coating, and Asgrow pelleting have no deleterious effect on field germination or resultant stocking of black spruce.

2. FMC encapsulation inhibits field germination of black spruce seed but promotes better stocking than does pelleting or coating.

3. Screening increases field germination and stocking of black spruce either by preventing seed depredation and/or seedling destruction by mamamls, birds, or insects, or by creating a more favorable environment through shading.

4. Short of actually covering the seeds, as recommended by Horton and Wang (1969), pressing black spruce seeds into prepared seedbeds has no salutary effect on either germination or resultant stocking.

5. Black spruce seeds should be sown no later than July to obtain the best combination of germination and stocking. By inference, sowing earlier in the season, i.e., spring sowing, should promote even better stocking as resultant seedlings would have more time to become established and therefore be better able to survive the first late-fall/winter/early-spring period during which the greatest reduction in stocking seems to occur.

Although I have dealt only with so-called isolated effects of individual treatments in both experiments, common sense tells us--and even preliminary factorial analyses confirm this--that treatment combinations may have more influence than do individual treatments on the success or failure of direct seeding. Therefore, one may with some justification synthesize the results of these experiments and Winston's (1975), and conjecture that sowing untreated black spruce seeds onto prepared seedbeds consisting of mineral soil or a mixture of mineral soil and humus, as soon as the danger of spring frost is past, will result in more successful direct seeding with this species than heretofore.

The final answer to whether it is practicable to direct seed black spruce successfully must await completion of these and other experiments and the outcome of field trials to test prescribed treatments and procedures arising from these experiments. It will depend to some extent also on management criteria of success and acceptable costs. Meanwhile I suggest that the answer to the immediate question posed in the title of this paper, as indicated by our interim results, is that *direct seeding black spruce is indeed feasible.*

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DISCUSSION

STARR

Mr. Winston, was survival based on the number of scalps that were seeded, or on stocked milacre quadrats on the seeded area?

WINSTON

The scalps were laid out on a 6.5 ft x 6.5 ft grid pattern, so they were milacres, but the measurements were based on actual seedspots.

STARR

Is 40% stocking based on an acre or on the number of scalps?

WINSTON

On 40% of all the scalps, but you can translate that directly into acres.

AULD

You got the best results on mineral soil or mineral soil mix but you didn't mention anything about sphagnum mosses.

WINSTON

No.

FRASER

I didn't either. My results were from the preferred seedbed that Winston confirmed was better for black spruce.

AULD

But not necessarily better than sphagnum because sphagnum wasn't tested?

FRASER

That's correct.

McCLAIN

Mr. Winston, could you tell me the basis for your selection of dry and moist sites?

WINSTON

Partly eyeballing and consultation with Ministry staff, and partly because the dry site had supported jack pine and the wet site had supported spruce. We took some preliminary measurements and they were much as we had expected.

McCLAIN

Presumably you measured moisture in some manner. Did you find your moisture regimes actually reflected your dry and moist sites?

WINSTON

Yes. Moisture measurements from the upper areas of the dry sites were 6% to 25% by weight. On the wet site they were considerably higher, and fluctuated.

STENEKER

Mr. Winston, from your experience on those two sites with the Bracke cultivator do you have any suggestions about modifying the machine? You talk about a lot of flooding; I've seen the thing working in Saskatchewan, and on some of the sites I wasn't too happy with the seedbeds it created.

WINSTON

I wasn't particularly happy either but I made a lot of overtures to Ministry staff at the time and the feeling was that it couldn't be modified to get a shallower seed spot. Nevertheless, we got 39% stocking by hand seeding in the spots which the Bracke prepared, rather than by seeding with the Bracke which tends to bury them.

COOPER

Mr. Winston, did you not recently suggest in the Forestry Chronicle that seed germination of black spruce was affected by temperature? You brought forth the proposal that if you seed black spruce, perhaps on snow, there's some pregermination.

WINSTON

Yes. Haavisto and I did a long-term trial in the laboratory and black spruce seeds started to germinate at 1/2°C, just about the freezing point. Snow and ground temperatures during the winter have shown that, in any given year, the ground doesn't necessarily freeze but stays around 1/2° C to 1° C. Therefore, seeds sown on the ground in late fall can experience some preimbibition or even early stages of germination by the next spring due to the snow melting and being absorbed by the seed. A theory that may account for lack of success with fall-sown spruce seed is that such preimbibed seed is ready to germinate, and is therefore susceptible to damage from a cold snap after the snow is gone. On the other hand, warm temperatures might spring it to life faster. We haven't followed that through yet.

BAX

Was there a waiting period between the time of scarification and seeding, and if so what was it? Did you let the soil settle after being scarified, or did you seed immediately after scarification?

WINSTON

It was sown immediately afterwards.

FRASER

We have another trial at Manitouwadge where black spruce was actually sown in the Bracke scalps a year after the scalps had been made. After the third-year assessment the stocking is between 45% and 50%.

SHOULD WE MANAGE BLACK SPRUCE?

D. E. Ketcheson, Economist
Canadian Forestry Service
Great Lakes Forest Research Centre
Sault Ste. Marie, Ontario

*The fact that black spruce (*Picea mariana *[Mill.] B.S.P.) is the most important commercial tree species in Ontario is not sufficient reason to justify managing it for the future. Factors such as expected future demand and the objectives and policies of forest managers must be considered. Other species will likely surpass black spruce in importance.*

*Le fait que l'épinette noire (*Picea mariana *[Mill.] B.S.P.) est l'essence commerciale la plus importante de l'Ontario ne constitue pas une raison suffisante pour l'aménager dans l'avenir. On doit considérer des facteurs tels que la demande prévue et les objectifs et les politiques des aménagistes. D'autres essences forestières surpasseront probablement l'épinette noire en importance.*

INTRODUCTION

Forest management is undergoing a period of rapid change in Canada and Ontario. Over the next few years investment in forest management activities designed to produce wood for the future will increase significantly. For instance, Ontario has begun a 10-year program of rapid growth in expenditures on silviculture designed to double the present size of the program. Already there is talk of increases beyond this level (Reynolds 1975). The major reason for the growth, at least in Ontario, appears to be that current utilization of the conifer resource, the major source of raw material for industrial activity, is approaching such a level that, without reinvestment on a large scale, the resource base will deteriorate to the detriment of the forest-based economy.

Growth in the scale of management programs will offer some interesting challenges to the foresters involved in planning and implementing the programs. Historically, the emphasis in forest management has been on protection and provision for an orderly depletion of the resource. This is changing. Foresters are now going to have to produce forests on a large scale. The question is, what kind of forests? Or more to the point of this symposium, should we manage black spruce (*Picea mariana* [Mill.] B.S.P.)?

While recognizing the current value of the black spruce resource to Ontario, the question of whether or not to produce black spruce is valid for two reasons. First, although budgets for silviculture operations are being increased, they will never be unlimited. Therefore, the forester will have to choose between species and between treatments to meet his objectives. The choice will involve balancing what he wants to do with his sites against what he can do, given his limited financial resources. As a result, the best course of action may be to convert black spruce sites to some other species that is less expensive to regenerate.

Second, since the production period for a forest is from 50 to 100 years there is some flexibility in the species that can be grown. Within the limits imposed by site, all of the options available should be considered. Over time, as real prices of wood products have risen and preferred species disappeared, manufacturers have been able to use a wider variety of species or qualities of wood (Zivnuska 1975). The tendency of the forest manager, therefore, is to say, "What we have is what we want". Changing from one species to another may be an economically viable option. However, this is not sufficient justification for replacing currently high-value species with less desirable ones.

Before we can answer the question "do we want to manage black spruce?", there are two things to consider. First we must consider the resource base and the demand for the species. This information forms the basis for future expectations on the suitability of species. The second item to consider is the objectives of the forest management agency and the policies pursued in the light of these objectives. The policies should outline the resources available for management of the total resource and the implications for the management of a particular species such as black spruce.

The Resource Base and Demand

Black spruce is the most abundant species in Ontario in terms of areal extent and volume. The annual net merchantable allowable cut for spruce is about 5 million cunits[1] (14.2 million cu. m) and represents 48% of the total annual net merchantable allowable cut (Timber Sales Branch, Division of Forests, Ontario Ministry of Natural Resources). There are about 43 million acres (17.4 million ha) of productive forest lands in the black spruce working group. Approximately 19.5 million acres (7.9 ha) are classed as pure black spruce stands which are generally located on peatland sites. The remaining 23.2 million acres (9.4 million ha) generally support mixtures of black spruce, balsam fir (*Abies balsamea* [L.] Mill.), jack pine (*Pinus banksiana* Lamb.) or trembling aspen (*Populus tremuloides* Michx.) on upland sites (Ketcheson and Jeglum 1972).

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[1] The allowable cut figures are for both black and white spruce. Black spruce is generally held to represent 80% of the total.

In 1973-1974 2.4 million cunits (6.8 million cu. m) of spruce were harvested from Crown lands (Anon. 1974). This represented about 48% of the total wood from Crown lands. In terms of volume of wood, spruce has been the major species cut from Crown lands since at least 1946 (Fig. 1). The 1973-1974 cut represented about 55% of the spruce allowable cut.[2] Within the next 5 years it is expected that current demand plus planned industrial expansions will result in the total allowable cut being utilized (Reynolds 1975).

The figures on allowable cut reflect the current level of management of black spruce. Judging from the current regeneration effort, one suspects that the allowable cut will begin to fall unless more areas are treated for black spruce regeneration. Of the total area of Crown land treated for regeneration, only about 30% is treated for black spruce (Anon. 1974). At the same time black spruce cut-over areas represent close to 50% of the total volume of spruce cut. This situation may be changed somewhat with the expansion of the management program. However, considering the bias against black spruce in the current program, it seems likely that much of the area currently stocked to black spruce stands may be converted to other species.

Figure 1 shows that the proportion of spruce to the total cut is falling. This is probably due to two factors. First, spruce has become relatively scarcer over the period in question. Even though volumes well below the allowable cut were harvested, by the late 1940s the major users of spruce were established in their current locations. While not actually consuming all of the available volumes, they controlled much of the productive and readily accessible forest lands. The remainder of the spruce volumes were generally located in more remote areas. Thus, new industrial growth tended to be based on other species, rather than on the more remotely located black spruce resource.

The second and more important factor influencing the greater utilization of other species was the introduction of the bleached sulphate pulping process to Ontario in the post-war years (MacDonald 1969). This process permitted the use of many other species, especially jack pine, for the production of kraft pulps. Figure 2 shows the total volume of pulpwood and the volume of spruce and balsam[3] used by all pulping processes from 1920 to 1972. It is quite obvious that from 1945 to the present the growth in output, in relative terms, has been accomplished with species other than spruce.

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[2] The actual cut figure of 2.4 million cunits was inflated by 15% before it was compared with the allowable cut. This was done on the advice of Mr. G. Protich, Timber Sales Branch, Division of Forests, Ontario Ministry of Natural Resources to reflect industrial utilization patterns.

[3] The statistics on pulpwood used, by pulping process, presented in the Statistics Canada publication No. 36-204, Pulp and Paper Mills (see Fig. 2-5), do not separate the spruce from the balsam.

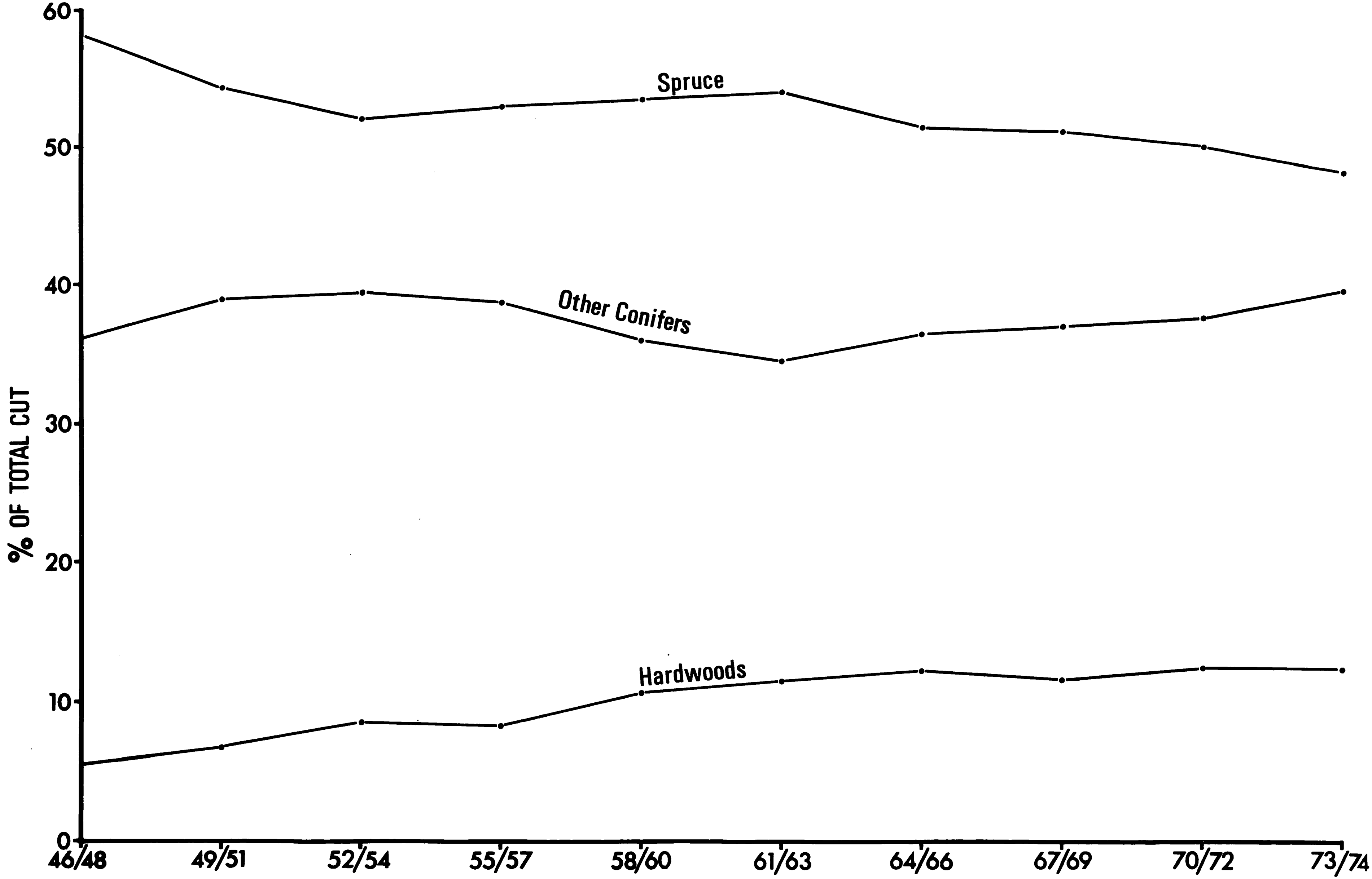

Fig. 1. Wood cut from Crown land expressed as a percentage of the total cut. (Source: Statistics 1974. Ontario Ministry of Natural Resources)

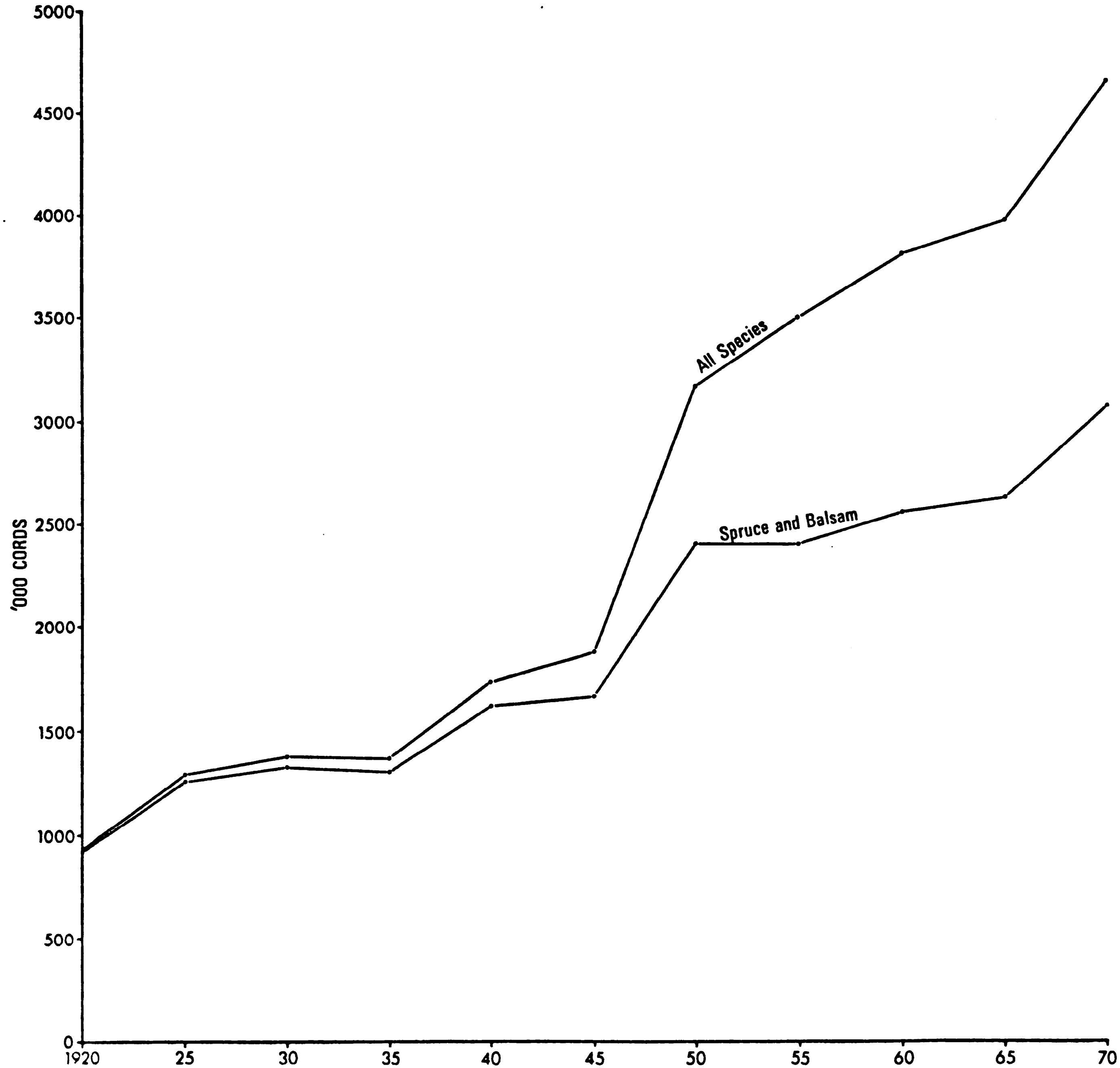

Fig. 2. Pulpwood used by the Ontario industry 1920-1970, all processes. (Source: Pulp and Paper Mills. Cat. No. 36-204. Statistics Canada)

Figures 3-5 show the volumes of spruce and balsam used with mechanical, sulphite and sulphate processes over the period 1920-1970. Again it is clear that while spruce is the predominant species, much of the growth in pulping capacity since 1945 has been based upon other species.

While black spruce is currently an important industrial species, the forest manager must be concerned about future demand since the production period is so long. The demand for black spruce is directly related to its superior physical qualities such as high density, long fibers and low resin content (Wellwood 1960) as well as to its availability. One would expect that these features will continue to make it highly desirable in the future.

Canada and the United States are the major markets for Ontario pulp and paper products (Tucker and Ketcheson 1972). Demand projections for these areas indicate that demand will continue to be strong for conifer-based paper products for the foreseeable future (Manning 1970, 1971, Manning and Grinnell 1971, Josephson and Hair 1974, Manning 1974). While the projections do not specifically refer to products produced in Ontario, there is every reason to expect that Ontario's industry will benefit accordingly.

To summarize the foregoing discussion of the black spruce resource base and demand, it is obvious that black spruce is the most important industrial species in Ontario. At the same time other species are gaining wide acceptance by the forest industry and especially the pulp and paper industry. Thus, while black spruce is important, other species may eventually replace it as the most important one.

The expectation of a strong demand for forest products, especially conifer-based products, leads one to suspect that there will be a continuing strong demand for black spruce in the future. This is especially so in light of its structural characteristics. However, continuing strong demand is not sufficient reason for ensuring that the black spruce resource will be managed for the future. The justification for this statement can be seen when one considers the history of the white pine resource of eastern Canada.

Forest Management Objectives

The second factor to consider in determining whether black spruce will be managed for the future is the objectives of the forest management agency. The objectives of the Division of Forests of the Ontario Ministry of Natural Resources as recently stated by Dr. J. K. Reynolds, the Deputy Minister, are "to provide for an optimum continuous contribution to the economy by the forest-based industries, consistent with sound environmental practices; and to provide for other uses of the forest." (Reynolds 1975). In support of these objectives a policy has been formulated through a program of silviculture designed to produce an annual allowable cut of 9.1 million cunits (25.8 million cu. m) by the year 2020.

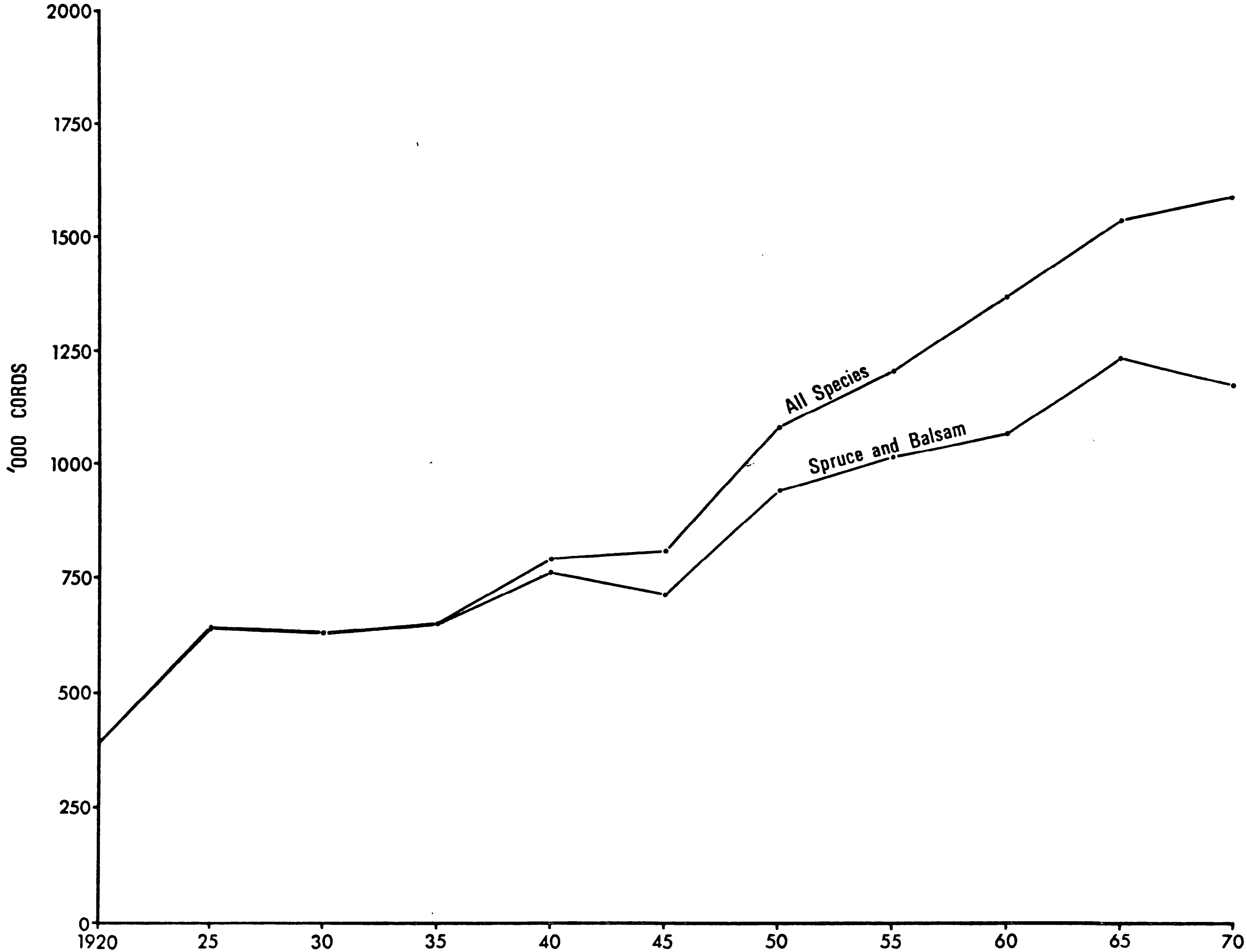

Fig. 3. Pulpwood used by the Ontario industry, 1920-1970, groundwood process. (Source: Pulp and Paper Mills. Cat. No. 36-204. Statistics Canada)

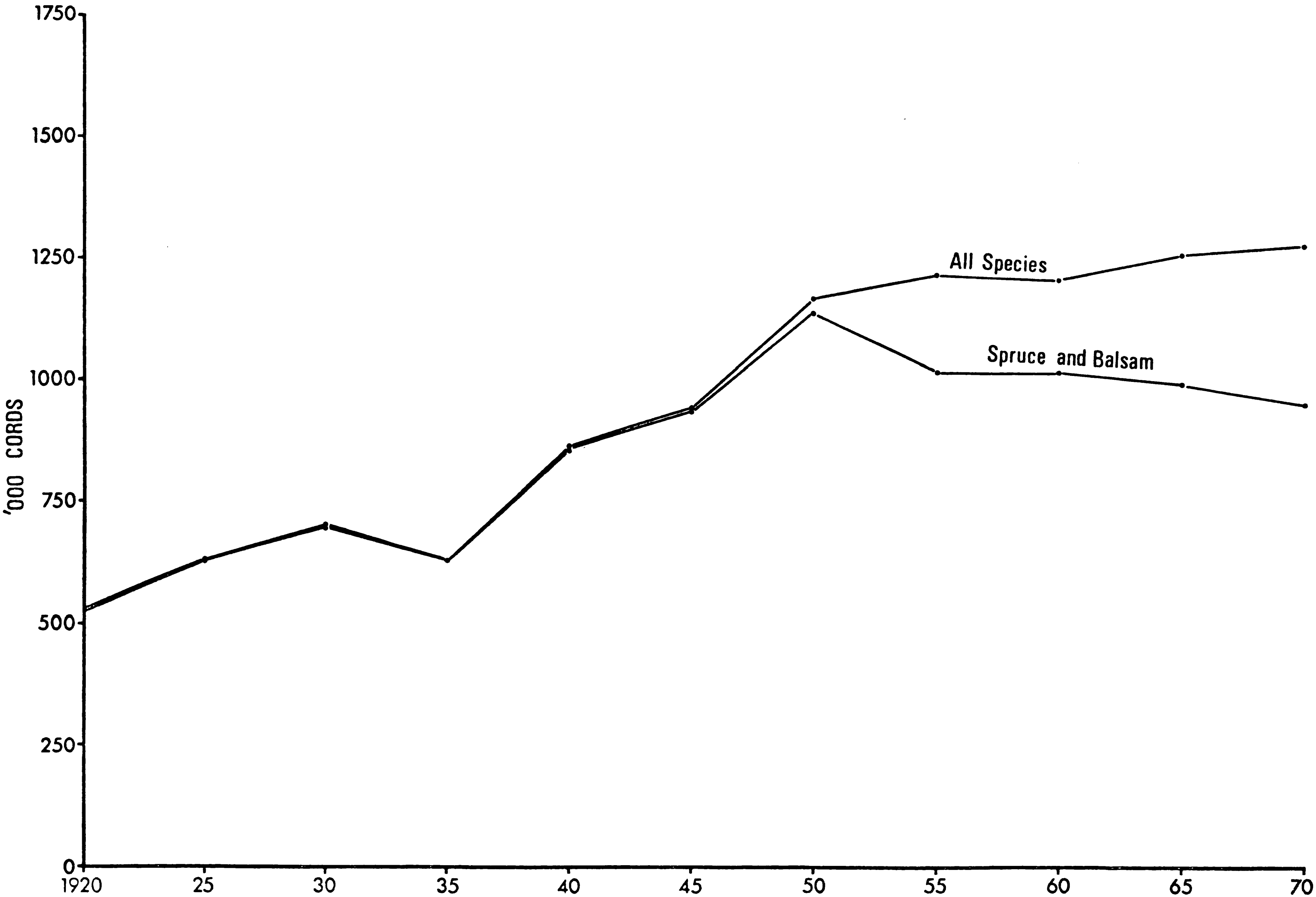

Fig. 4. Pulpwood used by the Ontario industry, 1920-1970, sulphite process.
(Source: Pulp and Paper Mills. Cat. No. 36-204. Statistics Canada)

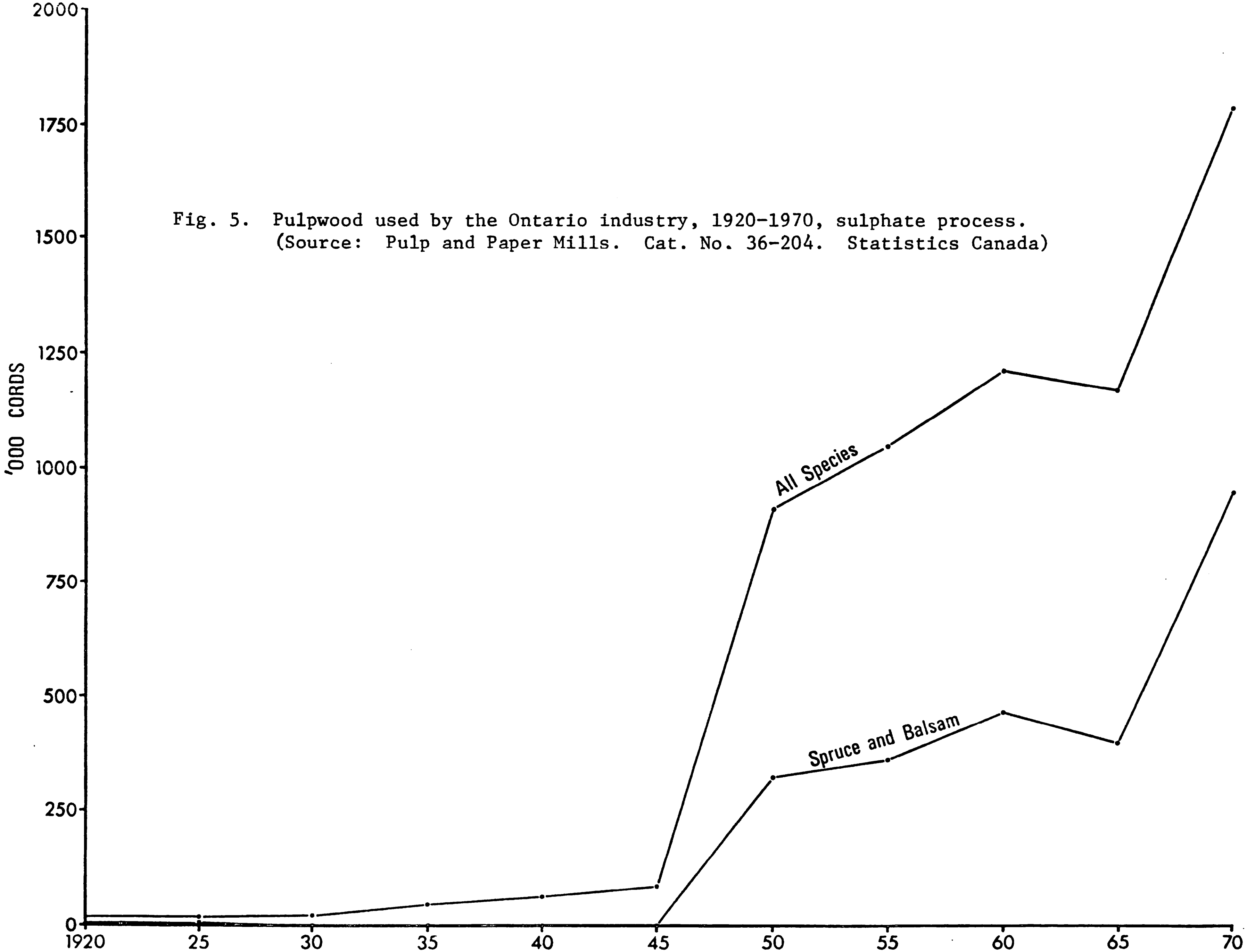

Fig. 5. Pulpwood used by the Ontario industry, 1920-1970, sulphate process.
(Source: Pulp and Paper Mills. Cat. No. 36-204. Statistics Canada)

The objectives and policy of the Division of Forests provide the administrative framework within which the decision of whether or not to manage black spruce is made. The policy states production targets and the funds available for management. If there were no budgetary constraints, site conditions, silvicultural characteristics of species, and technology would largely determine what treatments are to be made. However, funds are always limited, and this has an effect on the selection of sites and species to be regenerated as well as methods of treatment.

Within this general framework, the strategy for managing black spruce could range from attempting to regenerate every acre of cut-over black spruce to converting all black spruce sites to alternative species, or to leaving everything to nature. However, the options are not really that wide. The decision to manage black spruce should not ignore current and expected demand. In areas where industry is dependent upon black spruce and where there are few alternatives the decision not to manage black spruce would be very difficult to make. An example of such an area is the Clay Belt in northeastern Ontario.

Another factor restricting management options is environmental considerations. The second part of the objective of the Division of Forests" ... to provide for other uses of the forest", implies that cutovers should be managed to maintain nonfiber production uses. Thus, in those areas where there are alternative uses for the black spruce forest there will be pressure to manage the black spruce sites.

However, these considerations are general and largely the concern of head office foresters. The unit manager who has to make the final decision for a given site is likely to be more concerned with factors such as:

1. The distribution of sites in the unit

2. His annual budget and production targets

3. His ability to treat specific sites for particular species.

The type and distribution of sites to be treated determines the magnitude of the management job and has a strong bearing on the management options open to the forester. If an area contains a high proportion of mixed black spruce and jack pine, for example, the management strategy is much more flexible than if the area is mostly swamp black spruce.

The available funds for silvicultural operations limit the capability of the manager to meet the management objectives of his unit. He is expected to treat all of the areas requiring treatment and at the same time meet the overall objectives of the organization. This may not always happen. The unit manager is most concerned with his budget from the point of view of how many acres can be treated rather than what combination of treatments will yield the greatest return. The problem with this is that the general quality of the forest resource may be downgraded over time owing to a divergence in the objectives of the unit manager and the organization. This situation is most likely to occur where the budget at the unit level is inadequate, where there is a strong emphasis on initial treatment of areas and inadequate follow-up on results, and where the general objectives are poorly defined and results are poorly documented. While the unit manager may meet his narrow objective of treating his areas with a given budget, if his results are poor the organization's objective will not be met. Areas may be treated inadequately or lower-value species given preference over more valuable ones, thus degrading the resource base. At head office, where budget allocations are made, not only the number of acres to be treated but also the nature of the forest to be produced must be specified if the objectives of the organization are to be met. Thus the objectives of the unit manager should be based on the funds he has, the areas he has to treat, and the kind of forest he is expected to produce in order to meet the organization's objectives.

The third factor having a major impact on the management decision for a particular species is the general level of success of the regeneration techniques available to the manager. In Ontario there has been considerable success in regenerating jack pine and as a result most of the jack pine cutovers are treated, yet probably no more than 25% of the black spruce cutover area is artificially regenerated to black spruce.[4] While we can understand why this type of situation arises we must also recognize that the course of least resistance may not give the greatest returns.

In summary, the unit manager is strongly influenced in his decision whether or not to manage black spruce by his budget and by the cost of managing black spruce in comparison with the cost of managing other species. Whether considerations of final product or even the objectives of the organization have equal influence probably depends upon how well formulated the concept of the "new forest" is at head office. The practical problems of managing black spruce will probably outweigh the advantages that black spruce may have as a final product. However, the responsibility for weighing the pros and cons of long-term benefits and short-term costs should fall to the head office planners rather than to the unit manager. Given the problems and costs of treating sites for black spruce, we can expect that there will be strong pressures on the unit manager to move away from black spruce.

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[4] F. C. Robinson, Boreal Forest Silviculturalist, Ontario Ministry of Natural Resources, personal communication. Mr. Robinson emphasized that his assessment of the situation is not well documented.

DISCUSSION

The question posed at the outset of this paper was, "Should we manage black spruce?" Obviously the answer is yes. But the real question is, "How much of the management effort will be devoted to black spruce and where will this occur?" From our review of the resource base, the current demand and expectations of future demand, it is obvious that as long as black spruce is available it will be utilized. However, this does not necessarily mean that it will be managed according to its current importance to the forest economy.

Ontario has instituted a forest management program which will attempt to produce an annual cut of about 9.1 million cunits (25.8 million cu. m). Previously, the program was treating sufficient area to support a cut of about half the new target. In proportion to the volume of black spruce harvested, the degree of management has been low. With the new program and production targets we can expect more emphasis on black spruce management. However, the new program does not alleviate the silvicultural problems associated with black spruce management, nor does it make black spruce less expensive to manage.

When we consider the black spruce resource, we cannot think of it as a homogeneous unit. The major division of the resource lies between the upland or mineral soil sites and the lowland or peatland sites. The management options and costs vary between the two categories. The upland sites are probably more amenable to operation and conversion to other species. At the same time they are probably more productive sites. Thus, the real costs of conversion may be relatively low in the face of viable alternatives.

On the other hand the peatland sites are almost exclusively black spruce sites. Therefore, they must be either managed for spruce or abandoned. Since these sites are generally difficult to treat artificially and by their nature are expensive to treat, the latter is not an unlikely alternative. However, since the alternatives are limited, one would expect the major effort in black spruce management to be on the peatland sites. Where there is the opportunity for stand conversion, it is obvious from the current program that this opportunity is being exercised. Without some change in the success and cost of managing black spruce, this trend will probably continue. This is mostly due to the fact that it is very difficult if not impossible to differentiate between final values derived from different species. Thus the initial costs of establishment carry the most weight in the investment decisions.

An important aspect of the black spruce management question is whether or not every acre cut over requires treatment as the current management program implies. If we relax this assumption, the management strategy on peatlands may be radically altered. The major criterion for determining whether a stand is adequately regenerated is the stocking standard. Pure black spruce stands have to be 60% stocked to be considered adequately regenerated (Robinson 1974). At the same time only those with less than 40% stocking are considered failures. However, there are indications that natural regeneration on peatland sites will generally fall in the 40%-60% stocking range.[5] If this is in fact the case then the question becomes, "Is it worth attempting to bring these stands to the acceptable stocking level considering that the natural regeneration will be lost in the attempt?" Obviously the payoff will be less than in the case where the expenditures bring a site from below 40% as is probably the case on the uplands. Thus, above the specified 40% stocking level the management strategy should be dependent upon the expected stocking weighted by the real cost of establishment.

In light of such a strategy, the forest manager will have to consider whether the production targets can be met when part of the area is less intensively managed. This should be dependent upon the level of the target and the extent of the productive forest area. In Ontario's case it would seem that this strategy will be viable. It will tend to force regeneration investments onto the more productive sites where the prospect of a higher yield is more likely. While it will not prevent a shift away from spruce on upland sites, it will permit Ontario to take advantage of its relatively large areas of productive forest land, and at the same time concentrate its expenditures on the more easily managed sites.

Returning to the question of how much black spruce we are likely to produce, the answer lies somewhere between what we have from nature and what we are likely to get from the current level of management. The fact that there are large areas suitable for growing black spruce ensures its continued importance. The fact that it is relatively expensive to produce ensures that its importance will gradually decline.

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DISCUSSION

JEGLUM

Mr. Ketcheson, something didn't click properly when you talked about the idea that the greatest effort would have to be put into the peatlands. What was your reasoning behind that?

KETCHESON

If you don't regenerate lowland black spruce sites you lose sites from productive forest land. On the other hand, you have more options on upland sites where you may take a loss going to a lower value species and still have something left to work with for the future.

JEGLUM

This contradicts the general regeneration trends, where you have more or better regeneration, in general, on peatland sites. The big problem in regenerating black spruce is on upland sites. You have to balance that with the idea of more species to work with on upland sites.

KETCHESON

If that's true that's great. I'd like to see it well documented. That may change any sort of analysis, but on the basis of the management program at the present time you have to infer that they're switching away from black spruce to other species on the uplands, and the lowlands are being left to themselves.

JEGLUM

Doesn't it also contradict the idea that the best growth is on upland sites?

KETCHESON

You're looking at net loss, not at loss in annual increment. If you can replace spruce with jack pine or with aspen, your net loss is probably going to be less than if you replace spruce with nothing.

HAAVISTO

You're assuming if you don't do anything with the peatland sites they will go out of production.

KETCHESON

Yes.

HAAVISTO

What are you basing that on?

KETCHESON

If you look at Ontario's 9.1 million cunit production target, that program assumes that if you don't treat sites they'll go out of production, and that's what I'm basing it on. That may not be a sound assumption, but if we're going to plan forestry we've got to be logical, we've got to look at what we're doing and say "Is this right, are we making the right assumptions, do we know enough to make a plan that says we have to treat every acre?"

HAAVISTO

From the recent regeneration survey (not yet published) in the Clay Belt and in the Central Plateau Section we concluded that the peatland sites are regenerating to a certain degree in what Robinson considers the gray area--between 40% and 60%. Many upland sites are not even conditionally stocked. With that in mind, can you say they're going out of production and we should be putting our emphasis on the lowland sites rather than the upland sites which, as Jeglum said, are the most productive?

KETCHESON

I look at the material before me and try to make some evaluation of the situation. If what you're saying is true, that's encouraging, and may change any analysis.

SWAN

I think the point Ketcheson is making is that if 40% doesn't regenerate to black spruce it will not regenerate to any other valuable species and therefore will go out of production, and I think it's as simple as that.

ROBINSON

Our head office policy in setting that 9.1 million cunit target is that the unit forester is probably the best man to decide the species. He knows his sites and his working groups, and we think he should make that decision. You're suggesting a reverse, that, maybe because of the pressures, he has to make his money go as far as he can, and he's going to regenerate jack pine or poplar because it's cheaper and he can treat more acres for a dollar. Are you suggesting that we should change our policy entirely?

KETCHESON

I'm suggesting that head office can't just say they want 9.1 million cunits. They've got to have a good concept of the kind of forest they want and if they don't have it then the unit forester certainly isn't going to have any concept of it. When you're talking about spending 20 to 30 million dollars, you're talking about a big bundle of money. You want to know where that money's going, you want to know what you hope to get back from it. I know when you get down to the unit level the manager is constrained. He's got to know, if he decides to go for upland black spruce, even though it's more expensive, that he's going to get support from head office because that's the kind of forest they want. But if they don't know whether they want upland black spruce, then he's probably going to go for aspen which is cheaper.

ROBINSON

I'd like a unit forester to answer that, to decide whether that type of decision should be made in Toronto or in the field.

KETCHESON

Earlier this afternoon Fry talked about release. He said we're not going to release the conifer because we'll do damage to the hardwood. Is he making that decision because he knows that you want a higher percentage of hardwood than conifer? What are his guidelines? It's hard for him to decide what is the most valuable species and what will maximize the return on his budget allocation over time. At head office you should be thinking of these things.

BURGER

The unit foresters are the major factor. They work in conjunction with the companies. They know what companies can use. If they can use poplar they'll get poplar.

KETCHESON

That's true, but if you look at current management programs you wonder what the company has been using for the last 25 to 40 years. They've been using spruce (primarily black) and yet we're producing everything but. You can only take that argument so far. I agree with what you're saying in a specific case, that the unit forester may be constrained, but if you look at the trends, they don't hold water.

BURGER

The question has been asked whether the decision should be made at head office or in the field. The problem at head office is that they do not know the local production system, what the ecosystems are, or what they can produce. The unit manager knows where he can grow potatoes, poplar, and spruce. It's as simple as that. So if management can say they need so much fiber to keep the industry going in this province then you unit managers, knowing the production systems, decide what you can grow on them--potatoes, poplar, or some other species.

KETCHESON

I agree. Certainly the unit manager is constrained by what he can grow in any specific area. I don't mean to imply that Robinson should specify for every square yard of forest in Ontario what should be grown. You said the unit forester has a selection. He can spend his regeneration budget on his easier sites--his less expensive sites--and grow poplar, or he can grow black spruce, and he's got a range of sites on which he has to make a choice. He's not going to be able to do it all. What should his response be to this seeming quandary about a range of alternatives and not enough money? I think this is where you've got to start looking at your forest policy. What kind of forest do you want? The way it is now, it seems as if we're going away from the more difficult species, the species we feel are more expensive in the short run, but we may be damaging our long-run prospects. This is the whole history of white pine.

GRINNELL

Basically the philosophy and policy are to produce what the land capability indicates can be best produced. The next question is: What are the industrial demands? How much do you alter or try to alter the land-use capabilities to fit the industrial demands, i.e., to provide the product industry needs, and will need in the future? If, in this framework, the unit manager hasn't decided, then there's no reason why he can't contact head office.

SESSION C

CONTINUOUS PLANTING OF SEEDLING BLACK SPRUCE[1]

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*The effect of planting date on stock survival and growth of black spruce (*Picea mariana *[Mill.] B.S.P.) was examined under experimental field conditions. Results indicated that planting outside periods of potentially high survival may mean longer rotations and future fiber losses. Differences between stock in relation to planting date and site are discussed.*

*L'auteur étudia les effets de la date de plantation sur la survie et la croissance de l'épinette noire (*Picea mariana *[Mill.] B.S.P.) lors d'expériences sur le terrain. Il en résulta que la plantation en dehors de périodes durant lesquelles les plants peuvent meiux survivre peut entrainer des révolutions plus longues et moins de fibres. L'auteur discute les differences entre les groupes de plants en relation avec la date de plantation et le type de station.*

INTRODUCTION

Rapid consumption of our forest resources has invoked a certain urgency in reforestation programs. This urgency is becoming increasingly acute as a proportion of newly established plantations end in total failure or achieve marginal success (MacKinnon 1974).

Silviculturists, foresters, and experimenters continually work toward the development and implementation of new techniques and the improvement of traditional ones to establish vigorous new stands economically and quickly. Diversification in regeneration methods has been the result of these efforts. The implication of diversification is that the capabilities of the regeneration techniques now available to us must be defined according to their effects on stand establishment and growth so that they may be efficiently integrated without flouting silvicultural principles (Sutton 1968).

Interest in the influence of planting date on survival and subsequent growth of bare-root planting stock has therefore developed, and in some cases has led to the extension of operational planting periods.

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[1] This paper is Contribution No. 1003 from the Division of Forests, Research Branch, Ontario Ministry of Natural Resources.

A variety of white spruce (*Picea glauca* [Moench] Voss var. Albertiana (S. Brown) Sarg.) in Alberta was investigated in this regard by Crossley (1956) and later by Ackerman and Johnson (1962) in a follow-up study of Crossley's original work.

Preliminary results by Crossley (1956) indicated that tree mortality was low throughout the planting years and that height growth was variously depressed, depending upon the time of planting. Ackerman and Johnson (1962) confirmed these results and further showed that the effect of month of planting on current annual height growth was still evident in the fifth year after planting.

In northern Idaho survival rates of four coniferous species were compared for 3 consecutive planting years between fall and spring plantings (three plantings in each season) (Sinclair and Boyd 1973). Survival of spring-planted trees was generally better than that of fall-planted trees. Fall plantings were generally more variable, being influenced by species x planting date interaction and moisture stress.

In Ontario, Burgar and Lyon (1968) investigated the possibility of extending the planting season of white spruce (*Picea glauca* [Moench] Voss) by planting continuously throughout the frost-free season. They compared 2 + 2 white spruce that had been freshly lifted with that which had been spring lifted and then cold stored. Survival counts were made for 3 consecutive years for the bimonthly plantings. Results indicated that the freshly lifted stock exhibited a high survival rate throughout the spring and summer months except for that period of development in which rapid elongation and bud formation took place. Although spring-stored stock also exhibited a high rate of survival throughout the spring and summer growing months, height development was progressively affected as storage time approached 3 months. Beyond this time height growth was found to be unsatisfactory owing to the high incidence of leader mortality and regrowth from the lower stem.

Mullin (1968) investigated fall and spring planting of black spruce seedlings and transplant stock and found little difference between the fall and spring planting in rates of survival and growth. In a later examination of the same work Mullin and Howard (1973) again found little difference in rates of survival and growth.

Evidence to date strongly suggests that the time of planting affects stock survival and growth. It follows, therefore, that evaluation of the relationships among time of planting, stock age and site as they affect survival and growth of each planting species is essential. Such information has not been completely documented for black spruce (*Picea mariana* [Mill.] B.S.P.), the most valuable pulp fiber source in Ontario.

Consequently, to investigate the above basic relationships and to develop methodology for future trials a pilot study was initiated by the Northern Forest Research Unit in cooperation with the Thunder Bay District and was carried out in the Dog River area of Great Lakes Paper Company Limited. It is the results of this field investigation with which this paper deals.

FIELD METHODS

Two ages of black spruce stock were planted at 2-week intervals throughout the spring, summer, and fall of 1971 on two contrasting planting areas.

Study Areas

In the Dog River area two black spruce sites representative of typical reforestation situations were selected by the managers of the Shebandowan Management Unit in the Thunder Bay District. The lowland was a clear-cut black spruce swamp with impeded drainage (Fig. 1). The upland once supported an overmature black spruce stand interspersed with trembling aspen (*Populus tremuloides* Michx.) and white birch (*Betula papyrifera* Marsh.) (Fig. 2). This area was clear cut and subsequently scarified in 1969 with shark-finned barrels. The topographic relief of the upland site was undulating, with the soil (a stoney silt loam) varying in depth over bedrock and large boulders. A portion of the upland site graded into a lowland site.

Fig. 1. Lowland site selected for planting.

Fig. 2. Upland site selected for planting.

Experimental Design

A randomized complete block design was utilized with three replications. Within each block paired planting lines were located running across the rectangular blocks and each was randomly assigned a planting date. Each pair of lines was planted with 50 trees, 25 of each age class. Spacing between trees in the rows was variable owing to ground conditions, while spacing between individual lines in a pair was approximately 1.2 m (3.9 ft) and between pairs of lines a minimum of 3.7 m (12.1 ft).

Black Spruce Stock

Operational 2- and 3-year-old seedling stock (seed zone 3W) was selected for testing. To decrease variation sufficient trees were reserved in two beds of black spruce stock at the Thunder Bay Forest Station. During the period spent in the seedbeds seedlings were subjected to standard nursery practices.

Planting

In 1971 plantings took place every 2 weeks and began concurrently with operational plantings in nearby reforestation areas. The reserved stock, 300 trees for each of the 11 plantings, was usually lifted the day before the scheduled planting date (Table 1), packed in moist moss in planting buckets and stored over night in a refrigerated cooler. Occasionally, the stock was lifted and transported on the day of planting. Table 1 also provides a summary of biweekly rainfall and temperature data in relation to planting date.

Table 1. Planting sequence, rainfall distribution, and high-low temperatures for 1971 planting season.[a]

Planting no.	Planting date	Rainfall between plantings (cm)[b]	Temperature (C)[c] Max.	Min.
1	May 26	1.3	26.8	-6.6
2	June 9	1.2	26.8	0
3	June 23	2.8	30	4.2
4	July 7	6.5	26.7	4.6
5	July 21	2.0	26.5	0.2
6	August 4	1.1	32.4	4.2
7	August 18	1.2	32.2	-6.7
8	September 1	5.4	32.1	4.3
9	September 15	5.6	17	-6.1
10	September 29	8.6	14.8	-1.0
11	October 13	4.4	20	-6.1
	TOTAL	40.1		

[a] Data collected from the Dog River Silvicultural Project Camp.

[b] 1 cm = 0.4 m

[c] F = (9/5 C) + 32

On the lowland area, the planting lines were generally confined to the cleared strip roads but where it was necessary to maintain reasonably straight lines the logging slash was cleared away and a compacted cleared scalp was made. The trees were planted in the moist-to-wet fibrous decomposing moss or peat layer. Difficulty was often encountered in firming the roots because of the fibrous spongy nature of the rooting medium.

On the upland area, wherever possible, the planting lines ran along the furrows made by the scarification equipment. The trees were planted in mineral soil at or near the bottom of the furrow or in cleared scalps where the furrow could not be used.

Assessment and Analysis

Tree survival, height, and current annual height increments were recorded annually. Analyses were carried out separately for each site. Survival percentages (1974) were subjected to an analysis of variance using an ARCSIN $\sqrt{\%}$ transformation. Mean 1974 seedling heights, factored by percent survival to account for mortality, were also subjected to an analysis of variance. Treatments were considered significant at the 95% level of probability.

RESULTS

Site Conditions

By 1974 both the upland and lowland planting sites were occupied by competing vegetation. Most prevalent were grass, sedge, raspberry (*Rubus* spp.), birch (*Betula* spp.), and poplar (*Populus* spp.) on the upland site while Labrador-tea (*Ledum groenlandicum*), *Sphagnum*, and blueberry (*Vaccinium* spp.) were dominant on the lowland site. Operationally, a competition rating of high could be applied to both sites and it is likely that release would be necessary in both areas to ensure survival and growth of those trees still alive.

Stock Survival

The 1974 survival rates for 2 + 0 and 3 + 0 planting stock both on the upland and lowland sites are shown in Figure 3. Analysis of these data indicated real differences between stock types and among planting dates and their interaction on each site (Table 2).

Differences between the 2 + 0 and 3 + 0 stock are easily observed in Figure 3. The 2 + 0 stock showed a decisive survival advantage over the 3 + 0 stock on both planting sites, though to a lesser extent on the upland site. On the lowland, survival of 2 + 0 stock was 28% higher (67% vs 39%) than that of 3 + 0 stock; on the upland, the 2 + 0 stock had a 13% survival advantage (67% vs 54%).

Equal in importance to the inherent capabilities of stock to survive on various sites is the definition of those periods in time characterized by high survival rates. On the upland, the 2 + 0 stock exhibited greater than 70% survival from May 26 through late July with one apparent exception (June 23). Although survival rates increased from a low of approximately 30% in early August, survival did not surpass 70% until early September; the latter rate occurred again only with the October 13 planting. The 3 + 0 stock had quite a different pattern on the same site. Only the first two plantings (May 26 and June 9) resulted in survival rates greater than 70%. The lowest survival was noted for August 4 for both 2 + 0 and 3 + 0 stock. Survival increased for the August 18 planting, but decreased consistently thereafter until the October 13 planting.

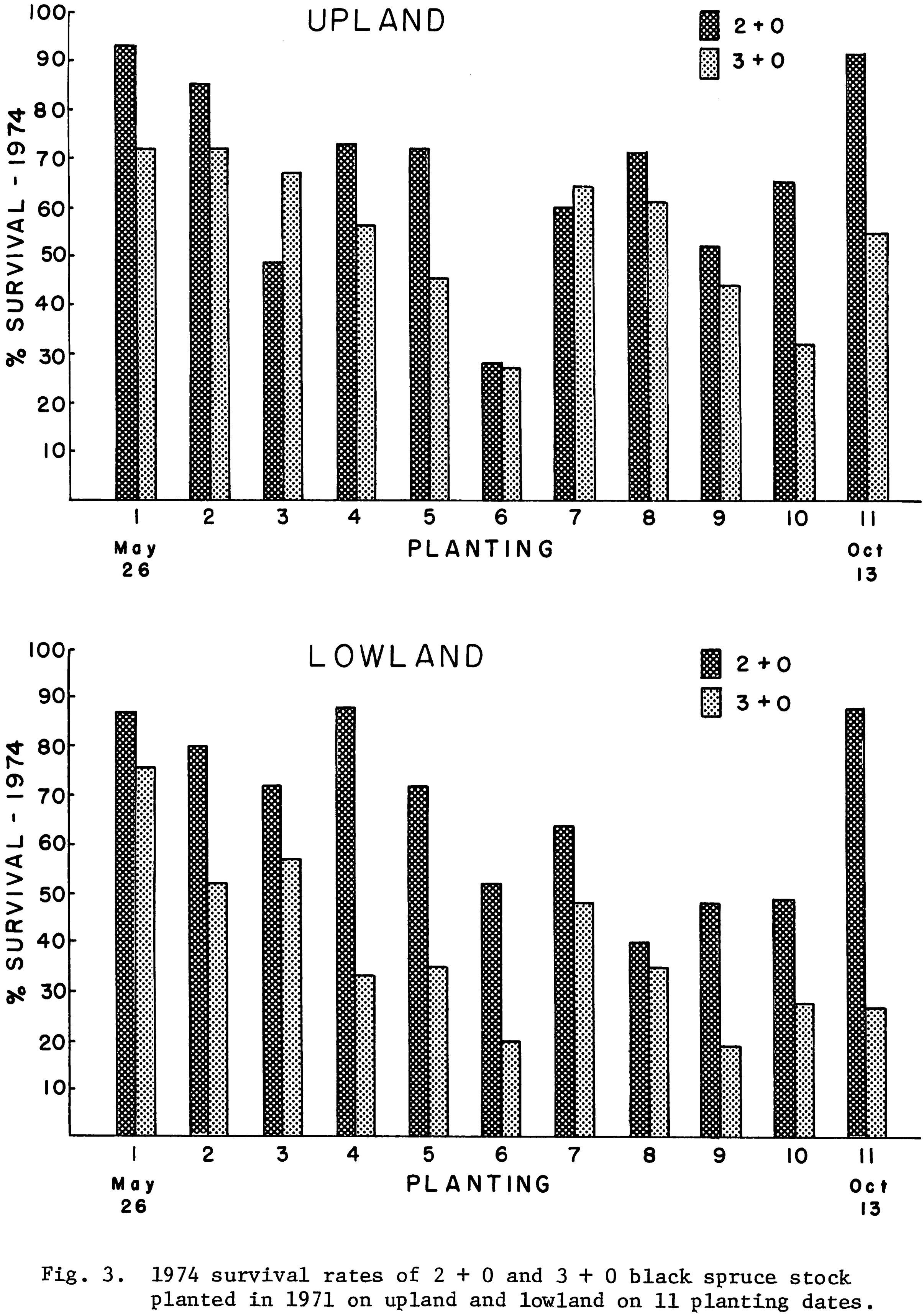


Fig. 3. 1974 survival rates of 2 + 0 and 3 + 0 black spruce stock planted in 1971 on upland and lowland on 11 planting dates.

Table 2. Analysis of variance of 1974 survival rates using ARCSIN transformations on upland and lowland sites.

Source of variation	Degrees of freedom	Mean squares	F values
	UPLAND		
Total	65		
Main plots			
blocks	2	1,085.82	6.81**
planting date	10	799.68	5.02**
error (a)	20	159.34	
Subplots			
planting stock	1	1,237.01	21.70**
planting stock x planting date	10	178.88	3.11**
error (b)	22	57.46	
	LOWLAND		
Total	65		
Main plots			
blocks	2	384.38	4.11*
planting date	10	530.68	5.68**
error (a)	20	93.40	
Subplots			
planting stock	1	5,382.96	115.07**
planting stock x planting date	10	256.61	5.49**
error (b)	22	46.78	

* Significant at 95%
** Significant at 99%

On the lowland, the 2 + 0 stock exhibited a more consistent pattern of survival, attaining greater than 70% survival May 26 through July 21. Survival for August and September plantings varied from 65% to 40%. As on the upland, the October 13 planting survival rate was surprisingly high (90%). The 3 + 0 stock survival rates were very low regardless of the date of planting. Only with the earliest spring planting was survival greater than 70%.

Growth

Tree height: Tree heights at the end of the 1974 growing season for the experimental stock are shown in Figure 4. An analysis of height indicated that planting date and stock type, as well as their interaction, were significant, but only on the lowland site (Table 3). Regardless of site, the 3 + 0 stock showed greater average height than the 2 + 0 stock.

Table 3. Analysis of variance of 1974 mean tree heights proportioned to account for mortality on upland and lowland sites.

Source of variation	Degrees of freedom	Mean squares	F values
	UPLAND		
Total	65		
Main plots			
blocks	2	95.02	6.48**
planting date	10	64.74	4.42**
error (a)	20	14.66	
Subplots			
planting stock	1	1.53	0.44ns
planting stock x planting date	10	20.58	5.86**
error (b)	22	3.51	
	LOWLAND		
Total	65		
Main plots			
blocks	2	65.23	9.59**
planting date	10	35.43	5.21*
error (a)	20	6.80	
Subplots			
planting stock	1	95.21	19.51**
planting stock x planting date	10	19.98	4.09**
error (b)	22	4.88	

* Significant at 95%
** Significant at 99%
ns not significant

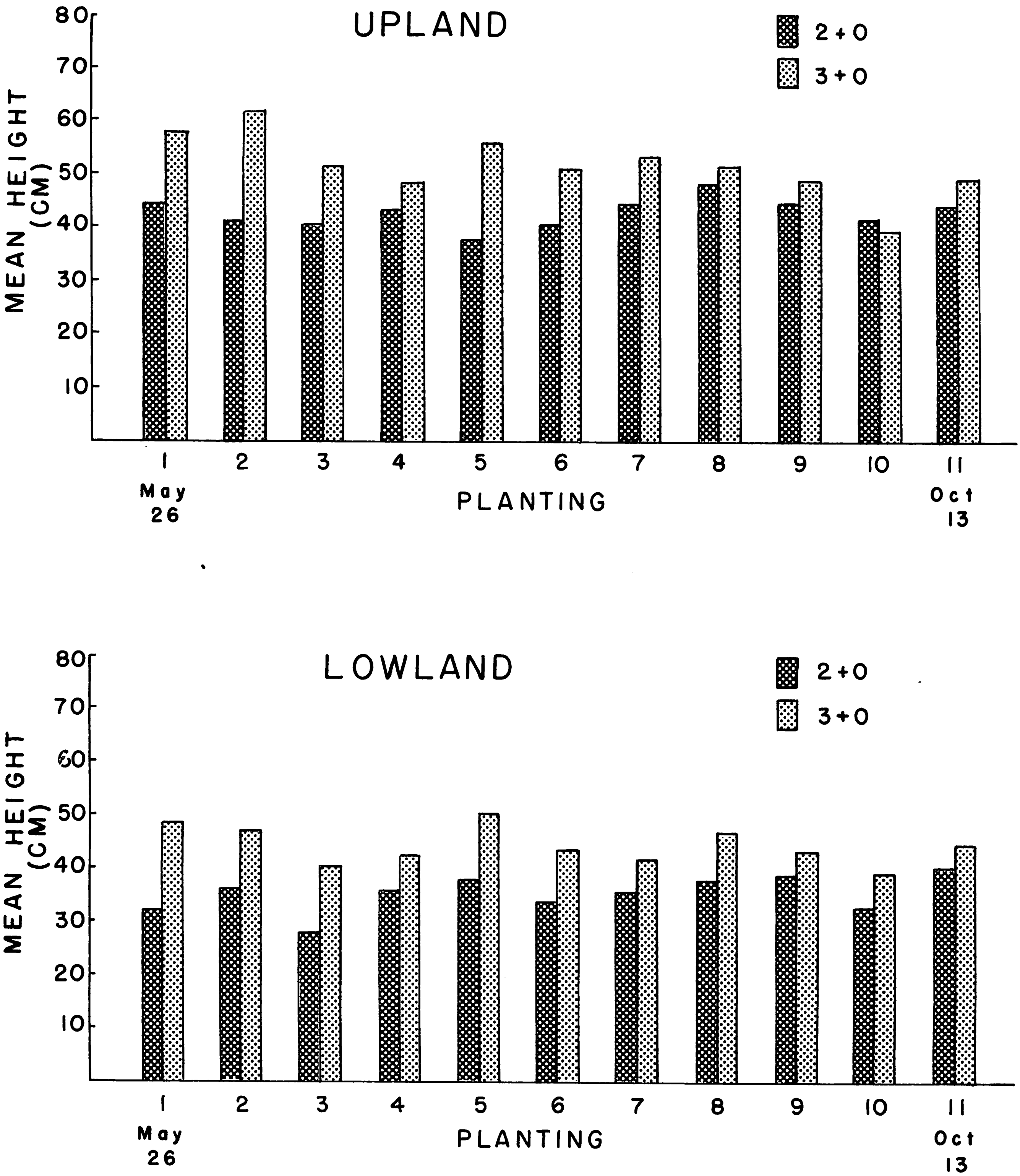


Fig. 4. 1974 mean tree heights of 2 + 0 and 3 + 0 black spruce stock planted in 1971 on upland and lowland on 11 planting dates.

Current annual increment: Current annual height increment for the 2 + 0 and 3 + 0 planting stock achieved in the planting year (1971) and for three growing seasons after planting (1972-1974) is presented in figures 5 and 6, respectively. The 1971 regression is sigmoidal in shape, indicating the extent of growth that occurred during the planting year. Whereas height growth of trees planted early in the season occurred entirely under field conditions, that of trees planted late in the season occurred under nursery conditions. Trees planted during mid-season grew in both environments. It is noteworthy that stock planted early in the season did not express its fullest height growth potential.

During the first year after planting (1972) the height growth regression was rather depressed, being concave across planting times. This trend was not continued in 1973 and 1974 as height increments were, in general, irregularly but consistently depressed downward from spring plantings to late season plantings. Additionally, current annual increments increased each year regardless of planting date. Current annual height increments were greater for the upland plantings than for the lowland plantings.

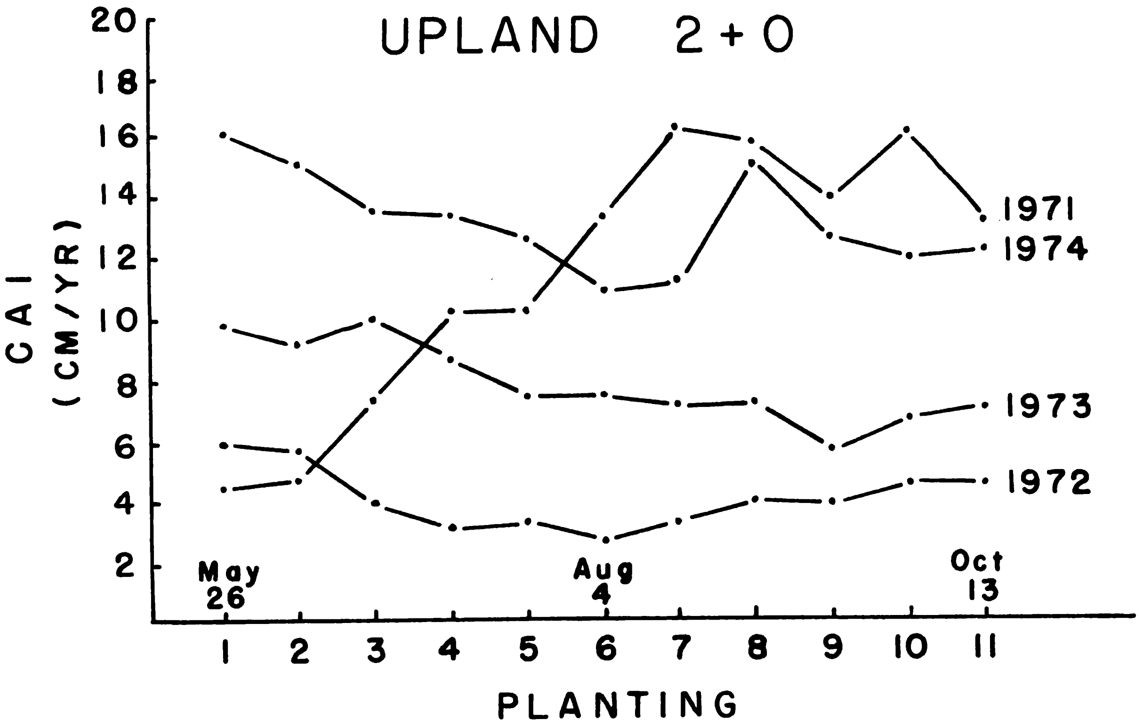
On comparing each stock type individually by site, it was found that the better-drained, mineral soil upland site promoted greater tree growth while the more poorly drained, organic site restricted potential tree development. Site differences reflected in the yearly growth of each stock type are examined in Table 4. In all instances mean current annual height increments were greater on the upland with the effect of site greatest on the 2 + 0 stock.

DISCUSSION

Survival

There appears to be a relationship between field survival of seedling black spruce nursery stock and planting date (Table 2). The relationship is unique for each stock type and is influenced significantly by planting site conditions (Fig. 3).

It is difficult to account for all the factors and the degrees to which they influence stock survival after field planting. Traditionally, factors such as stock treatment after lifting, stock quality, planting method, postplanting weather, site moisture conditions at the time of planting, etc., were considered most critical for planting success and they still partially explain survival trends observed in this study. The observed low (Planting 6) in survival for both stock types on the upland may well be attributed to high temperatures (32.4 C, or 90.3 F) and low rainfall (1.1 cm, or 0.4 in.) (Table 1). Physiological conditioning was probably another controlling factor influencing



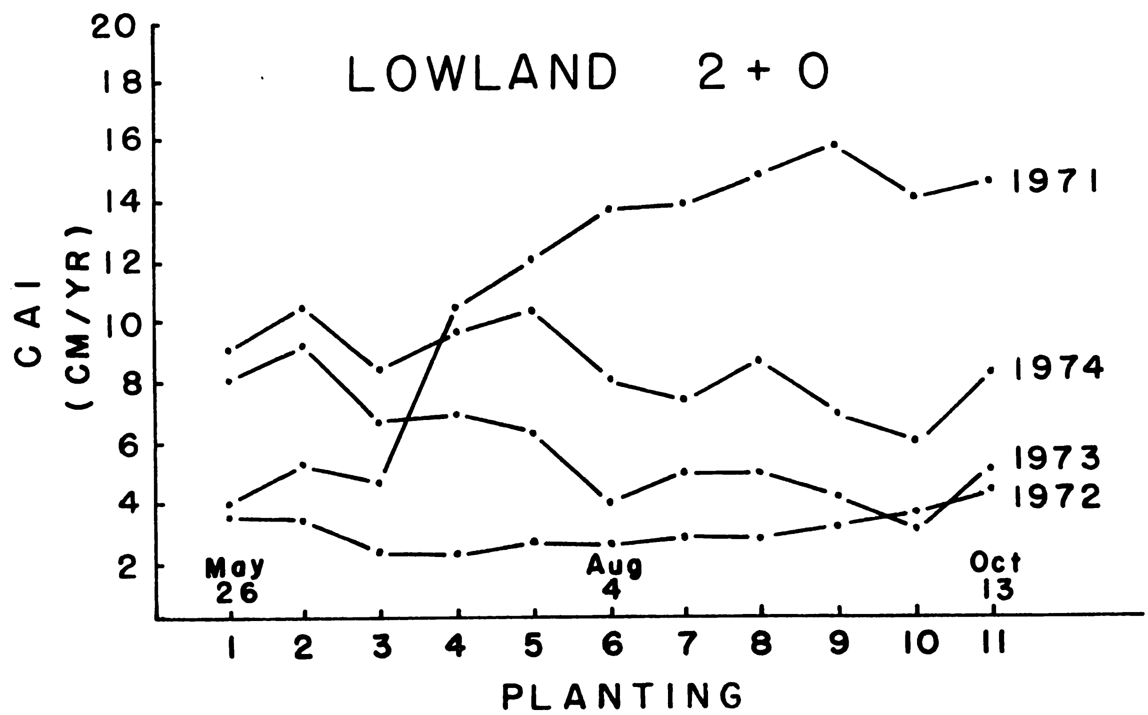


Fig. 5. Mean annual height increments for 2 + 0 black spruce stock planted on upland and lowland sites on 11 planting dates.

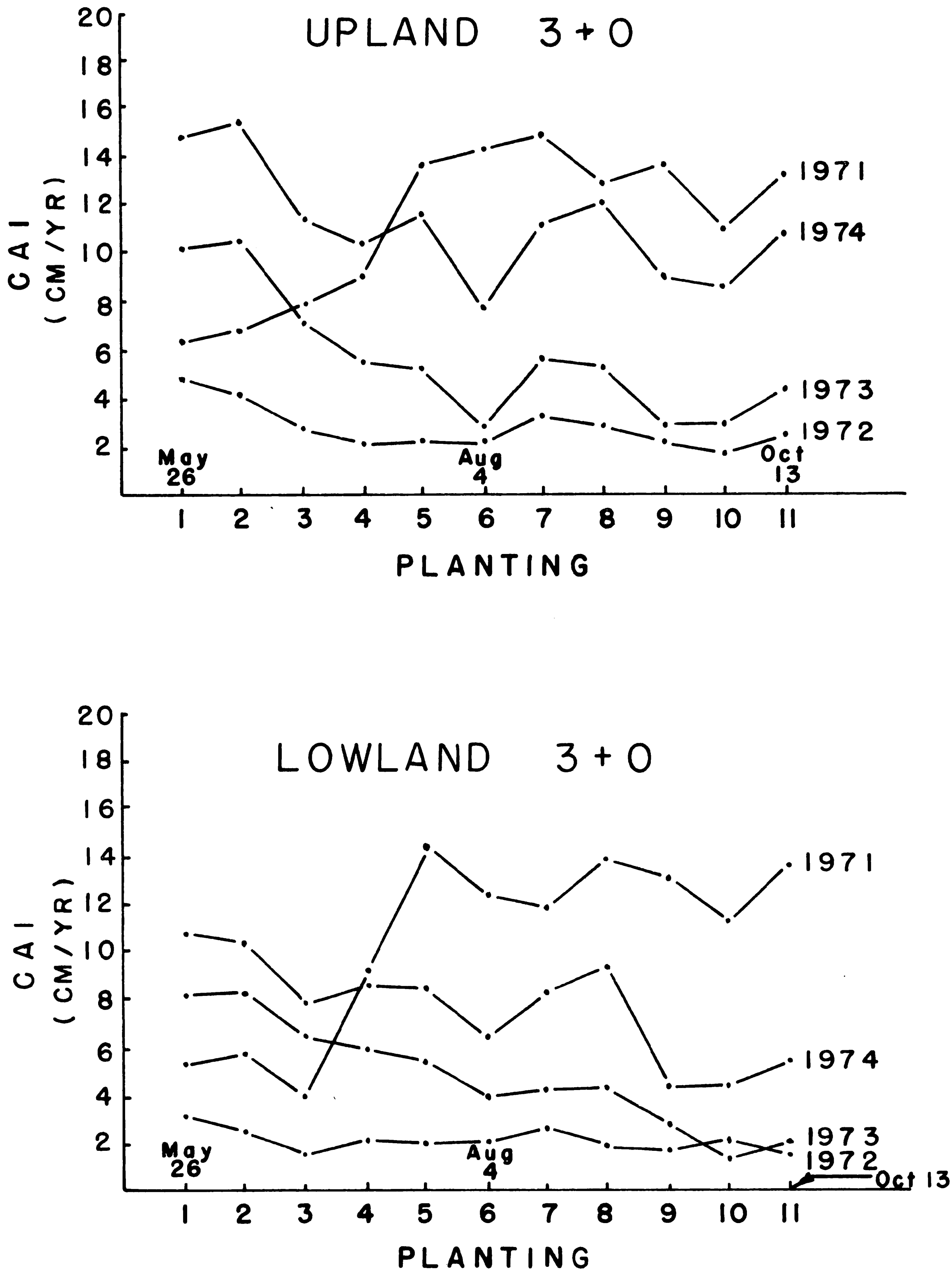


Fig. 6. Mean annual height increments for 3 + 0 black spruce stock planted on upland and lowland sites on 11 planting dates.

survival. That the 3 + 0 stock had a higher survival rate than the 2 + 0 stock on the upland at Planting 3 perhaps reflects a period of lower physiological activity for this stock type which renders it less vulnerable to desiccation.

Table 4. Mean current annual increments and percent differences, by year, for 2 + 0 and 3 + 0 black spruce stock planted on upland and lowland sites (values calculated on the basis of all 11 plantings).

Year	Current annual increment (cm/yr)[a] Upland	Lowland	Percent difference
	2 + 0		
1972	4.08	2.98	36.9
1973	7.87	5.93	32.7
1974	13.38	8.65	54.6
	3 + 0		
1972	3.00	2.18	37.6
1973	6.40	5.55	15.3
1974	11.78	8.46	39.2

[a] 1 cm = 0.4 in.

More recently, however, investigators (Stone and Schubert 1959, Stone et al. 1962, 1963) have examined the less obvious feature of rooting periodicity or root development to explain and quantify the seasonal probability of survival of field-planted trees. Recently, root regeneration potential was investigated for some boreal forest conifers by Hambly (1973), who showed that for black spruce, root growth was low in mid-season and high in spring and late-season periods. A comparison of this information with that presented in Figure 3 could assist in explaining the survival patterns obtained in this study.

Indirectly, it also suggests that 2 + 0 and 3 + 0 black spruce stock may have different capacities to regenerate new roots or elongate older ones. On the lowland, adventitious rooting may be an important factor influencing stock survival.

It is interesting that the October 13 planting of the 2 + 0 stock (really 3 years old) maintained a high rate of survival up to 1974 on both the upland and the lowland sites. Root growth may again account for this trend. Hambly (1973) found that black spruce seedlings planted late in the frost-free season showed over a 100% increase in their root surface area index. Additionally, stock planted in the fall has perhaps attained sufficient carbohydrate supplies for overwintering and early root growth in the spring.

Growth

Success of outplantings must not, however, be gauged solely by the percentage of surviving trees at a predetermined time after planting, usually 5 years (Robinson 1974). Equally important is the growth of the young trees. Although total tree height is useful in describing plantations it provides little information unless compared with a standard. Current annual height increment, on the other hand, is descriptive and useful in assessing plantation development, particularly in this study where it is important to assess the early effects of deferred planting on growth.

It was demonstrated (Fig. 5 and 6) that the rate of annual height increment decreased with increasing deferment in planting for both stock types on each site. Although the annual height increments increased for each planting with the passage of time for both stock types, growth was still generally depressed 3 years after planting for trees planted later than spring. This relationship contrasts with the annual height growth patterns exhibited by each stock type during the planting year (1971); figures 5 and 6 show that further height growth of the trees planted early in the season was depressed. Despite cessation of height growth after planting, secure establishment of the seedling must have occurred to condition it for rapid development the following year.

Lifting and field planting during periods of active growth may have produced a physiological shock in the seedlings through root attrition, high internal moisture stress, and planting site conditions. It is conceivable that those seedlings which survived will require considerable time to recover, perhaps many years. However, it is inappropriate to extrapolate what the relationships portrayed in figures 5 and 6 will be in the future. According to Ackerman and Johnson (1962) growth differences in white spruce for spring through fall plantings existed even 5 years after planting (see also Crossley 1956). Lyon (personal communication, see also Burgar and Lyon 1968) has also noted for white spruce that a similar situation still existed 10 years after planting. In this study it is therefore unlikely that trees planted other than in spring will assume the growth position of spring-planted trees; however, this assumption requires further testing.

If continuous planting of black spruce throughout the summer and fall is undertaken to meet our reforestation needs it is likely that growth will not be up to potential; hence fiber yields will be lower on an area basis in relation to an equivalent area originally planted in the spring.

This situation in turn could culminate in lengthened rotations disrupting long-term forest management planning. Site also affects growth significantly and the relative magnitude of these differences should be realized and accounted for.

SUMMARY AND CONCLUSIONS

During the 1971 growing season the Forest Research Branch and the Thunder Bay District cooperated in a field investigation to examine the effect of planting date on the survival and early growth of seedling black spruce and to develop methodology for future investigations. An upland and a lowland site were selected and planted at biweekly intervals within a statistical design with freshly lifted 2 + 0 and 3 + 0 black spruce stock from the Thunder Bay Forest Station.

Tree survival, height, and current annual height increments were recorded annually. The 1974 assessment revealed that distinct survival patterns existed in relation to site and time of planting. The 2 + 0 stock demonstrated a survival superiority over 3 + 0 stock under the conditions of the experiment. Regardless of stock age, better survival and growth occurred on the upland site. Current annual increments for surviving trees, when considered in relation to planting date, maintained depressed growth with deferment in planting.

In view of the objective of this field trial several tentative conclusions can be drawn. These are listed below. However, it should be noted that these conclusions are based on the results of a single year of planting in one geographical area. Therefore, the results will not necessarily reflect the entire variation one may experience in reforestation projects with black spruce.

1. Seedling black spruce, namely 2 + 0 and 3 + 0 stock, has characteristic field survival patterns; hence, these stock types should not be planted indiscriminately throughout the frost-free period without due regard to their survival potential and the site that is to be planted.

2. The experimental 2 + 0 stock exhibited a greater adaptability to planting site conditions than did the 3 + 0 stock. It may be concluded

that 2 + 0 stock is suitable for reforestation purposes. Further testing of 2 + 0 black spruce stock should be undertaken on a wider range of sites to examine its potential more fully, and 3 + 0 black spruce stock should be reassessed.

3. Moderately high survival rates may be expected from planting freshly lifted 2 + 0 stock from May through July on upland sites. If it is deemed necessary to extend the planting of bare-root stock and if survival is the only consideration it may again be planted from mid-August onward with moderate success. On lowland sites 2 + 0 stock could be planted for a longer initial period than on upland. September plantings should be avoided. October plantings should be investigated.

   On both the upland and lowland sites 3 + 0 stock appears restricted to early spring plantings only for high planting survival. Lowland plantings of 3 + 0 stock should perhaps be eliminated entirely.

4. Although average tree height was greater for 3 + 0 on both sites, the progression of current annual increments was found more indicative of the rate of stock recovery after planting.

5. Regardless of stock class one may expect larger current annual increments for trees planted on upland rather than lowland sites. Apparently 2 + 0 stock will outperform 3 + 0 stock, a comparison which further emphasizes the need to field test 2 + 0 black spruce stock for reforestation purposes.

6. With deferment in planting from the optimum spring period the forest manager may expect depressed tree growth. Potential fiber losses and/or longer rotation periods may result, thereby disrupting long-term forest management plans. It follows, therefore, that each regeneration technique should be evaluated and employed where necessary to achieve maximum benefit. Considerably more effort is required to elucidate the long-term nature of the above relationships.

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ECOSYSTEM MANAGEMENT OF BLACK SPRUCE ON SHALLOW SITES IN THE LAKE NIPIGON—BEARDMORE AREA

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*Successful trials using modified cutting to achieve natural regeneration of black spruce (*Picea mariana *[Mill.] B.S.P.) have been carried out in the Lake Nipigon—Beardmore area over the past 15 years. The principal guidelines for these trials were obtained from observations of the workings of the natural black spruce ecosystem on shallow till sites.*

*Dans la région du lac Nipigon et de Beardmore, l'auteur effectua des coupes modifiées expérimentales en peuplement d'épinette noire (*Picea mariana *[Mill.] B.S.P.), et ceci permit la réussite de la régeneration naturelle durant les 15 dernières années. Ces coupes expérimentales furent le résultat d'observations sur les mécanismes de l'ecosystème naturel de l'épinette noire sur till peu profond.*

A few words of introduction are perhaps in order. For some, forestry is a science; for me, forestry includes an element of art and intuition. I am a practising forester, that is, one who puts his knowledge of, and concern for forestry into practice, and I have been trying to do just that for a good number of years in the Lake Nipigon—Beardmore area. During that time, it has been possible for me to use educated eyes, and other powers of observation and interpretation, to arrive at certain conclusions. That these same conclusions have been reached by others doing similar experiments either on their own or on research grants in no way detracts from my efforts. One could classify them as "parallel investigations". I have derived much encouragement in these endeavors from the work of scientists and foresters mentioned in my references, and from discussions with them. The thoughts I offer today are the result, therefore, of personal experience in the field and conclusions based on the work of others engaged in similar or related work.

For the last quarter of a century I have witnessed large-scale clearcutting of pure coniferous stands on various sites in the boreal forest region, particularly in the Lake Nipigon—Beardmore area. This past harvesting of black spruce (*Picea mariana* [Mill.] B.S.P.) stands or mixture of black spruce and jack pine (*Pinus banksiana* Lamb.) left us with large cutovers, some of which were restocked to jack pine by scarification or by site preparation and seeding.

The regeneration techniques of scarification and site preparation, with or without direct seeding, that seem to work fairly well for jack pine could not be duplicated for black spruce in the Lake Nipigon—Beardmore area, and the problem of black spruce regeneration remained with me.

Large-area clear cut management of even-aged black spruce stands has often been defended as a good forest management practice based on "scientific principles". I have seen and examined the results of such management; I have challenged it and will do so again.

Chapman (1950) in his chapter "Plans for Development of Forests" states: "In the concentration on the business of logging, the fact is over-looked that in order to establish an enterprise in forestry, definite intentional measures to provide for regeneration of the desirable species must be taken at the time of logging, else it may not take place."

It seems to me it is time we realized that forest managers, regardless of their specialization and employment, should be concerned about all facets of forest management, and they cannot afford poorly restocked black spruce cutovers any more.

I should remind you that the management of Crown lands in Ontario is not strictly an internal affair of the government and logging companies. Outside forces are increasingly influencing the public climate within which we all must work. You all know that those forces are not really enthusiastic about the practice and performance of large-area clearcutting.

Keeping these factors in mind, and appraising the possibilities open to the forest manager, one has a choice of two basic approaches to the regeneration of black spruce.

The first is the natural ecosystem approach through modified cutting; the second is the artificial approach, by means of tree planting. In the Lake Nipigon—Beardmore area, on shallow, productive glacial till sites that will be managed extensively, I have, owing to their fragility, chosen the natural ecosystem approach. However, on deeper, very productive sites, I have established two of the largest black spruce plantations in Ontario, to be managed more intensively.

The General Description of the Forest Area

The forest section extends along the east side of Lake Nipigon to a depth of approximately 50 miles (80.47 km). The climate is characterized by long, cold winters and short, hot summers. The growing season is, on an average, 150 days, with a frost-free period of approximately 80 days. The mean date of the start of the growing season based on a mean temperature of 42 F (5.6 C) is May 10. The mean date of the end of the growing season is October 10. A mean of 28 in. (71 cm) of precipitation falls annually in the area. The average annual total snowfall is approximately 100 in. (254 cm). During spring, which is frequently short and dry, this snow cover may have evaporated to a large degree. The mean date of the last occurrence of frost (32 F, or 0 C) in the spring is June 15 and the mean date of the first occurrence in the fall is September 5 (Chapman and Thomas 1968).

The topography varies from rolling to slightly undulating, and is often broken by steep cliffs and terraces. Shallow glacial deposits cover most of the forest section, although extensive areas are discontinuous and much exposed rock is present, a condition aggravated by severe and repeated wildfires that have swept throughout the region (Bedell and MacLean 1952).

Merchantable high volume black spruce stands with some mature jack pine, poplar (*Populus* spp.) and birch (*Betula* spp.) can be found on many site types, from well-drained, gentle lowland slopes, to wet flats; from extremely dry, rocky ridges and rock flats to sites exhibiting a combination of patterns. A shallow veneer of glacial till, silty sand and sandy loam usually covers most of the upland sites and several inches of organic peat over silty sands can be found on poorly drained lowlands.

In most of these conditions, the underlying bedrock, flat or broken, is not far from the surface. The general shallowness of the soil, the very prominent layer of feather mosses, and the surplus or shortage of water on these sites are very characteristic marks of the Lake Nipigon—Beardmore forest.

The thick carpet of feather mosses is usually made up of several species of which *Pleurozium schreberi* (Brid.) Mitt., *Hylocomium splendens* (Hedw.) B.S.G., *Ptilium crista-castrensis* (Hedw.) De Not., and *Dicranum scoparium* (Hedw.) are the most important. These mosses can be found in the later stages of black spruce and jack pine stand development. In the early stages of stand development, *Polytrichum commune* Hedw. also plays a very important role.

Most of our black spruce and spruce—jack pine stands were established from very similar stands as a result of large wildfires that swept through the area approximately 120 years ago. Black spruce is one coniferous species that is able to reproduce itself in this way, even on extremely shallow soils and glacial tills, and on humus over bedrock.

When black spruce stands are burned by wildfire, a unique form of site preparation takes place on the seedbed. The microsites prepared by the wildfire may vary from site to site, depending on the intensity of the fire and the condition of the stand. However, the feather mosses are only partially burned off. The many logs previously buried in the feather mosses may become exposed and serve as an excellent germination medium and seedbed. The same applies to some parts of the lower strata of mosses, usually the partly or fully decomposed layer which will be exposed at least around the circumference of the deep-burned trunks and roots of standing timber. In all mature black spruce stands, windfalls are common. The whole tree is overturned, including the large root system, thus exposing an equally large surface of mineral soil in pockets between the bedrock. Protection of these seedbeds is provided by the remaining tracts of burned forest, whether standing or flat on the ground. There is never a shortage of seed in the crowns of black spruce, and this seed is adequately and frequently dispersed. Dispersal may continue for several years after the fire.

At this point, it is wise to elaborate on the supply of seed. In the old, natural, fire-origin or blowdown black spruce stands, seed is nearly always available, and comes down for many years. It is often held in the cones of the dead standing trees. Under natural circumstances, the seed is dispersed all across the site, to both favorable and unfavorable niches, from standing, dead or living trees, or partially supported blowdowns. However, in extensive clearcuts, the crowns are all down on the ground at once. Some cone-bearing crowns are run over and smashed up by heavy equipment and are pushed into the ground. Usually the seed of the cones is available from the exposed upper side of each felled crown only at that place, and only if the crown is exposed to sunlight and dries out. The seedbed is in part diminished because of the thickening layer of falling needles from the dry crown.

The cones on the underside of the crown remain damp and wet. They usually do not open and, being smothered, rot away. This seed never emerges from the cones, and is usually lost. The crowns are gradually suppressed under the weight of the snow, and in 3 years or less, all the remaining seed from the more exposed side of the crown is useless. The net effects of all this[1] are as follows:

1. the seed normally available from the stand is reduced considerably;
2. whatever seed may be available from each tree accumulates on the ground in one place instead of dispersing;
3. the seeding-in effect is reduced to 3 years or less.

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[1] A. G. Gordon, Ontario Ministry of Natural Resources, Forest Research Branch, Sault Ste. Marie, Ontario (personal communication).

It is well known that seeding-in behavior under jack pine slash is quite different, mainly because the crowns are much less dense. Nevertheless, the black spruce natural ecosystem can prove its stability and resilience only in relation to natural disturbances such as wildfire and windthrow. In extensive man-made disturbances such as large-area clearcuts, all trees and cover are usually removed, exposing the entire site. This may cause drastic changes in the function of the total system. Feather mosses dry out and are unable to serve as germination media; they also lose their ability to intercept and preserve moisture, and their function with other biotic agents as nutrient suppliers is diminished. The continuous dry layer of desiccated feather mosses covered by slash decomposes very slowly and may prevent immediate establishment of other species. On extremely shallow sites, erosion of the dry feather mosses occurs, exposing the bedrock. The available microsites usually dry out or flood easily, depending on elevation. The dry sites become drier and the wet sites wetter. Of course, the seed supply is removed, and if the site is supplied temporarily by seeding, the chances of germination are minimal. In many instances, if germination of black spruce does occur, the exposure of the germinates may be fatal.

I would now like to mention, in very general terms, some of the obvious impacts of large-scale clearcutting on the environment.

Solar radiation, through the action of photosynthesis, is a primary source of energy for the forest ecosystem. It affects evaporation and transpiration, by means of which much of it is converted to heat. On a large clear-cut area, the net radiation input to the site does not change as much as does the distribution. Less solar energy is reflected and the temperature of the surface on the site increases considerably. In turn, there is much greater re-radiation of energy from the clear-cut area. It appears that the heat energy of clear-cut sites may triple, while evapotranspiration may be reduced by half (Marquis 1972). The high surface temperatures in a clear-cut area may have many effects. They may reduce germination and survival of black spruce, causing direct injury and of course speeding surface soil drying. Temperatures up to 140 F (60 C) at the surface are not unknown during our dry period in summer. Measuring the temperatures in the clearcut and in the stands, I noticed differences similar to those documented by Marquis (ibid.). During this summer's heatwave, temperature on the surface of large black spruce cutovers reached over 140 F (60 C).

A few words are in order about nutrient cycling and soil erosion. It has been documented that in uncut black spruce stands, the living feather mosses are acting as traps for incoming nutrient supplies in dust and precipitation.[2] It also appears that the mosses affect the storage of moisture in the fully decomposed layer of humus in the lower strata above the soil interface. The mosses may also distribute this moisture, together with nutrients--especially mineralized nitrogen--on demand to the

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[2] G. F. Weetman, Faculty of Forestry, University of New Brunswick, Fredericton (personal communication).

tree roots in the upper strata of the humus, where the feeding roots of black spruce are located. This process, of course, may become extremely important in times of drought.

After large-scale clearcutting, all feather mosses usually die off, and are unable to intercept and supply moisture. This affects the hydrology of the site drastically and causes increased runoff. In some instances, the water may carry away soil particles and nutrients that would otherwise stay in place. On many clear-cut sites in the Nipigon—Beardmore area, where nitrogen leaching losses were no doubt accelerated, and no vegetation was established immediately, the situation may have caused problems in establishment and development of a new black spruce forest.

The foregoing comments should answer the question, frequently asked, of whether the result achieved by nature, or to some degree by modified cutting, could be duplicated by the conventional method of large-area clearcutting. It may be possible to duplicate some of these processes. However, it is very difficult to control the interrelationship of these processes and their very complicated environmental impact. I know that exceptionally favorable conditions may establish a black spruce forest on some upland sites, primarily on northern slopes, but this happens very rarely, and is based on pure chance.

In conclusion, the objective of intelligent forest managment should be to get the optimum return from the forest site without destroying its capabilities. Unfortunately, in many instances, using the large-scale clear-cutting approach in the past, just the opposite occurred on the site as described. This is particularly unfortunate because these sites are very difficult to rehabilitate and they do encompass such a large portion of our productive forest area in the Lake Nipigon—Beardmore area.

Modified cutting is not a panacea and does not always bring the results desired; however, it is a good tool for a conscientious forest manager who wishes to see black spruce stands growing again on sites such as we have in the Lake Nipigon—Beardmore area.

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MODIFIED HARVEST CUTTING IN THE THUNDER BAY DISTRICT

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*Modified harvest cutting is advocated as an alternative to clearcutting to promote regeneration of black spruce (*Picea mariana *[Mill.] B.S.P.). Specifically, alternate strip cutting reduces drying and erosion on rocky sites and flooding on wetter sites to provide a suitable seedbed and growing site. Ways of eliminating slash, the principal problem, are discussed.*

*L'auteur préconise la coupe modifiée pour remplacer la coupe à blanc, ce qui améliorerait la régénération de l'Epinette noire (*Picea mariana *[Mill.] B.S.P.). Spécifiquement, la coupe par bandes réduit la sécheresse et l'érosion en station rocheuse, et l'inondation en station très humide. Ainsi la station devient propice à l'ensemencement et à la croissance. L'auteur discute les moyens d'éliminer les rémanents, cause principale de problèmes.*

Modified harvest cutting as an alternative to clearcutting was first initiated in the Camp 41 area of Great Lakes Paper Licence in 1957. Since 1963 alternate strips and varying sizes of block cuts have been carried out on the Abitibi Licence on an experimental basis. In 1973 alternate strip cutting was used to promote the regeneration of black spruce (*Picea mariana* [Mill.] B.S.P.) on an operational basis, again on the Abitibi Licence. This type of modified harvest cutting has been used not only to provide seed to regenerate the cut areas but also to maintain the site, i.e., to provide a suitable seedbed and growing site for black spruce. It has been observed that modified harvesting reduces the amount of drying and erosion on the rocky sites and reduces flooding on the wetter sites.

Much preliminary field work must be done before modified harvest cutting can be undertaken. The sites (usually rocky or wet) must be located and identified before access roads are built. The identified areas must then be walked and if alternate strip cutting is required the layout of the roads and the strip direction are planned. Usually the layout of the strips is quite intricate and requires much careful marking and flagging. The cooperation and interest of the company's cutters and strip foremen are needed to ensure successful completion of the cutting operation.

Many different widths of strips and blocks were used during the experimental years. Blocks 4 or 5 chains (80.47 or 100.58 m) wide were cut in earlier years but the more recent strips are cut at 2½-chain (50.29-m) widths. It is felt that the narrower widths permit greater seed coverage and afford better protection to the site than do the larger cuts.

The foregoing has been a brief description of the history, rationale and work involved in implementing modified harvest cutting. This paper will describe the results in terms of regeneration obtained.

I must state at the outset that the regeneration obtained to date has not been an overwhelming success. In fact, it has been rather disappointing. The disappointment stems from the fact that had treatments been conducted differently greater success could have been realized. However, some encouragement can be gained from the survey data. Basically, they show that the principle of partial or modified harvest cutting has great potential in regenerating black spruce, but great care must be taken in its implementation. A careless modified harvest cut will yield poor results (Table 1).

Table 1. Percentage regeneration by species

Area	Year cut	% stocking by species[a]					Unstocked	Total
		jP	S	P	wB	B		
Pace Lake	1968	15	41	17			27	100
Garden Lake Road	1968-1969	-	46			3	51	100
Mile 52-53 Hwy 800	1970	8	64	5	7	16	-	100
Martin and Verdi Lake	1970-1971	16	22	30	20	1	11	100
Smiley	1972	25	26	4	30	1	14	100
Fisher	1973	-	71		18	11	-	100

[a] jP = jack pine; S = spruce; P = poplar; wB = white birch; B = balsam

Sphagnum, mineral soil and moist duff seedbeds yielded good regeneration (Table 2). Slash and dry duff were the two most common seedbeds which yielded little or no regeneration (Table 3).

Slash is the real killer. It not only makes a poor seedbed itself but it also restricts the effectiveness of scarification. Poor scarification, in turn, leaves a lot of dry duff.

Table 2. Successful seedbeds

		Successful seedbeds as % of total plots stocked to black spruce				
Area	Year cut	Duff	Mineral soil	*Sphagnum*	Other mosses	Total
Pace Lake	1968	28	6	44	22	100
Garden Lake Road	1968-1969	10		80	10	100
Mile 52-53 Hwy 800	1970	47	2	22	29	100
Martin and Verdi Lake	1970-1971	31	15	39	15	100
Smiley Lake	1972	37	7	21	35	100
Fisher Lake	1973	33	8	3	56	100

Successful Seedbeds

Through modified harvest cutting an abundance of seedfall can yield excellent regeneration if the seed falls on a suitable seedbed.

1. Moist *Sphagnum*: Two basic *Sphagnum* types have been noted in surveys in the Thunder Bay area, *Sphagnum capillaceum* (Weiss) Schrank and *S. girgensohnii* Russ. *Sphagnum capillaceum* has a moist, tight-knit top which provides an excellent growing surface for black spruce. Because the top is close knit and because this moss grows at a relatively slow rate, the seed can germinate and grow with little competition from its living seedbed. *Sphagnum girgensohnii*, on the other hand, grows fast and has a loose-knit crown. Although it provides a moist substrate for black spruce seed it has one definite drawback: the seed often falls down between the stems and is smothered by the moss itself. Hence, only a fast-growing spruce can outgrow *S. girgensohnii* in its first few years of life.

Table 3. Unsuccessful seedbeds

Area	Year cut	Unsuccessful seedbeds as % of total unstocked plots									
		Slash only	Duff only	Slash and duff	Slash and *Sphagnum*	Slash and other mosses	Bedrock	Flooded	Skidway	*Sphagnum*	Total
Pace Lake	1968	12	3	53	13	13	6				100
Garden Lake	1968-1969			9	38	38	6			9	100
Mile 52-53 Hwy 800	1970		2	17	8	58				14	100
Martin and Verdi Lake	1970-1971	1	3	72	4	13	1	4	1	1	100
Smiley Lake	1972			72		22	3	1	2		100
Fisher Lake	1973	18		72					10		100

Other mosses provide a suitable seedbed but generally only in wet summers; in dry summers they do not hold their moisture during July.

2. Mineral soil: Mineral soil is obtained through heavy scarification. For a period of 2-4 years after scarification, mineral soil is exposed and provides a good seedbed. After this time, duff, needles and small wood particles wash over and cover the exposed soil. The regeneration survey that was used in the preparation of this paper showed much regeneration on duff. In many cases (the survey was taken 2-7 years after scarification) this duff was in the scarification furrows and it is suspected to have washed in during the intervening time.

3. Moist duff: A surprising amount of regeneration was obtained on moist duff. The beauty of narrow strip cutting is that the trees in the uncut strips hold much moisture on the cutover site. In clearcuts this moisture runs off.

Unsuccessful Seedbeds and What to do about Them

1. Slash: Slash is an unavoidable product of the logging process, although the amount of slash varies from operation to operation. In the full tree logging system almost no slash is to be seen, but many cones are lost. With modified harvest cutting there is a tolerable cone loss, but poor utilization.

Slash problems occur in the tree-length and short-wood logging systems. Not only do tops and branches occur on the cutover but much merchantable wood is wasted as well. I think most companies can easily find areas in which 1 to 1½ extra cords per acre (0.4-0.7 cu. m/ha) could easily be gained through better utilization. To the company, better utilization means that fewer roads have to be constructed and overhead is less because fewer moves have to be made. To the black spruce silviculturist higher utilization means less slash and therefore more good seedbeds. Companies in the Thunder Bay area are considering the benefit of better utilization very carefully. It is hoped that the slash problem will be reduced as a result.

The Ontario Ministry of Natural Resources has begun tougher cut inspections. Within the limitations of the Crown Timber Act, Ministry officials are insisting that all merchantable wood be skidded to landings. In the past, because of staff shortages, cut inspections tended to take a back seat, but now that the success of the modified harvest cut depends on good utilization, such inspections are a high priority.

2. Dry duff: With less slash, dry duff will become less of a problem because scarification will be more effective. Even with good utilization, however, slash will still occupy sites which could make good seedbeds.

In the past, we have waited two summers before scarifying. This allows the slash time to rot and gives better scarification results. However, the results would be even more satisfactory if slash were eliminated entirely. The 2-year wait adds to the return time before companies can make a second cut. With the deterioration of roads and the need, on the companies' part, to obtain wood in a reasonable time, this technique is less than desirable. The longer the waiting period the greater the chance of blowdown.

The ideal solution to the problem is to eliminate the slash entirely, and the only way to do this is to burn it. Burning has the added advantage of turning slash into nutrients which leach into the soil in a form that tree roots can absorb. The Whistle Lake black spruce plantation was planted in the fall of 1971 immediately after a fire; in fact, the chicos were still smoking at the time of planting. Some of these trees grew at a rate of over 1½ ft (45.7 cm) per year. Survival on the site was over 90%. Thus, if slash were burnt, subsequent scarification would be many times more effective in promoting good regeneration and the potash resulting from the burning would encourage rapid growth of the new seedlings. Problems connected with controlling the burn are currently being worked out by the Ministry's Forest Protection Branch.

In summary, the modified harvest cut design provides an abundant seed source to cover the cutover area. It also provides three suitable seedbeds which might be lost on clearcuts: moist *Sphagnum*, mineral soil, and moist duff.

The big problem is heavy slash. Greater utilization by the company and vigilance on the part of Ministry officials can reduce the amount of this slash. The ultimate solution to the problem, however, is to eliminate slash by burning it, thereby turning it into potash which helps to grow black spruce. With the elimination of slash, the modified harvest cutting technique becomes a sound viable practice for regenerating black spruce.

OPERATIONAL PROBLEMS OF MODIFIED CUT HARVESTING

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Modified cuts create logging difficulties, but will likely increase yield per acre and reduce costs in the second rotation. Substituting a detailed site—species plan for the present layout method of systematic alternate strips would reduce harvesting difficulties. Modified cuts would be irregularly shaped to conform with forest type and site boundaries.

Les coupes modifiées créent des difficultés d'exploitation, mais elles augmenteront probablement les rendements à l'acre et elles réduiront les coûts lors de la deuxième révolution. En substituant un plan détaillé fondé sur la station et l'essence à l'actuelle méthode systématique par bandes, on pourrait réduire les difficultés lors de la récolte. Les terrains où l'on fait des coupes modifiées pourraient être de forme irrégulière se conformant aux limites des types de peuplement et de station.

Abitibi Paper Company Ltd. has been engaged in a program to develop a modified-cut system as an alternative to the clear-cut method of harvesting timber on its Lakehead freehold and licence areas since 1952. We are indebted to Leo Vidlak, Stan Losee, George Breckenridge and Ken Hearnden for their pioneering research at the Raith Woodlands Laboratory (now Abitibi—Lakehead University Centre for Forest Resource Studies).

I will deal with the Abitibi Provincial District as I have been involved with the modified harvests in this area for the last 9 years. Operational modified cuts were started in 1963 and since that time over 5,000 net acres (2,000 net ha) have been harvested by modifying the cutting pattern (Table 1). This represents close to 10% of our harvest in this period.

The Provincial District is the southern half of timber licence 328000-3. This 1,000-sq.-mile (2,600-sq.-km) area lies from 30 to 80 miles (50-130 km) north of Thunder Bay. We operate from two major camps, 228 and 230, which harvest approximately 100,000 cords (362,500 cu. m)

Table 1. Abitibi Provincial District modified cutting summary, 1963-1975.

Year	Location	Camp	Net area (ha)[a]				
			Alternate strips	Alternate blocks	Seed tree groups	Seed trees	Total
1963	Spruce River Rd, Mile 37-46	228	97				97
1964	Spruce River Rd., Mile 47-54	228	142				142
1964	Hosking Lake Rd	228	36				36
1966	Spruce River Rd, Mile 28-36	228		121			121
1967	Verdi Lake Rd	228		112			112
1967	Garden Lake Rd	230	20				20
1968	Michael Lake	230				34	34
1968	Taurus Lake	228				14	14
1968	Pace Lake	228	70				70
1969	Spruce River Rd, Mile 67-72	230		81			81
1969	Martin Lake	228		97			97
1970	Martin Lake	228	81				81
1970	Whistle Lake	230				142	142
1972	Hosking Lake Rd (2nd cut)	228				40	40
1972	Mott Lake Rd	228	57				57
1973	Fisher Lake	230	29				29
1973	McGaughey Lake	228	34				34
1973/74	Mott Lake Rd	228	154		101		255
1973	Smiley Lake	228			38		38
1973	Spender Lake	230			109		109
1973	Garden Lake Rd	230	109				109
1974/75	Mott Lake Rd	228	195		15		210
1975	Garden Lake Rd (2nd cut)	230	20				20
1975	Adderley Lake Rd	228	153				153
	TOTAL		1,197	411	263	230	2,101
1975	Not completed (owing to mill strike)	228	66				
1975	Not completed (owing to mill strike)	230	95				

[a] 1 ha = 2.47 acres

by the conventional cut and skid method to mobile slashers, and 35,000 cords (127,000 cu. m) per year by Koehring harvesters.

The predominant cover type is composed of a mixture of white spruce (*Picea glauca* [Moench] Voss), black spruce (*Picea mariana* [Mill.] B.S.P.), balsam fir (*Abies balsamea* [L.] Mill.), white birch (*Betula papyrifera* Marsh.), and trembling aspen (*Populus tremuloides* Michx.). The secondary cover type is composed of black spruce and jack pine (*Pinus banksiana* Lamb.) stands or mixtures of these two species.

As a result of severe ice action during the last glacial period, most of the area is covered with thin, glacial tills often only a few inches to 1 foot (0.3 m) thick. Bedrock exposures are frequent and swamps or poorly drained areas are small and scattered. The topography of the area is characterized by low, gently rolling hills and by rocky ridge systems situated in parallel rows and oriented northeast to southwest.

Our major forest cover type is normally found on sites with deeper soils. Most of this area is site prepared by scarifying or burning after harvesting, and planted to spruce. Hardwood residuals, advance growth, and poor accessibility prevent complete treatment.

The secondary cover type of black spruce and jack pine is normally found on the poorer, shallower sites and is the area with which I shall be concerned in this presentation. These mature, fire-origin stands 80-110 years old yield an average of 18 cunits per acre (190 cu. m per ha).

Untreated clear cutovers of this type normally produce unsatisfactory stocking of patchy jack pine and some black spruce near residual seed sources. As these cutovers cannot be successfully planted with conventional stock owing to a lack of soil depth and extreme microclimate conditions, preharvest planning must be done. As early as 1968 our 5-year operating plans designated all the major areas that should undergo modified harvesting within that plan period.

Our modified cuts have been of several types: alternate strips from 1 to 4 chains (20-80 m) wide, alternate blocks of 5 to 15 acres (2-6 ha) residual seed trees and seed tree groups.

The following operational difficulties have been encountered as a result of modifying the cut rather than clear cutting:

1. increased road cost
2. restricted operating flexibility
3. extra moving of equipment and service buildings
4. restricted species separation

5. increased layout and planning cost

6. increased blowdown, resulting in increased operating cost

7. lower yield per acre owing to (a) blowdown (b) residual seed patches

8. extra cost of returning for a small volume of wood on second cut.

These operating difficulties are counterbalanced by the following beneficial gains:

1. black spruce regeneration stocking and growth are improved;

2. the limit is made accessible sooner;

3. slash fuel is broken up for easier fire control;

4. the scenic value of the area and the uses to which it can be put are increased;

5. the wildlife habitat is improved.

As previous speakers have probably sold you on the good points of modified cuts, let me expand on the operational difficulties I mentioned previously.

Any increased cost represents a difficulty and conversely any added difficulty results in increased cost (Table 2).

Increased Road Cost

If we harvest only half of the stand volume in an area, we will have to build twice as much road now. When we make the second cut we won't have to construct any road. Therefore, the extra cost involved would be the interest on half of the road cost for 5-10 years when we are able to reap the full benefits of the road. With today's high inflation, this cost is partially offset. So far we have not been able to recover any interest cost from the Ontario Ministry of Natural Resources.

The other road costs are due to increased maintenance. While we are harvesting the first cut, we are maintaining twice as much road as in a clearcut for the same volume. When we return for the second cut the same holds true, and in addition we have to repair culverts, bridges and washouts and regrade the roads. In the case of winter roads the costs are greater because the time spent getting frost into the ground, snow-ploughing and sanding applies to one cut only.

Table 2. Additional costs resulting from modified cutting at Camp 228, 1975 regeneration agreement.[a]

Layout @ 4 ha per man day	11 x \$74 =	\$ 814.00
Board loss @ \$11 per man day	11 x \$11 =	121.00
Transportation for layout crew	90 x \$.30 =	27.00
Flagging tape 22 rolls @ \$1.25 =		28.00
Road maintenance @ \$492 per km	2.4 km x \$492 x ½ =	590.00
Additional Koehring moves	10 x \$52.50 =	525.00
		\$2,105.00
Cost per ha		\$46.78
Cost per acre		\$19.14

[a] Alternate strips, Block D, 45 net ha (110 acres)
Cutting method: Koehring harvesters

Restricted Operational Flexibility

This refers to the constraints of a cutting area limited in size. In the case of narrow strips, more time is spent making the initial trails to the back of the strip through solid timber, thereby reducing cutter or harvester efficiency. Normally, the cutting is performed by working along a timber face, falling the trees into the open cutover for limbing and skidding--or for processing, in the case of Koehring harvesters.

On uneven ground, another problem arises. The machines must stay within the cut strip, which is not always the quickest or best route out to roadside.

Soft ground conditions present similar problems. Restricted travel routes and restricted maneuvering room result in more lost time and more difficulties for the assist machine.

Because of the restricted travel routes, we often have to leave parts of strips to be cleaned up in the winter. This adds to our wood cost because we have to build more gravel roads and return for a small volume of wood.

Extra Moving of Equipment and Service Buildings

With alternate strips or blocks, moving within the area will be twice as far or twice as often as with clear cutting. Supervisors will also have to travel more to control their men and equipment.

Restricted Species Separation

On the Koehring Harvester alternate strip operation we separate black spruce from jack pine. The strips are laid out systematically, thereby crossing type and site boundaries. The harvesters have to follow a straight line because of the limited maneuvering room, cutting all trees in their pass. On a clearcut the harvesters can harvest pure types and in the mixed types they can pick out patches or individual trees of one species for each load.

Our newsprint mills require pure species separation so that they can meter in the 10%-15% maximum amount of jack pine in their furnish.

Increased Layout and Planning Cost

Extra planning time is required to keep the operational constraints to a minimum, to limit blowdown, to provide good seeding, etc. Marking the strips with flagging tape or paint so that they can be easily identified, day or night, is an expensive but necessary procedure.

Increased Blowdown

I don't know of any blowdown volume studies in our area. From my observations, I would estimate that in mature spruce-pine stands we average 1% blowdown per year. By leaving alternate blocks we would increase this blowdown to 2%, while on alternate strips blowdown would reach 3% per year. Residual seed patches and seed trees lead very precarious lives, often standing no more than a few years. We have some bad blowdown belts in the Camp 230 area where we have lost up to 30,000 cords (109,000 cu. m) in a day. Blowdown timber is very difficult to harvest, costing $5.00 to $10.00 per cord ($1.38-$2.76 per cu. m) extra as well as reducing the value of the tree.

Lower Yield per Acre

Most of the blowdown occurs in the first or second year after cutting. By the time we make our second cut 6 to 10 years later this blowdown wood is rotten. Residual patches left for seed amount to about ½ cord per acre (4.5 cu. m per ha) or 2% of total volume.

The overall volume loss on alternate strip cuts and residual seed tree groups would amount to 10% per acre for this rotation and could be much more in some areas.

Extra Cost of Returning for a Small Volume of Wood in Second Cut

Most of our modified cuts are from 2,000 to 5,000 cords (7,250-18,100 cu. m) in size. With our present mechanized operation, we would consider areas of less than 10,000 cords (36,200 cu. m) to be economically undesirable. We would have to split our operation into several areas, and this would result in more travelling time and less efficiency.

By now you may have the impression that I am against modified cuts. This is not so, but I do believe we can improve our methods and layouts to make them more acceptable to industry and accomplish their stated function more effectively.

The following are some of the problems we must solve in alternate strip and block cuts.

1. We have no entirely satisfactory method of regenerating the leave strip or block.

2. We have been treating for average area conditions and not for individual sites and types.

3. Straight lines are ugly and unnatural in nature--beauty is in the curve.

4. Species separation--this is a serious problem for us at the present time.

5. We must give more consideration to wildlife habitat.

6. We must plan the management of lakeshore reserves.

Some of these problems can be solved by more intensive planning. We must study the area and map out sites and species on these types in detail (Fig. 1). (In our area, the sites are mainly narrow [1 to 5 chains, or 20 to 100 m, wide] but long [5-100 chains, or 100-2,000 m]). We must then pick the sites that present the most serious problems: black spruce swamps and very rocky black spruce uplands.

These are the areas we must cut on the first cut (Fig. 2). If the types are too large for seeding, we will have to leave seed blocks--preferably 1 acre (0.40 ha) or more--within them. These seed blocks can be harvested in the second cut. The best skid routes can be utilized through the 'leave areas'. The second cut will be on the remainder--the spruce—jack pine mixed and pure pine types usually growing on patches of soil between the bedrock. These areas will be seeded from the jack pine cones in the slash and could be sweetened up with some planted spruce. At present our strips mostly cross topographic and species—type boundaries (Fig. 3). This makes scarifying difficult as we are dragging over bare rock one minute and getting stuck in swamps the next, instead of simply scarifying the area in between as we should be doing.

Harvesting season is also an important factor in reducing site deterioration. The first cut should be in winter as a rule, and the second in summer or in winter.

As a trapper I am very concerned with our lake and river shoreline reserves. Beaver require poplar or birch close to the water courses,

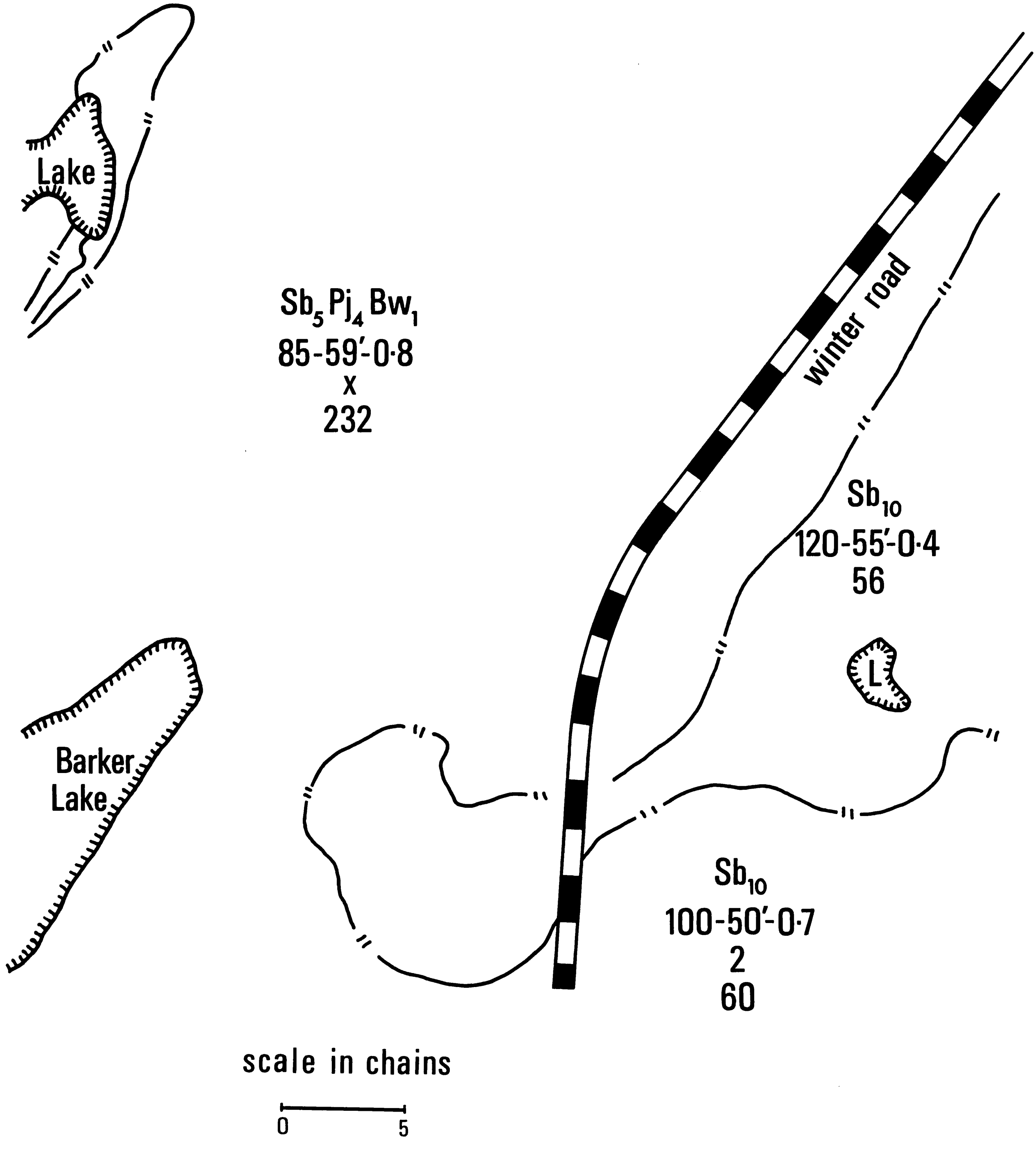

Fig. 1a. Inventory typing.

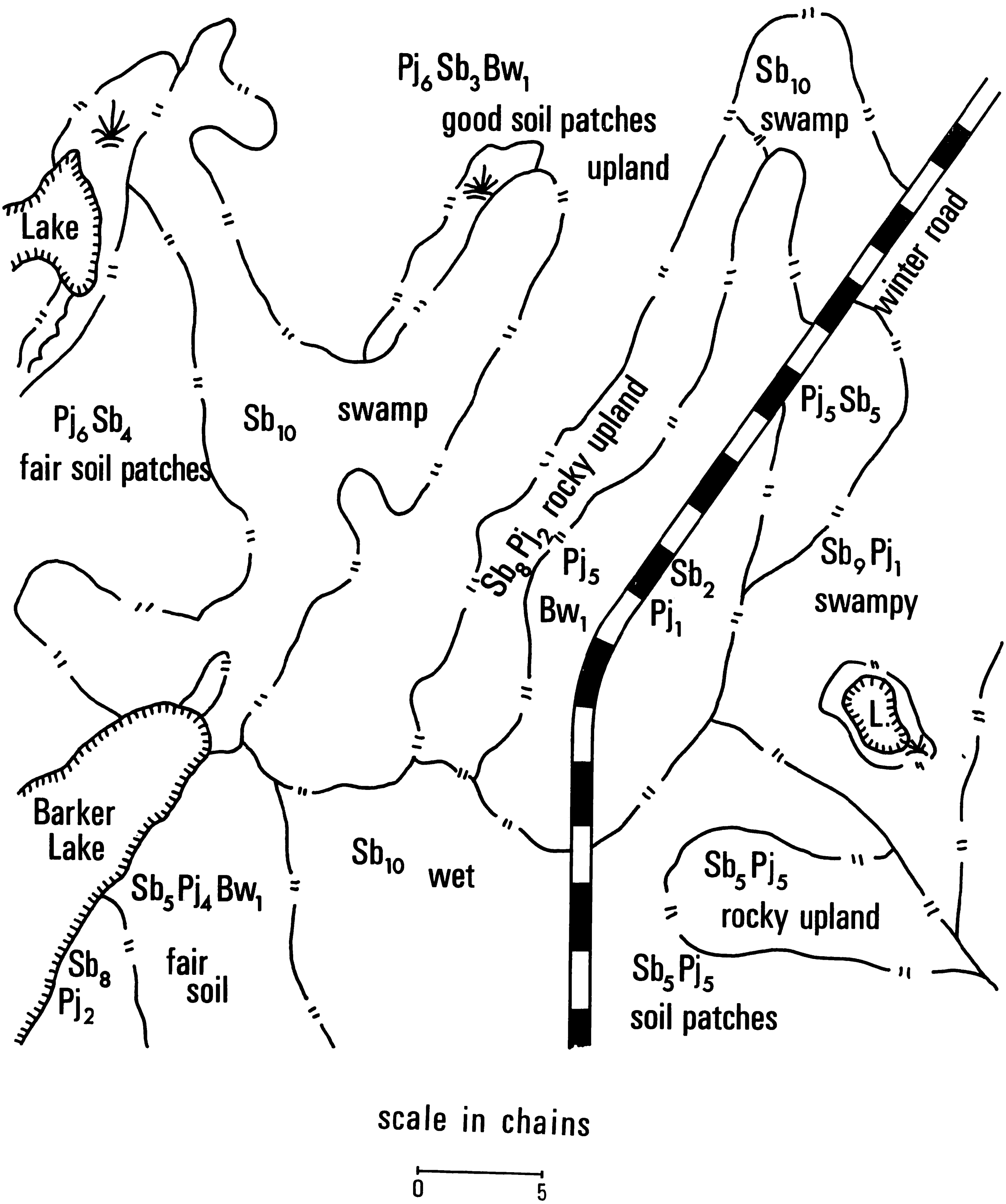

Fig. 1b. Detailed typing

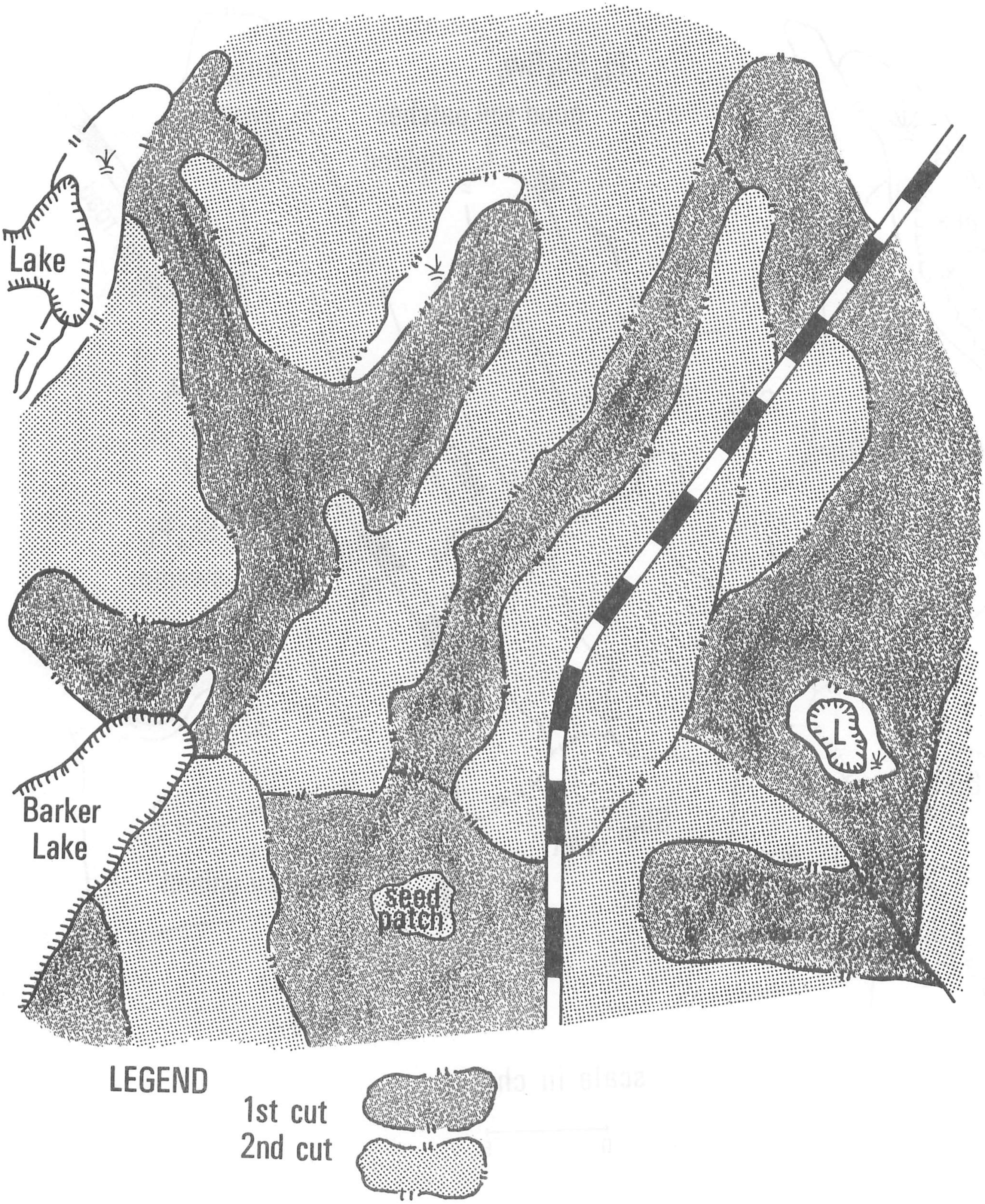

Fig. 2. Peacock's modified cut layout.

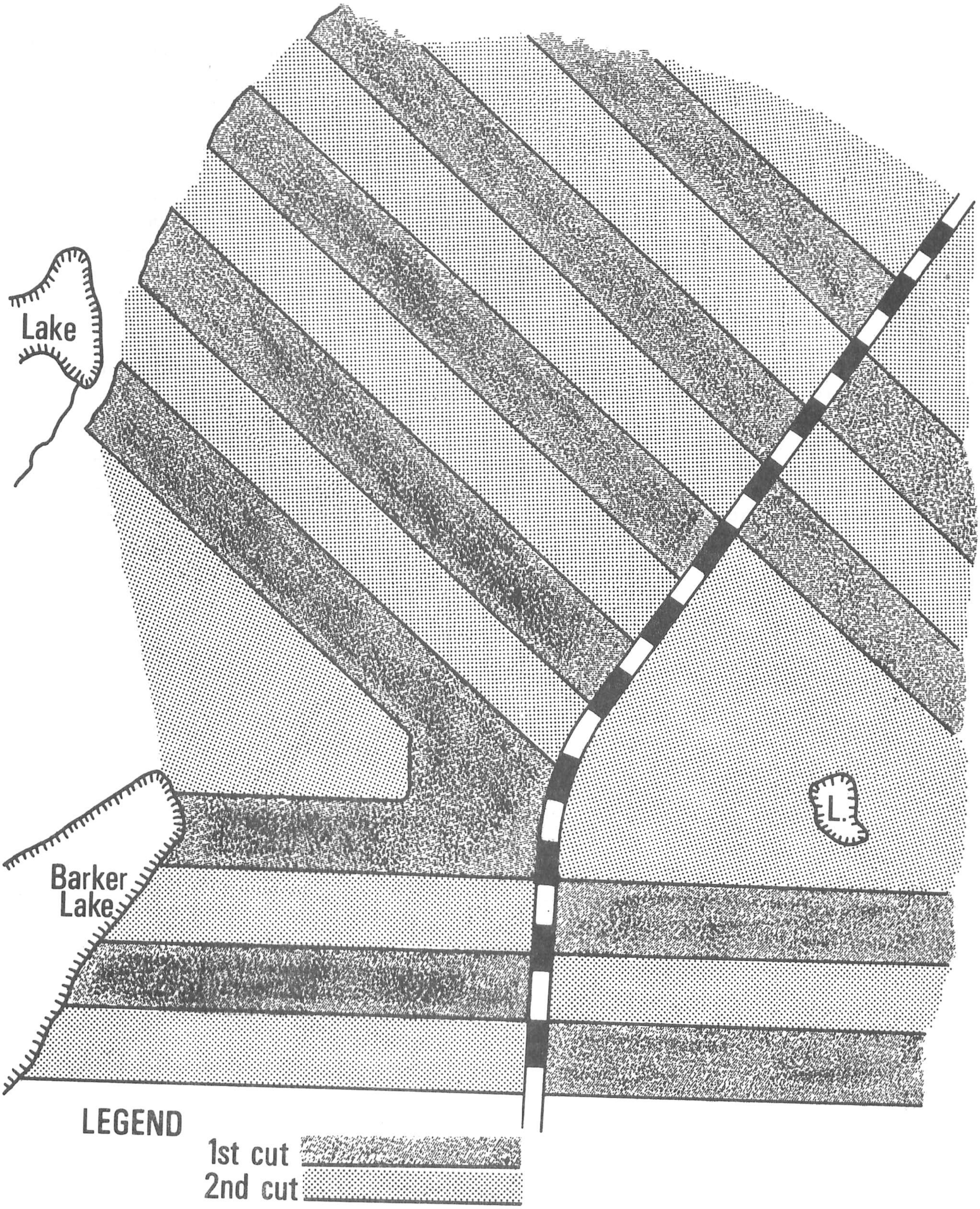

Fig. 3. Alternate strip cut, February 1975.

usually within 150 ft (46 m). In this area the hardwoods are drying out or have been utilized already by the beavers. These hardwoods are being replaced by balsam fir and spruce. Thus, the beaver population is decreasing owing to a lack of proper food. Modified cutting right to the lake or river bank will permit new growth of both hardwoods and softwoods.

From the company's viewpoint, these shore reserves are lost volume in most cases. The only time we can economically harvest this timber, or parts of it, is when we are cutting the adjacent area. Surely it is poor management to leave mature and overmature timbered shorelines as we are doing now. Modified cutting could improve the area for camping, hunting, berry picking, etc., for years to come.

I would like to point out to those of you who believe modified cuts should be performed on all our spruce cutting areas, regardless of soil condition, that areas which can be clear cut and planted will gain from 5 to 15 years on rotation time over the two-cut modified harvest system, which depends on natural seeding. I believe that planting will also permit more mechanization in the second rotation owing to the even age, size and spacing of trees.

DISCUSSION

STANEK

What is modified cutting? What are you modifying?

MAREK

To me, modified cutting means small-area clearcut management as opposed to uncontrolled large clearcuts. It can mean any change in normal commercial clearcutting such as strip cuts, seed tree system, shelterwood or selection.

STANEK

But wouldn't it be much better to say it's a strip cut, block cut, or whatever you do, rather than say modified cutting? Eventually this becomes confusing.

MAREK

It's definitely confusing right now. You are right; it would be better to define the type of cut.

HAAVISTO

Mr. McClain, you've shown that planting early in the year is better than planting later on. Your first planting date was May 26. Is there such a thing as planting too early?

McCLAIN

If the tree can be placed in the soil and it subsequently lives, and if survival is the only criterion for success, you can't plant too early. However, if current annual increment is to be considered, you *can* plant too early, as is evident from the depressed growth for the May 26 planting in comparison with that for the June 3 planting.

HAAVISTO

But physically there is nothing that says it's going to be detrimental to later growth. Something like planting early in May.

McCLAIN

From one of the slides I showed earlier of height growth increment, you may recall for the first planting on May 26 current annual height increment showed a slight depression relative to the second planting, which was the first planting in June, so perhaps May 26 during that year was a little early. Frost at this time of year is not uncommon in the Dog River area, and may have contributed to depressed growth.

KETCHESON

Mr. Auld, have you compared fire and drag scarification in terms of cost?

AULD

We can do a prescribed burn for less than $10 an acre, but scarification now costs $25 or $30 an acre. Another advantage of using fire, as opposed to mechanical means, is that you can cover both wet ground and areas where a lot of material has been left on the ground. You can go through that with fire whereas it's more difficult with mechanical scarification. I would like to see fire used on modified-harvest cut strips to get rid of the slash and I would like to try a combination of fire and scarification so that I could mix the potash into the soil. I don't think the duff layer or the organic layer will burn with the slash to any great degree (except in the very hottest of fires) and if subsequent scarification mixes them I think you will provide an excellent seedbed.

MORGENSTERN

Mr. McClain, the planting date is not defined very specifically, and previous speakers showed there's a great deal of variation in planting stock between different nurseries, different years, etc. Have you additional information on the stock used in terms of shoot:root ratio, root growth, and so on? I think more specific data are required to indicate the condition of the planting stock.

McCLAIN

I haven't. This project was started to develop methodology and to get an insight into existing basic relationships. These data showed there were interesting relationships which should be elucidated. This year we started a very extensive all-summer planting program where we were planting, at 2-week intervals, freshly lifted 1½+1½ and 2+0 stock, and spring-lifted and stored 1½+1½ and 3+0 stock. Paralleling this major planting program, we're also looking at root regeneration over a 4-week period after planting, and specific root-regeneration patterns do exist for each of the stock types. We must determine what these are so that each stock type can be finely tuned to site and time of planting to coincide with the active periods of root growth.

JOHNSTON

Mr. McClain, why did the 2+0 stock grow better than the 3+0?

McCLAIN

My theory is that as 2-year-old seedling black spruce stock enters its third growing season in the nursery a disproportionate growth pattern seems to develop. At the Thunder Bay Nursery, these patterns are such that we have very active and very extensive top growth of the stock, but for some reason or other the root systems do not show comparable growth. Consequently, the top:root ratio is out of balance, unlike the 2+0 stock which has a very good top:root ratio. I feel that the root is more in tune with the top and vice versa. So, 2+0 stock when planted, becomes established and more vigorous than 3+0 stock, which has to develop adventitious roots before it continues to develop.

HAIG

Mr. Auld, you had excellent and interesting observations on, and reasons for, the success or failure on quite a few strip cuts. As you didn't give any figures on percentage of success I presume there were none available. Wouldn't that large block of strip cuts with carefully recorded history represent an excellent opportunity to assess what happened on them?

AULD

I did an extensive survey prior to writing my paper but didn't include the data here because I've been bored by too much data at previous symposia. The survey data indicated that regeneration wasn't an overwhelming success, but there was hope because we used the right technique. There were places where there was only 30% to 35% successful regeneration 6 to 7 years after harvesting. I attribute this mostly to slash and poor scarification. There were areas with 100% stocking, and others with 60% to 80% stocking. In one particular block surveyed a few years ago we were down around the 30% level, but this year, five growing seasons later, we're up around 65% to 70%. We've had quite an increase in stocking in the last few years, which says something for leaving the strips for a longer period if you can keep them standing.

STARR

Mr. Auld, could you comment on Peacock's problems of getting the strip cuts done? What would be the Ministry's attitude to cost, if the benefits you derive require more adequate compensation?

AULD

When you negotiate with a company on extra costs you're in a very poor negotiating position if you don't know anything about them. To negotiate more intelligently with companies, we've been doing time studies on the extra cost items submitted to us. We then negotiate on the basis of our time studies, encourage the company to do the same, and usually arrive at a reasonable figure. Peacock has suggested we cut the strips in a different manner and we're going to work on that this coming year in the Mile 43 area where the terrain is extremely difficult. We're going to try to run the strips (there might be a two- or three-cut system) along the terrain and cut the high land first, because that's where the most blowdown is, and then cut the midslopes and swamps at a different time. As for cost and its ramifications, we're trying everything under the sun to obtain regeneration at a reasonable cost.

SKEATES

Mr. Hearnden started the discussion on Tuesday on an interesting note pointing out some major problems in forestry, most of which tend to be social and political rather than technical. We then proceeded to discuss technical problems for two days. Quite a glimmer has come through this morning, and it's very encouraging that we have some company and government cooperation on regeneration problems. Obviously this is the successful result of confidence being built up between individuals. I'd like to see more discussion on the policy that encourages this type of cooperation.

DAI

Mr. Auld, you say you have extensive surveys of strip cutting. I hope these data will be available to the public. You have strip cutting planned in this upland area--surface erosion here is very important! Do you plan a regular layout of the strips or will they follow the topography?

AULD

In the first place, most of our information is collected for record-keeping purposes. It hasn't been our habit to publish a great deal of it although anyone is welcome to look at it. Perhaps it would be a good idea to publish and advertise our work to a greater degree. Foresters are not very good propaganda men. In the second place, next year in the Mile 43 area we are going to locate the strips along the pattern of the ground rather than across it. Whether this will be the best technique silviculturally remains to be seen.

F.C. ROBINSON

There's been a lot of talk of blowdown. There's been a lot of talk of organizing the strips in relation to cost, topography, etc., but I really haven't heard anybody say how he's organizing the strips to *prevent* blowdown. Is advantage being taken of natural wind-firm edges? I understand that Northwestern Pulp and Power in Alberta had a lot of trouble with blowdown, and they're starting to get fairly good success now with better organization and layout of their strips. Maybe somebody would talk about that.

MAREK

That's a problem we won't solve until we get more brains and understanding from our bureaucrats. We were in this dilemma for many years and let me point out one very important thing. Behind all this talk about modified cutting small-area clearcut management, better ecological approach, better regeneration, etc., is the whole problem of the philosophy of proper forest management. If the Ministry and the companies in Ontario are going to have, for a change, good black spruce regeneration (I'm challenging anybody to claim that we do have good black spruce regeneration) we have to decide how to develop this area, and here comes the plan. It will require that people with brains get together and say: Could I strip cut 10 acres, 15 acres, 100 acres, 500 acres, 2,000 acres and, in Domtar's case, probably 2,500 to 2,600 acres annually? Our experience has shown that if you start pushing the issue with the company and say, all of a sudden, "Tomorrow you must strip cut 150 acres here", you're going to wind up in an awful mess. I went through this. You're going to have blowdown, you're going to have improper layout, you're going to have people running like chickens, cursing each other, putting the blame on each other and so on. And Domtar is a good example of it, because we did it. And we learned from it. When Domtar began to understand regeneration of black spruce, and were willing to have regeneration of black spruce, we marked out these areas in advance and said, "Here are the large areas which have to be modified; plan your whole operation in such a way that you will get the least blowdown, have the fewest problems and you will have planned this whole thing much better." I said at the beginning that we haven't got backing on this philosophy. No, we don't have it because we haven't a policy on modified cutting yet. I'd like to challenge our Directors, Executive Directors, Assistant Executive Directors, Deputy Directors--I don't know who else--these are the people to whom we are subordinate. I have a relationship with Domtar which is excellent. Sure we have our squabbles. We can solve our problems, but my problem is the Ministry.

SWAN

This spring I had the pleasure of making a tour with 25 company, provincial and federal foresters of the southeastern United States. They don't fool around relying on natural regeneration. They have decided it is important to grow wood and to grow it as fast as possible. They do a first class job of site preparation. They clear off everything after the harvest. In most cases they do a double pass with double-disc cultivators. Then they use bedding plows and they leave an area that is almost like a wheat field ready for planting. Then they plant genetically improved stock, and aim for extremely high productivity, 6 cords per acre per annum on some of their better sites. And I ask why we don't try the same approach in Ontario and in Canada. I understand that Heeney was much enthused by what he saw in the southeast and he told me he was hopeful of getting the same sort of thing going in Ontario in several places.

It seems to me it would make a great deal of sense to take some of our better sites and do a first class job of site preparation, a first class job of planting, and then consider the total cost concept. In other words, the cost not only of the planting, but also, after 35 or 40 years, the cost of the harvesting operations. It is much easier, less expensive, more efficient, to harvest trees planted at uniform spacing in rows than to harvest trees dotted all over the place. I suggest this should be done on several thousand acres to see what we could achieve in this way.

MAREK

This is a good challenge. However, let me warn you that thousands and millions of acres of the boreal forest are just not suitable for this approach.

SWAN

I agree with that completely. We have to use the easy sites.

MAREK

I go back to Armson's statement yesterday: "Make up your mind what you're going to do here, what you're going to do there." There are isolated areas where we can grow timber just as they do in the southeastern United States, just as Irving does. Why don't we go with that? I'm all for it. However, for heaven's sake, don't come to me and ask me, if on the pile of rock in the area you saw yesterday I will use the methods which are appropriate in Georgia, Alabama, or I don't know where. That is a different ecosystem, that is a different material with its own problems. For years people were telling us in northwestern Ontario that we should adopt methods used in southern Ontario for red pine, white pine, and I can show you the results. It's time we realized the true potential of the land base and made a wise decision for intensive management or extensive management, but for heaven's sake, before you do that, look at the land base and know something about it.

SWAN

Is it not true that quite a big percentage of our land in Ontario, perhaps 20%, could be dealt with by this intensive forest management method?

MAREK

I agree.

SWAN

I'm sure that on that 20% we would surprise ourselves by the amount of wood that we could grow--probably 200 cu. ft per acre per annum.

MAREK

I agree. But for heaven's sake allocate this very carefully.

SWAN

Also, I'm sure that people who are spending their own money growing trees (such as Irving in New Brunswick) wouldn't dream of relying on such a chancy system as strip cutting or natural regeneration or even direct seeding. Irving is interested in getting results. He is interested in getting 60 cords per acre at 35 years, and goes ahead and does a first class job of planting.

AULD

Where did you get your information that modified strip cutting is chancy?

SWAN

You quoted figures that represent what I regard as very unsatisfactory stocking: 40%. You're quite proud of 70%. Irving is not satisfied unless he gets 90% and the foreman responsible for planting who gets less than 90% is in trouble with Irving. Seventy percent is not good enough. Why waste your land, why increase your harvesting costs later on for 70%? Also, in direct seeding, people were talking about the best results obtained with direct seeding, about 40%, yet [F.C.] Robinson told us 40% was unacceptable. The average result of direct seeding was about 25% if I remember rightly. Twenty-five percent stocking is obviously not acceptable. I can't see why, in this day and age with the value of wood rising and about to rise rapidly (wood is becoming a scarce and valuable commodity), we go on fooling around with these obsolete and chancy techniques when we could be doing a thorough job of planting our best sites.

HAAVISTO

If we're going to culture our areas this way, it's going to cost money. Where's that money going to come from? Also, if the areas you speak about have such a potential why don't they plant potatoes and get the same return on an annual basis that you expect in 40 years from trees?

SWAN

First I'd like to mention cost. The companies we visited down south were very free about giving us information, and you'd be surprised how little it cost them to site-prepare and plant an acre. Their costs were running around $40 to $50 on site preparation, and about $40 to $50 on planting, so they finished up with a prepared and planted area at around $100 to $120/acre. I think that compares quite favorably with some of our planting costs in Ontario. Where's the money going to come from? It seems to me we have to take a more realistic view of this thing and realize that those who benefit from the utilization of the forest should pay for its renewal. In Canada, who benefits? The federal government takes almost 50% of the profits, the provincial government takes a big whack from stumpage, ground rents, etc., and of course there are wood-using industries. What we should do is work out a formula by which the costs will be shared by the federal government, provincial government, and industry, and then go ahead on that basis. It is not all that expensive. When you take into account the total cost, the shortened rotations, the higher productivity, and the lower harvesting cost, it will make a great deal of good sense to do the job properly.

SKEATES

Dr. Swan talked about chancy operations. We have average figures for survival of plantations in Ontario somewhere in the neighborhood of 60%. This is not very far off natural regeneration figures. It boils down to policy. Are we taking this seriously? Are we going to spend the money to do the job that is necessary? Who is going to do it? Who can do it better? Who can develop it? Is this a government or an industry function? Is cooperation or legislation needed?

CLASSIFICATION OF SWAMP FOR FORESTRY PURPOSES

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Great Lakes Forest Research Centre
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A wetland classification system proposed by Jeglum et al. (1974) for the Northern Clay Section of the boreal forest in Ontario is outlined. Essentially a descriptive system based on vegetation (the most important feature of wetlands), it could be modified by inclusion of various abiotic features as more information on ecological relationships becomes available.

Notes sur un système de classification des stations très humides, proposé par Jeglum et al. (1974), sises dans la partie ontarienne de la section des Argiles du Nord, région forestière boreale. Essentiellement un système descriptif fondé sur la végêtation (la composante la plus importante de ces stations très humides), il pourrait être modifié par l'addition de divers facteurs abiotiques à mesure que l'on en saura plus sur les relations écologiques.

Two of my colleagues and I have recently proposed a wetland classification for the Northern Clay Section of the boreal forest in Ontario (Jeglum et al. 1974). This section is overlain by clays deposited in glacial Lakes Barlow—Ojibway. The relief is moderately broken, and includes extensive areas with slightly sloping to flat surfaces. It has been estimated that 51% of the land area is covered with peatland, peats being relatively shallow to moderately deep (Ketcheson and Jeglum 1972). Merchantable black spruce (*Picea mariana* [Mill.] B.S.P.)-dominated forests occupy 84% of the productive forest area of the section, and about half of the merchantable black spruce grows on swamp sites (ibid.).

The classification was intended primarily for forest managers; hence it focused on the swamp segment of black spruce forests. If it was to be useful to foresters, it required units that would (i) be relatively easy to recognize in the field, (ii) relate to differences in tree growth, (iii) relate to differences in regeneration, and (iv) be interpretable from air photos. It was also desired that the classification complement and augment work done on wetland classification by a Canadian study group (Zoltai et al. 1974).

In the work we have done in Ontario (Jeglum et al. 1974), physiognomy and dominance of vegetation were stressed because we felt that these would best satisfy the purposes (i-iv above) of the classification. In the proposed classification, wetlands are first divided into four 'formations': bog, fen, marsh, and swamp. Brief definitions of these have been appended to this paper (Appendix A). These are the same units as those proposed by the above-mentioned Canadian study group on wetland classification. The formations are further divided successively into subformations, physiognomic groups, dominance types, and site types (ibid.).

Since the main emphasis of forestry operations in Canada is on land which supports merchantable forests we shall bypass marsh, fen and bog, and focus on swamps. Table 1 shows the breakdown of swamp into physiognomic groups, dominance types and site types. (Subformations were not recognized for the swamp formation. Also, site types are given only for the Black Spruce dominance type.)

Table 1. Classification of the swamp formation (1)[a] into physiognomic groups (3), dominance types (4) and site types (5). (Subformations (2) were not recognized for the swamp formation, and site types are given only for the Black Spruce dominance type.)

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1 - Swamp

- 3 - Thicket swamp
- 3 - Hardwood swamp
- 3 - Conifer swamp
    - 4 - Tamarack (*Larix laricina* [Du Roi] K. Koch)
    - 4 - Eastern White Cedar (*Thuja occidentalis* L.)
    - 4 - Black Spruce
        - 5 - Black Spruce/Feather Moss
        - 5 - Black Spruce/Speckled Alder
        - 5 - Black Spruce/Sphagnum
        - 5 - Black Spruce/Labrador-tea

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[a] Site index for each plant was determined by obtaining total heights and ages (at stump height) for three dominant black spruce, and converting the means of these values to height at age 50 using Plonski's (1956) height—age curves.

I will now concentrate on Black Spruce swamp site types. For comparison I will include a composite type, Black Spruce on mineral soils, and two treed bog site types. The site types of swamp and treed bog were recognized on the basis of species that dominated the understory. This served to satisfy criterion (i) of the classification, i.e., that types be easily identifiable by foresters in the field. Figure 1 is an example of Black Spruce/Feather Moss[1] swamp. It is often located adjacent to and downslope from mineral soil upland, and is the driest swamp type, at least in the moss layer. This type is actually a mix of Schreber's Feather Moss (*Pleurozium schreberi* [Brid.] Mitt.) which is the dominant moss, and Sphagnum. Usually the type is on distinct slopes. Figure 2 illustrates Black Spruce/Sphagnum (often *S. girgensohnii* Russ.) swamp. This type is one in which Sphagnum is dominant, but some Schreber's Feather Moss may be present. Usually the type occurs on relatively flat sites with dense tree canopy cover. Figure 3 shows Black Spruce/Speckled Alder (*Alnus rugosa* [Du Roi] Spreng.) swamp. This type is located where there is subsurface seepage of groundwaters. Figure 4 shows Black Spruce/Labrador-tea (*Ledum groenlandicum* Oeder) swamp, located where drainage is poorer than it is for the Speckled Alder type. Figure 5 is Black Spruce/Leather-leaf (*Chamaedaphne calyculata* [L.] Moench) (with *S. fuscum* [Schimp.] Klinggr.) treed bog. Finally, Figure 6 illustrates Black Spruce/Few-seeded Sedge (*Carex oligosperma* Michx.) (with *S. recurvum* P.-Beauv. treed bog).

To aid the manager in the recognition of Black Spruce-dominated types of swamp and treed bog, I have appended a key (Appendix B). I believe that most of these site types are found quite commonly throughout the province, and would encourage foresters to recognize and use them in the description and treatment of swamps. I would like to know whether or not these units are useful to working foresters, and if not, how they may be improved.

Criterion (ii) required that the units relate to tree growth. Table 2 shows mean site indices (height at 50 years) for some of the site types, with a ranking from highest to lowest, as follows: 1 - Black Spruce on upland, 2 - Black Spruce/Feather Moss swamp, 3 - Black Spruce/Speckled Alder swamp, 4 - Black Spruce/Sphagnum swamp, 5 - Black Spruce/Labrador-tea swamp, 6 - Black Spruce/Leather-leaf treed bog, and 7 - Black Spruce/Few-seeded Sedge treed bog. It is apparent from the ranges of values that there is considerable overlap of site indices, particularly among the upland and swamp site types.

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[1] Several species of mosses, often with feather-like appearance, occur in the ground layer of upland coniferous forests, swamps and bogs. Included are *Dicranum* Hedw. spp., *Hylocomium splendens* (Hedw.) BSG, *Pleurozium schreberi* and *Ptilium crista-castrensis* (Hedw.) De Not.

Fig. 1. Black Spruce/Feather Moss swamp. The darker colored moss is the feather moss *Pleurozium schreberi*.

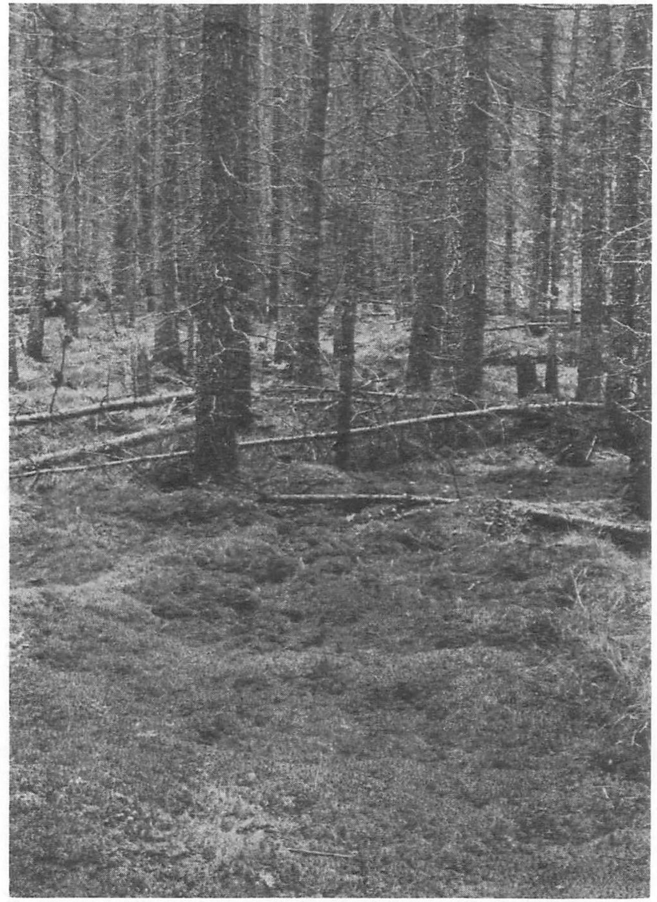

Fig. 2. Black Spruce/Sphagnum swamp. *Sphagnum girgensohnii* is the dominant moss.

Fig. 3. Black Spruce/Speckled Alder swamp.

Fig. 4. Black Spruce/Labrador-tea swamp.

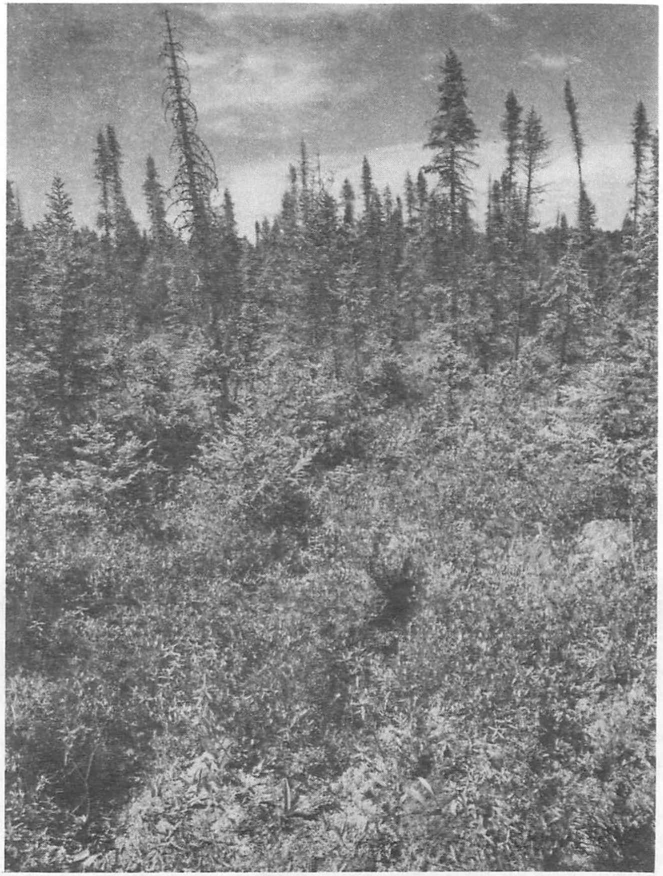

Fig. 5. Black Spruce/Leather-leaf treed bog. *Sphagnum fuscum* is the dominant moss.

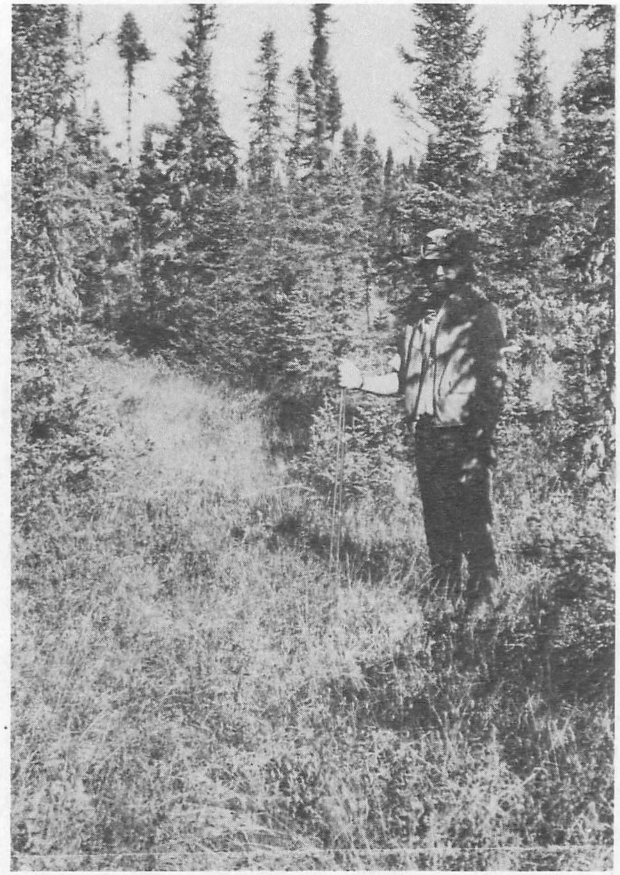

Fig. 6. Black Spruce/Few-seeded Sedge treed bog. *Sphagnum recurvum* is the dominant moss.

Table 2. Site indices for Black Spruce site types, Northern Clay Section, Ontario.

Site type	Site index (m at 50 yr)[a] Mean	Range	No. of plots[b]
Upland			
Black Spruce on mineral upland	10.5	7.9-13.7	24
Swamp			
Black Spruce/ Feather Moss	8.3	7.0-12.3	12
Black Spruce/ Speckled Alder	7.8	3.9-10.1	21
Black Spruce/ Sphagnum	7.4	3.4-11.6	16
Black Spruce/ Labrador-tea	6.2	1.4-11.5	63
Treed Bog			
Black Spruce/ Leather-leaf	3.1	0.9-5.4	41
Black Spruce/ Few-seeded Sedge	2.9	0.9-4.8	3

[a] Site index for each plant was determined by obtaining total heights and ages (at stump height) for three dominant black spruce, and converting the means of these values to height at age 50 using Plonski's (1956) height—age curves.

[b] 'Plots' varied in size from 2 m x 2 m to 0.04 ha.

How does the classification of site types satisfy criterion (iii)? The results of a recent survey[2] suggest that natural black spruce regeneration is inversely related to productivity, the poorest regeneration being on the most productive sites, the best regeneration on the least productive sites (Table 3). For other species the trend is reversed. (Data were not obtained for the Feather Moss, Sphagnum, or Few-seeded Sedge site types.)

Table 4 relates regeneration to the two major seedbeds. The low regeneration on productive sites is related to high cover of Feather Moss, a dry seedbed. Conversely, the high regeneration on nonproductive sites is related to high cover of Sphagnum, a moist seedbed which is favorable to both seedlings and layerings (Stanek 1968). It is noted that the four swamp site types are based on major seedbed types (Feather Moss, Sphagnum) as well as on the chief competitors or inhibitors influencing seedling establishment, survival, and growth (Speckled Alder; Labrador-tea; fast-growing, loosely compacted Sphagnum; Leather-leaf; wet Sphagnum).

The site types recognized are those seen in undisturbed forests, and one aspect of the types that needs more study is habitat change and vegetational succession following cutting. Often cutting is followed by water table rises owing to the sudden cessation of forest transpiration (Holstener-Jørgensen 1967). The Speckled Alder, if abundant in the original stand, can develop rapidly into dense thickets and suppress growth of Black Spruce seedlings. In some cut-over areas there may develop a dense growth of sedges, commonly Sheathed Sedge (*Carex vaginata* Tausch.) and Three-seeded Sedge (*C. trisperma* Dewey), or grasses, commonly Bluejoint (*Calamagrostis canadensis* [Michx.] Nutt.). These sedges and grasses often develop on wetter cut-over sites such as the Sphagnum and Speckled Alder site, and particularly where wheeled skidders have caused deep rutting and exposure of dark peat and muck during harvesting or during scarification treatment. There are conflicting opinions about the influence of the graminoids, and of dark peat and muck surfaces, on seedling regeneration.

With respect to criterion (iv), air photo interpretation is under way at present on transects for which I have ground truth information. Interpretation is from 1:15,840 black and white photos, and 1:8,000 natural color and color infrared photos. I will cover only a few of the principal conclusions reached as a result of this preliminary work.

(1) It is important for photo interpreters to attempt to separate upland forests from swamps. These main types are related to a basic operational distinction, summer cut versus winter cut, as well as quite different regeneration characteristics and problems. Sometimes there is a

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[2] Fraser, J. W., V. F. Haavisto, J. K. Jeglum, T. S. Dai, and D. W. Smith. 1975. Black spruce regeneration on strip cuts and clear cuts in the Nipigon and Cochrane areas of Ontario. Can. For. Serv., Sault Ste. Marie, Ont. (unpublished report)

Table 3. Mean stocking for black spruce and other species for several site types from the Northern Clay Belt. (Data taken from a survey by Fraser et al.[a] in which each plot was based on 20-50 quadrats.)

Site type	Stocking (%) in 2 m x 2 m[b] quadrats		No. of plots
	Black Spruce	Other species	
Upland			
Black Spruce on mineral upland	38	53	18
Swamp			
Black Spruce/ Feather Moss	-	-	
Black Spruce/ Speckled Alder	51	31	34
Black Spruce/ Sphagnum	-	-	
Black Spruce/ Labrador-tea[c]	71	31	33
Treed Bog			
Black Spruce/ Leather-leaf	94	14	1[d]

[a] Fraser, J. W., V. F. Haavisto, J. K. Jeglum, T. S. Dai, and D. W. Smith. 1975. Black spruce regeneration on strip cuts and clear cuts in the Nipigon and Cochrane areas of Ontario. Can. For. Serv., Sault Ste. Marie, Ont. (unpublished report)

[b] Quadrats 2 m x 2 m are almost exactly equivalent to milacre quadrats.

[c] In the survey by Fraser et al. the Labrador-tea site type included types that had only sparse development of this shrub, and that would have been better classed, for the most part, as the Sphagnum site type.

[d] Limited sample of five 2 m x 2 m quadrats, not from Fraser et al.[a]

Table 4. Comparative regeneration, major seedbeds, and seedling constraints for the principal site types of black spruce swamp and treed bog.

Site type	Black Spruce regeneration	Major seedbeds: Sphagnum	Major seedbeds: Feather Moss	Possible seedling constraints
Upland				
Black Spruce on mineral upland	Low	Low	High	Dry Feather Moss
Swamp				
Black Spruce/ Feather Moss				Dry Feather Moss
Black Spruce/ Speckled Alder				Dense Speckled Alder
Black Spruce/ Sphagnum				Fast-growing Sphagnum
Black Spruce/ Labrador-tea				Dense Labrador-tea
Treed Bog				
Black Spruce/ Leather-leaf				Dense Leather-leaf
Black Spruce/ Few-seeded Sedge	High	High	Low	Wet Sphagnum

distinct topographic break between upland and swamp; sometimes there is not. In the Northern Clay Section, the presence of trembling aspen (*Populus tremuloides* Michx.) usually indicates upland, whereas pure black spruce is almost always swamp. It is suggested that a distinction between swamp and upland should be made in forest inventories, or should be more explicit and precise in cases where the distinction is already being made.

(2) Interpretations of the wetland formations (bog, fen, marsh and swamp) and the physiognomic groups are easier than interpretations of the finer units of dominance types and site types. Usually there is a fairly

distinct border between swamp and treed bog, the latter being recognized as 'treed muskeg' on forest inventory maps. Separations between open bog, and marsh and fen, are not as clear, especially in the case of sedge bogs, but physiographic considerations aid in making distinctions. The least clear division at the level of formations is between marsh and fen, and it may be that these formations should be combined for an initial breakdown of wetlands into three main units--swamp, bog, and marsh plus fen.

The separation between dominance types is more difficult but it can often be accomplished with ground truth even from provincial inventory photos (scale of 1:15,840). It is not possible to distinguish the different site types of Black Spruce swamp because the canopy is in the way. One can make some good guesses with respect to site types from such features as physiographic location, canopy closure, drainage lines, etc. However, it is probably not critical that we be able to identify down to the level of Black Spruce site types from air photos before harvesting. At present, forest inventory maps are based on composition, height, and canopy closure, and these are what are needed in planning for harvesting. It is important to add to these mapping units by characterizing the stands on the ground according to ground vegetation and soil conditions, so that the harvesting techniques can be better integrated with techniques of reforestation following cutting.

(3) There would be definite value in obtaining color infrared and/or natural color photos of cutovers in addition to black and white photos. In the trials on film types, the color infrared clearly distinguished a Speckled Alder-dominated swale as pink, while blue tones indicated areas with moss-dominated ground surfaces. This distinction was not as clear on normal color photos, and was indistinguishable on black and white photos. It is suggested that color infrared and perhaps natural color be taken along with black and white photos in cut-over areas, in order to give more detail on seedbed conditions. This should be done following scarification (if scarification is to be done), to allow the assessment of the treatment as an element in the production of desirable seedbeds.

To conclude, we have put forward a first approximation of wetland classification in an attempt to make it easier for workers in various segments of wetlands to understand and communicate about the kinds of wetlands with which they are dealing. This is basically a descriptive system based on the most apparent feature of wetlands--the vegetation. Of course, other aspects of the wetland ecosystems--e.g., moisture and nutrient status, soils, surface morphology, hydrology and succession--must be described for the vegetational units. As more is learned about ecological relationships these abiotic features may be used to modify and improve the classification. However, in our proposal we believed we would best serve the potential users by classifying vegetational physiognomy and dominance, and by adding other information about the habitat as descriptive information for the types.

Since this classification is a first proposal, we would appreciate comments and criticisms from other workers to aid in developing and improving the units.

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APPENDIX A

Brief definitions of the main units

In the proposed classification, wetlands are first divided into four main units called 'formations'--marsh, fen, swamp, and bog (Zoltai et al. 1974). Very briefly, marshes are reed, rush, grass and sedge-dominated wetlands, usually with standing or slowly moving minerotrophic water. Fens are sedge- or grass-covered peatlands, with minerotrophic groundwaters, water levels close to the surface and, sometimes, low shrubs or scanty cover of tamarack (*Larix laricina* [Du Roi] K. Koch). Swamps are forested and thicketed wetlands with minerotrophic groundwaters. Bogs are *Sphagnum*-dominated peatlands, underlain by a relatively continuous horizon of *Sphagnum* peat, fairly isolated from the influx of minerotrophic waters. Bog includes transitional bogs that are weakly minerotrophic but have developed a relatively consolidated upper horizon of *Sphagnum* peat moss.

APPENDIX B

Key to the Black Spruce site types of Swamp and Treed Bog

1a Upland sites underlain almost directly by mineral soil; usually less than 30 cm of organic accumulation (litter, fermentation and humus); groundwater not close to the surface, and virtually no puddles or pools of open water; plants typical of uplands but not wetlands include Mountain Maple, Green Alder, Bristly Sarsaparilla, Beaked Hazel, Trembling Aspen, and Mountain Ash . . . . Uplands

1b Lowland sites underlain by organic rich or peat soils overlying mineral soil; usually more than 30 cm of muck and peat accumulated over mineral soil or bedrock; groundwater close to the surface, usually within 50 cm of the average ground surface; small puddles, pools and channels are frequent; plants include a high proportion of peat-forming species, such as Sphagnum and Sedges . . Wetlands

(= Mires, mostly Peatlands) 2

2a Wetlands not dominated by Black Spruce forests . . . . Open Bogs, Fens, Marshes, and Swamps (other than Black Spruce Swamps)

2b Black Spruce-dominated wetlands . . . . Black Spruce Swamps and Treed Bogs 3

3a Closed-canopied, tall forests with greater than 30-40% canopy cover; Labrador-tea or Speckled Alder dominant shrub, or shrub layer inconspicuous and moss layer most apparent; topography with gentle slopes (1-5%), sink holes and channels present, sites underlain by moderately decomposed to well-decomposed peat . . . . Black Spruce-CONIFER SWAMP 4

4a Tall or low shrub layer not present or sparsely developed, total shrub cover less than 25% 6

5a Feather mosses are dominant . . . . Black Spruce/Feather Moss site type (Fig. 1)

5b Sphagnum mosses are dominant . . . . Black Spruce/Sphagnum site type (Fig. 2)

4b Tall or low shrub layer present, total shrub cover exceeds 25% 5

6a Speckled Alder is the dominant shrub (Labrador-tea may be present in the low shrub stratum) . . . . Black Spruce/Speckled Alder site type (Fig. 3)

6b Labrador-tea is the dominant shrub (Speckled Alder may be present in lesser abundance . . . . . Black Spruce/Labrador-tea site type (Fig. 4)

3b Open-canopied, low forests with 10 to ca 30-40% cover of individuals $\geq$ 135 cm high (breast height); Leather-leaf is the dominant shrub; topography flat, sites underlain by relatively continuous horizon of undecomposed Sphagnum peat ... TREED BOG 7

7a Leather-leaf dominant, groundwater level slightly below to well below the ground surface ... . SHRUB-RICH TREED BOG . . . . . . Black Spruce/Leather-leaf site type (Fig. 5)

7b Medium-sized graminoids dominant, leather-leaf sparse to moderately abundant on slight rises, groundwater level slightly below to slightly above the ground surface . . . GRAMINOID-RICH TREED BOG . . . . Black Spruce/Few-seeded Sedge site type (Fig. 6)

THE ROLE OF LAYERINGS IN BLACK SPRUCE FORESTS ON PEATLANDS IN THE CLAY BELT OF NORTHERN ONTARIO

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This paper investigates the role of black spruce (Picea mariana *[Mill.] B.S.P.) layerings in the Clay Belt of northern Ontario a) in virgin, overmature stands, and b) in succession stands after clearcutting and horse skidding, and after clearcutting and wheeled skidding.*

Cet article étudie le rôle des marcottes d'Epinette noire (Picea mariana *[Mill.] B.S.P.) à l'intérieur de la ceinture argileuse (Clay Belt) de l'Ontario a) dans des peuplements vierges sur le retour et b) dans des peuplements venus sur des buchés à blanc après débusquage par traction animale et après débusquage au tracteur à roues.*

INTRODUCTION

Layering[1] is a mode of vegetative propagation which takes place when branches become imbedded in a rooting medium and develop roots.

Natural layering in black spruce (*Picea mariana* [Mill.] B.S.P.) is a characteristic feature of the species and occurs within the range of its distribution. It has been described in Loudon (1854) and subsequently by several authors (Kenety 1917, Gates 1938, Bannan 1942, Stanek 1961, etc.).

The connection of a layering to the parent tree may persist for a long time and, when it can be traced from the layer to the parent tree, provides proof of origin. Trees of layer origin can also be detected by microscopic examination of the layer "root" which retains the primary xylem and phloem structure of a branch (Stanek 1961).

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[1] The term "layering" designates a tree of layer origin that grows independently of the parent tree. It also designates the process of layer formation. "Parent tree" in this case may be any tree from which a layering originates. Correctly, only a tree originating from a seedling should be called a parent tree and any subsequent layerings should be classified as layering generation 1, generation 2, and so on. According to the Empire Forestry Association (Anon. 1953), a layer is an attached branch that has rooted and is capable of independent growth.

Vincent (1965) reported that black spruce layers developed as well as, or better than, seedlings when exposed to similar conditions and that trees of the same initial size, regardless of origin, did not differ much in response to release. Kenety (1917), Bellefeuille (1935), LeBarron (1948), Hosie (1954), Shoenicke and Schneider (1954), and Stanek (1961, 1968) found that trees of merchantable size could develop from black spruce layers.

The objective of this study was to assess the role of black spruce layerings in natural merchantable stands growing on peatlands and in the reproduction of peatland areas after clearcutting with saws and either horse skidding or wheeled skidding. It is based on observations made and data collected during several periods (see Stanek 1959, 1961, 1968) and during the summer of 1975.

METHODS

The peatland forest stands were classified by their physiognomic dominance—site types according to Jeglum et al. (1974). The types investigated, all of which belong to the conifer swamps, are as follows: Black Spruce/Speckled Alder, Black Spruce/Feather Moss, Black Spruce/Labrador-tea, Black Spruce/Sphagnum, Eastern White Cedar, and Tamarack/Sphagnum.

The evaluation of the black spruce layering component in natural merchantable stands was made according to data collected near Cochrane, Ontario (Stanek 1961, 1968).

The evaluation of the role of black spruce layerings in regenerating areas exposed to clearcutting with saws, mainly $\approx$ 5 m or $\approx$ 1.2 m (16 ft or 4 ft) log length, hand bunched or horse skidded, was based on data collected on limits of the Abitibi Paper Company Ltd., Iroquois Falls, Ontario, and in 1975 in the Cochrane Forest District. In the 1975 survey five stands were located on each site type. In each stand a circular plot 20 m (65.6 ft) in diameter was established. On each of the plots five random points were located, and at each of these, or as close as possible to them, one sample each of the following tree size classes was located: small trees, up to 2 cm ($\approx$.8 in.) to 10 cm ($\approx$3.9 in.) DBH, and large trees over 10 cm ($\approx$3.9 in.) DBH. Small and medium-sized trees were examined for existing layer connections or excavated to determine how they originated. Large trees were classified as layerings when their stem form indicated layer origin (see Stanek 1968) and they grew in clusters typical of trees that originated by layering.

The role of black spruce layerings after clearcutting by chain saws, skidding in tree lengths by "logalls" or wheeled skidders to the pile, and delimbing at the road, was assessed on the basis of data collected on the limits of the Abitibi Paper Company Ltd. at Iroquois Falls, Ontario, near Camp 29, in 1975. Surveyed were cut-over peatland areas several hectares in size, the yield of which at the time of logging was estimated at 119 solid cu. m per ha ($\approx$17 cunits per acre). These had been logged in 1968-1969, 1972-1973, and 1974-1975, i.e., 7 years, 3 years, and immediately after logging. In each stand 10 circular plots per ha, 20 m ($\approx$65 ft) in diameter, were randomly located. On each circular plot 10 randomly distributed milacre plots (2 x 2 m, or $\approx$6.6 x $\approx$ 6.6 ft) were examined with respect to stocking to layerings and to seedlings. This coverage is comparable to a 4% cruise. A milacre plot was considered stocked when it contained at least one black spruce or balsam fir (*Abies balsamea* [L.] Mill.) tree that could be counted as healthy reproduction.

RESULTS

Role of Black Spruce Layerings in Natural Merchantable Stands

Most of the peatland sites in northern Ontario provide favorable conditions for the establishment of layerings. The proportion of layerings in a stand depends on the stand history. It is generally accepted that many of the best black spruce stands originate after fire in natural stands which provide a suitable seedbed for the establishment of seedlings. Seeding takes place from the cones not destroyed by fire. At maturity most of these stands are of uniform age, and well stocked. The trees are relatively densely spaced and very few still have preserved green branches at their bases. There is little undergrowth present.

It appears that approximately 120 to 180 years after the fire these stands begin to deteriorate. Trees die, and openings occur in which reproduction, mainly layerings, become established. These stands, when left to their natural development, become progressively uneven aged, more open, and eventually are composed almost entirely of layerings.

Examples of the effects of stand history on the proportion of layerings are given in Table 1 in percentages of stand volumes contributed by layerings in several black spruce swamp types.

Role of Black Spruce Layerings in Restocking Areas after Clearcutting and Horse Skidding

On horse-skidded areas a substantial part (approximately 55% according to Stanek 1959) of the advance growth survives. Layerings play a major role in the composition of the succession stands because most of the advance growth is of layer origin. Frequently, layerings are the only means by which the species can perpetuate itself (Table 2). In Western White Cedar, Tamarack/Sphagnum, and Black Spruce/Labrador-tea swamps, all the small black spruce examined were of layer origin. In the Black Spruce/Feather Moss type black spruce trees were mainly of layer origin; however, balsam fir, frequently of layer origin as well, made up

Table 1. Dominant height, average DBH, volume per hectare, and proportion of volume made up of layerings in natural, merchantable black spruce swamp types of varying stand history (after Stanek 1968)

Swamp type, description and history	Dominant ht (m) SI/100[a]	Avg DBH (cm)	Vol per ha (m^3)	Layerings as % of vol
Black Spruce/ Labrador-tea, well stocked, 150 years after fire	13.5	19.0	309	≈0
Black Spruce/ Labrador-tea, open stand, 180 years after fire	10.6	15.0	205	≈10
Black Spruce/ Labrador-tea, well stocked, 250 years after fire	10.6	18.5	392	≈94
Black Spruce/ Feather Moss, uneven-aged, well drained, 150 years after fire	14.6	18.3	255	0
Black Spruce/ Feather Moss, uneven-aged, undisturbed by fire	16.2	17.5	256	≈95
Black Spruce/ Speckled Alder, uneven-aged, well stock, undisturbed by fire	16.2	17.5	256	≈95
Black Spruce/ Speckled Alder, well stocked, on deep peat, undisturbed by fire	12.2	17.5	267	$\leq$100

[a] SI/100 = Site index at the age of 100 years

NOTE: 1 cm = ≈.4 in., 1 m = ≈3.3 ft.,
1 m^3 per ha = ≈0.143 cunits per acre

Table 2. Participation of black spruce layerings in advance growth smaller than 2 cm (≈.8 in.) DBH after clearcutting and horse skidding of peatland forest types

Swamp type	No. of plots examined[a]	Species composition % of total trees[a]				No. of black spruce trees 2 cm DBH[a]		Black spruce layerings <2 cm DBH (%)[c]
		black spruce	balsam fir	tam-arack	white cedar	No.	CV[b]	
Eastern White Cedar	1	22	52	0	26	4,123	-	≈100
Black Spruce/ Labrador-tea	6	90	10	0	0	2,540	33	≈100
Black Spruce/ Feather Moss	2	3	97	0	0	570	43	90-100
Black Spruce/Sphagnum								
Black Spruce/ Speckled Alder	5	86	14	0	0	5,522	54	90-100
Tamarack/Sphagnum	2	81	18	1	0	10,689	5	≈100

[a] Based on Stanek 1959

[b] Coefficient of variation in percent of mean value

[c] Based on survey in 1975 of virgin and second growth stands

NOTE: 1 cm = ≈.4 in.
1 ha = ≈2.47 acres

the bulk of the advance growth. In the Black Spruce/Sphagnum and Black Spruce/Speckled Alder types most of the black spruce were of layer origin. From the data it appears that in all clear-cut and horse-skidded peatland forest types the succession stands will consist of a large number of black spruce layerings.

Role of Black Spruce Layerings in Restocking Peatland Areas after Clearcutting and Wheeled Skidding

Skidding by wheeled skidders, in contrast to horse skidding, destroys most of the advance growth. Very few black spruce trees of layer origin are able to survive (Table 3). However, skidding also scarifies the site and provides a suitable seedbed for seedlings. Within 7 years of logging, the stocking due to seedlings improves, and in proportion, the importance of layerings decreases. Seven years after logging only a small percentage of black spruce layerings contributes to restocking peatland areas.

Table 3. Summary of regeneration survey of three areas of similar productivity, clear-cut and wheel-skidded during summer, 7 years, 3 years, and immediately after logging[a]

		Stocking % of total			
Year of logging	% stocking	black spruce, seedling only	black spruce, seedling and layering	black spruce, layering only	Balsam fir only
1974-1975	20	0	0	90	10
1972-1973	55	30	17	40	13
1968-1969	61	88	5	5	2

[a] Remains of vegetation indicated that the forest stands before logging were of the Black Spruce/Sphagnum, and Black Spruce/Speckled Alder type with small pockets of Black Spruce/Feather Moss.

DISCUSSION

Obviously black spruce layerings play an important role in natural, merchantable, uneven-aged black spruce stands on peatlands undisturbed by fire, and in the composition of the advance growth in such stands. In older cutovers (hand-cut and horse-skidded) black spruce layerings also constitute a major portion of the succession stands, because the method of harvesting tends to preserve advance growth.

However, mechanized logging is the prevailing logging method used today. It destroys much of the advance growth, but creates seedbeds suitable for the establishment of coniferous seedlings. The reproduction on cut-over areas, which supported black spruce swamp stands of relatively good productivity rating 7 years after logging, consisted mainly of seedlings. The stocking of milacre plots amounted to 61%. Although only one area of logging operations has been surveyed, casual observations in several widely scattered locations showed that a similar pattern of reproduction occurs throughout similar cutovers (see also Fraser et al., unpublished report). Obviously, in all cases a seed source must have been available, possible from uncut trees or slash.

It appears, however, that approximately 10 years after logging on these areas, the competition to the young trees from vegetation, mainly alder, will become severe. Observations of cutovers overgrown with alder in the Ontario Ministry of Natural Resources Leitch Township Silvicultural Area, Cochrane Forest District, showed that many of the established conifers require release from alder competition to grow successfully above the alder canopy.

It is probable that the ground cover of grasses, mosses, and ericaceous shrubs, which apparently takes hold from 4 to 10 years after logging, will prevent the establishment of many seedlings, so that layerings, favored by the site conditions, will again partake in the development of the succession stands.

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PEATLAND BLACK SPRUCE SEED PRODUCTION AND DISPERSAL IN NORTHEASTERN ONTARIO

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The seed production capabilities and the patterns in seed dispersal in peatland black spruce (Picea mariana *[Mill.] B.S.P.*) *are described.*

L'auteur decrit le potentiel de rendement en graines et les types de dispersion des graines de l'Epinette noire [Picea mariana *[Mill.] B.S.P.*) *en terrain tourbeux.*

INTRODUCTION

The importance of black spruce (*Picea mariana* [Mill.] B.S.P.) to the economy of Ontario is well recognized. The fiber and pulping qualities of this species make it the preferred raw material for the numerous pulp and paper concerns situated in northern Ontario.

Forty-eight percent of the coniferous growing stock in Ontario consists of black spruce (Dixon 1963), which occupies 41%, or 43 million acres (17.4 million ha), of the province's productive forest land (Ketcheson and Jeglum 1972); of this, about 19.5 million acres (7.9 million ha) occur on peatland conditions. The remaining 55% of the productive black spruce working group supports mixtures of balsam fir (*Abies balsamea* [L.] Mill.), jack pine (*Pinus banksiana* Lamb.), trembling aspen (*Populus tremuloides* Michx.), and/or white birch (*Betula papyrifera* Marsh.), along with the black spruce.

According to Dixon (1963), the actual harvest of the spruces, both black and white (*Picea glauca* [Moench] Voss), was only 52% of the annual allowable cut. However, with an ever-increasing demand for paper, paper products, and even saw-timber from the small-diameter trees, it is likely that the annual cut of black spruce will approach the annual allowable cut in the very near future. One must remember that much of the timber included in the allowable cut calculation is actually quite inaccessible; therefore, in certain areas the actual cut might exceed the allowable cut. With the demand as indicated above, the importance of maintaining the productivity of sites presently being harvested is realized.

To date, regeneration of black spruce on cutover lands has been considered problematic. A series of surveys, however, has indicated that peatlands as a whole regenerate at least to a level of conditional acceptability (between 40% and 60% stocking to black spruce by milacres [Robinson 1974]), whereas mineral soil sites do not attain this percentage[1]. Numerous cut modifications have been tried over the past several decades with varying success. It has been shown that certain site-preparation techniques can be effective aids in the establishment of black spruce regeneration on specific site types. The planting of bare-root and containerized black spruce has met with only limited success on unprepared peatland sites. Direct seeding of black spruce has not proven very successful on unprepared sites, but unpublished studies which I have undertaken indicate that direct seeding with appropriate ground preparation can be quite effective on sites rich in peat moss. As reported by Vincent (1965), surface compaction, surface disturbances of varying severity, and scorching with fire have, in some instances, produced satisfactory seedbed conditions in *Sphagnum*-rich areas for the germination and early survival of black spruce.

It is toward the development of successful natural and direct seeding techniques combined with appropriate ground preparation, or the most economically feasible but practical methods of artificial regeneration, that the studies presented herein (seed production, seed dispersal) have been done.

SEED PRODUCTION IN BLACK SPRUCE

According to the Woody Plant Seed Manual (Anon. 1948), the cone-bearing age of black spruce ranges from 30 to 250 years, with the optimum age being about 150 years. Good seed years reputedly occur at intervals of 2-6 years, and there usually is some seed production every year. Since black spruce has semiserotinous cones, the number of cones per tree and, consequently, the number of seeds per tree can be considerable.

A study to compare seed production in black spruce trees of different crown classes was conducted in the Kennedy Black Spruce Area, near Cochrane, Ontario. Five trees were taken each year from 1965 to 1967 inclusive, and all the cones were harvested. Each cone was dated to determine its year of origin; then it was dried and the seeds were extracted. The extracted seeds were subjected to an ethanol flotation test to separate the empty seed from the full seed (floaters from sinkers, respectively). A sample of the sinker seeds was tested for viability.

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[1] J. W. Fraser, V. F. Haavisto, J. K. Jeglum, T. S. Dai, and D. W. Smith. 1975. Black spruce regeneration on strip cuts and clear cuts in the Nipigon and Cochrane areas of Ontario. Can. For. Serv., Sault Ste. Marie, Ont. (Unpublished report)

The results indicated that dominant crown class black spruce (hereafter called dominant trees) had, on the average, almost three times as many cones per tree as either the codominant or the intermediate crown class trees (Table 1). When the mean numbers of seeds per cone are compared, it is evident that about two thirds of the seeds are empty (i.e., lacking in germinative capacity) according to the ethanol flotation test. Intermediate trees have almost twice as many seeds per cone as the dominant trees, whereas the number of seeds per cone on codominant trees is between that of the other two crown classes.

Table 1. Mean number of cones per tree and mean number of sinkers, floaters, and all seeds per cone in black spruce of different crown classes in the Kennedy Black Spruce Area, Cochrane, Ontario (includes cones of all ages).

Crown class	Mean no. of cones per tree	Mean no. of seeds per cone		
		sinkers	floaters	all seeds
Dominant	13,784	1.9	4.4	6.3
Codominant	4,695	2.7	5.2	7.9
Intermediate	3,943	3.5	6.9	10.4
All trees	7,474	2.3	5.0	7.3

Annual cone production probably varies with the physiological condition of the tree, prevailing site factors, and the present and previous years' weather (Vincent 1965). Where previous counts (Millar 1936) indicated that the maximum number of cones a tree can produce in any one year is about 800, Table 2 shows that the average of the dominant trees for the 1964 cone year was 1,146. Cone production in the codominant and the intermediate trees was only about half that for the dominant trees. One dominant tree produced 2,865 cones in 1964.

It is interesting to note that in Table 2, the ratio of potentially viable (full) seed to empty seed per cone remains about 1:2, reflecting the averages of the whole cone population in Table 1. However, the mean number of seeds per cone is considerably higher in Table 2 than in Table 1.

Cones disperse some of their potentially viable seed (Fig. 1a) and considerably more of their empty seed (Fig. 1b) during the first 5-6 years.

This trend levels off subsequently. The most pronounced seedfall is from the intermediate trees, and the least from the dominant trees (Fig. 1c). The number of seeds per cone, especially the number of potentially viable seeds per cone, is not materially different in the three crown classes after 6 years.

Table 2. Mean number of 1964 (good seed year) cones per tree for trees of different crown class, and mean number of sinkers, floaters, and all seeds per cone in the Kennedy Black Spruce Area, Cochrane, Ontario

Crown class	Mean no. of cones per tree	Mean no. of seeds per cone		
		sinkers	floaters	all seeds
Dominant	1,146	3.1	7.1	10.2
Codominant	582	4.4	11.1	15.5
Intermediate	647	6.7	14.1	20.8
All trees	792	4.4	10.0	14.4

With the large store of seed that is potentially available owing to the serotinous nature of the cones, it is imperative that we know the trends in viability of the seed within the cones. From groups of trees harvested during 3 consecutive years, the viability of the sinker seed from cones of the first 5 years averages 53% (Fig. 2). The viability drops very fast in the 6- to 10-year group, and subsequently decreases to almost nil in the 20-year to 20-year+ group. Figure 3 shows the trend in seed viability by year of origin for the first 7 years. Very little change in viability occurs during the first 3-4 years, and by the fifth year the viability has decreased by only about 12% from the initial average of 56%. Subsequently, the viability drops drastically to produce the trend shown in Figure 2.

SEED DISPERSAL IN BLACK SPRUCE

During 2½ years of seed trapping in northwestern Ontario, Losee (1961) found that annual seedfall in 70-year-old black spruce stands ranged from somewhat less than 0.4 million seeds per acre to 5.1 million seeds per acre (1.0–12.6 million seeds per ha). This reflects differences between poor and good seed years. Similar figures were obtained by Howard (1962) in Newfoundland.

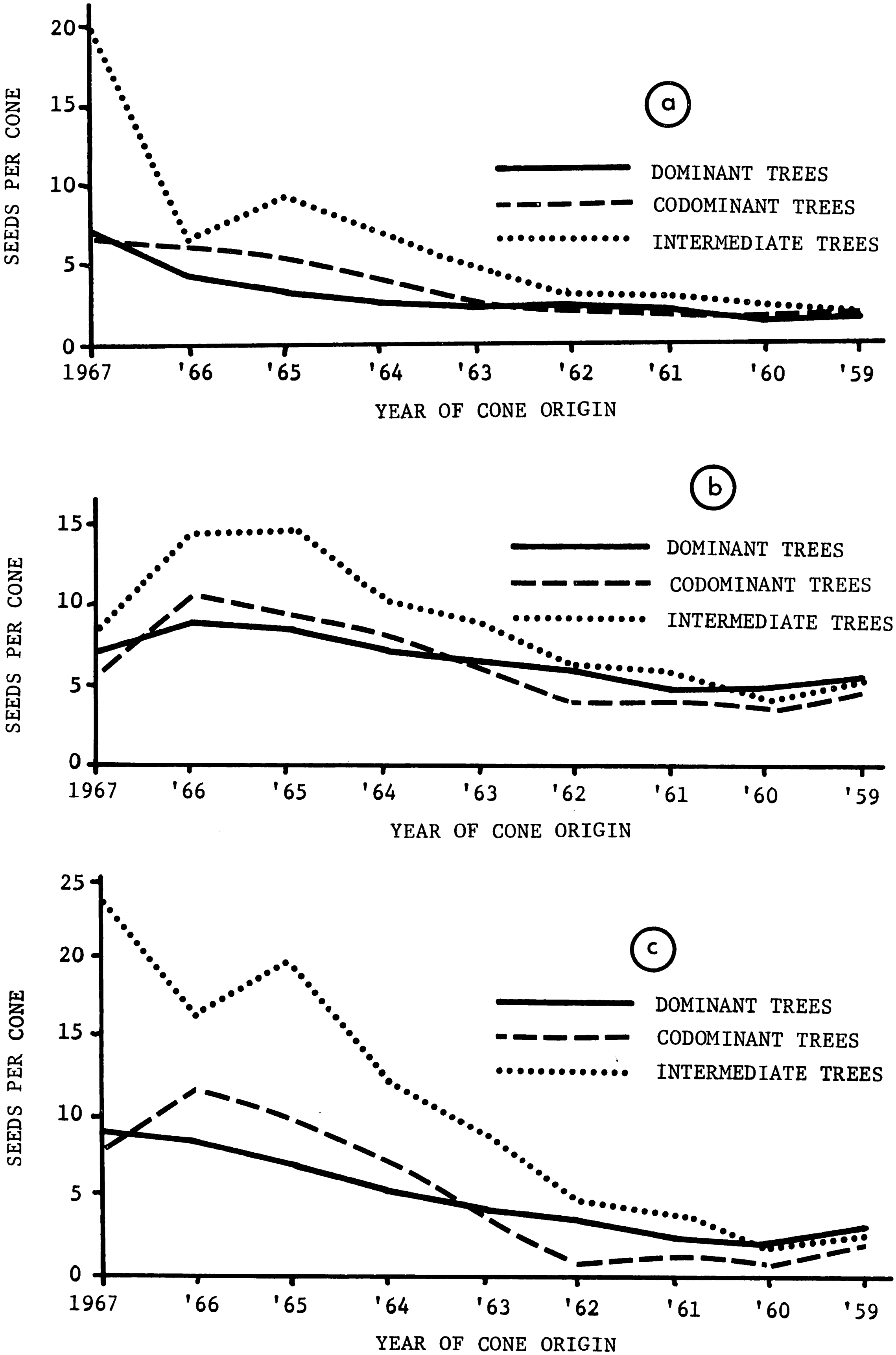

Fig. 1a. Numbers of full black spruce seed per cone.
1b. Numbers of empty seed per cone.
1c. Numbers of seed per cone.

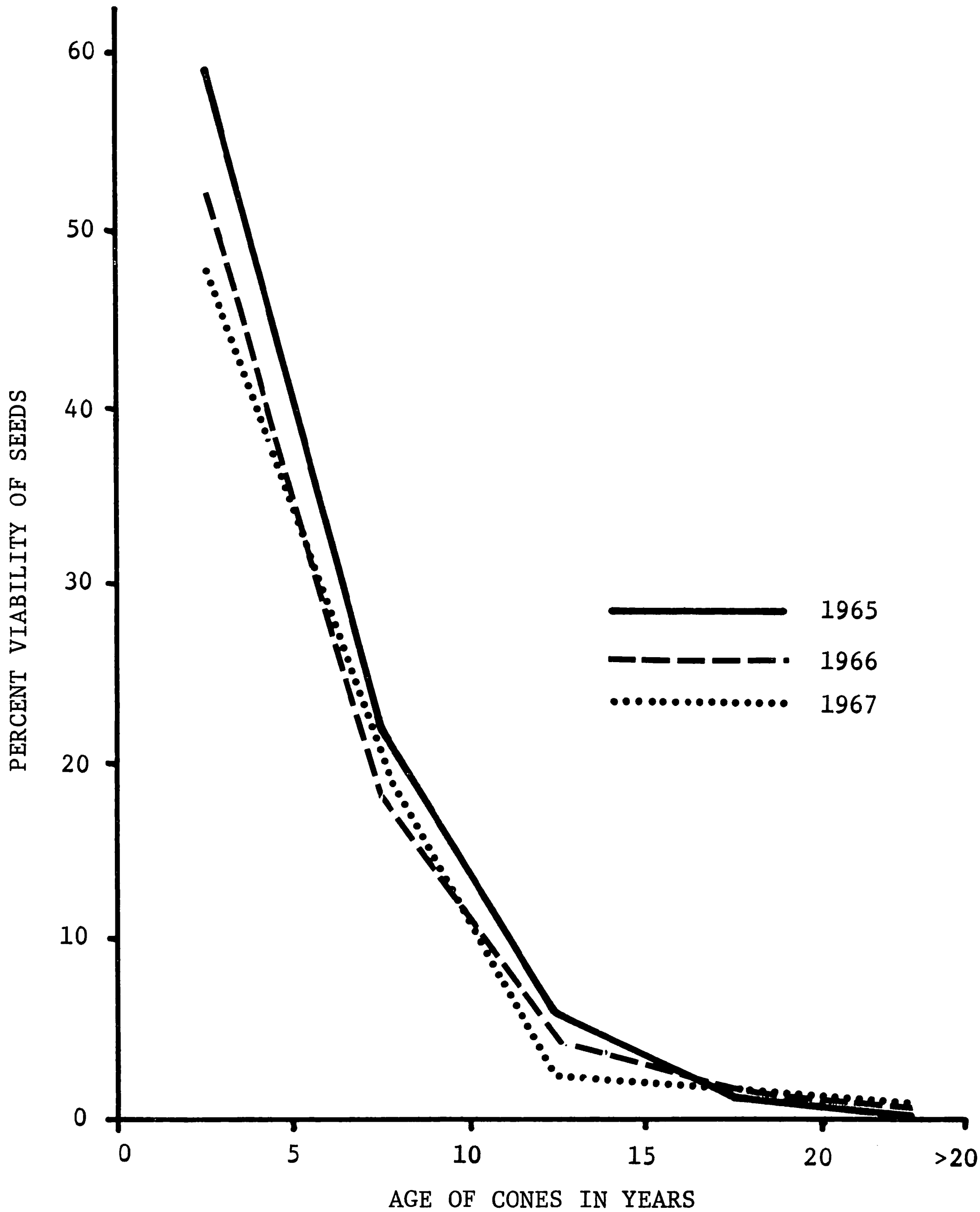

Fig. 2. Trend in average viability of black spruce sinker seeds by 5-year cone groups from three successive annual collections.

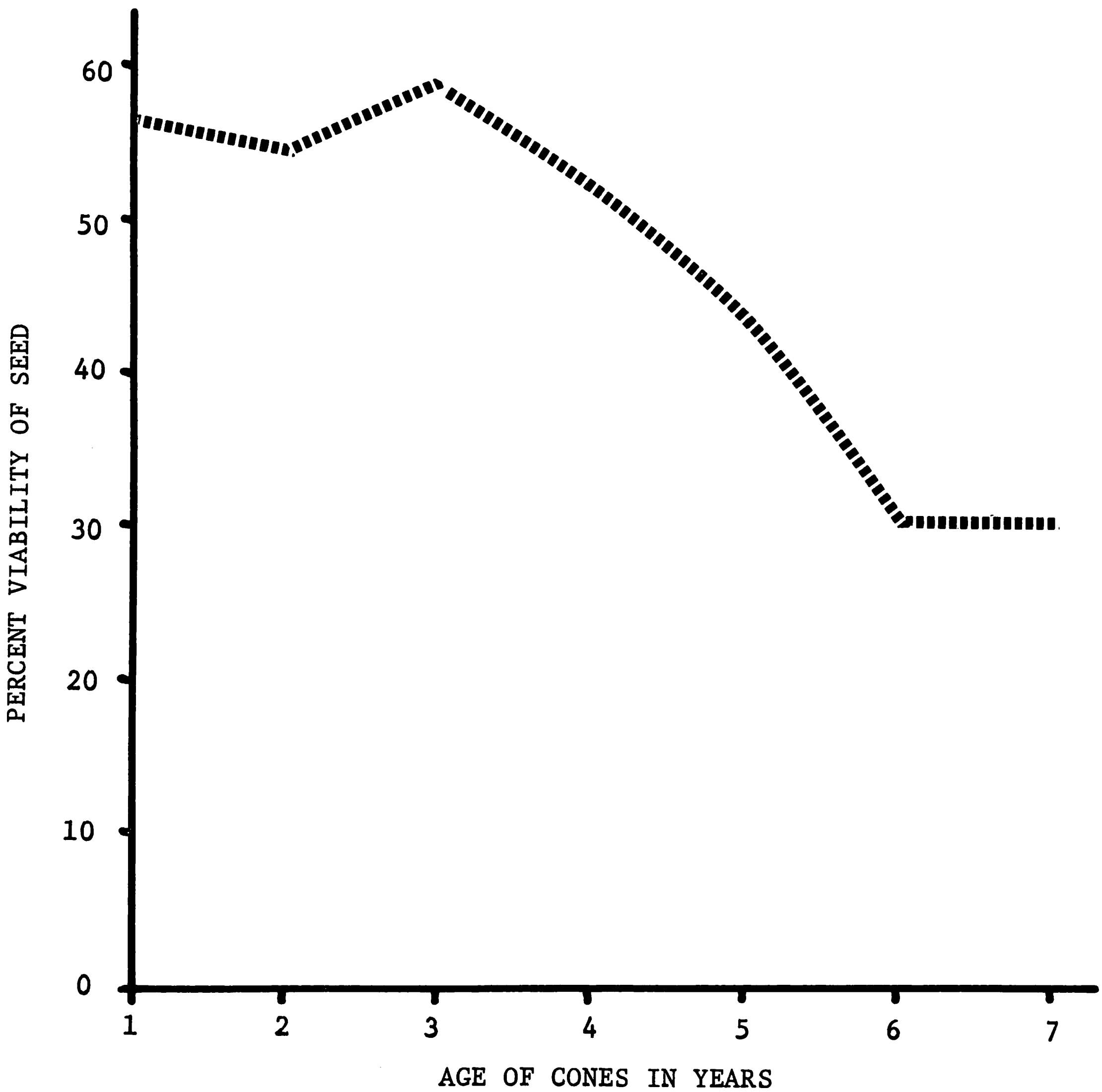

Fig. 3. Trend in viability of black spruce seed in cones for first 7 years (based on averages of 15 trees).

In 1965, 1 ft^2 (25 cm^2) screen-bottomed seed traps were established in five 0.5 x 0.5 chain (10 x 10 m) grids in the Kennedy Black Spruce Area. During the 5-year seed-trapping study, I found that black spruce seed collected under stands indicated average annual seedfall ranging from 0.4 million to 2.0 million seeds per acre (1.0–4.9 million seeds per ha) (Table 3). Since the highest number of seeds was collected during 1968, largely during the spring collection, it is reasonable to think that 1967 was a good seed year (i.e., a year of good cone production). Seed collected during 1968 also had the highest viability for the 5-year sampling period. It should be noted that during 1969, the year following dispersal of seed during the good seed year, considerable numbers of seeds were collected, but the viability was very low.

Table 3. Mean annual seedfall per acre[a] and percent viability in black spruce seeds collected at five locations in the Kennedy Black Spruce Area, Cochrane, Ontario (1965-1969 inclusive)

	1965	1966	1967	1968	1969	Annual average
Million seeds per acre	1.18	0.44	0.38	2.01	0.97	0.99
Percent viability	14.7	13.7	19.1	25.2	4.4	15.4

[a] 1 acre = 0.40 ha.

Vincent (1965) quotes results of studies conducted in Minnesota (Anon. 1939a) and Newfoundland (Howard 1962) when he states that seeds of black spruce fall throughout the year. In order to substantiate this for Ontario conditions and to ascertain the quality of the seed falling at various times of year, a 2-year study was conducted in a black spruce swamp near Sault Ste. Marie, Ontario (Haavisto, unpublished manuscript). Table 4 shows that 58% of the average annual seedfall was dispersed during the months of March, April and May. More important is the fact that 76% of the viable seed dispersed during the year also falls during this period. The 2-year averages also show that 67% of the average annual seedfall was empty seed, 21% was viable seed, and the remaining 12% was made up of those seeds that were damaged or had a germinative capacity but failed to germinate.

Table 4. Average (2-year) monthly dispersal of empty, viable, and all black spruce seeds in Goulais Swamp, Sault Ste. Marie

Month	Empty seed		Viable seed		All black spruce seed	
	No. per acre	% of total	No. per acre	% of total	No. per acre	% of total
January	6,700	1.3	2,200	1.4	10,400	1.4
February	36,800	7.4	10,300	6.6	54,600	7.4
March	107,800	21.6	15,800	10.1	135,300	18.3
April	100,200	20.1	68,900	44.2	189,900	25.6
May	59,200	11.9	34,400	22.1	101,100	13.6
June	17,600	3.5	6,100	3.9	26,400	3.6
July	27,600	5.5	3,200	2.1	31,300	4.2
August	40,600	8.1	3,700	2.4	48,300	6.5
September	30,400	6.1	1,200	0.8	36,000	4.9
October	17,800	3.6	1,300	0.8	22,300	3.0
November	45,700	9.1	4,700	3.0	70,200	9.5
December	8,900	1.8	4,000	2.6	14,900	2.0
TOTAL	499,300	100.0	155,800	100.0	740,700	100.0

[a] Seedfall per hectare = No. of seeds per acre x 2.47

Of extreme importance in the dispersal of black spruce seed is its capability of being wind-transported. From a Minnesota study (Anon. 1939b) I concluded that black spruce seed is a limited air traveller, travelling to a maximum of 300 ft (30.48 m). McEwen's (1971) wind tunnel experiments indicated that the distance travelled by black spruce seeds is dependent on tree height and wind speed. Even though Dickson and Nickerson (1958) found adequate stocking to black spruce only up to one tree length from the stand edge, it is self-evident that seedling stocking (as distinguished from seedlings of layer origin), even though inadequate at much greater distances from seed sources, must have resulted from natural seed dispersal. A study of the chronology of seed dispersal (Table 4) indicates that black spruce seed can be transported considerable distances on the snow surface as reported by MacArthur and Gagnon (1959) and Haavisto (unpublished manuscript).

During seed dispersal studies (1965-1969 inclusive) using 1 ft^2 (25 cm^2) screen-bottomed seedtraps placed at 1-chain (20-m) intervals across 10-chain (200-m)-wide strips oriented east to west in the Kennedy Black Spruce Area, it became evident that a considerable number of seeds reached all parts of the cutover. Figure 4 shows the average annual seedfall across the two strips. Even though the stands on either side (south or north) indicated average annual seedfalls in excess of 1 million seeds per acre (2.5 million per ha) except for the north side of Strip IV (700,000 black spruce seed per acre, or 1.7 million seed per ha), there was no significant difference in the number of seeds regardless of location in the cutover. A somewhat higher number of seeds was collected nearer the edges of the stands. It should be noted that 75% of the seeds collected were dispersed during the period from mid-September to late-May, and this substantiates the trends shown in Table 4.

To evaluate the relative seed dispersal rates across strips of different widths, a study was established in the Sangster Township strip-cut area. Here 20 $in.^2$ (50 cm^2) screen-bottomed seed traps were used during a 2-year period (1972-1974). Figure 5 illustrates the 2-year average seedfalls obtained across 2-, 3-, and 5-chain (40-, 60-, and 100-m)-wide strips oriented north to south. It is evident that the seeding stands on the west side of the strips provide more seed than those on the east side, and that the seedfalls within the stands indicate that considerable seed was released. The results show that more seed is deposited at various points across the narrow strips than across the wide ones (Fig. 5a). Even where the number of black spruce seeds is lowest on the 5-chain (100-m)-wide strip, over 8,000 seeds per acre (20,000 per ha) were received annually (Fig. 5c).

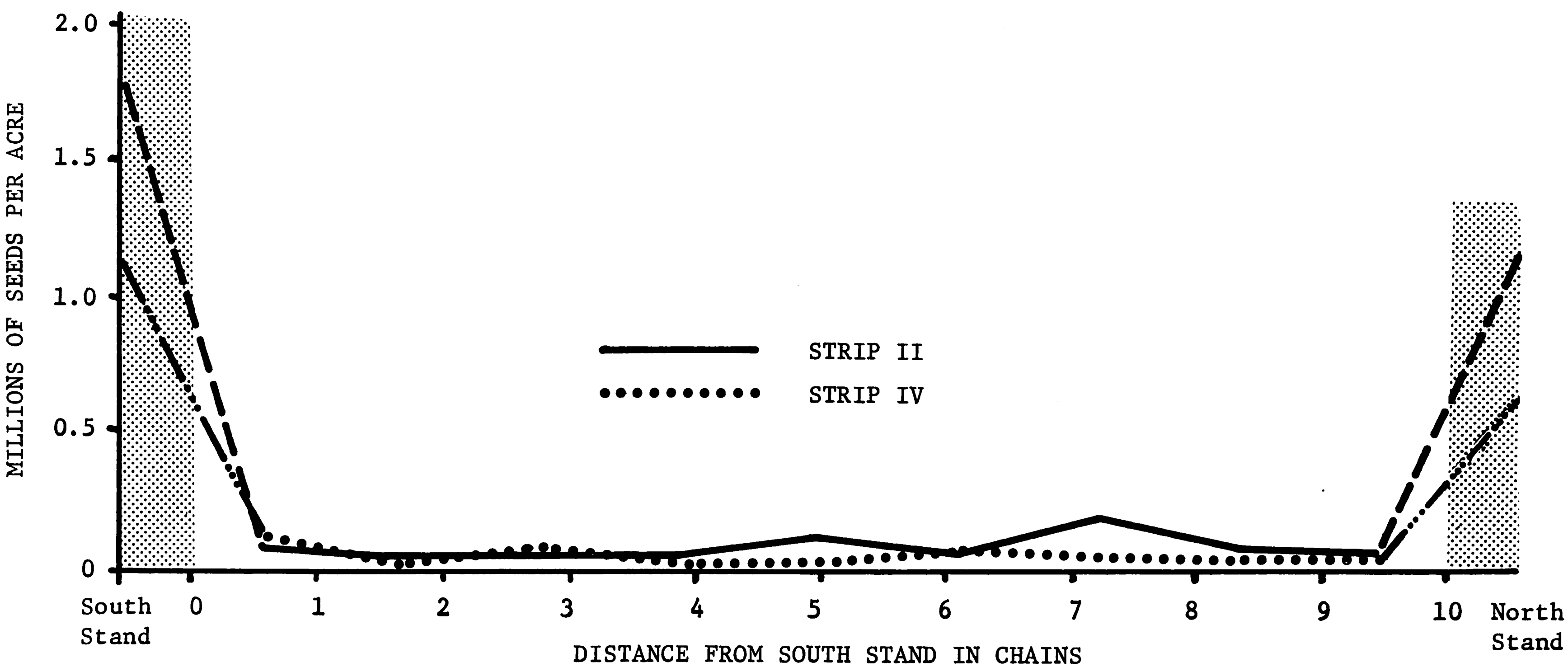

Fig. 4. Average annual (5-yr avg) black spruce seedfall across 10-chain (200-m)-wide east-west oriented strip cuts in Kennedy Black Spruce Area, Cochrane, Ontario.

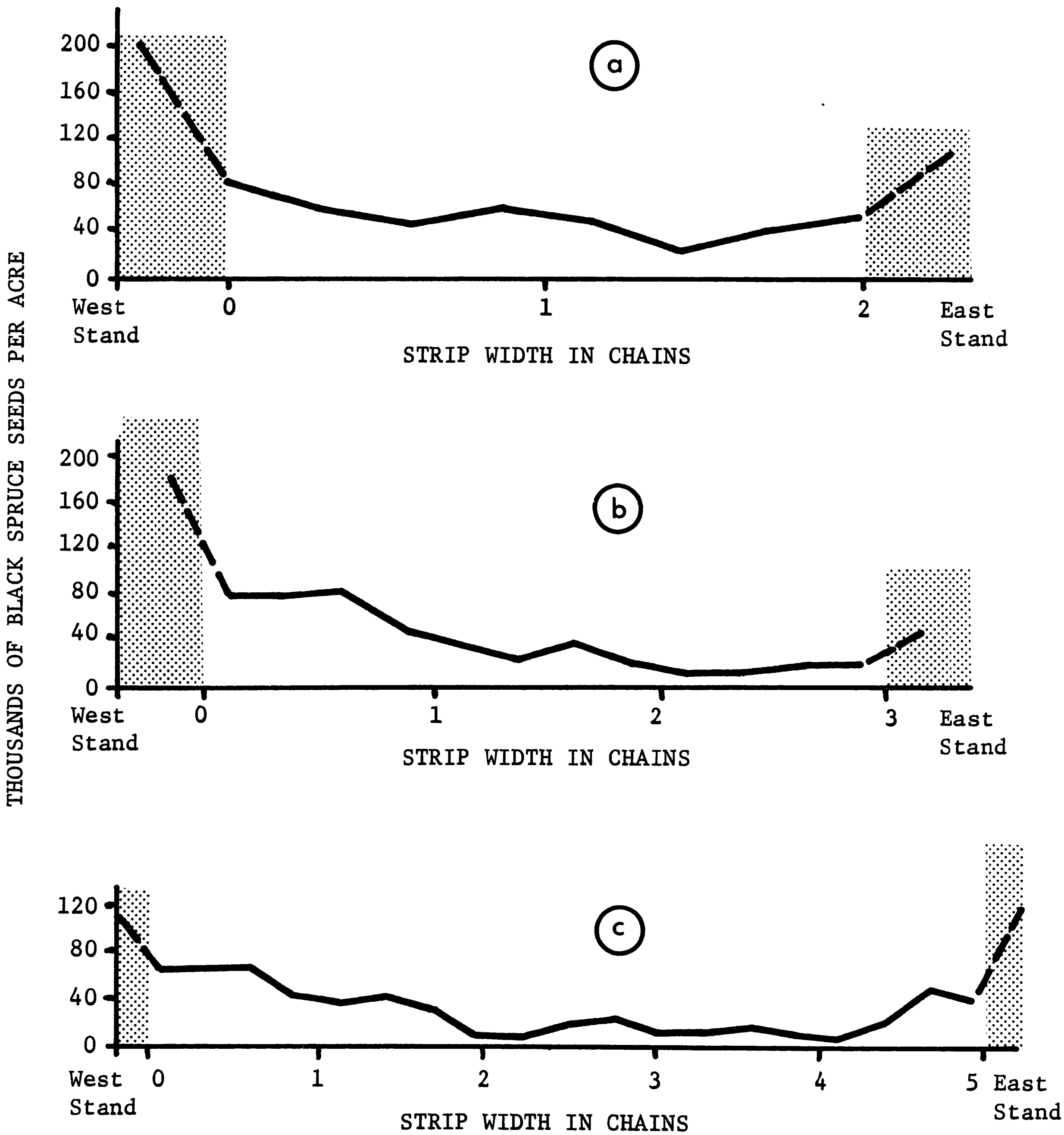

Fig. 5. Annual black spruce seedfall across 2-chain (a), 3-chain (b), and 5-chain wide (c) north—south oriented Sangster Township strips.

SUMMARY

Black spruce is a prolific seed producer. Good seed years occur every 4 ±2 years. Owing to the serotinous nature of black spruce cones, much of the annual production of seed remains on the trees for considerable lengths of time (exceeding 25 years).

Dominant black spruce annually produce and retain the highest number of cones per tree. During good seed years, dominant trees can produce in excess of 1,000 cones. Intermediate trees have only about one third the number of cones, but almost twice as many seeds per cone, as the dominant trees. Codominant trees are similar to intermediate trees with respect to cone and seed production. Regardless of crown class of tree, two thirds of the seeds in cones are empty and one third are potentially viable.

Seed dispersal is largely dependent on weather. It is self-evident that if cones are wet and the weather is cold, cone scales will not flex and seed will not be released. Conversely, if the weather is dry and warm, cones can open readily and release seed. Laboratory experience has shown that several repeated flexings of the cone scales (repeated wettings and dryings) are required to release all of the seed. Studies summarized herein indicate that cones retain more than half of their seed for at least 5 years. During this time the viability of this seed remains virtually unchanged. Hence, with a suitable seed source the potential for successful natural regeneration is high if conditions amenable to seed germination and early seedling survival prevail.

Another important silvicultural implication of these seed production studies is that cone collection for subsequent large-scale seedling production is not as critical as is considered at present. It is not imperative that only the present year's cones be picked, and at specific times of year (i.e., immediately after cones ripen in the fall). With the retention of viable seed in the cones, more seed can be harvested from an area, and mechanization of cone picking can become a reality.

In order to capitalize on natural seedfall and high viability of the seed immediately after dispersal (it quickly loses viability once on the ground), it is necessary to know the annual trends in seed release. Studies conducted near Sault Ste. Marie, Ontario suggest that the major portion of the annual complement of black spruce seed (58%) is released in early spring (March-April-May). This is also the season when almost all (76%) of the year's complement of viable seed is released. Hence, if any silvicultural operations are to be performed or if we are depending on the prevailing winds for seed dispersal, we should aim for performing the operation to take advantage of the very early spring for dispersal of the highest quality black spruce seed.

The distance that black spruce seed can be wind-transported is dependent on the height of the seed tree and on windspeed. Maximum distances of 300 ft (90 m) have been reported in the literature (Anon. 1939b) but regeneration of seedling origin does occur at considerably greater distances from seed sources in unrestricted clear-cut areas. Seeds can be wind-blown considerable distances along the snow surface when dispersed in the early spring.

Strip cutting assures the presence of a seed source. Studies have shown that 2-chain (40-m)-wide strips oriented north-south receive more seed than wider strips (i.e., 3-5 chains, or 60-100 m wide). However, even the central and more easterly parts of the Sangster Township 5-chain (100-m)-wide strips received an average minimum of 8,000 seeds per acre (20,000 seeds per ha) annually.

From the results of these studies, I conclude that large quantities of seed are annually produced and dispersed by black spruce in peatland conditions. Seed dispersal across cut-over areas, even though only a fraction of that falling in the stands, seems to be no real problem. If, however, the viability of the seeds being transported across cut-over areas is taken into consideration, the number of seeds settling on receptive seedbeds, germinating and surviving annually might be very small. Hence, it is important to ensure proper seedbed preparation as soon as possible following harvesting to capitalize on the lack of competition. The seed source and site conditions amenable to successful regeneration are also important, but critical weather factors can negate their value.

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PRACTICAL ASPECTS OF REGENERATION ON ONTARIO'S CLAY BELT PEATLANDS

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Regeneration of black spruce (Picea mariana *[Mill.] B.S.P.) on Ontario's peatlands is a very important and complex problem. Many peatland sites do not regenerate naturally within a reasonable period after mechanical logging. Artificial regeneration methods now being tried on these sites and problems that must be overcome are discussed.*

En Ontario, le problème de la régénération de l'Epinette noire (Picea mariana *[Mill.] B.S.P.) en sol tourbeux s'avère très important et complexe. La régénération naturelle dans plusieurs stations tourbeuses est trop lente après exploitation mécanisée. L'auteur discute les méthodes de régénération artificielle essayées dans ces stations et les problèmes qui restent à résoudre.*

INTRODUCTION

To forest managers working in Ontario's northern Clay Belt (Fig. 1), the regeneration of peatlands represents a very important and complex problem.

According to Ketcheson and Jeglum (1972) black spruce (*Picea mariana* [Mill.] B.S.P.), Ontario's most important commercial species, dominates 80% of the productive forest area of the Clay Belt. Thirty-nine percent of the productive forest area (almost half of the spruce-dominated forest), is on peatlands. No other commercially exploited region of Ontario has such a high proportion of its productive forest area dominated by black spruce, or such a proportion of its black spruce type in peatlands. The level of cutting in the Clay Belt is high, approaching 67,000 acres (27,114 ha) per year, while the present level of artificial regeneration treatments is about 16,000 acres (6,475 ha) per year. An estimated 26,000 acres (10,522 ha) of this cut are in peatlands, and probably less than 10% is treated annually, for reasons which will be outlined in this paper.

I will attempt to describe briefly the present state of spruce regeneration, both artificial and natural, in the Clay Belt peatlands, concentrating on some of the aspects which make the problem so complex.

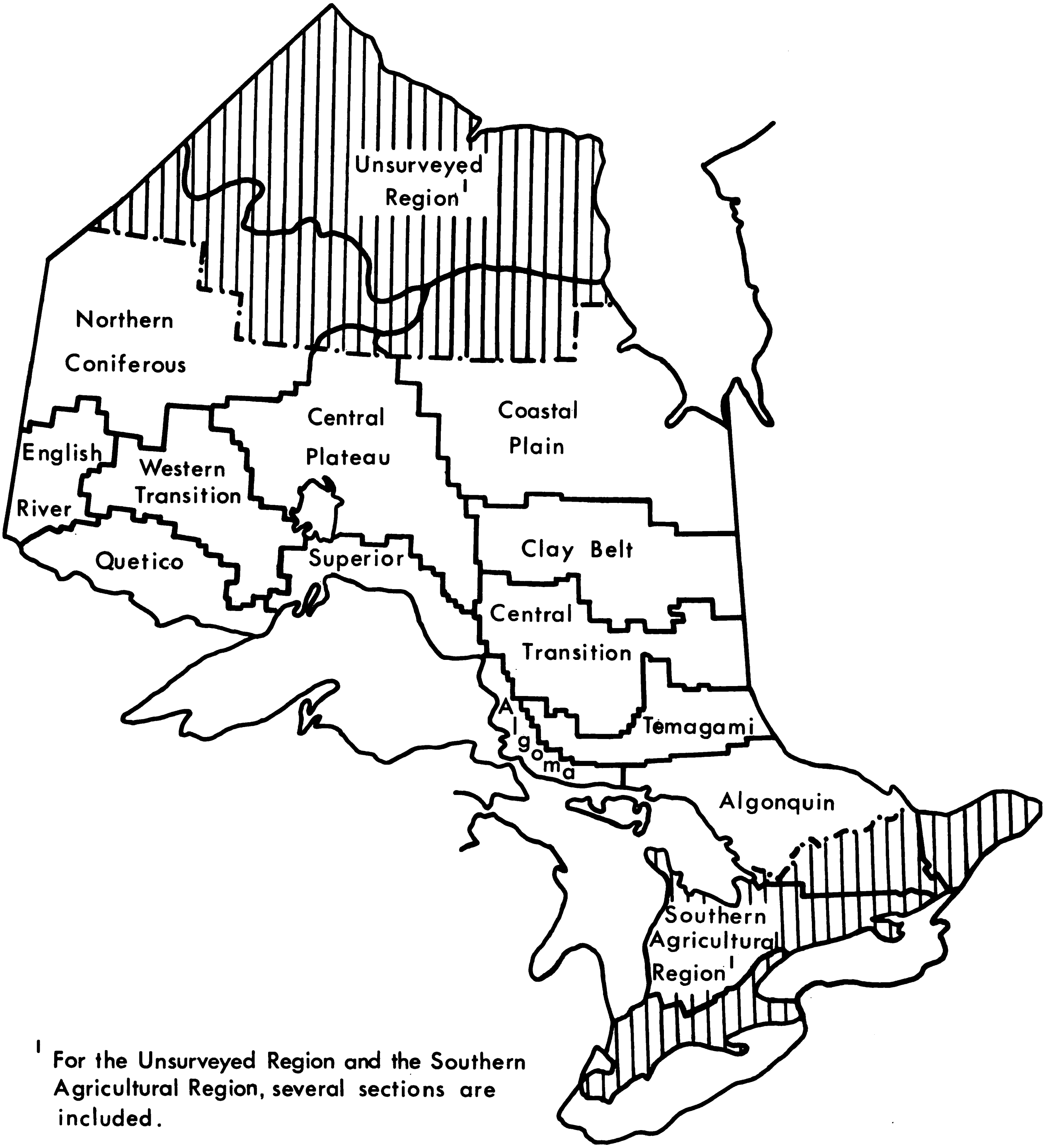


Fig. 1. The Province of Ontario by ecological sections showing the location of the Clay Belt (from Ketcheson and Jeglum 1972).

Some areas in which significant improvment must come before much headway can be made towards solving the major puzzle of lowland spruce regeneration in this region will also be pointed out.

NATURAL REGENERATION

One may reasonably ask, "Is black spruce lowland regeneration really a problem? Will these areas not come back naturally?"

These are good questions. Regeneration surveys dating as far back as the 1920s and 1930s by Spruce Falls Power and Paper Company in Kapuskasing indicate that spruce lowlands did indeed produce adequate natural regeneration after conventional cut and horse-skid clearcutting. The trend in the second-growth forest was to a much greater balsam fir (*Abies balsamea* [L.] Mill.) component than was originally present, but the conifer stocking after 5 to 10 years would be considered satisfactory by our present stocking standards. So where is the problem?

Several studies (e.g., Moore 1973) and the observations of a number of people indicate that the successful natural regeneration which occurred on the lowlands during the horse-skidding era could be attributed largely to advance growth not damaged fatally during logging, and to layerings. It is my opinion, from field observation, that the coming of the wheeled skidder to the logging scene has changed the natural regeneration picture on these peatland sites drastically. Particularly on summer operations, a tremendous amount of advance growth is badly damaged or destroyed. Potential sources of layering are often tramped deep into the muck. Drainage is sometimes impeded. Deep ruts are sometimes created and become filled with water, and heavy sedge and grass cover are encouraged by the churning up of the black swamp peat. A few years after cutting, many of these sites are heavily invaded by alder and the resulting leaf litter that builds up soon covers over any potential spruce seedbed that remained. Thus, the former primary sources of natural regeneration on these sites are reduced and seeding-in is not encouraged even when there happens to be a nearby seed source.

This is at present just a theory based on observations. It is unfortunate that for economic reasons the Spruce Falls surveys were curtailed about the time that the switch to wheeled skidders occurred. Ontario Ministry of Natural Resources staff are currently attempting to build up a data bank of stocking survey information which, it is hoped, will confirm or reject this theory. Information gathered so far suggests that peatland natural regeneration is still far better than natural regeneration on upland sites, but is not adequate by our stocking standards within the given time constraints. At present, however, we do not have sufficient data to prove this generalization conclusively.

In the meantime, Ministry staff in the Clay Belt are proceeding on the premise that in many cases the peatlands need help to achieve adequate spruce regeneration within a reasonable period of time.

ARTIFICIAL REGENERATION

Once it has been established that there is a problem in obtaining enough natural regeneration, artificial means of obtaining the desired spruce stocking must be considered. What is being done?

Nursery Stock Planting

In the Clay Belt it appears that artificial regeneration has for years been considered synonymous with nursery stock planting. However, this treatment has traditionally been aimed only at the upland sites and the bare fringes of the peatlands as they fall off from the uplands (Fig. 2).

Some of the reasons for this concentration of treatment on the upland sites are as follows:

1. In the past, uplands seemed to present greater problems to the achievement of natural regeneration.

2. Labor and capital resources are limited, and it seems reasonable to apply them to highly productive, well-drained sites

3. Site preparation and accessibility on low sites present technological problems.

Obstacles to the future expansion of this form of treatment into the peatlands include:

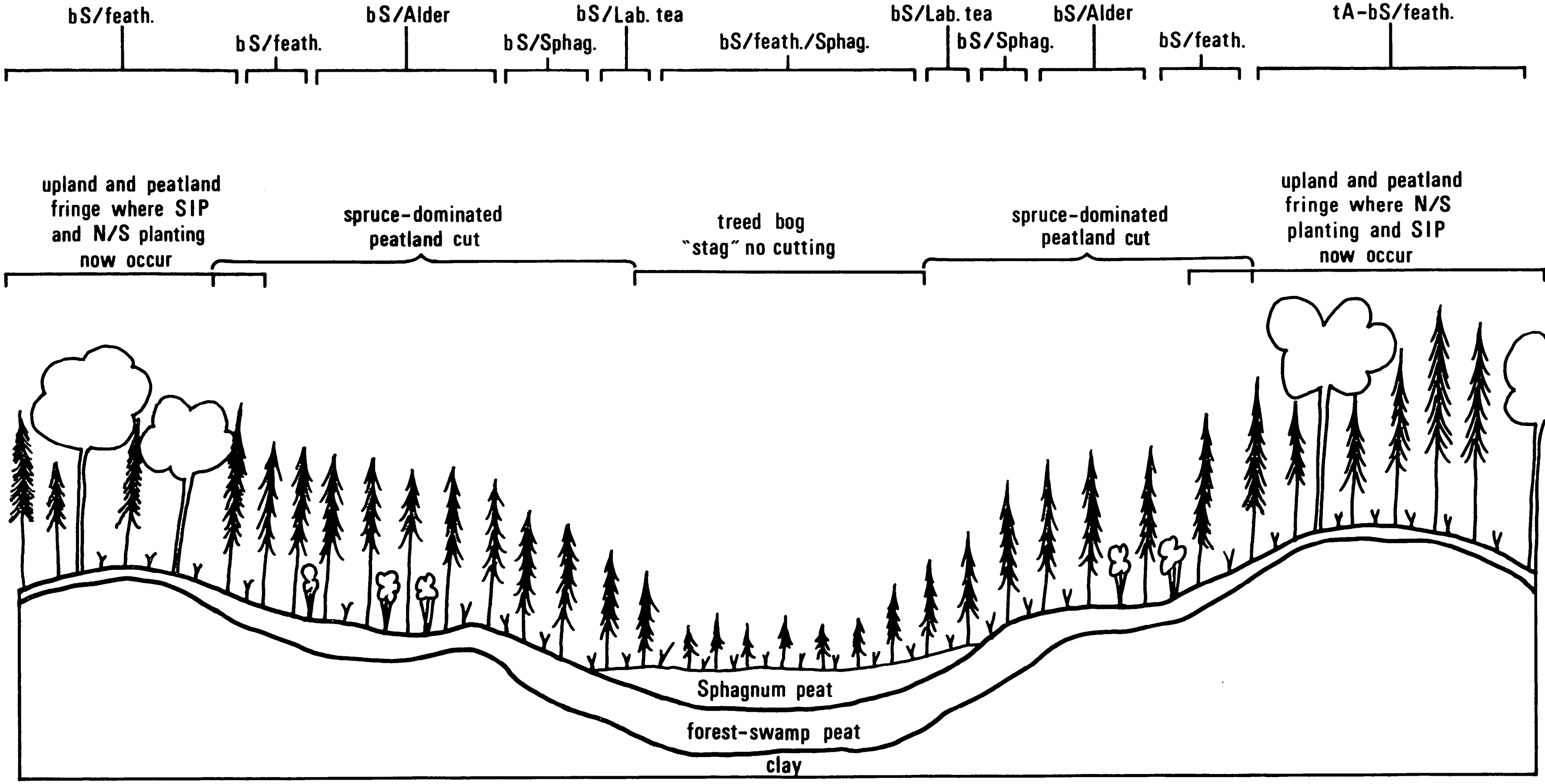
1. poor survival and stocking owing to extremely heavy competition (largely alder and grasses) and the large element of human involvement which often results in poor stock handling and/or poor planting quality;

2. continuing labor shortages;

3. a shortage of good transplant stock that can stand the competition;

4. continuing problems of accessibility both for tree planters and for tree delivery;

5. high cost with low benefits;



bS = black spruce   feath. = feathermoss (primarily Pleurozium schreberi)
Sphag. = Sphagnum moss   Lab. tea = Labrador tea   leath. = leatherleaf
Alder = speckled alder   tA = trembling aspen
N/S = nursery stock   SIP = site preparation

Fig. 2. Conceptual diagram relating typical site types in the landscape of the Clay Belt to what is being treated now and to the area of concern in this paper--the spruce-dominated peatland cut. (adapted from a figure which appeared in Vol. 4, No. 2 of the Forestry Research Newsletter)

6. inability to plant an adequate number of trees per acre owing to poor coverage obtained from site preparation treatments or no site preparation at all.

Container Stock Planting

Container stock planting with either the Ontario tube or paper-pots is not suitable for peatlands. This treatment has most of the same disadvantages as nursery stock planting; furthermore the size of the stock precludes survival, given the amount of competition generally present. The Ontario tube also has a tendency to frost heave when planted in exposed black muck. Both Ontario tubes and Japanese paper-pots are used to a limited extent on upland sites in the Clay Belt.

Site Preparation

It is a generally accepted philosophy in Ontario that on most sites, site preparation of some form or another is desirable if not absolutely necessary before, or as part of, any form of artificial regeneration treatment.

As far as I am aware, with the exception of prescribed burning, all site preparation done to date in this province has made use of a tracked or wheeled vehicle pulling something, pushing with a blade, or simply tramping. The problem on peat sites is that all of the conventional vehicles of this nature get bogged down, or make severe ruts on the shallower sites where they may be able to travel slowly.

Even before the treatment of peatland sites was considered, D7 and D8 tractors which pulled drags on the uplands to prepare for nursery stock planting were constantly getting stuck in high-land swamps and when crossing low areas to get from one knoll to another. The variation in ground conditions is extreme yet subtle to the eye, even on the generally upland sites.

In 1973 Ontario Ministry of Natural Resources staff in the Kapuskasing District tried to use wheeled skidders, either alone or pulling a light form of drag, to site-prepare various types of sites. The initial trials carried out in the fall of 1973 showed that skidders would not achieve the desired results on peatlands since they created deep ruts in the black muck which soon filled with water. The machines also had problems with the higher stumps often found in winter-cut areas. Sometimes they got stuck in the peat. The initial trials showed promising results in terms of speed and the job done on upland sites. Subsequent work the following summer showed, however, that the wheeled skidder had the same problems as conventional tractors in coping with the terrain variations.

During the summer of 1974 trials of a special D-6 wide-tracked tractor on peatland sites were initiated in Kapuskasing. In the trials this machine, which has 36-in. (91-cm)-wide pads and applies only about 3 lb surface pressure per sq. in. (0.21 kg/sq. cm) to the ground, showed a great deal of promise pulling various drags and tramping. The machine is limited in what it can pull because of poor traction associated with the low ground pressure, but this did not cause too much concern since light drags were all that we wish to pull on low sites anyway. The problem that has now occurred with this high-flotation wide-tracked tractor is a mechanical one. Heavy slash and especially fresh stumps are extremely hard on the wide tracks and their bogies. It is now questionable whether this machine can withstand the rigors of a full program of site preparation work.

Another machine which was given a short test in Kapuskasing swamps this summer is the Muskeg Tractor Jimmy made by Bombardier. This vehicle which has 14 in. (36 cm) ground clearance and a ground pressure of less than 2 lb per sq. in. (0.14 kg/sq. cm) proved to be too light for the job. It had no problem pulling the light anchor chain until the drags got caught on a stump. When this occurred and the machine was forced to use its winch, the winch pulled the machine backwards rather than freeing the drag. The Jimmy also showed that it had traction problems related to its light weight (9,400 lb, or 4,264 kg) and low ground pressure when crossing stumps and areas of heavy slash.

For about a year now, Ministry staff members in the Clay Belt have had their eyes on the F.M.C. forwarders for possible peatland site preparation work. F.M.C. makes two high-speed tracked forwarders, the 200 BG model with a bunk and grapple, and the 200 CA model with a winch and choker arch. Both of these machines have a 19 in. (48 cm) ground clearance and apply just over 5 lb per sq. in. (0.35 kg/cm^2) ground pressure. The low pressure is gained through spreading the weight of the machines over longer-than-normal tracks rather than over wide tracks.

To date, the 200 BG (bunk and grapple) has been the only model available for testing in Ontario. Preliminary tests of this machine last fall in the Thunder Bay area and, to a limited extent, in the Cochrane area, were encouraging but showed that the 200 CA model (winch and arch) would probably be better for site preparation work. The grapple and bunk on the 200 BG model simply got in the way as well as adding 2 tons (1,814 kg) of unnecessary weight to the unit. Besides this, it became obvious that a winch is absolutely necessary for drag work. It is strongly recommended that extensive trials of the 200 CA model should be carried out on peatland as soon as the machine is available in Ontario.

Even when a machine capable of traversing the peatlands without getting stuck or creating deep trenches is found or developed, we must still decide on the kind of results we want from site preparation. What is a good seedbed for spruce on peatlands and with what kind of attachments or arrangements can it be consistently obtained? Before it will be possible to achieve good results from direct seeding or strip cutting, these questions must certainly be answered.

Perhaps the answer to the question of peatland regeneration does not lie in mechanical site preparation at all. Prescribed burning has been attempted recently in the peatlands and to the surprise of many, these wet sites do burn. It is really too soon to tell how effective this treatment is. Initial observations show that a very dry black crust of charred organic matter about ½ in. (1.3 cm) thick forms on the surface of the ground. It is felt that this crust will not encourage germination and seedling establishment because of its dryness, but perhaps the burning will stimulate layerings. At present prescribed burning is being used mainly for slash reduction and site preparation for tree planting on upland sites. Perhaps it can be carried out before mechanical site preparation on peatlands to reduce slash and allow the machinery that is developed to work faster. Further studies of the effects of burning on peatlands are definitely warranted.

Direct Seeding

Direct seeding of black spruce is still a big question. Over the past few years in Kapuskasing District about 700 acres (283.28 ha) of peatland have been treated in this manner. Rates ranging from 40,000 to 60,000 seeds per acre (98,850-148,250/ha) have been used. For the most part seed has been applied in late March and early April and both skidoo seeders and fixed-wing aerial applications have been tried. The major projects were carried out on shallow peatland sites which had been prepared by wheeled skidders pulling anchor chains or had been disturbed at the time of logging by the tree-length harvesters and forwarders employed in the operation. No stocking results have been obtained to date, but from observations made the outlook is discouraging.

In the project seeded in March, 1974 on the harvester-cut area, where the machines disturbed the site adequately, good germination resulted during the spring and summer of 1974. Most of the germinates, however, were frost heaved in the fall of that year.

Observations made this summer of the area seeded in March, 1975 on ground prepared during the summer of 1974 by skidders and anchor chains indicate that germination is poor.

Next spring Kapuskasing District expects to reseed some of the areas previously seeded. It will be the last year for sizeable seeding projects in the district until a good assessment can be made of the efforts to date.

Even though direct seeding of black spruce has not been proven successful thus far, I feel strongly that operational trials, and comprehensive assessment and analysis of them, should continue. It is imperative that direct seeding become a viable tool for use on peatlands. Its development would facilitate the treatment of large acreages with low labor input, relatively low costs and little handling. Direct seeding would be particularly useful after the second cut took place in an alternate strip cutting system.

When the key to successful direct seeding of black spruce is found, we will be faced with the problem of how to collect seed in the large quantities required, particularly if broadcast seeding is the prescription. Because of the limitations implied here, it is my opinion that direct seeding will never be the complete answer to spruce peatland regeneration, but it should become an important phase of the program. More effort must go into the development of this treatment.

Modified Harvest Cutting

Although some forms of modified cutting have been practised on a small scale for nearly 20 years in the Clay Belt, this means of promoting natural regeneration is still in its infancy in the region.

In 1961, after about 4 years of experimentation with forms of modified cutting which were either too hard to control or too expensive, Cochrane District initiated a long-term (30-yr) plan for alternate strip cutting in Fournier Township. About 40 or 50 net acres (16-20 net ha) per year are cut from this block. To my knowledge no comprehensive analysis of the regeneration results obtained has been made to date, or at least no conclusive results are available, probably because of frequent staff movements. Some stocking surveys have been completed recently but the results are not available at the time this paper is being written. What information is available suggests that regeneration is adequate in some places but that success is not consistent.

Recent years have brought the expansion of operational experimentation with modified cutting in Clay Belt peatlands. Since 1971 Cochrane District has been cutting approximately 250 net acres (101 net ha) per year, using the alternate strip method, in Sangster, Case and Fournier townships. In 1972-1973 Kapuskasing District attempted about 200 acres (81 ha) of a group seed-tree modified cut, and has carried on in the last 2 years with about 200 net acres (81 ha) per year of alternate strips. The strips in all of these recent operations have ranged from 2 to 5 chains (40-100 m) in width. The patches of seed trees which were left in the Kapuskasing 1972-1973 experiment were about 1 chain (20 m) in diameter, regularly spaced about 3 to 3½ chains (60-70 m) apart from center to center.

Although a great deal has been learned about operational problems encountered in planning, laying out and implementing these forms of cutting, it appears that little conclusive information on the regeneration results of these methods is available at this time. It is perhaps too early to make final judgment on any of these recent projects, but one thing is clear, that field staff are finding it difficult to do justice to this work in terms of adequate follow-up. It appears that only the Cochrane District Sangster Township block, in which the Canadian Forestry Service is involved, is being monitored closely on an annual basis by both OMNR and CFS staff. Some of the interim results from the Sangster strips are encouraging.

The problems that OMNR staff are encountering with the promotion of modified cutting in the peatlands are numerous. Some of these are:

1. an inability, at present, to site prepare these strip cuts adequately to create acceptable seed beds for spruce;

2. the lack of conclusive, positive results from previous strip cuts in our peatlands and the problem this creates when we attempt to promote these ideas among operators who consider strip cutting a costly pain in the neck;

3. utilization and cut control problems with bushworkers paid on a piecework basis;

4. additional logging costs ($30-$36/net acre, or $12-$15/ net ha cut), which the government subsidizes at present, largely because road construction and maintenance costs are very high in the Clay Belt.

5. lack of time and manpower for an adequate follow-up assessment of the system.

In any discussion of the possibilities of strip cutting, concern is inevitably expressed that so much of our spruce forest is in the mature and overmature age classes and that blowdown will be a problem. In my opinion this should not be a major stumbling block to strip cutting since it appears that we are losing a fair amount of timber each year to blowdown even in uncut stands. Steps can be taken to reduce the effects of winds in the strips. Moreover, if the system can be developed further, the interval between successive cuts can be as short as 3-4 years. Mr. George Marek's work with strip cutting near Nipigon is apparently producing results quickly enough that the second cut can take place 3 years after the first. This would reduce blowdown loss tremendously.

Modified cutting of black spruce peatlands followed by site preparation has so many potential advantages for silviculture, site protection, wildlife habitat, and aesthetics, that every effort should be made to find the right formula to make it work. This will take a well coordinated, concentrated effort over the next few years and a great deal of money. Nevertheless, I am reluctant to claim that we are managing our black spruce peatland forests until this development and the development of the necessary second-phase treatment of site preparation followed by direct seeding come about.

CONCLUSION AND RECOMMENDATIONS

Black spruce peatland management (particularly the regeneration aspect of it) is in many respects still in the Dark Ages. Forestry staff in the Clay Belt are groping for answers but so far are only coming up with more questions. Some of the reasons for this situation are as follows:

1. the regionally localized problem of having such a high proportion of productive forest in lowland peatlands, and the resulting slow development of specialized equipment for logging or silviculture because the market is limited;

2. the high turnover of technically qualified staff, including foresters and technicians, in the area;

3. lack of a well-coordinated, year-round applied research effort tied in with the operational silvicultural program;

4. the fact that the main thrust of research effort over the past 15-20 years has been aimed at jack pine (*Pinus banksiana* Lamb.);

5. lack of an adequate site classification for use in the subtly varying terrain of the Clay Belt.

The concept of output targets was and is a good one, and is a necessary step in the evolution of forest management in Ontario. However, the concept has been implemented in the peatlands about 10 years too soon. The means of achieving desirable stocking levels, in the time allowed, on the number of acres of peatland involved in the targets, have not yet been developed.

On the brighter side, things are improving gradually. Communications are improving among OMNR staff in the different districts, and between CFS staff from the Great Lakes Forest Research Centre and OMNR staff. Trials are being carried out at various levels. Money for equipment development is gradually being made available.

The following changes need to take place, however, before any real headway can be made on the peatland regeneration problem.

A stable forestry staff, willing to remain in the Clay Belt until some answers are obtained, is required.

An intensified, applied research effort, with research people working year-round in the Clay Belt districts side by side with management people, is necessary. If such researchers are not available, either from the Ontario Ministry of Natural Resources or from the Canadian Forestry Service, then a second, less desirable alternative is a reversion to the system of having management foresters and silvicultural foresters in each of the districts.

A practical site classification system that is easily understood is needed so that information gained and progress made in one area can be effectively applied to other similar sites. John Jeglum, Art Boissonneau and Fred Haavisto of the Canadian Forestry Service have made a good start (Jeglum et al. 1974), but a great deal more must be done to make a workable system.

Industry must be willing to cooperate with government to improve utilization and tie together harvesting and silviculture. This will certainly involve large expenditures, but it is necessary to prevent future wood shortages and public criticism of industry, government and the forestry profession.

The government must be willing to spend large sums of money on access over the next 10-15 years. Accessibility is a major obstacle to both forest management and silviculture. Only winter access is necessary to harvest peatlands, but year-round access is needed to manage them and to promote regeneration. Accessibility both by improved road networks and by further development of off-road machinery is an absolute must.

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DISCUSSION

WHITNEY

Dr. Jeglum, in our root rot studies we found 10 to 40 times as much root rot in black spruce on upland sites as on swamp sites. This root rot is directly related to windfall and to other losses in black spruce. We found that lower moisture was a contributing factor to the greater abundance of root rot on the upland sites. Other factors that have been suggested are higher soil temperatures on the upland site and better aeration in the soils. Have you obtained any data on these two factors in the course of your studies?

JEGLUM

I have some information on water levels in different types and some information on ferric:ferrous ion ratios which suggest that there is a higher oxygen aeration status in upland soils. It is lower on the swamp sites but remains surprisingly high. On treed bog sites the ferric:ferrous ion ratio is very low, probably reflecting the fact that the poorest aeration is related to the poorest drainage. My information suggests that there is higher aeration in upland soils than in lowland soils. I would want to know something about the ecological requirements of the pathogens involved in the root rot. These pathogens cannot exist as well in anaerobic conditions.

WHITNEY

Do you have any information on soil temperatures?

JEGLUM

No, I haven't done any specific studies on temperature differences between sites. Information is available in the literature on relative temperature differences between upland and peatland soils, and the peat soils remain colder much longer into the spring and summer. You find lenses of frozen peat and ice as late as midsummer in parts of the Cochrane district. If you want to suck ice in the summer you dig in a peat bog, not in uplands. As for the relation of root rot to the different swamp sites, I suspect there will be relatively more rot on the better-aerated sites, and less on poorer-aerated sites.

MORGENSTERN

Mr. Haavisto, you pointed out that there were approximately five seeds per cone. This figure is extremely low according to our estimates from large sampling across the province. Our figures were as high as 15 seeds per cone. Also our viability was much higher than yours. Have you any additional information to explain why your figures are so low for both factors?

HAAVISTO

I think your data will corroborate mine because five was the number of viable seeds per cone and, assuming there are twice as many empty seeds per cone as there are viable seeds, we are both talking about 15 seeds per cone.

MORGENSTERN

No. Our average was 15 full seeds per cone and 80% to 90% of them germinated. So our numbers are still higher.

HAAVISTO

Were your cones collected from upland conditions? I suspect there is a considerable difference between upland and lowland conditions.

MORGENSTERN

They included both upland and lowland.

MAREK

Mr. Virgo, your comments from the Clay Belt do not sound any more encouraging than ours from northwestern and northern Ontario. You have lots of problems. If your implementation schedule is readjusted and increased, and your efforts have to be doubled, what kind of situation will you be in?

VIRGO

I don't think it will change very much from the situation we're in now. We'll simply be further in trouble. We're increasing our efforts tremendously in terms of research. I think perhaps our biggest problem is in not having someone who has had the length of time in our conditions that you've had in yours, and we've got to stop moving around like blackflies.

MAREK

As a professional forester and a professional manager, what are you going to do to cope with this situation?

VIRGO

I am recommending a greater amount of research effort in our kind of conditions. I don't think we can wait 20 years as we did for jack pine. I think we have to get serious about providing answers now. One of the ways to do this is to change the structure of the research effort in various conditions. I think research should be closely related to operational aspects, and I would like to see some applied research people working alongside management people. One of the biggest flaws in terms of research effort is that it's haphazard and lacks follow-up simply because of time constraints. It needs coordination.

LANE

Mr. Haavisto, why do you say you get the same yield from different ages of cones? Our many tests show that the yield from current-year cones averages about 8 oz per bushel whereas, if you collect even one-year-old cones, the yield drops to about 1.5 oz per bushel.

HAAVISTO

I base my results on studies in Kennedy Township. We collected all the cones from the trees, we aged them by years to 25 years plus, and we extracted the seeds according to your techniques. Remember, the trees were from northeast of Cochrane, so the results may be related to local climate. The indications are that the number of viable seeds per cone does not change materially with age and most of them remain viable for as long as 5 years.

LANE

Your results are different from ours when Horton was working on mechanical collection. We have never been able to get the high yield from other than the current year's cones, so you may have a local situation.

HAAVISTO

Initially, although some of the cones Horton collected may have been 20 years old, 68% of the seeds were viable. I am still using seeds from that collection and according to my tests they are 100% viable now.

LANE

Between 98% and 100% of the seeds from cones Horton collected mechanically were viable originally. The point is that the yield from the mechanically collected cones was well down, in the 2.5 oz per bushel range, compared to an average of 8 oz per bushel from conventional collections, yet extraction costs are the same.

MAREK

Mr. Lane, how long can we afford to collect only one-year-old black spruce cones? We are collecting 2- and 3-year-old jack pine cones; why can't we do this for black spruce?

LANE

We can if we're willing to accept the additional costs. Black spruce is now $128/kg. As you drop from the current year's cones down to 2-year-old cones which have opened and closed several times, the yield per hectoliter is going to be well down. The yield from one-year-old cones is about one eighth the yield from the current year's cones. So the question is: Can we accept a higher price per kilogram for black spruce?

MAREK

The present demand for seed is tremendous. Our collection quotas are out of this world if we can only collect from the current crop. It's coming to the point where, because we are running out of good black spruce stands and have difficulty meeting our quota even at high wages per hectoliter, we will have to collect older cones.

LANE

Horton proved that you can collect cones mechanically, and take those from all years, but the costs go up tremendously.

HAIG

I was involved with Horton in that study. The objective was to determine whether we could collect cones fast enough mechanically to offset the lower yield. Allowing for a lower yield from mechanically collected cones and higher seed extraction costs, the total seed collection costs from a steadily working machine should be lower, but no one has made such a machine.

LANE

I agree that the collection cost would be lower, but the cost per kilogram of clean seed would be much higher.

HAIG

Admittedly, machine-collected cones were dirtier and some of them were harder to open, and this would increase extraction costs, but surely these problems could be solved by technology.

MORGENSTERN

There seems to be a conflict between the results that Haavisto got from the Cochrane area and those Lane reported. More seed was retained in the cones in Haavisto's northern samples than in the overall sample of the province. This ties in with my observations of the regional variation in cone opening during provenance studies. When we started sampling at Turkey Point in the south of the province, the cones were beginning to open and it looked as if the seeds would be shed within a very short time. But in our northernmost samples the cones were closed; even after storage for considerable time in the seed extraction plant, they were still closed, and many of them required repeated moistening and heating to open fully. I believe if we took a sample from south to north we might find a gradient of cone opening which indicates easy opening in the south and very restricted opening in the north.

GORDON

Mr. Haavisto, your intermediate trees had a higher yield than the dominant trees. Were the figures for the dominant trees an average of the 20-year collection, or were they for single years?

HAAVISTO

The first table was a summary of the numbers of cones, by years, for the past 25 years. The next table was for 1964 cones only, and the ratio of nonviable to viable seeds per cone was still 2 to 1.

GORDON

So in any cutting, the seed available to the strip is coming from the inferior trees. It seems unusual that in some years some of the dominants wouldn't be carrying more seeds than the intermediate trees. But it may well be that the intermediate trees are intermediate because they're precocious and are good cone bearers.

HAAVISTO

The figures show that the number of cones and the total number of of seeds in the cones or dominant trees exceed those on either the intermediate or codominants, and there isn't materially any difference between them.

JOHNSTON

Dr. Stanek, how do layers stack up as future crop trees, and if they are better, would winter logging be worth the effort to preserve these?

STANEK

They are very much the same, and similar in performance. Of course, winter logging would preserve many layerings, and we would save many years thereby making up for any slight deficiency in growth performance. Yesterday we saw a rather good stand of advance growth. I must confess, my heart was bleeding when I saw the huge scarification machines breaking the trees down. Instead, one could fill in the opening with planted seedlings and in 20 to 30 years we would have a beautiful stand. The same applies to layerings. We could organize our logging operations to preserve regeneration. On the other hand, we saw that after logging, which disturbs the site very much, we obtain regeneration from seedlings. Therefore, I would like to see silviculturists, like Marek for instance, go into such areas and assess if planting, filling in of existing holes, would result in good stocking, or if any other measures should be taken.

CONCLUDING REMARKS

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This symposium differed from others held in the past 2 years in that it did not deal with an operational subject such as "Direct Seeding", "Containerized Forest Tree Seedling", or "Forest Fertilization", but with a single species, and it crossed a range of subjects dealing with this species.

I might add that it was one of the most tightly organized and controlled symposia ever held. Speakers were rigidly held to their allotted time, and no smoking was allowed in the auditorium.

A review of the papers indicated that a great many questions still require answers:

1. Can we afford to plant bare-root stock at all? There has been discussion of the size of stock and some apparent conflict of opinion on the best sizes, but little direct mention of the horrendous planting costs per acre, and the fact that we may have to plant container stock or not plant at all.

2. What is the optimum stocking and density? Fundamental questions on stocking and density standards still haven't been answered. Although a great deal is known about the earliest stages of the growth of black spruce, very little is known about the juvenile (10-60 years) stages, and the best stocking and density throughout a stand's life, to achieve desired results at maturity.

3. What is the true situation with respect to strip cutting, particularly on peatlands? We heard conflicting reports on the width of strip required and whether modern logging prepared a good seedbed which overcame the destruction of advance growth in the form of layerings. Are some of these differences of opinion due to geographical differences? If strip cutting is the answer, how can we ensure its success?

4. Should we have a regional symposium concentrated solely on the Clay Belt black spruce problems? It may be of benefit to foresters who have never worked in this area--the single most important area for black spruce pulpwood in Ontario.

The papers were logically divided into five categories: Stocking Standards, Stock Production, Direct Seeding, Upland Spruce Regeneration and Peatland Spruce Regeneration. However, as the presentations progressed, it became evident that there were two broad categories as well: the papers by Hearnden and Ketcheson might be called philosophical and all the others technical.

Hearnden delved into history to illustrate that there has been a demand for black spruce regeneration since the inception of pulp and paper mills three quarters of a century ago, and expressed the opinion that the most serious obstacle to management of our spruce forests has been socio-political rather than technical. Ketcheson reinforced this view indirectly with the statement "What we have is what we want", which expresses the viewpoint of industry, i.e., if other species regenerate more easily than black spruce, use the other species. Better utilization, of course, calls for the use of all species, which should not preclude efforts to regenerate the desirable black spruce.

Ketcheson pointed out that while 50% of cutover is in the spruce working group, only 30% of treated cutover is in that working group. The figures are even more disproportionate for peatland spruce considered separately.

Almost all speakers quoted figures to emphasize the importance of black spruce, and Hearnden's figures are representative: "The volume of production has expanded from almost zero in 1900 to 2 million cunits per year at present. Black spruce represents 48% of the volume of coniferous growing stock in Ontario with an estimated volume of 520 million cunits."

Hearnden believes the present Ontario regeneration agreements separate logging from silviculture and create "two solitudes" which should be bridged. Surely it is possible to combine the two within the framework of these agreements? Their true objective is the cooperation of industry with government, and this should lead to a union of logging and silviculture, not a separation.

Ketcheson quoted part of Dr. Reynold's paper delivered at the Pulp and Paper Convention in Montreal last March to illustrate the objectives of the Ontario Ministry of Natural Resources, and went on to show how they often conflict with the more limited objectives of a unit forester. The latter tends to treat as many acres as possible within his budget. Since the spruce working group is the most expensive and chancy to treat, he emphasizes the surer and cheaper working groups and species to enlarge the acreage, a very natural but unfortunate procedure.

Robinson's paper was a clear exposition of the difficulties of relating stocking percentages to density and of determining the density and stocking required, and hence the best quadrat size. Robinson recommends a size of 1/2,000 ha and lists his reasons for doing so.

It is surprising that we are still at the guessing stage with respect to so fundamental a matter, although, as was stated, if we were to reach a high level of competence and quality in our regeneration efforts, we would no longer need survey standards.

Sleep's paper on "Forty Years of Stocked Quadrat Surveys in the Clay Belt" emphasized some of the same problems considered by Robinson: what the size of quadrat should be, how numbers of trees per acre should be measured, and what present stocking should be to obtain full stocking at maturity. Sleep offered his company's permanent sample plot data to any interested scientific research body, an offer which, I hope, will be accepted.

From stocking surveys we proceed logically to Armson's paper on the "Establishment and Early Development of Black Spruce". Armson decried the lack of knowledge available on spruce growth, particularly in plantations, at intermediate stages, thereby reinforcing some of Robinson's points. Plantations can be readily established and the species can be grown from seed as either bare-root or container stock and may be planted in the spring or midsummer (July 15—August). Patterns of annual height growth indicate that large planting stock retains its advantage over smaller stock and maximum rates of 40-60 cm per year can be expected within 5 years of planting.

Payandeh's paper represented a distinct change in topic. He presented the results of a growth and economic analysis of a 40-year-old drainage experiment near Iroquois Falls in the Ontario Clay Belt. His results indicated that, on the basis of current drainage cost and projected stumpage prices, the rate of return from drainage could be as much as 6%. Because of technological advances in forest drainage, and savings realized in logging and transportation costs as a result of growth improvement, the expected future rate of return from the best drainable sites could be about 10%.

Perhaps somewhere in the future a research agency can undertake, on a larger scale, a well-designed experiment of drainage on marginal spruce peatlands.

Fry called for an improvement in quality of nursery stock, although he conceded that a number of factors are involved in the generally poor results of planting black spruce (e.g., storage, poor planting quality, adaptability of stock to site).

Fry believes that, in his Terrace Bay District, black spruce stock of the old 2+2 quality or the more recent 1½+1½ quality is required. This is the "heavy" size class.

Wynia stressed that nursery managers and field foresters must agree on stock specifications. He stated that black spruce has several specific characteristics that make it particularly suitable for container stock transplanting, and outlined the advantages of containers, particularly the Spencer-Lemaire Bookplanter (Ferdinand model).

Wynia also stated that black spruce is the most difficult of any species to grow in a nursery. Results to date show that the quality of $1\frac{1}{2}+1\frac{1}{2}$ stock is much more reliable than 3+0 stock.

Reese called for new standards in describing the required characteristics of planting stock. The old age-class method will no longer do, and we must have critical standards related to site. We are well along in monitoring procedures for nurseries and transport of stock, but not for outplanting. Planting will increase in absolute acres, but decrease as a percentage of regeneration measures.

An important point made by Reese is that the planter, not the nursery, should specify the type of stock needed. He believes future development will be toward greenhousing rather than field raising, and this might mean a definite swing to containers.

Morgenstern gave a comprehensive review of the problems and opportunities in establishing seed orchards of superior black spruce stock, either from seedlings or, preferably, clones.

Until enough seed orchards are in operation, the use of seed selection and production areas is recommended as a method that will provide some improved seed rapidly.

The advantages of artificial regeneration, i.e., the control of spacing, reduction of rotation ages, and elimination of thinning, can be realized fully only through the use of superior stock.

Do these advantages mean that Reese may be wrong when he predicts that planting will decrease in importance as a regeneration method?

Winston's paper summarized field experiments to evaluate black spruce seed germination under different site and climatic conditions in northern Ontario. Hand scarification to expose humus or mixed humus plus mineral soil horizon seedbed has been successful as a means of obtaining stocking in excess of 40% on both very dry and moist sites. Survival rates of one seedling per eight black spruce sown were obtained. Thirty percent of the mortality was attributed to clipping of newly germinated seedlings by cutworm, while flooding also caused high mortality on the moist site. Screening studies of seedspots to assess rodent predation of seed were inconclusive. Further studies of rodent and cutworm damage appear worthwhile.

Fraser's paper dealt with the question "Is planting black spruce feasible?" and answered with an emphatic yes, based on interim results of trials in the Central Plateau Section of the boreal forest. Management criteria with respect to the kind of forest that is ultimately desired, and acceptable costs for seeding and its attendant thinnings vs. planting, will affect the final answer.

Ketcheson, to whose paper I referred at the beginning of this summary, poses the question, "Do we want to manage black spruce?" He weighs the undisputed importance of the species against the high cost and risk of regenerating it.

McClain spoke on the effect of planting date on stock survival and growth, and this led to some interesting comparisons:

1. McClain: "2+0 stock showed a decisive survival advantage over 3+0 stock on both planting sites" (upland and lowland).

   Wynia: "The 3+0 seedling has been our major product during the last few years and the source of many of our problems."

2. McClain: "With deferment in planting from the optimum spring period, the forest manager may expect depressed tree growth."

   Armson: "Summer (mid-July to August) planting has the advantage that maximum root development can take place in the season of planting, frost-heaving is eliminated and subsequent height growth is uninhibited."

Marek's paper was on the natural ecosystem approach of regenerating black spruce through modified cutting rather than through the artificial means of planting. Modified cutting is chosen particularly because of the fragile, shallow glacial till of the Lake Nipigon forest district.

Modified cutting was also the subject of the next two papers by Auld of the Ontario Ministry of Natural Resources and Peacock of Abitibi Paper Company Ltd. Auld used an excellent slide presentation to illustrate the intricate layout of alternate strips and blocks. Past experimentation has shown that a strip 2½ chains (165 ft) wide produces the best results, but regeneration to date has been disappointing. Nevertheless, the principle of modified harvest cutting has great potential if proper care is taken in its implementation. Excessive slash is the greatest obstacle to preparation of a good seedbed of *Sphagnum*, mineral soil, or moist duff.

Peacock listed additional logging difficulties arising from modified cuts and called for a change from a systematic layout of alternate strip cuts to a system based on site types, eliminating strips crossing the topography. He cautioned that modified cutting should be practised only where planting is not feasible, i.e., on swamps and thin, rocky soils.

Jeglum proposed a wetland classification for the Northern Clay Section of the boreal forest. It is intended to be of use to forest managers and is focused on the wetland section of the four wetland "formations" proposed: bog, fen, marsh and swamp.

The black spruce-dominated swamps are divided into four site types--Feather Moss, Speckled Alder, Sphagnum, and Labrador-tea. Two treed bog types, and a composite upland type, are included for comparison, and a key to the types is provided. Jeglum suggests that four criteria of differentiation are necessary if the classification is to be useful to foresters: The site types should exhibit characteristics that are relatively easy to recognize in the field, they should relate to differences in tree growth, they should relate to differences in regeneration, and they should be interpretable from air photos.

The papers presented by Stanek and Virgo, both men of experience in the Clay Belt, deal with the problems of regenerating black spruce on peatlands.

Stanek pointed out that natural swamp forests, when left undisturbed or logged by old horse-skidding or hand logging methods, regenerate primarily by layerings. New machine methods destroy this advance growth but tend to prepare a seedbed for seedling regeneration, and Stanek found 60% stocking 7 years after logging. Only 8% of this restocking was due to layering. He found that 10 years after logging, the spruce required release from alder growth.

Virgo also mentioned the destruction of layering by modern logging, but he does not believe that an adequate seedbed is prepared by wheeled skidders; consequently, regeneration is a failure. He stressed the lack of suitable machinery for silvicultural work in the peatlands of the Clay Belt, and the undesirability of planting.

Haavisto stated that 45% of the black spruce area of Ontario is peatland, and that peatlands as a whole regenerate at least to a level of conditional acceptability, which is a higher level than that achieved on uplands.

Haavisto presented valuable information on cone-bearing age, seed-year intervals, cones per tree, dominant trees compared with codominant and intermediate, viability and dispersal. All this is basic information required by foresters planning modified cuts in peatlands.

In closing, I would like to highlight a few of the major questions and problems raised by this symposium:

1. Hearnden perhaps is too optimistic about our technical expertise--we've come a long way since the 1950s, but we still have a lot to learn.

2. We need to know a lot more about stocking and density standards and the growth of juvenile stands on all sites.

3. What is the true situation on peatlands? (Stanek, Virgo, Haavisto). Can we use Jeglum's classification to further our knowledge and reconcile our differences on these important sites? Can we ensure the success of alternate strip cutting? How important are the climate and soil differences between the Clay Belt of northeastern Ontario and the north central and northwestern parts of the province?

4. Is the problem of drainage so far in the future that we should ignore it for the present, or should we start a large-scale experimental project on marginal and submarginal lands, e.g., the James Bay Lowlands?

5. What stock should the nurseries be producing? Are we not ready for another symposium on container stock? A symposium devoted to the Clay Belt?

6. We must speed up the production of superior seed stock.

7. Can we afford to plant huge areas or must we concentrate on direct seeding and modified cutting?

APPENDIX

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