MECHANIZATION OF SILVICULTURE IN NORTHERN ONTARIO

Proceedings of a Symposium sponsored by
Ontario Ministry of Natural Resources
and
Great Lakes Forest Research Centre
Sault Ste. Marie, Ontario
October 1, 2, 1974

GREAT LAKES FOREST RESEARCH CENTRE

SAULT STE. MARIE, ONTARIO

SYMPOSIUM PROCEEDINGS O-P-3

CANADIAN FORESTRY SERVICE

DEPARTMENT OF THE ENVIRONMENT

FEBRUARY 1975

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Copies of this report may be obtained from

Director,
Great Lakes Forest Research Centre,
Canadian Forestry Service,
Department of the Environment,
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FOREWORD

The Proceedings of a Symposium on the Mechanization of Silviculture in Northern Ontario comprise 17 papers delivered on October 1 and October 2, 1974 at the Holiday Inn, Sault Ste. Marie, Ontario. Brief abstracts in both English and French are included with each paper, and an appendix provides basic conversion factors or equivalents for all measurements used in the text.

Because of the nature of the Symposium it was inevitable that trade names would appear quite frequently in the papers presented. Nevertheless, the use of commercial names is solely for the information and convenience of the reader, and does not constitute endorsement by participants in the Symposium or by the organization with which they are affiliated.

In the original submissions there were wide variations in the form and spelling of equipment names. To be consistent, therefore, we have given the full names the first time they appear in each paper; where applicable, abbreviated forms have been used thereafter. It should be noted that equipment manufactured by Beloit prior to 1971 is now manufactured by Reynolds-Lowther.

For the sake of brevity and to avoid unnecessary repetition, Canadian Forestry Service, Great Lakes Forest Research Centre and Ontario Ministry of Natural Resources are printed in full the first time they appear in each paper; thereafter the abbreviations CFS, GLFRC and OMNR, respectively, are used.

INTRODUCTION

It is generally recognized that if Canada is to retain its share of the increasing world market for wood, forest lands dedicated to fiber production must be managed so as to achieve their full potential. Unfortunately, the necessary silvicultural operations such as nursery stock production, planting, and thinning are labor-intensive, and unit costs are high. An additional problem is the critical shortage of woods labor. Consequently, silvicultural programs are not being undertaken on a scale necessary to achieve maximum forest production, or even to maintain it at current levels.

Mechanization appears to have the potential to increase man-day productivity and reduce the unit cost of silvicultural treatments. This in turn should permit a substantial increase in the scale of these operations.

Recognizing the potential benefits of mechanization, the Ontario Ministry of Natural Resources and the Canadian Forestry Service in 1970 initiated a cooperative program aimed at developing the necessary equipment and techniques to mechanize the more important silvicultural operations conducted in Ontario.

This symposium, which was sponsored by the two cooperating agencies, represented the first major progress report on the joint mechanization program. It also provided an opportunity to obtain input from the forestry community with respect to mechanization needs and opportunities, and suggestions for the further development of the program. Over 140 delegates from across Canada were in attendance, representing provincial forest management agencies, the forest industry, equipment manufacturers, universities, and colleges of technology. Seventeen papers were presented on various facets of the problem, and all papers are included in this publication. In addition, there was a field demonstration of site preparation, planting, and seeding machines, including a prototype of the Ontario Mark III Tree Planter, a totally new type of planting machine designed to treat the difficult sites typical of the Boreal Forest.

The symposium was considered successful, and the interest it generated is expected to stimulate further efforts to develop the equipment and techniques required for a fully mechanized silvicultural system.

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WHY MECHANIZED SILVICULTURE?

F. B. Armitage
Program Coordinator for Forest Production
Canadian Forestry Service
Environmental Management Service
Ottawa, Ontario

Mechanization of silviculture results from intensified wood production and social change. A systems approach is necessary to integrate the efforts of operational, administrative and research personnel responsible for developing mechanized procedures, to provide a framework for the necessary dialogue among these personnel and to deal with the complex implications of mechanization.

La mécanisation de la sylviculture procède des changements sociaux et de l'intensification de la production ligneuse. Une approche des systèmes de mise en oeuvre s'avère nécessaire à l'intégration des efforts du personnel exécutif et administratif et de la recherche appelée à développer les procédés mécaniques, ce en vue de fournir un cadre au dialogue indispensable entre ces catégories de personnel et d'affronter les implications complexes de la mécanisation.

Let us examine the proposition that mechanization of silviculture has become essential. *Why* has it become essential? Why are these silvicultural practices themselves necessary? They are necessary in this forested land of ours because the demand for wood is increasing and there could be shortages. They are also necessary because the use of exploitive methods in forestry will decline and intensive management and production methods will increase in response to need.

There will be no diminution, but rather an increase, in the demand for forest products. The most tangible of these -- wood -- entails harvesting methods that involve, or must be followed by, deliberate silvicultural treatments. As soon as we started to face up to the need to apply silvicultural treatments on an operational scale of any consequence, we encountered many important problems -- social and economic as well as biological. Most of them were accentuated by the scale of the job to be done. We turned to mechanization as the basic solution.

There is a new force influencing the need for intensive management. Formerly, inexpensive, government-owned stumpage was regarded as the primary obstacle to development and application of silvicultural practice. We then entered a phase when studies of intensive forest management seemed to be based on -- and therefore seemed to emphasize -- the economics of wood transportation. The emerging problem is that of getting people to work in the forest, coupled with the commuting distance to and from the forest. Harvesting and other work in the forest will have to be carried out within commuting distance of population centers where the workers are going to insist on living in order to meet their social needs -- centers with populations of 5,000 or more. This implies intensification of the operational effort (whatever its form may be) so that it can be concentrated in a specific and accessible place at any one time.

The magnitude of the job to be done and of the implications of large-scale management and use of the forest compel us to recognize that the total operation is fast becoming industrially oriented rather than agrarian in nature.

Mechanization as represented by machines is neutral. Machines can be operated to use or abuse the forest, the site, the residual stand. Mechanization of silviculture does not simply encourage intensification of the operations entailed. It provides the climate necessary for the development of equipment suitably mated to the biological needs and constraints of the forest.

The maintenance and other logistics involved in maximizing machine usage to achieve cost reduction, efficiency in the use of energy, minimal harm to site and residual stand -- all these things require the development of new and intensive planning, operational and control techniques -- new to forestry, that is. They are only now being introduced by forest harvesting companies. This points to an opportunity for us, concerned as we are with mechanization of silvicultural operations, to exert a beneficial influence on the harvesters.

We all know that the system with which we are concerned is highly complex. We should not allow that fact to daunt us. Let us bear in mind, though, that mechanization creates its own problems. Let us remember that usually we cannot foresee all the consequences of what we innovate -- not even all the major consequences. Therefore, while prosecuting our development programs vigorously, let us remember that it is usually wise to ease ourselves into new management systems rather than to jump in with methods inadequately tested in relation to the conditions to which they are to be applied.

What does all this imply? For one thing, it calls for an approach that will permit identification of the key operations and indicate where the development money and effort should be spent. We need an approach that will enable us to make the best choices from among the available biological/engineering methodology alternatives in relation to the kinds of biological/site/social/economic/operational situations with which we are faced. We need the means to look ahead with reasonable assurance to foresee at least the important social and economic consequences of what we do. Also needed are operations control systems to ensure that the operational effort is effective, not misdirected -- that it leads us towards the achievement of our defined objectives. We frequently recognize the need for -- but seldom quite manage to provide -- a terrain classification system to guide the silvicultural work and, incidentally, to strengthen operational links with the harvesting fraternity.

In short, I am talking about the systems approach that we must take because it will organize our thinking, our decisions and our actions. Above all, it will involve and bring together in a properly structured though not overly formal manner all people who should be committed to contributing to this vitally important and absorbingly interesting field: the field forester, the wildlife, recreation or other resource specialist, the engineer, the economist, the social scientist, the forest scientist, the industrial harvester, the resource administrator. To provide this sort of framework is the surest route to securing those frank interpersonal challenges, the teamwork and the climate for creativity and innovation that will enable us to achieve our goals.

As I understand it, that is what this symposium is all about.

The suggestions and comments of Mr. C. R. Silversides, Chief, Logging Development Program, Forest Management Institute, Ottawa, during the preparation of this paper are gratefully acknowledged.

DEVELOPMENT AND TRENDS IN FOREST NURSERY MECHANIZATION

H.H. deVries, Nursery Superintendent
Kemptville Provincial Nursery
Ontario Ministry of Natural Resources
Kemptville, Ontario

Development of mechanization in forest nurseries is a vital and integral function of management. It must result in improved stock quality, better working conditions and lower production costs. Nursery operations that have been affected by mechanization are seeding, transplanting, tending and harvesting. Developing technology will continue to influence bare-root reforestation.

La mécanisation est devenue essentielle et intégrante à l'aménagement des pépinières forestières en favorisant une qualité améliorée des semis, de meilleures conditions de travail et une baisse des coûts de production. Les opérations de pépinière qui furent affectées par la mécanisation sont l'ensemencement, la transplantation, les soins culturaux et la récolte. Le reboisement par plantation en racines nues sera de plus en plus perfectionné par une technologie croissante.

Mechanization in nurseries and, indeed, in all forestry operations and practices has been a vital and integral part of the manager's modus operandi. Our achievements to date have resulted from the imaginative and innovative capabilities of professional and technical staff alike in developing new production systems. We must continue in this manner if we are to reach our policy goals.

There are three objectives that mechanization should realize:

1. improvement of the quality of the product
2. improvement of working conditions so as to increase output and raise the level of supervision and quality control
3. reduction of production costs.

I would like to approach my topic by selecting four principal nursery operations that have been significantly changed by mechanization.

The first operation to feel the impact of mechanization was transplanting. Transplanting involves the transfer of 2-year-old seedlings from thickly sown seedbeds to other compartments where they are lined out at wider spacing to give them room for development into planting stock of a suitable size. Many workers were required to carry out the transplanting that began in the early spring and again in September. Several styles of hand-planting boards were in vogue in the early years. One of the most popular was the Yale.

A mechanical celery transplanter was adapted for planting seedlings; two of the units were placed parallel to each other and drawn by a water-cooled "donkey" engine. This was modified into a six-row transplanting machine, pulled by a farm tractor equipped with a special reduction attachment that permitted a transplanting speed of 12 ft per min. This reduced the cost of transplanting and increased the output to 90,000 trees per day.

The second operation was seeding. In the early days of reforestation, the sowing of tree seed in properly prepared seedbeds was a slow and arduous task. A standard seedbed was 4 ft wide by 30 ft long, formed by means of a horse-drawn plow (later tractor-drawn), levelled and shaped with garden rakes, firmed or packed and sown with a two-man roller. Each bed was framed with sideboards, stakes and support rails to hold the snow-fence rolls that shaded the seedlings during the first 2 years of growth. A predetermined quantity (by weight) of seed was hand sown or broadcast over the bed surface, followed by a uniform layer of suitable sand applied by hand shakes or screens.

A trail-type seedbed former, later hydraulically mounted, was developed to shape up or form the beds, making this a one-man operation. The laborious preparation for shading was replaced with a simplified 10-ft shade section with fold-down legs attached.

Hand seeding gave way to mechanical seeding when fertilizer and seed spreaders for lawns came on the market. Micrometer-like adjustments permitted the sowing of exact densities of seeds per square foot. Several models of bed sanders bearing the name of the particular nursery where they were developed (e.g., Michigan, Saratoga, etc.) soon appeared and became part of the standard practice of the day.

The next step was that of combining several operations into one, and thus the Orono seeder was conceived and developed. This machine passes over the formed seedbed surface, creating a ridged or hill-and-gully effect, and sows and covers the seed in one continuous operation.

Following seeding, the beds are covered with rye straw mulch for winter protection, applied from wagons straddling the seedbeds. The mulch is spread uniformly by hand and removed by hand when germination begins in the spring.

Within the past 2-3 years the cost of mulching has been reduced significantly by the use of a hydro mulcher to apply to the seedbed surface a thin layer of pulp fiber in a wet slurry. Germination takes place through the mulch cover which eventually disintegrates.

The third operation--tending or nursing the stock from early seedling stage through to harvesting--involves the use of modern tillage implements to prepare the soil for seeding and transplanting. Fertilizers must be properly placed for use by the seedlings, and selective chemicals, applied with power sprayers, are of great value for effective and economical weed control.

Hydraulically controlled, root-pruning blades pass through the root zone, severing the tap root and disturbing generally the entire root system. This encourages the development of fibrous roots and the maintenance of a better shoot:root ratio, both so important to outplanting survival.

Tree lifting is one of the last operations that has yet to feel the full impact of mechanization. In the early days, the trees were loosened in the soil by hand, using garden forks and spades. The need for some type of machine to speed up lifting was soon realized, and an early model of the mechanical tree lifter was introduced. A standard moldboard plow provided the basic unit. The plow beam and bottom were redesigned to support a blade assembly made from a discarded road grader and fashioned into a broad u-shaped pattern.

Then came hydraulics and remote control cylinders, and a variety of models and types of tree lifters were developed. This permitted the deployment of crews of laborers to lift by hand several thousand trees per man per day, and process them for shipping.

As the production of the nurseries increased so did the proportion of seedling stock, and new ideas for a materials handling system occupied the manager's time. All around us mechanical technology was at work making it possible for the agriculture industry to develop sophisticated machinery to process almost every conceivable type of farm produce.

As in so many previous instances, the mechanization of nursery operations has grown out of modifications and adaptations of agricultural machinery, and a two-row potato digger was purchased for tree lifting. This unit performed well. It lifted the trees out of the ground, eliminated most of the soil from the roots and deposited the stock back on the ground for field sorting or placing in tote boxes, from which it was transferred to the packing shed for processing.

We felt that a modified potato digger would permit us to handle trees from field to shed more efficiently. Therefore, in cooperation with Engineering Research Services, Canada Department of Agriculture, Ottawa, we constructed a modified digger, tested it and modified it again, changing from tote boxes to pallet bins. A production model was fabricated by Grayco Potato Harvesters of Heidelburg, Ontario, and is now in widespread use in North America. We have one of these at the Kemptville Nursery.

This model will lift the stock, shake off the soil and deposit the mass of disorganized stock into pallet bins for transfer to the packing shed where a grading belt assembly is used to sort, grade, count, root-prune and pack trees for holding in cold storage or direct shipment to the planting sites.

At the time we were still seeding broadcast and it was evident that we could improve our tree lifting operation by seeding in bands or drills, a common practice in the United States and one employed by the Thunder Bay Nursery. With some fairly simple modifications to the Orono seeder, we have achieved a uniformly spaced six-band seeding arrangement with two lines per band. In addition to horizontal root pruning which was done in broadcast beds we can now do a vertical root pruning between the bands and further improve the conformation of the root system.

Our current major mechanization effort is the development and testing of a six-row belt seedling harvester. This was initiated in cooperation with the Canadian Forestry Service (CFS) to resolve the handling bottleneck that exists with the Grayco harvester in that the stock is a disoriented mass in the pallet bin and has to be rehandled for the processing system mentioned earlier.

We want to harvest seedlings in such a way that we can retain the regular upright orientation of stock as it grows in the soil. In this way it can be packaged mechanically at the rear of the belt seedling harvester by a method that would be compatible with a stock handling system on the new Ontario Mark III Tree Planter. This will require the production of uniform-sized, good-quality stock and the field acceptance of bed-run stock with 10% cull, i.e., there would be no individual tree count, just an estimate based on density per lineal foot of seedbed.

The first prototype belt harvester (Fig. 1) was redesigned and built by Engineering Research Services, Canada Department of Agriculture, Ottawa. We tested the unit at Kemptville and after a series of field adjustments were satisfied that we were on the right track.

A second prototype model is being built by Hovey and Associates of Ottawa. This unit will see modifications made to improve the lifting in wet soil conditions prevalent in the spring, and as well improve the soil and root separation factor. There will be no major change in the bulk handling system at the rear of the machine. Research into and development of a packaging system will be the next phase. This second model will be placed in the north to build up staff experience at the northern nurseries.

Related developments and trials are concerned with new types of drill seeding machines. In addition to modifications to the Orono seeder mentioned earlier, trials are being conducted at several nurseries with different types of seeders such as the Stan-Hay precision seeder, the British Columbia Forest Service drill seeder using Planet-Jr. components, and a Norwegian metering device that divides evenly a given quantity of seed into six drills. The best features of several will be brought together to give nurserymen a unique Ontario seeder.

Future systems will see an increase in the use of greenhouse and container culture, thus allowing maximum use of field area, full utilization of growing seasons and extension of the planting effort for which much of the technology has already been developed and is being progressively updated by improved techniques.

The challenge of change is the elixir for our time, creating excitement and interest in nursery practices and procedures. I see mechanization and developing technology continuing to influence the future shape of this reforestation system.

Figure 1. First prototype of semi-automatic seedling harvester being developed jointly by OMNR and GLFRC.

THE MECHANIZATION OF CONTAINER-PLANTING SYSTEMS

J. B. Scarratt
Research Scientist
Canadian Forestry Service
Great Lakes Forest Research Centre
Sault Ste. Marie, Ontario

The status of container planting in Ontario, and factors likely to influence its mechanization, are discussed. Although containerized seedlings lend themselves to mechanization of the production—planting sequence, the need to retain operational flexibility demands that container-planting systems be compatible with both manual and machine methods.

L'auteur discute la situation des plantages en potets en Ontario et les facteurs susceptibles d'influer sur leur mécanisation. Bien que les semis en potets peuvent être mécanisés selon la séquence production—plantage, il faut que les opérations demeurent flexibles et pour ce faire, les systèmes de plantage doivent être faisables à la fois manuellement et à la machine.

Introduction

With the advent of mechanized harvesting systems and increased demand for wood products, the forests of Ontario are being cut at an ever-increasing rate. Prompt and adequate regeneration of cut-over forest lands is clearly essential if present harvesting levels are to be maintained or increased--yet the current scale of regeneration activity is quite inadequate to keep pace with depletion due to cutting and fire. While there is an acknowledged need to expand artificial regeneration programs substantially, any major increase in reforestation effort by conventional planting practices is obstructed by the high cost and limited capacity of existing techniques. In Ontario, as elsewhere, the planting of bare-root seedlings is largely a labor-intensive, manual operation, offering little scope for either cost reduction or improved labor productivity. Today, the situation is aggravated by rapidly rising labor costs and our inability to compete effectively for a share of the shrinking labor supply available for forestry-oriented activities. The short planting season for bare-root stock in continental Canada further restricts our capacity for expanding existing planting programs, emphasizing the need to develop planting techniques better able to meet present-day operational constraints.

Both mechanization of the planting operation and container-planting systems are attempts to overcome the restrictions outlined above--by reducing dependence on manual labor in the former case, and by increasing productivity, and planting capability in the latter. Although both approaches offer potential advantages independently of one another, without doubt the value of container planting can be enhanced by some degree of mechanization.

Of the numerous benefits attributed to container planting (Ackerman et al. 1965) the most significant relate to the potential for improved biological performance and increased planting capability. Ball-rooted seedlings generally survive better and are less prone to growth check than bare-root stock; they can be planted faster and therefore more cheaply; and, within limits, they allow a longer planting season than is possible with conventional nursery stock. Subject, then, to satisfactory growth rates, container planting appears to offer the opportunity for earlier and more successful reestablishment of cutovers, and a greater annual planting capacity.

Until now, most container-planting research and development in Canada has been concerned with the biological aspects of containerized seedling production and performance. Mechanization has been of secondary importance during this development phase and, even in those provinces with operational container-planting programs, has remained at a fairly simple level. However, it is clear that the economic viability of large-scale container programs of the future will depend largely on our ability to mechanize various processes in the production/planting sequence. Containerized seedlings, by virtue of their physical uniformity and the manner in which they are produced, are obviously highly amenable to mechanization, and during the next decade we will undoubtedly see a rapid expansion of mechanical techniques designed to increase efficiency, reduce manual effort and increase capacity.

The degree of mechanization attained in any situation will depend largely on the status of container planting within the overall planting program. In the discussion which follows, some of the factors likely to influence the mechanization of container planting in Ontario are examined.

The Status of Container Planting in Ontario

Although Ontario helped pioneer the technique of planting small, young seedlings grown in low-volume containers, the results of the early operational plantings were often disappointing. In retrospect, it is now evident that the small size of seedlings used in these early plantings was a major factor contributing to their poor field performance, as were planting too late in the season, poor choice of microsite and off-site planting. However, despite the early difficulties, much expertise and knowledge have been accumulated over the past decade. As a result, better production methods, and a greater awareness of the needs and limitations of container planting, have enabled substantial progress to be made in translating the container concept into a biologically viable regeneration technique. Nevertheless, when it comes to mechanization, there is clearly a danger of subordinating biological performance to economic expediency, and it is in these terms that we must initially look to past experience for answers.

What are the criteria by which we are to judge biological success or failure? First, we must recognize that, in Ontario, container planting is at present regarded as a supplement, rather than an alternative, to bare-root planting. Thus, arguments in favor of container planting relate primarily to the opportunities for extending the planting season into the summer months, and for equalizing seasonal labor requirements. Consequently, we are clearly looking for the same level of performance from containers as from conventional nursery stock in supplementing summer planting. A standard of performance has been arbitrarily set requiring that containerized seedlings have at least the same impact as bare-root stock, in terms of survival and growth, 3 years after planting. Planting season may be less of a restriction where mechanized planting is concerned, but is unlikely to affect these performance criteria, which are based on the average life of a scarification job.

In practice, it must be admitted that we have still not achieved the goal of equivalent impact, particularly for spruce (*Picea* spp.). By 1971, containerized planting stock was being produced with a survival impact comparable with that of bare-root stock, but growth performance still left much to be desired (Scarratt 1975). With the possible exception of jack pine (*Pinus banksiana* Lamb.), it may in fact be more realistic to anticipate a growth lag equivalent to at least one growing season for most species in Ontario.

Although many factors influence the performance of containerized seedlings, only three will be discussed here--factors which are under the direct, practical control of the forest, and which have a direct bearing on the application of container planting, viz., planting site, seedling size and planting season.

Planting Site: Results from the widespread planting of tubed seedlings in Ontario provide clear evidence that the spectrum of sites suitable for containerized seedlings is considerably narrower than that for bare-root stock. Off-site planting was undoubtedly an important contributor to the disappointing results experienced in the past, and greater attention to site selection is an obvious step in any efforts to improve container planting success.

Container planting is unadvisable on cold, wet soils, on sites with heavy accumulations of duff, and on grassy sites. It is out of the question on sites where there is a risk of suppression by competing woody vegetation--sites which can best be reestablished by the use of large, bare-root planting stock. This restriction excludes many of the more fertile upland sites in northern Ontario and, consequently, calls into question the suitability of white spruce (*Picea glauca* [Moench] Voss) for container planting in many areas unless there is a much wider acceptance of the need for early post-planting release.

On the basis of experience to date, container planting appears most suited to the easier, drier sites, supporting light to moderate vegetation of low competitive vigor. By inference, these are sites of lower productivity. Such sites also tend to be more suitable, both topographically and physically, for machine planting than are many richer sites.

Some form of site preparation--usually scarification--is normally considered essential for container planting. Although maximum control of vegetation is often the main consideration, the degree of scarification may be critical to early seedling performance. Many present-day scarification techniques tend to strip or windrow the more fertile soil/organic horizons, exposing the least fertile soil horizons for planting. For the spruces in particular, planting in such low-fertility soils may severely retard seedling development and the achievement of an established plantation. The problem should not be serious with hand planting, of course, since the planter is able to select each planting microsite. However, machine planting presents a different situation; not only is microsite selection no longer possible but, with present technology, the problem is exacerbated by the fact that most planting machines require a scalped area for efficient operation.

It has also been shown that the time of scarification is particularly critical to the initial success of containerized seedlings (Haig, unpublished). Ideally, it will be carried out in the summer before planting to allow the ground time to settle and to avoid survival problems associated with soil slumping and erosion. It might be added that considerations of this nature obviously detract from the appeal of machines designed to carry out site preparation and planting in a single traverse of the planting site. This and the preceding problem also bring into focus the ease with which biological performance can unwittingly be compromised in the search for mechanical efficiency.

Seedling Size: The small size of seedlings planted in the early years of the Ontario tubed seedling program was undoubtedly a major factor contributing to the high rates of mortality observed and the poor growth performance.

The importance of size at planting as a determinant of container-planting success was demonstrated by studies conducted in the White River district of northern Ontario. Of four seedling age classes (6, 8, 10 and 12 weeks from sowing), the oldest consistently gave the highest rate of survival after four growing seasons on all sites and for all species (Fig. 1). Differences between age classes were greatest in

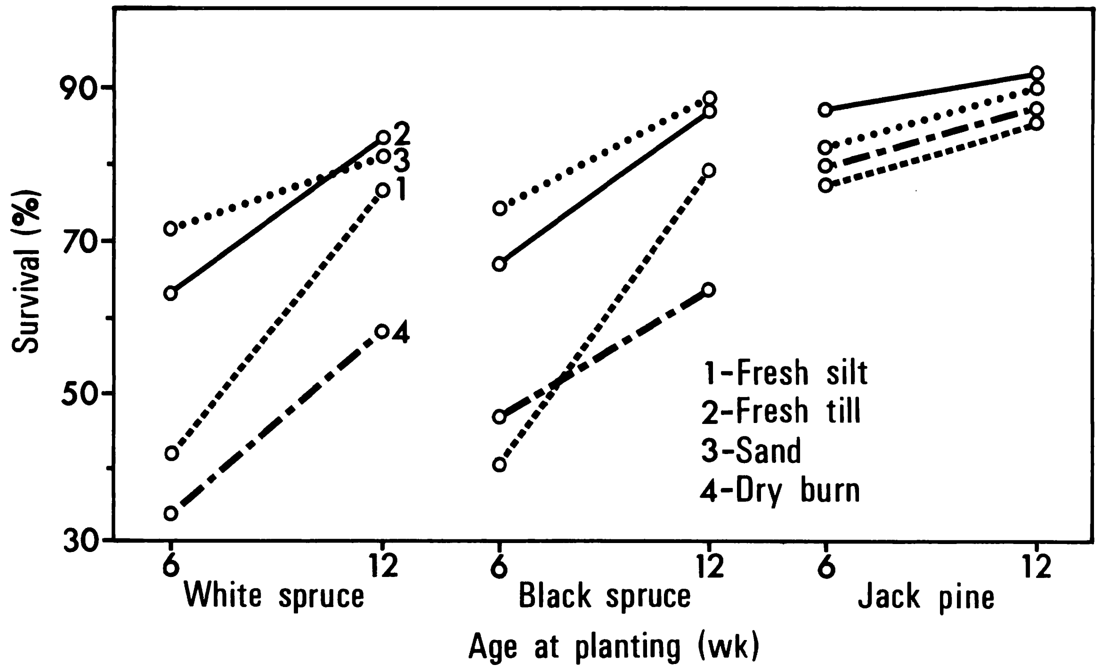

Figure 1. Survival, 4 years after planting, of 6- and 12-week old tubed seedlings planted on 4 sites.

the spruces, least in jack pine. However, it was evident that assessments based on gross survival gave an unrealistically optimistic view of seedling performance in the younger age classes. In many instances, these seedlings were of poor form or in a stagnant condition. Thus, by segregating seedlings into four morphological condition classes, a more meaningful picture of seedling survival was obtained, indicating that the use of older, larger seedlings favored not only a higher gross survival rate, but also a higher average quality of surviving seedling (Scarratt 1975).

Plantation success depends not only on a high survival rate but also on a reasonable growth rate coupled with unchecked and vigorous growth after outplanting. Height growth is probably of greatest interest initially, for it determines the ability of a seedling to keep ahead of competing vegetation during the early life of a plantation. Thus, there is practical significance to the finding that relatively small increases in seedling size/age at planting can have a significant and persistent influence upon the height growth of containerized seedlings during these critical years (Fig. 2).

Although the growth impact obtained in these studies was still not equivalent to that of most bare-root stock, it did indicate the potential benefits to be gained from the use of larger, more vigorous planting stock. Based partly upon these results, the following tentative specifications for containerized planting stock have been drawn up as an interim production goal aimed at meeting present performance criteria:

	Age at planting (wk)	Shoot height (cm)
White spruce	14-16	15
Black spruce	12-14	15
Jack pine	10-12	10

These are, at best, guesses based on rather limited evidence; obviously, much more work is needed to refine production techniques, and to define other morphological and physiological parameters of the potentially successful seedling. Nevertheless, it is evident that containerized seedlings of the future will be moderately large, with all that this implies in terms of the piecemeal or wholesale mechanization of the production/planting sequence.

<u>Planting Season</u>: Notwithstanding the fact that container planting is at present regarded as a summer supplement to bare-root planting in Ontario, this may well change if efficient mechanized planting systems become a reality. Consequently, there is practical significance to the conclusion that containerized seedlings do not provide a satisfactory vehicle for planting throughout the entire frost-free period, as was generally claimed in the past.

Container planting certainly allows us to extend planting into the summer months on sites where summer plantings of conventional nursery stock would undoubtedly fail. However, late planting of

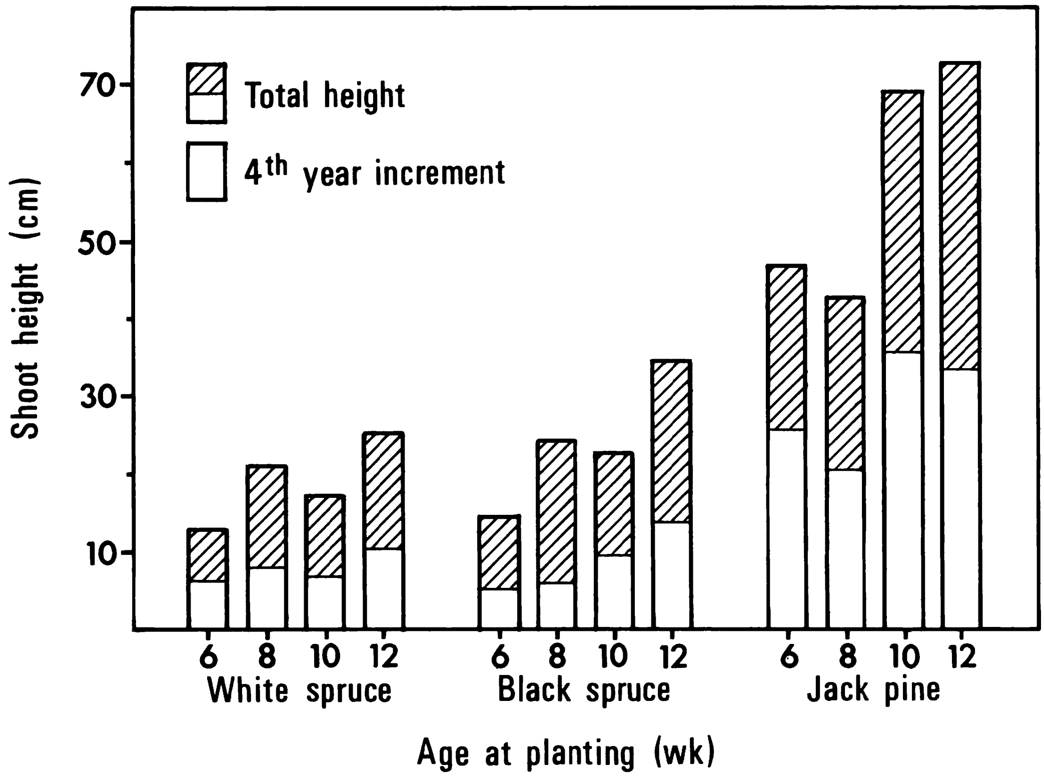

Figure 2. Height growth, 4 seasons after planting, of 4 age-classes of tubed seedling planted on a fresh till in midsummer.

containerized stock appears to have a severe adverse effect upon seedling performance, a phenomenon also reported for bare-root stock by Lyon (1972) and Sutton (see p. 98). In the studies referred to earlier, late planting led to a dramatic deterioration in average seedling condition compared with earlier planting dates (Fig. 3), an effect which persisted for the 4-year duration of the experiment. Height growth was also severely depressed in late-planted seedlings, with no indication that the effect of late planting might be compensated for by the use of older, larger seedlings (Fig. 4). In fact, 12-week-old seedlings, when planted late in the season, often performed little better than younger seedlings planted earlier.

In view of the persistence of the adverse effects resulting from late planting, it is recommended that the planting of containerized seedlings in Ontario be terminated by mid-August at the latest.

These, then, are some of the factors which influence the application of container planting in Ontario. In summary, containerized seedlings will generally be confined to the easier, less productive sites; they will be larger and more vigorous than seedlings planted in the past, and will be grown on relatively long production cycles; they will be used initially as a summer supplement to bare-root planting, but in any case will not be planted later than mid-August; they must be capable of about the same establishment impact as bare-root stock.

Aspects of Mechanization

Containerized seedlings readily lend themselves to mechanization, partly because of the nature of the product itself (a uniform package, usually in uniform modules) and partly because of the intensive manner in which they are produced. The seedling production phase especially lends itself to automation (Fig. 5), as is amply demonstrated by the wide range of commercial and locally constructed mechanical aids operating in this and other countries.

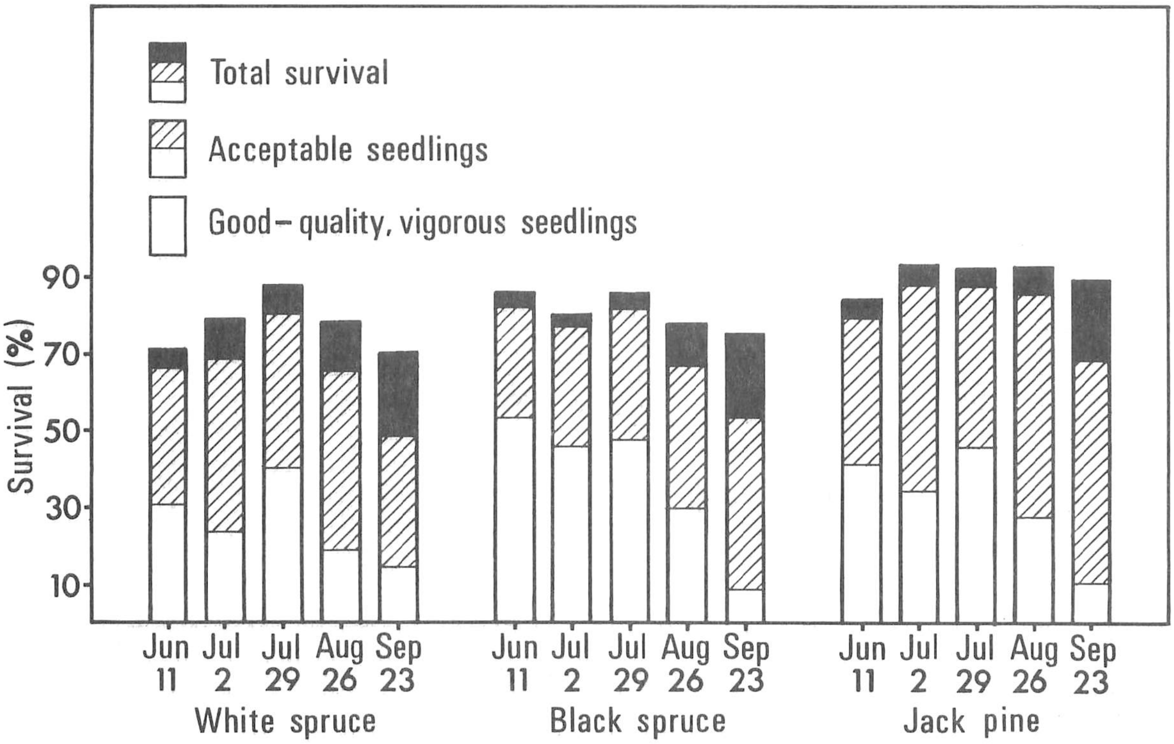

Figure 3. Survival, 4 years after planting, of tubed seedlings planted at 5 dates on a fresh till (averaged over all age-classes).

Although a fully integrated and mechanized production and planting system may be the dream of the mechanically oriented, it would obviously not find universal application under the varied conditions prevailing in Ontario. For most operations a combination of mechanical and manual methods is likely to remain the working order--because of the scale of operation, the labor situation, the terrain, or a host of other factors. Therefore, any containerized planting system adopted must be readily adaptable to a wide range of manual or mechanical options. For example, we should insist that any container adopted be plantable with equal efficiency, in biological terms, by machine or hand tools. Only in this manner can we ensure the flexibility for combining the components of the production/planting sequence into a fully integrated system, geared to the requirements of the individual user.

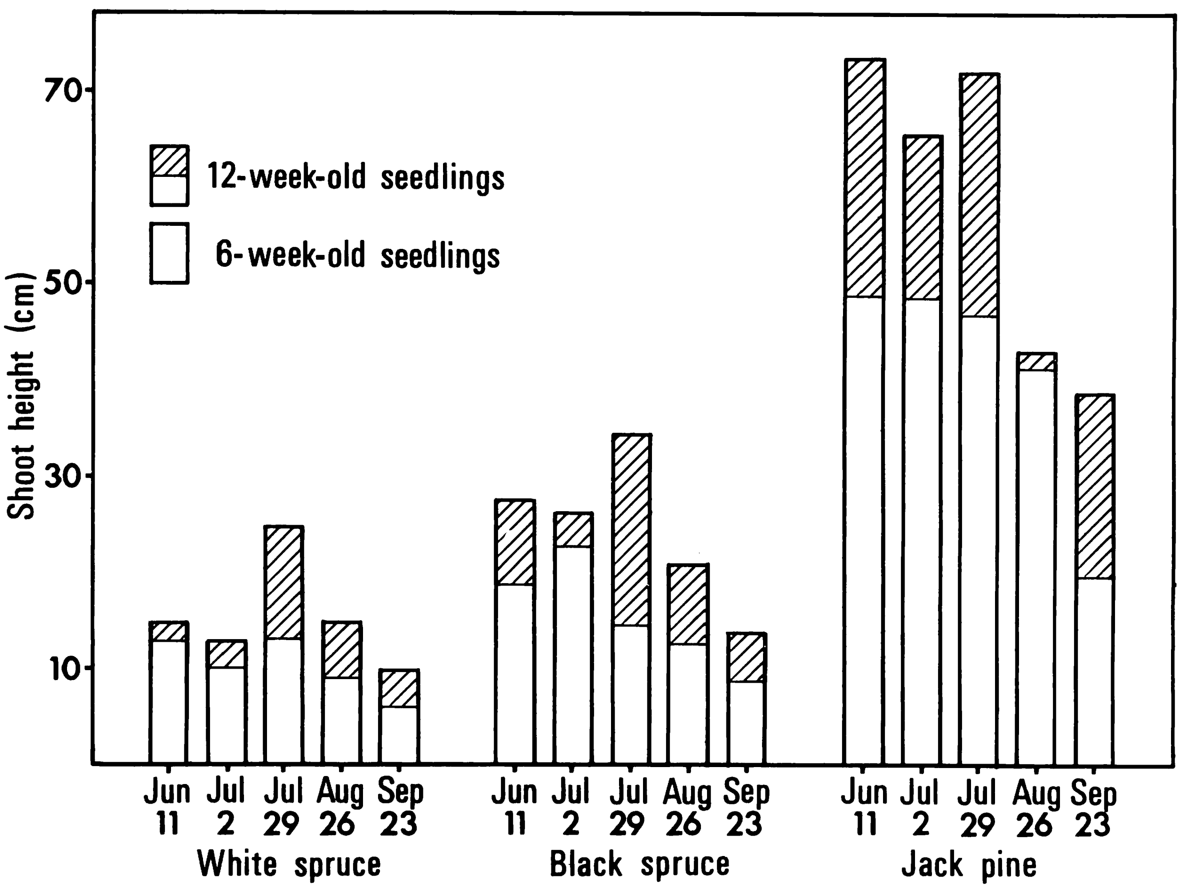

Figure 4. Height growth, 4 seasons after planting, of 6- and 12-week old tubed seedlings planted at 5 dates on a fresh till.

Figure 5. Seeding of containers on semi-automatic Japanese paperpot production line.

The physical form of most containers now available both facilitates, and in many cases necessitates, mechanical loading and seeding. The extent of and justification for mechanization will obviously depend on the size of operation. A number of machines are currently on the market which could load the total annual requirement of several nurseries in a few days. For example, a Finnish machine with a minimum capacity of about 40,000 containers per hour is available for loading and seeding paperpots; another machine is being developed in Ontario with a potential capacity for forming and loading 60,000 containers per hour. Such machines are expensive, yet are in use for a relatively short period each year; obviously their purchase can be justified only by large centralized nurseries. For the majority of operations producing only a few million seedlings annually, there are many smaller, efficient devices available at a fraction of the cost of these so-called "filling lines". Remember, too, that where a permanent labor force is employed, the need for high-capacity loading equipment can be substantially reduced by loading during the slack winter months.

No matter how simple or sophisticated mechanized loading may be, it must fulfill three basic requirements: 1) it must fill the container completely, and compact the growing medium uniformly to the desired density; 2) it must apply seed efficiently, centrally in the cavity, with a minimum of blank or over-seeded cavities (Blank cavities are costly in container operations, for unless they are later seeded by hand they cost just as much to carry through the production cycle as those containing seedlings.); 3) it should offer real savings in cost or time compared with less sophisticated or manual methods.

The demand for larger seedlings grown on longer production cycles undoubtedly commits us, in Ontario, to some period of greenhouse culture for container stock, especially with the spruces. The degree of greenhouse sophistication and automation of the growing process which can be justified on economic grounds warrants more detailed analysis, although a minimum level is obviously essential to achieve a uniformly satisfactory product, and to keep labor input to a minimum. Given adequate control over environmental conditions and optimization of growing schedules, we should look particularly to the benefits of centralization, and to maximum automation of such routine tasks as fertilization, watering, handling, etc., as a means of increasing production effficiency. It is not uncommon to see elaborate greenhouse facilities where the seedlings are laboriously watered by hand or where trays of seedlings are moved individually rather than on pallets or conveyers. With containers, these are often the easiest tasks to mechanize, yet all too often they remain a heavy and continuous drain on labor resources while smaller gains are attempted elsewhere.

Greenhouse culture is expensive, and the benefits must be reflected in higher survival and faster initial growth rates after planting. The trend of recent years toward expensive, permanent greenhouses with all the frills (humidity control, supplementary lighting, CO_2) may have passed, for we are beginning to see the return of cheaper, simpler and more practical designs in many operational situations. The degree of environmental control may be less, but so, too, will be the cost of operation, even though it may take a little longer to produce seedlings of the required dimensions. In this respect, we still have a lot to learn from the Scandinavian experience.

Superficially, containerized seedlings appear well suited to mechanized planting, given a relatively uniform shoot with a compact and uniform root mass. A prototype planter is currently being developed by the U.S. Forest Service specifically for planting paperpots (Edwards 1975), while in several other instances planting machines which, it is anticipated, will be compatible with container planting after simple modification, are being developed for bare-root stock. Mechanized planting of container stock will probably be possible on a range of sites within a very few years. However, irrespective of the extent to which mechanized planting becomes a reality, a large proportion of containerized seedlings will undoubtedly continue to be planted by hand. Therefore, as suggested earlier, the need to retain flexibility demands that the container system used be adapted to both methods of planting. Hand planting will be appropriate on steep or rough sites where machines cannot operate and on difficult soils, while on sites where careful microsite selection is important to survival and growth it may be the most efficient method of planting in terms of final establishment. We must bear in mind also the benefits bestowed on the planter by the use of those hand tools, such as the Finnish *Pottiputki*, specifically designed for container planting--by increasing planting rates and reducing operator fatigue due to bending. Hand planting reaches its peak in the system developed by Walters (1968), and raises the question of how much more, and at what cost, we can expect to increase container planting productivity by complete mechanization of the operation.

Discussion of the different types of container currently available has been deliberately avoided in this paper because it is felt that, from a biological viewpoint, the importance of container type has been greatly overemphasized. In most situations, seedling quality is a far more important determinant of seedling performance than the type of container in which it happens to be grown. The container has relatively little impact on the growing methods adopted and, with minor variation, we are able to adopt similar methods for the transportation, handling and manual planting of containers of all designs. Container type does hold some significance for mechanized planting, however, mainly because the physical characteristics of the package (or lack of it) determine the handling qualities of the seedling, its suitability for automated sorting and feeding, and its resistance to planting impact.

In practice, solid-walled containers are probably the most amenable to mechanized planting. However, two factors currently obstruct their widespread use: the fear of adverse biological effects related to the use of nonbiodegradeable materials, and the high cost of adopting containers of the dimensions required to meet current seedling size specifications (Scarratt 1972, 1973). The development of biodegradeable plastics may resolve the biological objections to solid-walled containers but, in light of the present economic situation, is unlikely to help the cost picture. At the other extreme, plugs, in which the containing device is removed before planting, appear to be the least suited to mechanized planting. A firm, well-developed root mass is absolutely essential for plug seedlings, both to bind together the growing medium and to facilitate handling. A plug seedling with a poorly developed root system presents many difficulties for manual planting, but even one with a well-developed root mass may not be able to withstand the stresses and rough handling likely to be associated with planting machines. In eastern Canada especially, the production cycle on which containerized seedlings are likely to be grown in the future does not favor the development of a dense root mass, particularly in the spruces. Consequently, some form of enveloping package, preferably biodegradeable, is considered essential to give support to the seedling and its rooting medium during handling and planting. However, irrespective of the type and form of container finally selected, mechanization of the planting operation should remain a secondary consideration--secondary to ease of handling, amenability to mechanized production, relative cost and biological acceptability.

> *There is one cautionary note to be added to this brief review of some of the factors which are likely to influence our approach to the mechanization of container-planting systems. Mechanization has the potential for drastically reducing labor input and increasing capacity, but the price may be high. Whether this cost is justified must be measured in terms of the final product--not the individual cost of producing or planting a thousand trees, but the total cost of an established plantation. However the job is accomplished, it must yield biologically acceptable results. Some sacrifice in biological performance may be acceptable in order to facilitate mechanization or to improve efficiency, provided that it does not compromise the effectiveness of regeneration. Conversely, investment in mechanized regeneration systems demands that biological techniques and materials be of the highest standard, whether they be seed, cultural method or planting stock.*

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ASSESSMENT OF SITE PREPARATION AND ITS EFFECT ON AERIAL SEEDING SUCCESS

L. F. Riley
Forestry Officer
Canadian Forestry Service
Great Lakes Forest Research Centre
Sault Ste. Marie, Ontario

Aerial seeding success is highly dependent on degree of site preparation and rate of seeding. Confusion exists as to the optimum combinations required to achieve a desired level of success. Preliminary results from operational trials of jack pine seeding indicate the relationships between these two factors and the way in which manipulation of degree of site preparation influences stocking and density levels at three different seeding rates.

Un ensemencement aérien heureux dépend principalement du degré de la préparation de la station et du taux d'ensemencement. Cependant la combinaison optimale de ces deux facteurs afin d'atteindre un niveau de succès convenable n'a pu être faite auparavant sans confusion. L'auteur, d'après les résultats provisoires d'essais opérationnels, indique les rapports entre ces deux facteurs, après avoir utilisé trois taux différents d'ensemencement.

Introduction

There can be little doubt that direct seeding has the potential to become a major, low-cost regeneration technique both in Ontario and in Canada as a whole. Its use increased greatly during the 1960s when almost 10 times as many acres were treated as in the previous decade (Waldron 1974). Undoubtedly this was due in part to the general increase in silvicultural activity that began about this time and has continued to the present. Nevertheless, seeding is only a minor segment of the total regeneration picture (14.5% of crown land treated in Ontario in 1973, Anon. 1973).

The Direct Seeding Symposium held in Timmins, Ontario in 1973 made it clear that opinion is still divided with respect to the effectiveness of seeding. However, there was also a very strong feeling that more diligent and thorough application of current knowledge, coupled with further investigations, could considerably improve the rather poor picture of seeding results reported by Waldron (1974). Given the soaring costs of planting, which even mechanization will not be able to stay indefinitely, I believe it is incumbent upon all forest managers to develop and utilize more efficient and economical regeneration techniques wherever possible. In this light, and with due regard to the quality of the results that can be obtained (as witnessed by some of the fine results obtained in Ontario since the early 1960s), direct seeding is due for increased attention.

In this paper I shall deal with some of the factors that have recently been the subject of operational trials by staff of the Great Lakes Forest Research Centre (GLFRC) at Sault Ste. Marie, Ontario, in cooperation with the Chapleau District of the Ontario Ministry of Natural Resources (OMNR). The preliminary findings presented here (the study is not yet complete) should indicate trends and should be a first step toward alleviating the confusion and doubt that surround some seeding practices. The results should be viewed as a guideline to improved seeding practice and not as definitive prescriptions guaranteed to achieve success.

Because it is the species most commonly used in operational applications in recent years, and because it is the only species under investigation in our studies, this paper will deal solely with jack pine (*Pinus banksiana* Lamb.). With no intention of downgrading other seeding techniques (e.g., scarification over slash or mechanized ground seeding), I shall also restrict the paper to aerial applications in the conviction that some of the information provided may be relevant to other species and other methods of application.

Scott (1966) has noted that rate of seed application, degree of site preparation and weather conditions are three of the most important factors affecting the success of aerial seeding. The last will be set aside for the present, not as being unimportant (for it is often the most critical), but as being the one factor of the three over which we have little or no control. It is sufficient to say that seeding must be carried out when full advantage can be taken of favorable weather conditions, but even then a seeding can be wiped out by an abnormal weather pattern before, during or after the period of germination and establishment. In our trials we hope to obtain some measure of the effect of weather conditions by extending the program over a period of several years.

The other two factors, rate of seeding and degree of site preparation, are under the direct control of the forest manager and, if the weather cooperates, the manipulation of these two factors would seem to be the key to success in jack pine aerial seeding. The paper will deal with some relationships between these two factors as determined by the work done to date. However, the results presented here should be considered a progress report only.

Methods

In 1969, GLFRC staff determined, through assessment of past aerial seedings, that there was a gap in knowledge of the relationship between degree of site preparation and rate of seeding that was tending to produce adequately stocked but often overly dense stands. It was quite apparent that mineral-soil exposure was necessary, if aerial seeding was to establish a new stand successfully, but questions remained as to how much scarification and how much seed were required to produce satisfactory stocking and density. The answers from field staffs were numerous, varied and often conflicting.

We then proposed a series of operational trials which would attempt to determine the optimum combination of degree of site preparation and rate of seeding for producing jack pine stands of satisfactory stocking and density. Our aim was to assess all possible combinations (nine) of three distinct degrees of site preparation (10%, 20%, 30% mineral-soil exposure) and three rates of seeding (10,000, 20,000, 30,000 seeds per acre). These ranges were chosen to bracket the most commonly used degrees and rates. To make these trials correspond as closely as possible to full-scale operations, equipment normally used by the local OMNR district (Chapleau) was employed and scarification and seeding were carried out at the same time as they were by the district.

In the first year, 1970, three main blocks were established, one for each of the seeding rates to be used. Each of these was in turn divided into sub-blocks with each sub-block in a given block being scarified to a different intensity of mineral-soil exposure. The setup has been followed in each of the succeeding years as well. Sub-block size varied from 15 to 20 acres depending on the overall area available. The basic premises governing site preparation were that jack pine is quite tolerant of extremes and that mineral soil, whether or not the best seedbed condition, is certainly acceptable and is much easier to obtain operationally than any mixed or other more desirable condition. Scarified but unseeded and unscarified/unseeded blocks were also established as controls.

To provide necessary replication, similar procedures were followed in 1971 and 1973 on sites near the 1970 treatment site. No trial was conducted in 1972 because no suitable cutovers were available in the vicinity. Owing to a malfunction of the seeding unit, the stocking of the 1970 area was not satisfactory, and it was reseeded in 1972 at the same nominal rates. The area treated in 1971 was inadvertently rescarified in 1972, and no results are available from this area. In all cases seeding was conducted by fixed-wing aircraft using a Brohm seeder. Costs of site preparation varied from a low of $12 per acre to a high of approximately $25 per acre for site preparation and aerial seeding combined (exclusive of seed cost).

Detailed information on techniques will be provided in a forthcoming publication on the trials. Suffice it to say that shark-fin barrels were used at 6-ft, 8-ft and 10-ft spacings on the towbar to provide the variation in site preparation in 1970, while 6-ft and 10-ft spacings plus a fire plow scarification (see Fig. 3, p. 36) provided the three degrees in 1973. I will not dwell on this any further since results subsequently achieved caused us to change our method of attacking the scarification/seeding problem, and at that point it became apparent that the means by which site preparation was effected was not the critical factor.

Site Description

The trials are located in the Shoals Park-Budd Lake area midway between Wawa and Chapleau. The area is part of the Missinaibi—Cabonga section of the Boreal Forest (Rowe 1972). The sites are typical outwash plains with deep, medium-dry to dry-fresh sand soils that supported good stands of mixed jack pine and spruce (*Picea* spp.) prior to logging. Tree-length harvesting took place generally in the winter before treatment. Slash conditions varied from light to moderate, but as front-mounted V-blades were used during site preparation, slash presented no problem. Duff thicknesses varied from <1 in. to as much as 8 in. and the deeper duff layers reduced the degree of mineral-soil exposure achieved by scarification.

Assessment

One chain of milacre assessment line is established for each acre of treated area. These lines are used to determine the degree of site preparation achieved and to assess subsequent germination and survival.

For the determination of degree of site preparation effected, each milacre on the cruise line is assessed for percentage of plot exposed to suitable seedbed. Suitable seedbed, while undoubtedly reflecting some subjectivity, is considered to be exposed mineral soil with a firm base, a *thin* duff/mineral-soil mix which will readily settle to a firm base, or firm mineral soil with a very thin duff layer, generally not more than ¼ in. thick. Mounded mineral soil, inverted sod layers, upturned stumps with mineral soil, etc., are not considered suitable seedbeds.

Each milacre is placed in one of the following categories, depending on the percentage of suitable seedbed: 0-5%, 5-15%, 16-25%, and 10% classes thereafter. The first category (0-5%) is considered unscarified in the assessment but some germination does occur on the small patches of mineral soil that are present. The overall percentage of acceptable seedbed is calculated but the discussion to follow should make it clear why we do not make extensive use of this figure.

Rate of seed application, though calibrated on the seeder in the normal way prior to seeding, is checked by the use of seed traps. At first, bed sheets were used for this purpose but subsequently these were supplemented and finally replaced by smaller wood and screen traps which are easier to handle and appear to give a more accurate measurement of seedfall.

Assessment of germination and survival is being conducted in the summers of at least the first, second and third years after seeding on the assumption that after 3 years germination will be complete, and the surviving seedlings can be considered "established". Seedlings are tallied on the same quadrats on which the percentage of acceptable seedbed was previously tallied. Stocking is recorded on each milacre whereas a tree count is taken on each fifth milacre along the line.

Results

Rather than discuss stocking and density in terms of average mineral-soil exposure, I wish to bring out the relationships among these factors through reference to the individual milacre plot assessments. Before I can do this the following basic premise must be accepted. If, for example, stocking is satisfactory on milacres with at least 20% mineral-soil exposure, then 1,000 milacres all scarified to the same degree should produce satisfactory stocking on that acre as a whole, and a similar situation would exist if all milacres on the entire work site were also scarified to a minimum of 20%. This, of course, presupposes that seed has been uniformly applied over the area, a situation which can be closely approximated if flight lines are controlled and all equipment is functioning as intended.

First let us examine what happens when seed is dispersed over an area at different rates, and again we shall assume uniform distribution. It's rather basic. If we employ a milacre grid and broadcast 20,000 seeds per acre, each milacre should receive 20 seeds. However, we know that a large proportion of the seed will fall on seedbeds that are not "receptive", i.e., not likely to be suitable for germination and survival. To paraphrase a point that Brown (1974) makes, the quantity of seed which is of use to us is directly proportional to the degree or percentage of scarification. That is, if it doesn't fall on suitable seedbed it is of little value and won't help us in the establishment of a new stand. Brown (ibid.) also suggests that further losses to seed and germinants can be expected for various reasons and that, in at least one district, the experience has been that five seeds are required *on receptive seedbed* to establish one surviving tree after 3 years. While this estimate may be somewhat conservative in the light of other studies being conducted by GLFRC staff, it appears to be a reasonable estimate and I have used this rate in developing the rest of this paper. On this basis Table 1 shows what happens to seed sown at different rates on areas with different degrees of receptive seedbed.

It would appear that, to obtain 100% stocking with one seedling per milacre after 3 years, at least 50% mineral-soil exposure *per milacre* is required if the sowing rate is 10,000 seeds per acre. Similarly, to achieve 100% stocking would require all milacres to be 25% receptive seedbed if the sowing rate is 20,000 seeds per acre, and 17% receptive seedbed if the rate is 30,000 seeds per acre. This, of course, presupposes that both site preparation and seed are uniformly distributed over the area. The minimum site preparation category for each seeding rate has been underlined in Table 1. Obviously, to achieve equivalent results at lower sowing rates the scarification effort must be increased.

Let us now examine what has happened in our field experiments to date. Because of the many difficulties encountered in 1970 and 1971, only the 1973 data are sufficiently reliable to present here. These are, of course, only first-year results and must be viewed with caution, but they indicate trends. Additional assessments of this area, plus similar assessments of aerial seeding operations carried out in 1974 and 1975 by the Chapleau District, should firmly establish what can be expected in the way of stocking and density when site preparation and seeding rates are varied.

For the 1973 job, the nominal seeding rates and those determined from seed-trap counts are shown in Table 2. The seed-trap counts correspond closely to the nominal seeding rates. No corrections in numbers trapped have been made for viability since tests conducted prior to seeding showed viability to be virtually 100%.

Figure 1 shows stocking after one year (assessment made in August, 1974) for the three seeding rates. The curves indicate the percentage of the plots in each site-preparation category that were stocked. It is readily evident (and to be expected) that, for a given degree of site preparation, stocking will increase as more seed is broadcast over the area. The intent here is to show the extent of the effect. Let us assume that the manager has chosen 80% stocking as his goal. It can be seen that, after one year, this can be achieved by uniformly distributing 58% mineral-soil exposure at 10,000 seeds per acre, 23% mineral-soil exposure at 20,000 seeds per acre and 15% mineral-soil exposure at 30,000 seeds per acre. (By coincidence these correspond closely to the minimum receptive seedbed requirements indicated in Table 1 for 100% stocking after 3 years, but no attempt should be made to draw any conclusions from this rather close agreement.) Obviously, the manager must decide what degree of site preparation he can efficiently and economically afford to

Table 1. Theoretical number of seeds received on each milacre and on receptive seedbed, plus expected third-year survival (Brown 1974)

Seeding rate (seeds/acre)		Amount of receptive seedbed/milacre (%)										
		0	10	20	30	40	50	60	70	80	90	100
10,000	no. rec'd/ milacre	10	10	10	10	10	10	10	10	10	10	10
	no. landing on receptive seedbed	0	1	2	3	4	5	6	7	8	9	10
	no. of trees resulting from 5:1 ratio	0	.2	.4	.6	.8	1.0	1.2	1.4	1.6	1.8	2.0
20,000	no. rec'd/ milacre	20	20	20	20	20	20	20	20	20	20	20
	no. landing on receptive seedbed	0	2	4	6	8	10	12	14	16	18	20
	no. of trees resulting from 5:1 ratio	0	.4	.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0
30,000	no. rec'd/ milacre	30	30	30	30	30	30	30	30	30	30	30
	no. landing on receptive seedbed	0	3	6	9	12	15	18	21	24	27	30
	no. of trees resulting from 5:1 ratio	0	.6	1.2	1.8	2.4	3.0	3.6	4.2	4.8	5.4	6.0

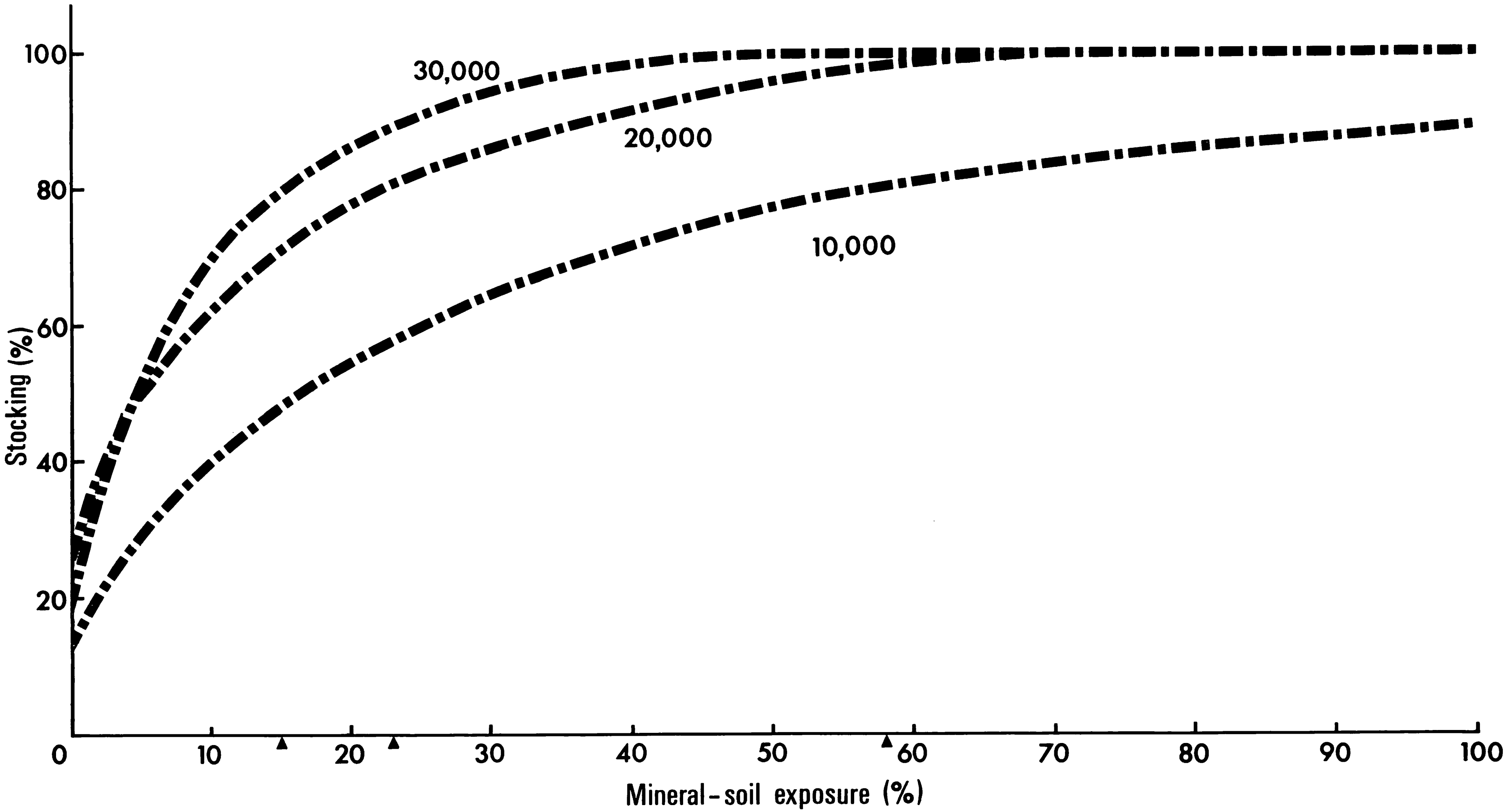

Figure 1. Stocking, by site-preparation class, achieved at three seeding rates in the first year after seeding.

Table 2. Prescribed and trapped seeding rates, 1973 CFS aerial seeding, Chapleau District

Prescribed rate (seeds/acre)	Trapped rate (seeds/acre)
10,000	9,230
20,000	18,990
30,000	27,990

achieve and then, having achieved it, choose the corresponding seeding rate. Conversely, seeding rates can be varied to match the degree of site preparation obtained.

While stocking remains the main criterion by which the success of seeding operations is judged, seedling density undoubtedly warrants more consideration. Figure 2 shows the first-year density figures achieved in this trial, as well as those to be expected using the aforementioned 5:1 ratio calculated by Brown (1974). In each case the density curves based on the trial data are above Brown's predicted values, suggesting that acceptable stocking and density may be achieved by the end of the third year after seeding.

Results from other GLFRC studies indicate that losses of first-year seedlings may be about 25% by the end of the second year. If this figure is applied, the density figures noted in Figure 2 will still be well above the 5:1 third-year ratio by the end of the second year. Indications are that success is assured in the trial area, because the drop in density, when averaged out over trees per stocked plot, is unlikely to cause a major drop in stocking, and third-year losses can be expected to be minimal under normal conditions.

How valid was our definition of receptive seedbed? This may be answered by Table 3, which provides a comparison between plots stocked on receptive seedbed and plots stocked on nonreceptive seedbed only.

If our definition had been unsuitable, the percentage stocking on receptive seedbed would have been much lower and nonreceptive seedbed percentages would have been higher. The fact that receptive seedbed stocking percentages were all over 90% indicates that the definition had a high degree of validity. It should be noted that some of the stocking on nonreceptive seedbed actually occurred on mineral soil, but this was on milacre plots which fell into the 0-5% category. They were considered

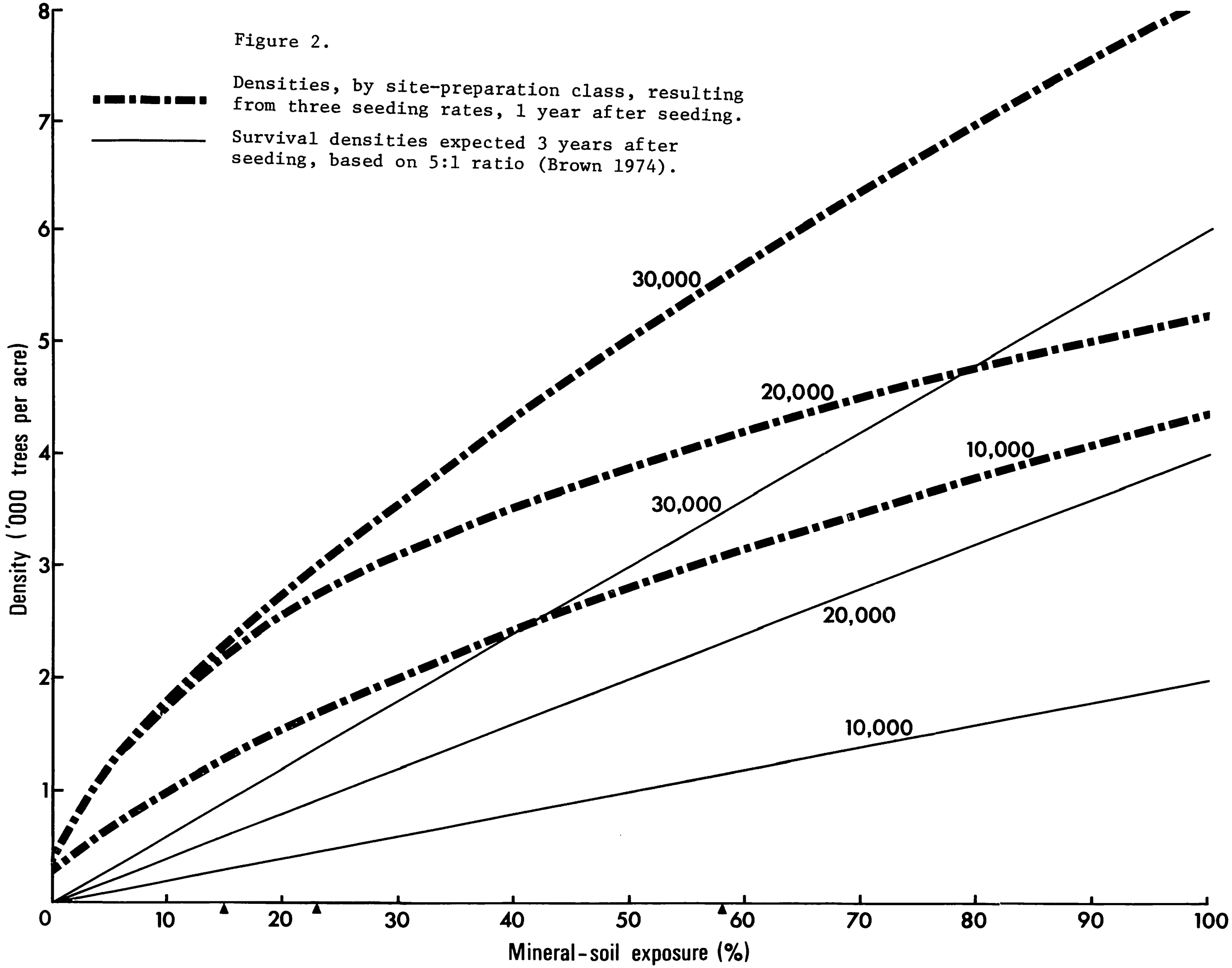

Figure 2.

Densities, by site-preparation class, resulting from three seeding rates, 1 year after seeding.

Survival densities expected 3 years after seeding, based on 5:1 ratio (Brown 1974).

Table 3. Comparison of percentages of stocked plots on "receptive" and "nonreceptive" seedbeds (as defined) at three seeding rates

Seeding rate (seeds/acre)	Plots stocked on "receptive seedbed" (%)	Plots stocked on "non-receptive seedbed" (%)	Total no. of stocked plots in sample
10,000	96.9	3.1	226
20,000	90.7	9.3	324
30,000	92.8	7.2	307

to be on nonreceptive seedbed since, by our criteria, mineral-soil exposures at this level were too low for us reasonably to expect that a stocked plot would result.

If at least one surviving tree per quadrat[1] is the objective, then density can also be expressed in terms of stocking, i.e., 80% stocking will result in at least 800 trees per acre. In each case the density requirement is also fulfilled by the amount of site preparation required to achieve satisfactory stocking. It can be seen, however, that the 10,000 per acre rate is again at a distinct disadvantage because it is far higher than that required to provide the minimum acceptable density (which is achieved at 40% mineral-soil exposure, according to Figure 2) and it requires that the ground be 58% exposed to mineral soil. Thus, after one year's results, it appears that a seeding rate of 10,000 seeds per acre cannot provide satisfactory stocking at minimum densities without a high site-preparation cost penalty.

Which of the other two seeding rates can be considered more effective? That depends on the individual manager and the stocking/density results derived from the continuation of the study. At present it is almost a tossup with the 30,000 requiring slightly less site preparation (8%) but 50% more seed. The cost of obtaining the

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[1] Quadrat size is not important to stocking success. It is the area of exposed mineral soil per quadrat that will determine success rates. Milacre quadrats have been used throughout these calculations but managers wishing to base stocking on quadrats of different size will find the data equally valid.

extra mineral-soil exposure is probably marginal but the waste in seed could be considered exorbitant, for as the amount of site preparation required to achieve a specified target drops, the amount of seed required rises sharply. Table 4 illustrates this by showing the amount of seed that falls on receptive and nonreceptive seedbeds at three levels of mineral-soil exposure and three rates of seeding. When seed supplies are high perhaps we can overlook this wastage, but when seed supplies are low and procurement costs are high, the waste of seed becomes significant. If genetically improved (and correspondingly expensive) seed is used, obviously it will be necessary to use minimum quantities. Under these circumstances the additional cost required to achieve a higher level of mineral-soil exposure may be fully justified.

Table 4. Seed losses incurred at three seeding rates at an arbitrarily chosen stocking percent

Seeding rate (seeds/acre)	Receptive seedbed required for 80% stocking (%)	Seed falling on receptive seedbed (seeds/acre)	Seed presumably lost (seeds/acre)
10,000	58	5,800	4,200
20,000	23	4,600	15,400
30,000	15	4,500	25,500

Conclusions

It is too early to draw firm conclusions from the results obtained to date, but from the following observations a definite correlation can be seen between degree of site preparation and rate of seeding as it applies to stocking and density.

1. Mineral-soil exposure is critical to jack pine seeding success.
2. Seeding rates may be lowered as mineral-soil exposure increases.
3. By determining the extent of mineral-soil exposure prior to seeding, the manager can calculate the seeding rate required to achieve the desired stocking and density.
4. Stem distribution, a major factor in good stand development and final tree form, can be more closely controlled in

seeded stands through more uniform distribution of mineral-soil exposure. This goal, though not easy, is not unattainable.

Summary

In the course of my ramblings, two questions have undoubtedly come to your minds: (1) Why am I telling you something that you are already practising? and (2) What has this to do with mechanization? In answer to the first, I would say that considerable seeding seems to be carried out purely as a matter of tradition or on the theory that "it worked for Joe, it will work for me". Brown (1974) candidly admitted that rates of seed and amount of site preparation required to produce fully stocked stands are unknowns. I indicated previously that this paper must be considered a progress report and I ask you to keep that in mind now. It can be expected that both stocking and density will drop somewhat, perhaps significantly, by the end of the second and third years, but the question is, by how much? (Other research suggests perhaps 25-30%.) And how will results from another 600-800 acres of assessment affect this overall picture? When all data are in we should have come a long way toward identifying the unknowns mentioned by Brown.

In answer to the second, it is obvious that the degree of mineral-soil exposure provided has a very significant bearing on both the stocking and density resulting from aerial seeding. In our discussions today and tomorrow we will be hearing more about site preparation and its mechanization. I think it is obvious that, at present, our site-preparation objectives are not well defined. If we are to improve our management of the forest resource and produce a high-quality product as efficiently as possible, we must consider all the variables under our control, and certainly site preparation is one of these variables. Therefore, in attempting to mechanize regeneration techniques we must also be more positive in our approach to this aspect of the problem. Let us determine what we need or want in the way of seedbed and give considerable thought to the attainment of these objectives during the process of equipment development, rather than attempt to use whatever equipment is available. Let us determine by what means we can achieve desirable stocking and density levels from direct seeding, and develop our techniques and equipment accordingly.

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Figure 3. Site preparation for aerial seeding using a modified SIECO fire plow and Michigan floating hitch can produce 30-35% mineral-soil exposure.

POWERED VS NONPOWERED SITE-PREPARATION EQUIPMENT

J.K.K. Heikurinen, Unit Forester
Ontario Ministry of Natural Resources
Swastika, Ontario

Three nonpowered pieces of equipment—the shark-fin barrel, Marttiini plow and Bracke cultivator—are compared with two powered flails in terms of power efficiency and mechanical and biological advantages and disadvantages. Powered flails show promise as site-preparation tools for the Boreal Forest of Ontario, but further refining is advocated.

L'auteur compare trois machins non mûs mécaniquement—le baril à nageoires de requin, la charrue Marttiini et le cultivateur Bracke—avec deux "flêaux" mécaniques en ce qui concerne leur puissance effective, et leurs avantages et désavantages mécaniques et biologiques. Les "flêaux" mécaniques sont prometteurs pour préparer le sol dans la forêt boréale de l'Ontario, mais ils devront être améliorés.

Introduction

Almost all forms of site-preparation equipment today are powered by some means or another. In this paper, however, I shall classify as "powered" any piece of equipment with a live rotary head, driven either by a self-equipped motor or by a power takeoff on the towing tractor. In either case, the portion of the machine that actually does the work is directly connected to the power source. All other pieces of equipment, whether they be drags, teeth, plows, rollers or discs, are classified as nonpowered for the purpose of this paper.

First, I would like to give you some background on powered site-preparation equipment. Then I shall compare the current powered equipment in Ontario with three nonpowered forms of equipment now in use in the Kirkland Lake District.

Past Efforts

Powered equipment has not been used widely in North America or anywhere else in the world. That which has been used, primarily in

Europe, can be classified in two main groups: (1) powered choppers and (2) powered cultivators or earth augers.

The powered choppers are essentially heavy, tractor-drawn mowers that chop up slash and scrub brush up to a diameter of about 4 in. The powered choppers usually leave the site ready for planting or discing. Common to all of them is a mulch on the soil surface. Various versions of powered choppers are the Wilder-Ramthorpe Scrub-Masta, the Nicolas Brush Cutter, the Rousseau Forestierre 150, the Konishi, and the Roanoke Hydraulic Brush Cutter.

The powered choppers are not designed to cultivate the soil surface, and therefore are not considered cultivators.

The powered cultivators that have been in use are primarily patch cultivators. Many of these patch cultivators are earth augers either manually held or mounted on tractors.

The Nardi rotary excavator is seemingly one of the most successful of the powered cultivators. It is essentially made up of a wheel with seven, self-sharpening blades rotating between 400 and 600 rpm. It takes a scalp of about 40 x 50 cm, returning a good portion of the soil to the scalp. The results are described as "inevitably good".

Other powered patch cultivators on the market are the Wühlmaus hole digger and the German AS4 two-man earth auger. Results from these machines are described as "highly satisfactory" even in hard clay soils.

Another cultivator which shows up in literature is the Finnish Lamu seeding machine. It is used in peat soils to seed spruce. It uses a rotary hoe for ditching and two cultivators on each side for disturbing the soil and mixing in fertilizer. I'm not aware of any results for this piece of equipment.

In Ontario we have three powered pieces of site-preparation equipment, all in the experimental or testing stages.

The YLO Finn Forester Planter has a rotary hoe that digs a furrow into which the planter plants a tree. The rotary hoe is no match for stumps and rocks; consequently, its use is very limited in the Boreal Forest of Ontario.

The other two pieces of powered site-preparation equipment are the Brohm-Klein flail and the single-furrow flail with which I am currently working. Both flails are still purely experimental and have had very limited use. They are designed to cultivate the top 4-6 in. of the soil surface. They cannot handle heavy slash and therefore must be used in conjunction with a light V-blade that will remove all heavy slash from the path of the flails. From tests that I have conducted, flail scarifiers or modifications of them show promise in solving some of our current regeneration problems.

Powered vs Nonpowered

Next I would like to compare the two powered machines, the flails, with the three nonpowered pieces of equipment, the shark-fin barrels, the KLM-240 Marttiini Reforestation Plow (Fig. 1) and the Bracke cultivator. The purpose of the comparison is not to prove the powered better than the nonpowered but to point out some of the features of the powered machines that will make their use suitable for some sites now considered very "difficult" to site prepare. I shall compare the machines from the point of view of their energy efficiencies and their mechanical and biological advantages and disadvantages.

Figure 1. The Marttiini KLM-240 Forest Plow, a rugged, rough-terrain scarifier for seeding and planting.

Energy Efficiencies

The powered flails have obvious power-saving advantages over conventional drag-type site-preparation equipment. The power on flails is applied directly to that portion of the machine doing the work at hand, i.e., mixing soil. It takes very little power to pull the machines themselves; consequently, the towing tractor can be a relatively small one. Nonpowered equipment is generally heavy (3-6 tons) and depends largely on a dragging action on the soil surface to do the job. Thus, the power requirements of the towing tractor are high and you end up using greater horsepower and extremely heavy tractors which in themselves require much power to move through our rugged terrain. In essence, with powered flails we use most of the power to scarify, not to move a lot of steel through the forest landscape.

To quantify the various power requirements of the powered and nonpowered equipment available to us at the Englehart Management Unit, we took some field measurements. The results are presented in Table 1.

It is obvious from Table 1 that the powered scarifiers use less power than the nonpowered. These power savings on the powered machinery can be converted to dollar values if one wishes. We have selected from manufacturers' specifications (see Appendix, p. 46) the tractors which come closest in their ratings to doing the job. The results are shown in Table 2.

Table 1. Power efficiency comparison for various S.I.P. equipment

	Nonpowered			Powered	
	Shark-fin barrels	KLM-240 Marttiini Reforesta-tion Plow	Bracke culti-vator	Single flail	Brohm-Klein flail
Test tractor	D 8 H	D 6 C	Timber-jack	Timber-jack	John Deere
Hp (net)	270	140	94	94	94
Weight (tons)	25	17	6	6	6
S.I.P. equip. weight (tons)	7	4[a]	3.2	0.7	1.5[a]
Weight of to-tal unit (tons)	32	21	9.2	6.7	7.5
Power req'd for S.I.P. equip.					
Drawbar pull (lb)	23,000	17,000	4,900	1,000	1,700
Hp	92	68	26	21	32
Tractor pull (lb)	3,500[a]	2,100	1,740	1,740	1,740
Hp	14	9	7	7	7
Total power used (hp)	106	77	33	28	39
Hp req'd[b]	176	128	55	35	48

[a] Estimated values

[b] Hp required = required tractor hp x 1.667 + S.I.P. equipment hp.

Table 2. Relative operating cost of equipment tested

S.I.P. equipment	Net hp tractor required	Tractor cost ($/hr)	Expected production (acres/hr)	Relative cost/acre ($)
Shark-fin barrels (6)	180	25.50	1.5	17.00
KLM-240 Marttiini Reforestation Plow	130	19.05	2.0	9.53
Bracke cultivator	90	10.70	2.0	5.35
Brohm-Klein flail	70	8.60	1.5	5.73
Single flail	70	8.60	1.2	7.16

Mechanical Considerations

The powered scarifiers tend to be rather complex machines compared to the nonpowered equipment. Because of their relative complexity, their original construction and their follow-up maintenance are a good deal more expensive than those of their nonpowered counterparts. As a general rule, the more complicated the machinery the more likely it is to break down. Under the rough Boreal Forest conditions frequency of breakdowns is an important consideration. Good engineering can, for the most part, overcome this disadvantage of the powered flails.

The flails currently in operation require a relatively clean, debris-free site prior to their effective use. On typical slash-ridden sites, the tractor towing the unit must be equipped with an efficient V-blade capable of minimizing the quantity of heavy slash in the path of the flails. The movement of this slash demands extra power from the towing tractor, and the V-blade must "float". On current-stock models of wheeled skidders available to us there is no "float" position on the blades. Consequently these tractors must be modified to include this feature.

The shark-fin barrels, the Marttiini plow and the Bracke cultivator are not impeded nearly as much as are flails by heavy slash conditions. Normally no special blade is required for the nonpowered equipment.

The portability of the flails makes them very desirable for small areas. This feature is often missing from the heavier nonpowered equipment. The portability of the light flails makes them desirable for use on small patchy areas, whereas nonpowered machines, especially the shark-fin barrels, require large clearcut patches.

The fact that the flails require very little power for pulling allows them to be used on steep terrain. Very few if any of the non-powered machines can be used on slopes of more than 20 degrees simply because the towing tractors cannot get enough traction. With the powered pieces of equipment, slope seems to be no obstacle owing to the low drawbar pull required.

Biological Considerations

What the flails lack in mechanical advantages they make up in biological benefits. The flails have a strong tendency to mix soils rather than scrape off the topsoil. Figure 1 shows a typical cross section of the soil profile left after a pass with a flail. The flails invariably leave a thin layer of mixed soil on the furrow. The thickness of the mixed soil depends largely on the shape of the shroud around the flail. Figure 2 illustrates the various shapes and their corresponding effect.

The ability to control to some extent the amount of mixing of the top soil layers gives the flails a distinct advantage over various nonpowered, drag-type scarifiers, especially in heavy soils and shallow soils. The drag-type scarifiers which, in effect, include all the nonpowered equipment now in use, scrape the top humus layers from their path and deposit them away from the scarified portion, leaving behind exposed mineral soil. We know that the best possible seedbed is not pure mineral soil or organic soil but a mixture of both in proper proportions.

Another biological advantage of the flails is their handling of the seeding operation directly after scarification. The flails do not penetrate deep into the mineral soils or fracture the surface with deep gouges or cracks. They leave a relatively firm base under 1/8-1/4 in. of mixed soil. Consequently, if seeding is done directly behind the flail, the maximum depth to which the seeds may be buried is 1/4 in. or less. A shallow covering over the seed is biologically beneficial.

The same cannot be said for the nonpowered scarifiers. It is generally felt that seeding behind the shark-fin barrels is undesirable because of the depth to which much of the seed gets buried. The same can be said for both the Marttiini plow and the Bracke cultivator. These disadvantages can be partly overcome by increasing the number of

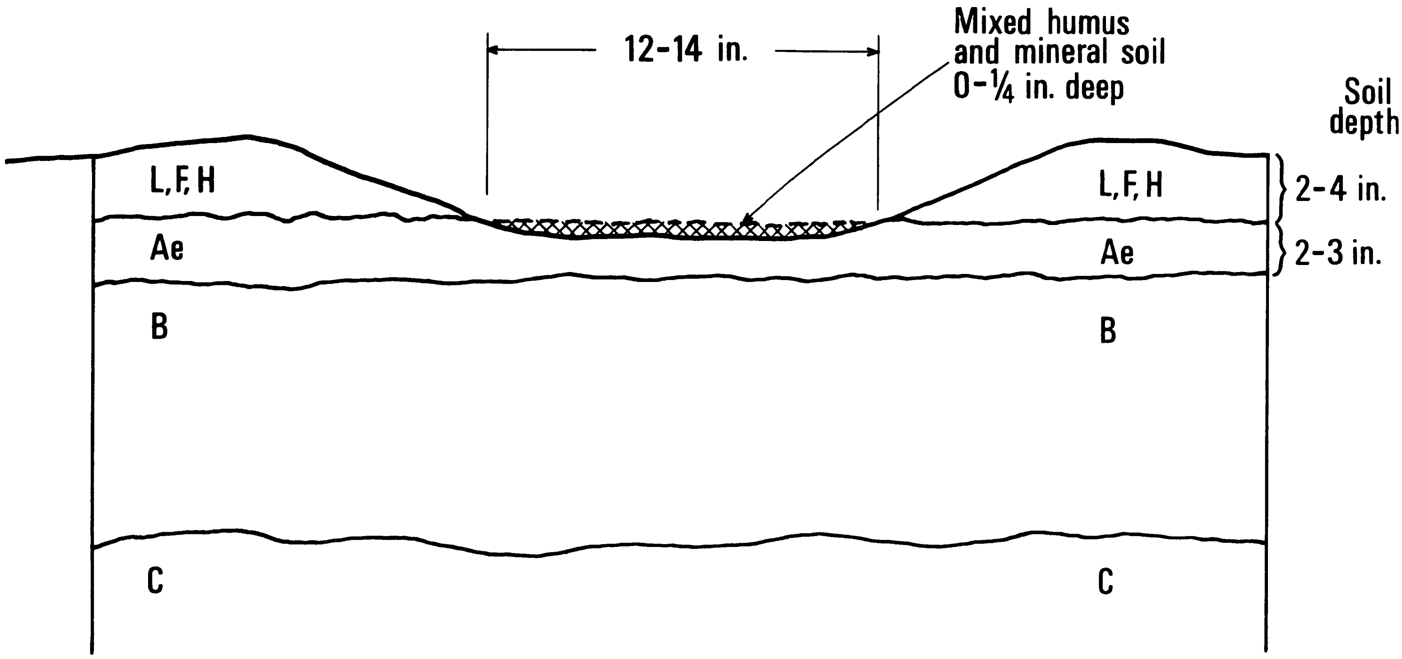

Figure 1. A typical flail furrow.

seeds sown behind these machines. But the best solution to direct seeding behind the nonpowered equipment is to allow for a period of settling and then to seed on a second pass.

All indications in the literature are that the powered cultivators tested so far have created a highly desirable seedbed and success has been invariably good. Even on heavy soils such as clay, leaving a mulch has proved successful in reducing losses due to frost heaving.

On steep terrain erosion can be a problem with equipment like the barrels or the Marttiini plow that completely cut through the root mat on the forest floor. The flails are far less severe, leaving a mulch and quite often some of the deeper roots. On shallow soils and steep terrain this may be what is required.

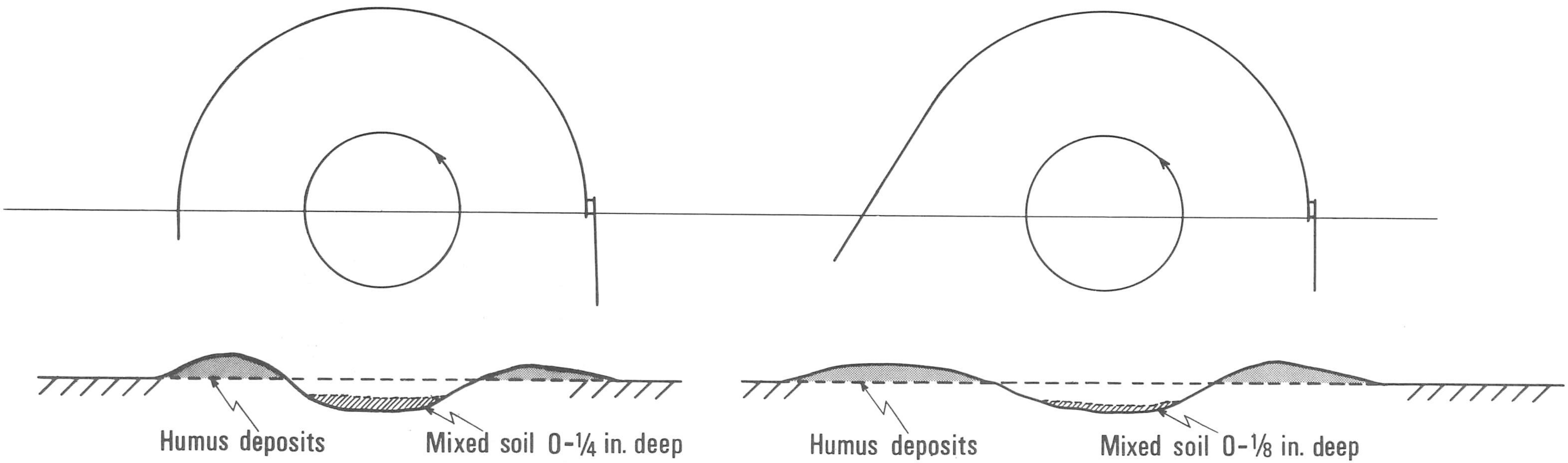

Figure 2. Typical shroud designs for flails, and their corresponding effect.

The Future

I strongly believe that to do a good job in regenerating all our forest lands we must have a variety of site-preparation tools. In our tool bag we must have both powered and nonpowered equipment.

There are several features that future powered equipment must have to make it successful. The power train that delivers the power to the rotating drum or disc must be very rugged in construction and at the same time very flexible. It seems that hydraulic power is the answer to this requirement.

The working portions of the flails or blades should be constructed from a very malleable but tough material to withstand severe shock. They should be attached by means of a pin or some kind of bearing arrangement which will allow them to pivot freely to reduce wear at the point of attachment. Height control of the working head is critical since flails, in particular, work only at the proper depth which is probably 6 in. or less from the soil surface.

Summary

Powered machines have advantages over nonpowered machines in that they require low drawbar horsepower tractors, they can be made very mobile owing to their light weight, and they mix the organic soils with the mineral soil leaving a mulched seedbed, the placement of which can be manipulated. These features of the powered equipment make them suitable for sites with heavy soil textures, shallow soils, steep terrain or small patchy areas. These are sites that our current nonpowered models are not now able to site prepare adequately.

As with all machinery, time, money and engineering expertise will be required to make the powered site-preparation equipment a practical reality. As long as good engineering practices are adhered to and enough time and funds are used to design the powered equipment properly, there is no reason that they will not be every bit as reliable a tool as their nonpowered counterparts.

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APPENDIX

Crawler Tractor Rating

Machine	Flywheel hp	Drawbar pull (lb)	Speed (mph)	Drawbar hp	Power train efficiency
IH TD-25C P.S.	285	50,250	1.5	201	70.5
IH TD-25C G.D.	285	63,272	1.5	230	80.7
IH TD-25B P.S.	230	40,200	1.5	160	69.5
IH TD-25B G.D.	230	47,000	1.5	185	80.4
IH TD-20C P.S.	170	28,500	1.5	114	67.0
IH TD-20C C.A.	185	26,440	2.2	145	78.3
IH TD-15B P.S.	125	22,000	1.5	88	70.4
IH TD-15B G.D.	125	26,915	1.5	99	79.2
IH TD-15B C.A.	135	19,740	2.1	106	78.5
Cat D9G P.S.	385	68,000	1.5	272	70.6
Cat D8H P.S.	270	45,000	1.5	180	66.7
Cat D8H D.D.	270	52,410	1.6	216	80.0
Cat D7F P.S.	180	31,000	1.5	124	68.8
Cat D7F D.D.	180	37,600	1.5	144	80.0
Cat D6C P.S.	125	20,000	1.5	80	64.0
Cat D6C D.D.	125	26,540	1.5	100	80.0
Cat D6C SA	156	18,750	2.5	125	80.1
Cat D5 P.S.	93	15,000	1.5	60	64.5
Cat D5 D.D.	93	17,330	1.7	75	80.6
AC HD21 B.	268	49,000	1.5	196	73.1
AC HD16 B.	195	33,000	1.5	132	67.7
AC HD16D D.D.	151[a]	34,600	1.4	120	80.0
AC HD11EP P.S.	137	22,000	1.5	88	64.2
AC HD11E D.D.	121	25,500	1.4	97	80.1
Terex 82-30 P.S.	215[a]	36,500	1.5	146	67.9
Terex 82-40 P.S.	265[a]	45,000	1.5	180	67.9

[a] Flywheel horsepower of naturally aspirated and two-cycle diesel engines corrected to SAE current standards.

THE INTEGRATION OF SITE PREPARATION WITH MECHANICAL REGENERATION

J.R. Gemmell, Unit Forester
Ontario Ministry of Natural Resources
Cochrane, Ontario
POL 1CO

Traditional site preparation and artificial regeneration techniques in the Clay Belt of northern Ontario are reviewed. Research trials are being carried out to integrate site preparation with artificial regeneration. Possibilities for the future include systems integrating site preparation with seeding and mechanical planting of container stock and nursery stock.

L'auteur fait la revue des techniques traditionnelles de préparation du sol et de régénération artificielle dans la zone des terres argileuses du nord de l'Ontario. On effectue actuellement des expériences pour intégrer la préparation du sol dans la régénération artificielle. Des systèmes futurs intègreraient la préparation du sol dans l'ensemencement et dans le plantage mécanique de plants (de pépinière) en potets ou non.

Introduction

This paper relates our experiences in the Clay Belt with respect to traditional methods of site preparation and artificial regeneration as well as our attempts to integrate the two systems into one mechanical operation.

Lowland Sites

Although silvicultural conditions in the lowland spruce (*Picea* spp.) sites have been debated at length, little has been done apart from the traditional research trials. Almost all of our effort in terms of artificial regeneration has been restricted to the upland sites.

In the past, the lowland spruce sites were considered to be regenerating adequately after harvesting. This may have been the case in the days of horse logging when much residual material was left standing and the skid trails were in essence prepared by the horse skidding. However, with the present mechanical methods of harvesting, the picture has changed drastically. Very little remains in a clearcut area. Progress has been slow in developing suitable methods for regenerating these lowlands but one fact is quite clear: modified harvest cutting is a necessity. A system of alternating strips maintains a source of seed and modifies the extremes of temperatures, wind and light. It also moderates the rising water table so characteristic of these areas after cutting.

Suitable seedbeds are a problem on many of the lowland spruce sites. We know that slow-growing *Sphagnum*, which grows on many lowland sites after cutting, creates an excellent seedbed for black spruce (*Picea mariana* [Mill.] B.S.P.) because of its ability to hold moisture. But how do we encourage this condition?

We know that many sites produce undesirable speckled alder (*Alnus rugosa* [Du Roi] Spreng.) competition but we don't know how important alder is in maintaining the productivity of the site. We do not even know how to deal effectively with the alder. Other sites produce heavy concentrations of dried-up feather mosses, a very unsuitable environment for black spruce regeneration. In many cases, mechanical site preparation in the form of compaction or disturbance by blade, anchor chains or shark-fin barrels might create the proper seedbed.

At present, research and trials continue. These lowland spruce sites represent a high percentage of our total forest resource. Although most of my paper involves the upland sites I want to emphasize the importance of the need for more research into regeneration of these lowland sites.

Upland Sites

The upland clay sites have always been considered a problem after cutting. Without some form of regeneration treatment, the well-drained, rich clay sites come back heavily to shrubs (willow [*Salix* spp.], alder, mountain maple [*Acer spicatum* Lam.]) and regenerate mainly to trembling aspen (*Populus tremuloides* Michx.) and balsam fir (*Abies balsamea* [L.] Mill.).

Silvicultural Techniques

The annual cut within our district is in the neighborhood of 40,000 acres. It is estimated that at least 30% of this area requires some form of treatment to encourage regeneration.

Much of this area cannot be treated for various reasons including accessibility, size of area and economic constraints. Consequently, our annual regeneration program amounting to 6,000 - 7,000 acres leaves quite a large backlog of unregenerated land.

At present, the average age of cutover that we treat is between 5 and 10 years. Since considerable amounts of competing vegetation are evident by this time, site preparation is a necessity.

The method generally used to treat these conditions is corridoring, using a crawler tractor with an assortment of equipment: straight blades, possibly with teeth attached, V-blades, Marden choppers, etc.

At least 70% of our regeneration program involves planting of bare-root nursery stock; most of which is done by hand using two major sources of labor: people hired locally on a piecework basis are responsible for two thirds of our hand planting program, while the remaining one third is carried out under a regeneration agreement with the major pulpwood producer in the area.

The regeneration agreement costs us almost twice as much as our own projects. However, we still feel it is justified because we have no camps and the areas are generally too far for commuting. Furthermore, we cannot hire enough local people to carry out our entire program. At the same time we are looking for alternatives not only because of the greater costs but also because the company cutters and day workers are increasingly unhappy with their work. Not only do they resent the actual planting but the average cutter on piecework has his daily wages reduced by 50%. For these reasons alone we would like to set an immediate goal for mechanical regeneration of one third of our hand planting program.

There are certainly other reasons. Quality in hand planting is highly variable. With 70-100 planters, there are just as many variations of where and how to plant a seedling. And although adequate supervision is maintained, only the obvious can be corrected (e.g., green side up, firmness of packing, spacing, etc.).

I don't think we can improve much on hand planting. Rather, I would propose that changes be made in the system. The obvious answer is to aim in the direction proposed by members of this symposium, that is, toward the mechanization of various methods of seeding, container-stock planting or nursery-stock planting.

Integration--Seeding

We have discussed the traditional methods of site preparation and artificial regeneration. What are the possibilities of integrating these two functions into a mechanical system?

Well, the simplest and probably the cheapest way of doing it is by seeding. On the upland sandy sites the Bracke cultivator is certainly one of the most promising systems. With the seeder attached, costs amount to less than $10 per acre.

Seeding, either natural or mechanical, appears to be the only avenue open for treatment in many lowland black spruce sites. If successful techniques can be found for preparing the site (some form of compaction, perhaps, or some way of encouraging the desirable *Sphagnum* species), then the integration would be simply site preparation combined with natural or mechanical seeding.

What about our upland sites? Well, again, if the problems of spruce seeding can be overcome, many possibilities exist. We have tested the KLM-240 Marttiini Reforestation Plow on the clay soils this year and feel that the quality and quantity of site preparation are very satisfactory. We have attempted seeding of black spruce and white spruce (*Picea glauca* [Moench] Voss) on these areas and again the results are encouraging. Perhaps a system of Marttiini with seeders attached would be feasible in our area.

Integration--Nursery Stock

The technique on which we have been concentrating during the past year is the planting of bare-root nursery stock by means of planting machines.

What characteristics are we looking for in any system of mechanized regeneration? Well, the most important are quality, quantity and cost. Other factors are availability of equipment (including planter, scarifier and tractor) and, of course, safety and comfort for people involved.

A piece of equipment which we have had the opportunity to test is the Taylor Drum Colter Planter. I am placing most of my emphasis on the Taylor in this paper, not because we have decided it is a revolutionary planter (it is not), but merely to illustrate the many factors we must take into consideration when attempting to integrate site preparation and mechanical planting.

The Taylor was brought to the Cochrane District in the fall of 1973 by the Canadian Forest Service (CFS). Although it has been tested in other districts in the northwest, our objective was to determine its suitability for conditions in our area. Many of the problems posed by the Taylor will be posed by other equipment as well, such as the Ontario Mark III Tree Planter. Nevertheless, each machine obviously has its own unique problems.

Description of the Taylor Drum Colter Planter

The principle of the Taylor is quite basic. A large rolling drum colter produces a continuous slit in the ground. A planting foot widens the slit. A planter inside the Taylor places a seedling in the slit and a pair of angled wheels packs the soil around the seedling.

The Taylor is mounted directly on the back of the tractor. The integral unit of V-blade, tractor and Taylor provides considerable *maneuverability*. The Taylor can be lifted hydraulically and can turn in restricted areas with relative ease.

Problems are encountered in obtaining suitable tractors to work with the Taylor. Most of the available tractors in the D6C-D7 range do not have auxiliary hydraulic systems to operate the Taylor. However, in our latest trial we used a Komatsu D65A crawler tractor (180 net hp) which does have an auxiliary hydraulic circuit that made it ideal for hookup.

The winch of the tractor has to be removed to allow connection of the Taylor flush to the tractor, and operators are generally reluctant to do this, especially on small jobs. Most of these tractors have hydraulic units which operate the winch but this system is a small unit and costly problems have developed when it was used.

These hookup requirements are relatively costly. With standby and shop time, before and after the job, costs on a small plant of 50,000 trees could add up to $8 per thousand trees planted. If many alterations are required to fit both the V-blade and the Taylor, the costs could easily double.

By contrast, the Ontario Planter is a self-contained unit with its own hydraulic system. As well, the hookup is done by a simple hitch. Both factors are advantages in tractor adaptability but not necessarily in maneuverability or maintenance.

Personnel

The quality of any mechanical operation is dependent on its personnel. The attitude and ability of the tractor operator, foreman and tree planter can make all the difference in an operation. This is especially so when equipment is being tested and conditions can get not only very frustrating but at times quite uncomfortable.

The Taylor is not the most comfortable machine within which to work. The planting foot kicks up when it hits debris. This can be rather painful to the hands if the planter is placing a seedling when the foot comes in contact with an obstacle. The ability of the tractor operator to manipulate around or over obstacles is very important as stumps and rocks can produce discomfort and injury to the person in the planter.

Everyone involved with the machinery is important in making suggestions for improvements both in the function of the machinery and in safety features.

Site

There are two factors which I consider to be critical in any attempt at mechanized regeneration. They probably determine the difference between success and failure of any system, including the Taylor with its simple ruggedness or the Ontario Planter with its advanced hydraulics. Both problems relate to the *variability* of site. The first is site as it pertains to the soil structure. The second is site as it pertains to vegetation.

We usually think of the Clay Belt as a uniform flat expanse of clay overlain with thick peat. This is the impression one might get from an aircraft. Actually, within the lowlands the peat conditions may vary from a few inches over clay to 30 feet over clay. The moisture regime may vary from muck to clay loam to heavy clay with perhaps varying amounts of clay till or even sandy till. For example, our latest trial with the Taylor was located and recommended by our regeneration crew. From the general comments recorded, the area appeared fairly uniform, gently rolling, with a few big stumps, a little heavy slash, and a few boulders. The machine worked parallel strips approximately 20 chains long, perpendicular to the road. The first 5 chains consisted of moss and grass over muck. The plowing action of both the blade and the Taylor in this muck reduced the planting potential to almost nil. Even the trees planted will likely have a very high incidence of frost heaving.

The next 5 chains brought a slight elevation to the site and with it fairly heavy alder cover mainly over muck. If the alder isn't sheared by the blade, the site becomes an obstacle course for the planter and as well the efficiency of the packing wheels is reduced considerably. If the alder is sheared, it tends to expose the pure muck and produces problems with planting and frost heaving.

Another slight rise in elevation and we're into our best site, a well-drained clay loam. Here the poplar (*Populus* spp.) overstory, young poplar and alder brush, stumps and heavy slash present problems. Nevertheless, in this area up to 70% of the seedlings are planted satisfactorily. At the height of land we're into a sandy clay with scattered stumps, slash and some rock outcrop. Planting here is also satisfactory in most places. Down the opposite slope we're into a heavy clay with mainly grass cover. The clay creates a problem of frost heaving if it is overexposed. As well, there is some difficulty in closing the slit.

Site and vegetational variability and debris on the sites are difficult to overcome. Equipment can be adjusted to suit a specific condition but not to suit five different site conditions in one planting chance. A more intensive survey must be done prior to planting to eliminate wetter areas (if possible) and to determine the best layout in terms of operating equipment.

Site Preparation

Probably the most critical feature and the key to success or failure of mechanical regeneration is the development of a V-blade or other similar device to clear brush, slash and stumps sufficiently to allow proper planting of seedlings. Both the Taylor and the Ontario Planter will plant trees in heavy clay. However, neither will plant trees satisfactorily in conditions of heavy brush or even in blueberry competition if some form of equipment such as a V-blade does not prepare a suitable site before the machine is introduced. In traditional site preparation it is desirable to clear competition for the full width of the blade so that three seedlings can be hand planted side by side at the usual 6-ft spacing. By contrast the planting machines plant only one continuous row and, therefore, the emphasis is on clearing a path directly in line with the row of seedlings.

The Taylor was originally accompanied by a V-blade with a scalping foot intended to remove debris from directly in front of the planting row while the blade, slightly raised above the ground surface, pushes larger material off to the sides. The foot was found to be too narrow to float the blade and the blade angle too wide, so that it tended to build material up in front much the same as a straight blade.

The CFS developed a V-blade last winter (Fig. 1). The center 'V' is a good angle for pushing material to the sides, and can be adjusted up and down depending on site conditions. It also has a front tooth to break up roots and debris in the line of travel followed by a rolling drum colter to aid in floating the blade and breaking up material. Undoubtedly this blade has the best combination of desirable features. The only possible improvements are a larger tooth, a larger colter or other adaptation to produce a floating action for the blade and, for the Komatsu, a wider blade to push more debris beyond the tractor tracks.

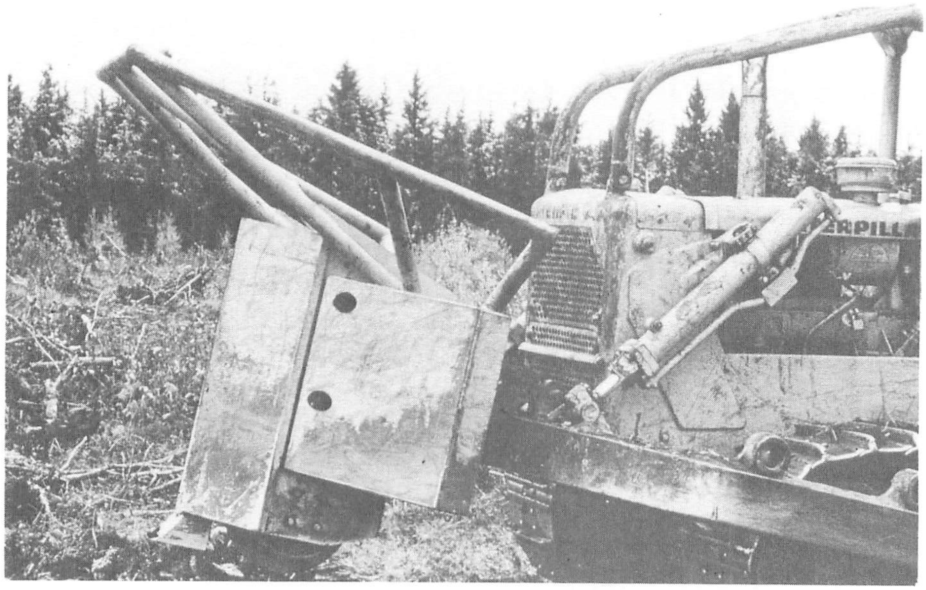

Figure 1. The CFS V-blade, designed for use with mechanical planters, is readily adaptable to different sizes and makes of tractor.

Of course, when they completed their research in the spring, the CFS picked up their blade and went home. This emphasized another problem in equipment development. Equipment money is rather difficult to come by. Therefore, we are forced to collect remnants, rebuild and hope for the best. Our attempt at rebuilding a remnant produced a blade which combines the features of the CFS blade in a rough sort of way. It also does the site preparation--in a rough sort of way.

Stumps will probably always be our main concern in site preparation. They are also the major cause of hangups. If they are removed they cause over-scarification and accumulation of debris. They play havoc with the person inside the planter. I don't know that any design of V-blade can overcome the problems caused by stumps but perhaps with a little more experience we will learn to cope with them.

Conclusion

I would like to emphasize the importance of ongoing research and trials in the development of mechanical regeneration. It is also important that we communicate between districts and between agencies. This symposium is a good example of communication, not so much through a paper such as I have presented to you, as through the informal discussion problems and developments by the symposium participants.

I don't think we have progressed a great deal beyond the Stone Age as far as site preparation and mechanical development are concerned. But progress is commensurate with the resources made available to carry out the research and trials. Unfortunately, in the annual assault on budgets, research is usually the first item to get hit. If progress is to be made, this policy will certainly have to change.

PRIME MOVERS AND CARRIERS: THEIR ROLE IN THE MECHANIZATION OF SILVICULTURE

J. F. Fowler, District Manager
FLECO Corporation
P.O. Box 2370
Jacksonville, Florida

Mechanization in silviculture seems to be imperative and prime movers in numerous configurations are already employed. Attachments such as rakes, V-tree cutters and rolling choppers are available for these prime movers in applications of site preparation.

La mécanisation en sylviculture semble nécessaire et déjà l'on utilise divers véhicules-moteurs. Pour la préparation du sol, on peut y attacher des accessoires tels qu'abatteurs en V, rateaux, rouleaux hacheurs.

The standard of living in any nation is normally raised when the output increases more rapidly than the population.

The key to a nation's growth lies in its most basic resource--its land. Developing countries must cultivate this resource, particularly for its agricultural potential. Even the more economically advanced countries must concern themselves with land, but more in the area of preserving land resources through good land management.

It is essential today to utilize the most advanced techniques in silviculture. Much has been learned in the past 20 years about the establishment and growth of forests, but if we are to make adequate provision for the forest products required in the forthcoming decade, we must become much more technical in our treatment of individual areas than we have been in the past.

Mechanization of silviculture is thought by many to be imperative. Prime movers in numerous configurations are already employed. Simplicity in design of attachments for prime movers is certainly desirable, but surely sophistication will find its way into the design of some future attachments.

Land Clearing

There are four basic methods of land clearing:

1. removing trees and stumps and piling into windrows and piles for disposal
2. shearing vegetation at ground level with sharp cutting blades and piling into windrows or piles for burning
3. knocking vegetation to the ground for later burning in place
4. plowing, chopping and incorporating vegetation into the top few inches of soil.

Another method known as spot clearing has been used for the eradication of sparsely scattered undesirable plants such as juniper and creosote in the western United States. Spot scarification will probably be employed to a greater degree in the future where timber is existent and natural regeneration is desirable.

The above methods have been used in the past and are still being used where applicable for agriculture and silviculture.

Prime Movers and Attachments

A. Track-type tractors

1. Caterpillar Tractor Co. markets the following models:

Model	Flywheel hp	Model	Flywheel hp
D9	385	D5	105
D8	270	D4	75
D7	180	D3	62
D6	140		

The D9 is used less than other models in land clearing.

2. Ground clearance

D9	17.1 in.	D5	14.6 in.
D8	15.2 in.	D4	14.0 in.
D7	15.3 in.	D3	13.6 in.
D6	14.6 in.		

3. Ground pressures range from 3 PSI top to 13.7 PSI - D6 CLGP - 4.2 PSI - D5 LGP - 3.8 PSI - D4 LGP - 3.0 PSI

B. Track-type loaders

983	941
977	931
955	

C. Wheel-type loaders

988	930
980	920
966	910
950	

The size of prime mover selected is governed by the scope of the job, speed of production, terrain and soil condition. Smaller machines naturally are more easily transported from one area to another. On the other hand, production efficiency increases with the larger prime movers.

D. FLECO attachments for site preparation

1. FLECO multi-application rakes are used to clear land of trees or rocks with a minimum of topsoil in the windrows or piles. These rakes are very effective in pushing over and piling trees and brush.

2. Rock rakes are designed especially for rock removal. Curved teeth tend to roll rocks and boulders.

3. Blade rakes can be attached to bulldozer blades and are easily removed when earth work is to be done. Blade rakes are for use in cleanup work to pile debris that has already been knocked down or uprooted.

4. Clearing rakes are available for Caterpillar wheel loaders. They remove trees, stumps and brush and pile them into windrows or piles.

5. Clamp rakes on wheel loaders clamp long trees or trash and hold them in position for moving to a truck or pile.

6. Stacker rakes for wheel loaders are used for piling debris. Longer teeth provide for a large load capacity.

7. V-tree cutters for the track-type tractor are used for cutting large trees or brush at ground level at a high production rate. For the removal of a large, undesirable tree, the operator drives the stinger through the tree at a height of 3-4 ft, weakening it so that it can be cut off with the main cutting edge. Stumps are severed at ground line after splitting with the stinger.

8. Rolling choppers are available for Caterpillar track-type tractors for use in chopping brush and small trees. The debris can be burned in places where burning is permissible, or left to decompose. Areas which have had this treatment are good for a natural seed catch.

E. FLECO attachments for logging

1. Tree shears cut trees at ground level. They are available for track-type tractors and front-end loaders.

2. FLECO grapples designed for the Caterpillar 518 Skidder improve skidding production. The operator can gather logs or tree-length pieces without getting off the machine.

3. Logging forks and millyard forks enhance a logging operation greatly. Logs can be loaded at the landing and handled in the millyards. FLECO forks load, unload and sort logs.

4. FLECO pulpwood loaders fit Towmotor lift trucks for handling short pulpwood.

As we progress in forestry, our efforts will surely become more efficient. There are phases in the total operation where hand labor is still the most desirable. Machinery manufacturers, however, have devoted much time to the study of present requirements and will become even more efficient in the years to come. Probably the best method of pursuit will be for governmental agencies, the forestry industry and the machinery industry to continue working closely as a team on selection, design and manufacture of required prime movers and attachments. Through these diligent cooperative efforts we can probably be in step with the times.

TESTING AND EVALUATION OF MECHANICAL TREE PLANTERS

D. A. Cameron, Forestry Officer
Canadian Forestry Service
Great Lakes Forest Research Centre
Sault Ste. Marie, Ontario

This paper presents a general outline of the method and conduct of mechanical planter trials. Included are some observations and results of 4 years of Canada-Ontario cooperative testing and evaluation of five commercially available planting machines in typical Boreal Forest cut-over conditions in northern Ontario.

L'auteur présente un aperçu général de la méthode et de la mise en oeuvre d'essais de machines à planter. Ce document inclut des observations et des résultats d'épreuves coopératives Canada-Ontario, en plus d'une évaluation sur base commerciale de l'efficacité de cinq planteuses en forêt boréale exploitée typique, dans le nord de l'Ontario.

Background

Despite considerable expansion of effort in recent years, the rate of regeneration in Canada has not kept up with that of harvesting, partly owing to budgetary limitations and partly to the high cost of labor-intensive methods.

New silvicultural methods are being explored under a cooperative Canada-Ontario program, the aim of which is to improve the biological and economic output of the forest through increased mechanization.

In mechanizing silvicultural work, primary attention is being given to reforestation. Specifically, there is a need for a mechanical planter capable of planting typical cutover in the Boreal Forest.

Two approaches are being taken: (1) the design and development of a mechanical planter to achieve the long-range goals of efficient and economical regeneration of forest lands, and (2) the testing of existing equipment which, though available, has never been used on a large scale in northern Ontario.

As part of the second approach, the Ontario Ministry of Natural Resources (OMNR), in its cooperative program with the Great Lakes Forest Research Centre (GLFRC) of the Canadian Forestry Service (CFS), purchased five different commercially available planting machines for testing. In this program, objective evaluation of the performance of these machines is the responsibility of the CFS.

Introduction

To evaluate the machines in a meaningful and measurable way, it was necessary to quantify the site factors which might have an effect on the operation of the machine, and then to record this effect through the use of work efficiency studies. The work done by the machine was measured through planting quality and productivity assessments. The long-term biological effect on the trees planted is being determined in a series of independent assessments being conducted by another member of the GLFRC staff.[1]

In 1971, the first year of planting machine testing, we set up a system of measurement of site factors, timing procedures and postplanting assessments which we have used since then. As well as individual machine assessments, the system gives comparative site and production data with which each of the machines in the program can be evaluated, one against the other.

Testing

Although one of the aims of the trials is to determine limiting site conditions for each planting machine, the initial efforts must be made on areas considered relatively "easy". Generally the trend with the planters has been to use the first trials more for familiarization with the equipment and determination of how it performs mechanically. Subsequent trials are then used to determine a machine's ability to cope with various sites.

Three factors help us decide where in the province the sites will be selected. First is the type of site and soil in relation to our concept of "easy" in the progression of trials from "easy" to "difficult".

Second is the availability of shop facilities. Because of the rugged terrain and untried equipment, it is expected that both repairs and field modifications will be required. Third, by far the largest percentage of planting in northern Ontario is done by hand. In introducing new planting ideas and as part of the trend to greater planting

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[1] R.F. Sutton's study entitled "Nutritional and physiological factors affecting the survival and growth of mechanically planted seedlings"

mechanization in the future, it is a good idea to get field staff from across the province involved by familiarizing them with the equipment and organization of machine planting operations. It also broadens regeneration thinking by adding the dimension of mechanized planting to the methods used.

The OMNR staff have been responsible for the operational aspects of these machine trials. They hire the tractors and operators and supply trees, area, planter men and supervision. The GLFRC staff conduct site assessments before the trial and machine work studies during the trial, and assess the quality of planting achieved. These two agencies cooperate in making changes to improve operational efficiency and modify equipment as necessary. An important feature has been the improvement of field procedures through on-the-spot discussion and correction of organizational problems.

Prior to planting, the sites are assessed for those physical factors which might affect the passage of the tractor or the planter, the mechanics of planting and packing and subsequent survival. Eight plots are usually set up in a 50-acre block. These plots are 5 chains long and 1 chain wide and are broken into one-chain-square subplots. The plots are oriented lengthwise to the direction of machine travel.

The plots allow sampling of the area to determine slash volume, stumps, residual trees, minor vegetation, humus depth, soil texture, soil depth, rock, moisture regime, and slope as a pretreatment survey. Once this has been completed, a time study of the planting operation is carried out to record each separate event as it occurs during the planting day, with reasons being given for each operational delay. These events are later grouped into time categories to give machine availabilities and productive and nonproductive times.

A post-treatment survey is carried out to record planting quality, nonplantable distance and spacing.

All of these factors are measured or enumerated for a number of reasons. Besides describing the site objectively, they form a base set of data for comparison with future trials, future machines, and other methods of regeneration. This information will also be used in developing a model or method of predicting the degree of planting success for a given planter on a range of site conditions.

Evaluation

Evaluation has been a two-part process in the trials. One part is the subjective "gut-feel" that the OMNR personnel, the contractors and the CFS staff have for a particular machine. Depending on whether or not a trial has run smoothly, the general attitude to mechanized planting will vary considerably. Given only a subjective evaluation, a machine that might have potential may or may not be given a second chance in our conditions.

Thus there is a need for an objective evaluation through compilation and correlation of data on tree spacing, planting quality, terrain and site encountered, machine speed, and cost.

I might add that one must be unfailingly optimistic when testing a "new" machine. It often happens that much tinkering and operational changing are necessary before a particular machine reaches its potential in our cutover conditions.

To aid in evaluating a machine and in demonstrating to others how a machine operates, we take 8 mm color movies of the planting machines in action while the trials are going on. We use these films as a means of providing year-round visual information to interested people, mainly OMNR personnel, and to refresh our own memories when certain questions arise.

Evaluation is done through careful measurement, observation, and consultation with all parties involved in the planting. One method of evaluation is that of planting the area mechanically and comparing the cost with the average total cost of site preparation and hand planting for similar areas. It should be noted that we are conducting a single-pass operation in which site preparation is provided by a V-blade mounted on the front of the tractor. The area thus prepared is then immediately planted by the planting machine attached to the rear of the tractor. Provided that the area was planted satisfactorily, the cost of one method versus the other is a good starting point.

Our evaluation is based on the number of trees planted per acre, amount of time spent planting an acre, planting cost per acre, planting quality, machine safety and a comparison with other methods available. Most tree planting machines that exist at present, either operational units or prototypes, are "terrain-crossing" machines (Bäckström 1970). These are the machines that cover the entire area with planted rows. Desired spacing of the seedlings is obtained by varying the width between the planted rows and the mean interplant distance in the advancing direction of the machine. We have had inter-row spacing of as little as 7 1/2 ft. Intertree spacing is generally 6 ft. Under ideal conditions, this would give us a theoretical 968 trees per acre.

To ensure proper planting, the seedling should be firmly packed in the soil and to a depth such that the general soil surface is level with or slightly higher than that of the root collar. Planter packing wheels have a tendency to mound the soil around the seedling while packing it.

We conduct both within-plot time studies and overall time studies. The overall study gives us an evaluation of general machine performance and aids in isolating weaknesses in the machine or the system. The within-plot times are used in comparisons with pre- and post-treatment results.

We note any needs for improvements to the machine, the organization, the planter operator, the tractor operator, the site preparation tool and the planting stock.

After collecting the data from the pretreatment survey, the time study and the post-treatment assessment, we group them by plot and subplot. Standard statistical tests are performed on these data. In a further step, the data are put on computer files for correlation so as to come up with a model that will predict planting success in different areas with different machines. It will also help to isolate those site factors which limit planting machine performance.

Results

During the trials, together with OMNR personnel, we have altered the support crew setup to get optimum planting out of the planter-tractor-V-blade unit. The planter is kept supplied with trees at regular intervals; planter operators are changed at regular intervals; servicing of the planter is done at regular intervals and chainsaws for debris removal and tools for field repairs and maintenance are kept on hand at the job site. Short but frequent chats are held with all crew members concerning operational and organizational changes which might be made to improve the operation and make the job easier. Feedback to the tractor operator and the planter man as to how well the objectives are being accomplished allows the tractor operator to get the feel of the V-blade and planter unit when they are operating properly while the planter man gets a feel for proper spacing and depth of planting. Safety is a very important factor in such a job and much of our effort is spent on ensuring that the machines are as safe as possible.

After the trials, major modifications discussed and agreed upon are carried out, usually in a commercial machine shop. These modifications could be in the form of safety additions, component strengthening and general beefing up for bush work. It has not been our practice to change the basic design or operation of the planter but rather to add only those features which adapt it to our Boreal Forest cutovers. Machines that do not perform without extensive modifications in basic design are dropped from the test program.

Operational trials of commercially available planting machines began in 1971 and continued until the spring of 1974. The Reynolds-

Lowther Crank Axle Planter has been well tested on typical jack pine cutovers and has proven useful for that site type. The Taylor Drum Colter Planter has been tested on both sandy and clay soils. The Reynolds-Lowther Dual Colter Planter has had a trial on both sand and clay.

The trials have been conducted on a variety of site types on the two major soil types to determine the limitations of these machines for use in northern Ontario and to provide data useful in assessing the performance of the Ontario Mark III Planter. The Ontario Planter is a new planting machine being developed by the OMNR for use in Boreal Forest cutover conditions in northern Ontario.

Discussion

The planting machines purchased under the program are listed with comments as to their operational capabilities and suitability for Boreal Forest conditions.

1. *The Timber Cat T40 Single Row Dibble Planter* (Fig. 1) had trouble planting on our easiest sites and was not rugged enough for our conditions. It was therefore deleted from further trials.

2. *The YLO Finn Forester Planter* (Fig. 2) required a three-point hitch not found in our bush tractors. We had reservations about the rotary screefer operating in stumpy and rocky conditions, and as we had three other machines which were more promising, the Finn Forester was sent to southern Ontario.

3. *The Reynolds-Lowther Crank Axle Planter* (Fig. 3) is basically a modified wildland planter with self-contained hydraulics. A rolling colter wheel cuts a slit, scalping wings throw sod or debris off to the sides and a planting shoe follows, holding the slit open and allowing the tree to be positioned. Two packing wheels then close the slit around the tree. The operator sits straddling the slit.

   In the context of our conditions in the Boreal Forest Region, the Crank Axle is not a safe machine. It may be possible to modify it to correct this feature. It was also found to be the roughest riding of the three machines that have been operationally tested. It has had five trials on sites ranging from easy to difficult in the Chapleau area. It performs well on sandy sites and planting quality has generally been very good.

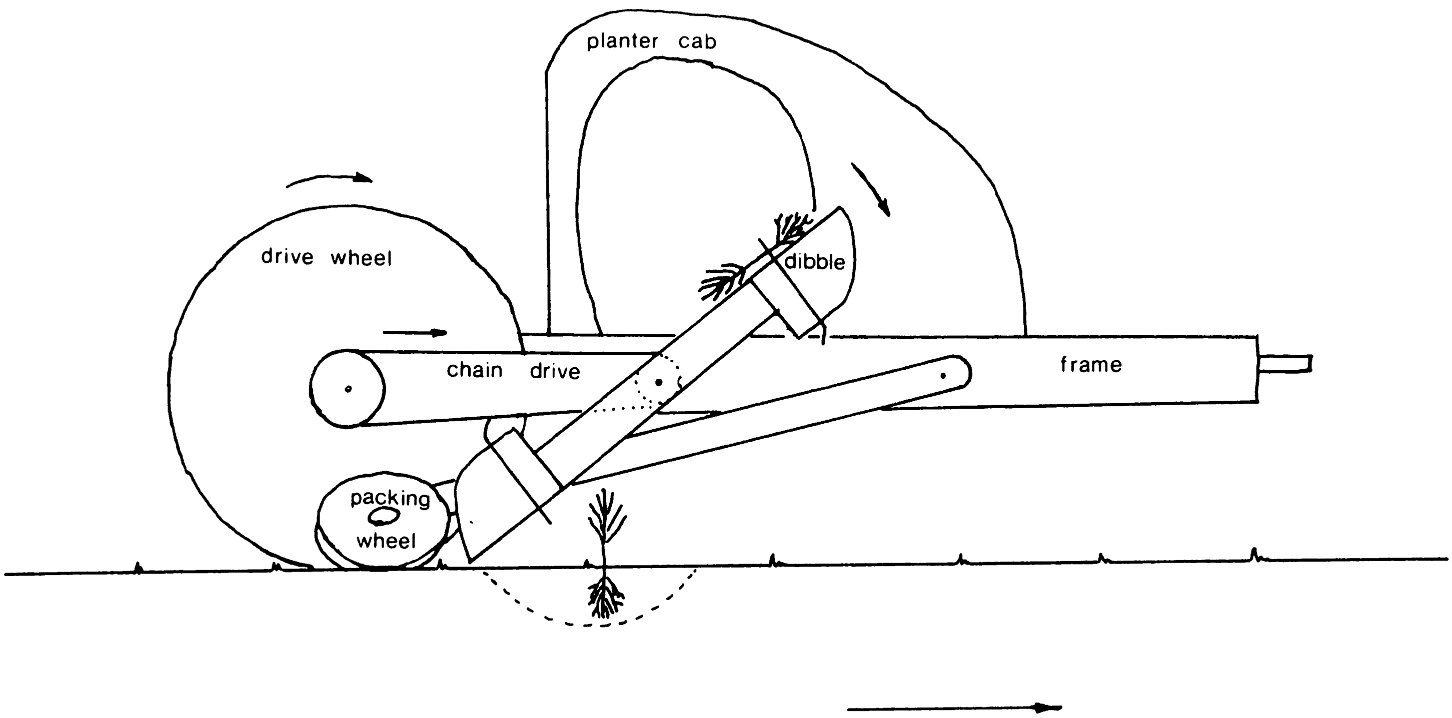

Figure 1. Schematic of Timber Cat T40 Single Row Dibble Planter

4. *The Reynolds-Lowther Dual Colter Planter* (Fig. 4) operates off the tractor hydraulics. It has two colter wheels, one to cut a planting slit followed by a planting shoe which holds the slit open for positioning of the tree. This is followed by a second offset colter to wedge the planting slit closed and then two packing wheels finish the job. The planter man sits to the side of the slit. This machine is safer than the Crank Axle in our cutover conditions and the ride is smoother.

The Dual Colter was designed with clay soils in mind. Clay is difficult to penetrate and once it is penetrated, the slit is hard to close. Clay soils also pose another problem. Scalping exposes the clay to baking, runoff, and frost-heaving. The second colter is one method of closing the slit while not scalping the soil.

The Dual Colter plants well on both sandy and clay soils and it is safe.

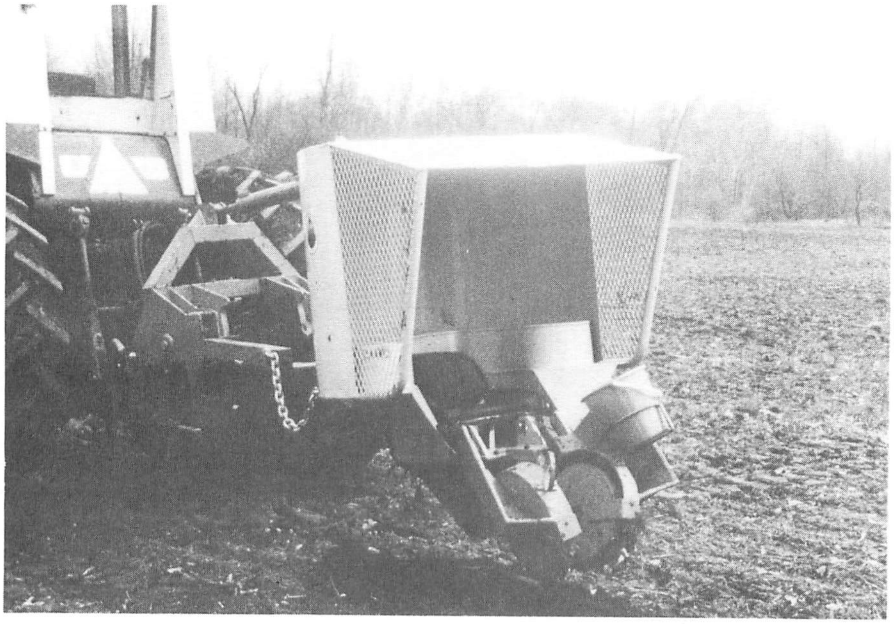

Figure 2. The YLO Finn Forester Planter

Figure 3. The Reynolds-Lowther Crank Axle Planter

Figure 4. The Reynolds-Lowther Dual Colter Planter

Figure 5. The Taylor Drum Colter Planter

5. *The Taylor Drum Colter Planter* (Fig. 5) operates off the tractor hydraulics as well. This is the only machine of the planters tested which must be bolted directly to the back of the tractor. It has a large colter wheel which cuts the planting slit, and a large drum built around the colter which sets the depth of colter penetration while crushing debris to either side of the slit. A planting shoe follows in the slit and allows positioning of the tree, while two packing wheels follow to close the slit. The planter man is seated straddling the slit.

   This machine plants well in both sand and clay. In clay soils no scalping is required and the sheer weight of the machine on the packing wheels closes the slit. This is by far the safest and most rugged planting machine we have tested.

6. *The Ontario Mark III Tree Planter* is under development as the main feature of this program. It was developed in response to a need for a planting machine for cutover conditions in the Boreal Forest and the lack of really suitable commercial machines available. The paper by Jim Scott will expand on the Ontario Planter.

Any discussion of mechanized planting would be incomplete if the observations made over 4 years of testing in Boreal Forest cutovers were not mentioned. All planters we have tested require slash and debris removal for best planting results. We have used tractor-mounted V-blades with an attached scalping foot to clear away debris for the planter passage. Because of the amount of debris that must be removed for the planter to pass in our Boreal Forest cutover conditions, we choose our tractors from the D-6 size class.

Uniformly sized trees, whether large or small, are much easier to handle and put through the planters than bundles containing trees that vary widely in size. Regular maintenance is a must. Corrective action with regard to a poor planting operation should be taken as soon as possible; otherwise a pattern of less than optimum performance becomes established, and is often hard to break.

Conclusion

Mechanized planting is another silvicultural tool to be used in regenerating typical Boreal Forest cutovers of northern Ontario. In certain localities where labor is hard to get it offers a viable alternative to site preparation and hand planting. Machine planting costs are comparable to those of hand planting plus site preparation when site preparation and planting are carried out in a single pass. This points to the need for a tractor- or planter-mounted site preparation tool which will do this job.

Both the subjective and the objective forms of machine evaluation are a necessary part of any mechanized planter testing program. Continuity and standards are required for purposes of comparison.

A key to optimum planting is regular servicing, a good maintenance program and a regular exchange of ideas among the people involved.

An optimistic, enthusiastic approach to mechanized planting is essential. When I think of some of our earlier trials with these planting machines, I sometimes wonder how we survived the experience. Constant breakdowns, improper use of the site preparation tools, seemingly insurmountable problems in relation to packing and increasing pessimism on all sides are a definite part of a testing and development program. Results from each succeeding trial have been increasingly rewarding and have made all our efforts worthwhile.

Reference

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RECENT DEVELOPMENTS IN MECHANIZED PLANTING AND THE FUTURE FOR ONTARIO

J.D. Scott, Development Specialist
Ontario Ministry of Natural Resources
Forest Management Branch
Toronto, Ontario

Until the 1970s most tree planting machines built were suitable for planting only on relatively open agricultural lands. There is a trend now, particularly in countries with a labor shortage, toward designing machines capable of planting on a much broader range of site conditions.

Avant les années 70, la plupart des machines à planter des arbres convenaient seulement aux terres agricoles peu ou point boisées. De nos jours, spécialement dans les pays où la main d'oeuvre est limitée, on se dirige vers la conception de machines planteuses tous terrains.

Introduction

The first tree planting machines to be built were based on principles borrowed from agriculture. The basic machine consisted of a colter for making a slit in the soil, a shoe for opening the slit and receiving the tree, and packing wheels for firming the tree in place (Fig. 1).

Even in the early 1970s the dominant functional principle of most planting machines seemed to originate either from nursery transplanting or from furrowing vehicles used in agriculture (Siren 1971).

When planting is done on abandoned farmland, the lowest planting costs, even today, are realized when simple, agricultural-type planting machines already in existence are used rather than special forest-land tree planters (Bäckström 1970). The problem is that in Canada, as in other forestry-oriented countries of North America and Europe, most of the abandoned agricultural land has been replanted so that the requirement now is for equipment capable of planting on a much broader range of site conditions.

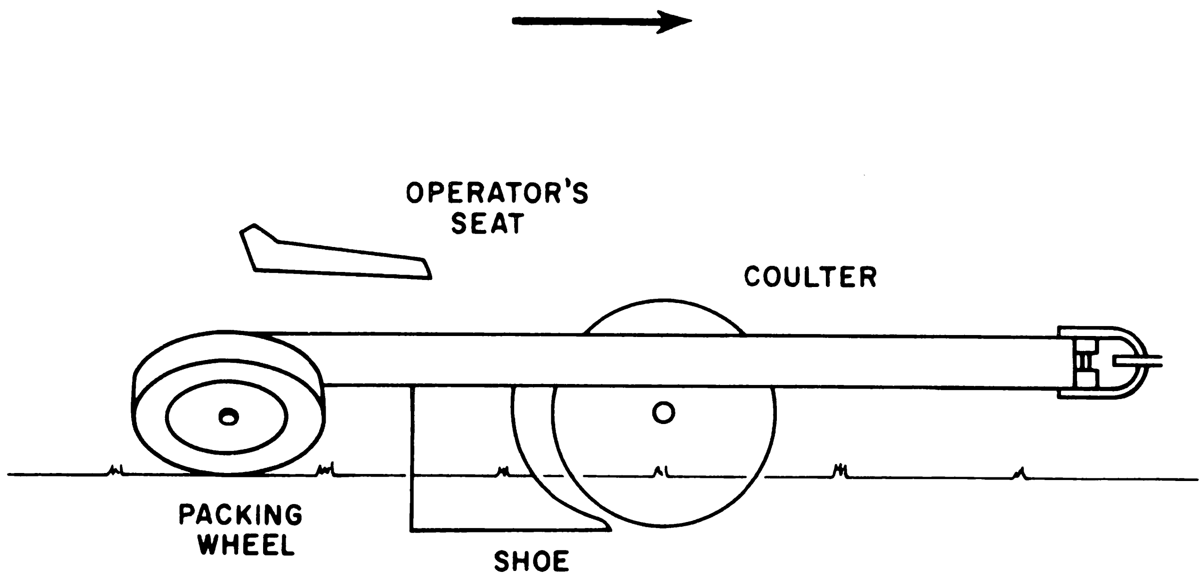

Fig. 1. Typical drag-type planter.

The purpose of this paper is to discuss some of the developments that have taken place in recent years in meeting the present and future needs of mechanized planting, particularly as it relates to Ontario.

History of Development

The first patent for a tree planting machine was issued more than 90 years ago. In the 1920s and 1930s two types were tested, one of them horse drawn. From 1943 to 1945 three prototypes were developed on much the same principle as most planting machines used today in North America (Bäckström 1970). By 1960 there were over 40 types of planting machines in use in the United States and Canada alone.

In preparation for the October, 1974 IUFRO symposium on stand establishment in the Netherlands, S.E. Appelroth of the Finnish Forest Research Institute sent a questionnaire to 62 manufacturers of planting and seeding machines. The planting machines recorded from the replies to this questionnaire were grouped as follows:

tractor-mounted:

continuous furrow	-	15
intermittent	-	2

trailer-mounted:		
continuous furrow	-	5
intermittent	-	1
auger planters:		
man-carried	-	8
machine-mounted	-	5
balled-stock planters	-	7
Total		43

Obviously the above list was not complete as several well-known manufacturers of planting machines were not represented. However, it does indicate a trend in planting machine development.

The first departure from the traditional design of agricultural-type tree planting equipment occurred in the 1960s with most of the development taking place in Sweden, Finland, Germany, the USSR and the United States (Bäckström 1970).

Finland introduced machines with rotary soil-cultivating devices in front of the planting shoe. These are exemplified in the YLO Finn Forester and TTS planters (Appelroth 1969).

In Germany, the USSR, Finland and Sweden, hole-digging machines followed by manual planting were tested (Bäckström 1970). The USSR and Sweden experimented with intermittent plows as well.

Other developments in planting machines during the 1960s included a West German machine in which the tree was carried into the ground between two flexible discs and an East German machine with six spokelike planting arms about a central axle (Bäckström 1970).

Perhaps the most important change to take place during the 1960s and early 1970s was the testing of a number of machines based on an intermittent approach to planting.

The Institute of Reforestation of the Swedish Forestry College in Stockholm developed the first intermittent planting machines. Several models were built in this series. The first prototypes were drawn units while the last three were rear-mounted on logging vehicles (Fig. 2) (Bäckström 1970). All machines were designed for planting container stock.

In 1968 an intermittent planter for container stock, the Druzba-2, was built in the USSR (Bäckström 1970, Volobueu 1972). The working principle of this machine, as illustrated in Figure 3, consists of an upper fixed tube and a lower movable tube. The lower tube swings

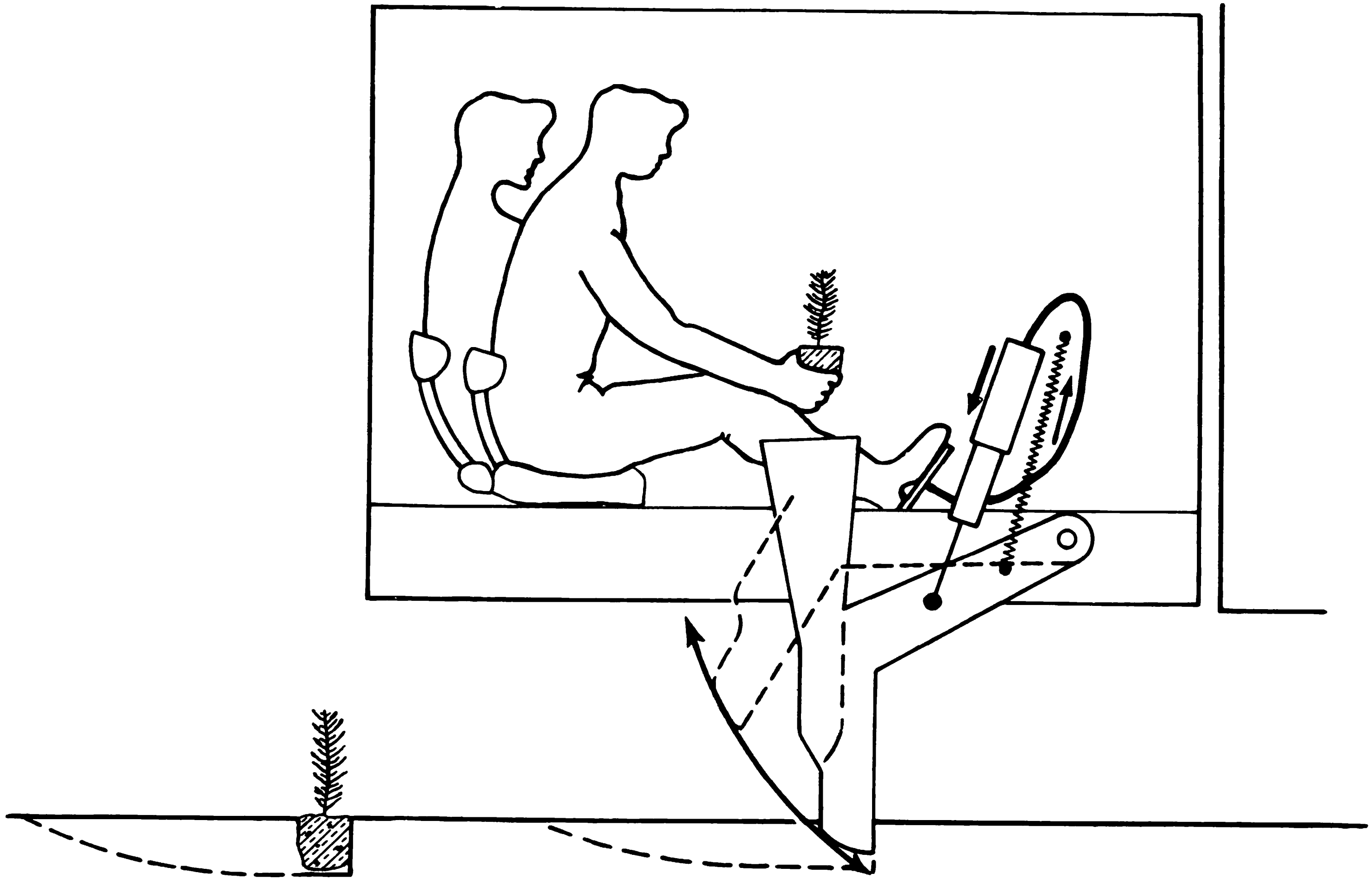

Fig. 2. Intermittent container planter (Swedish Forestry College planting machine).

down and forward from a general horizontal to a vertical position. The tip of the movable lower tube is plow-shaped so that when a foot pedal is depressed it activates a hydraulic cylinder which buries the plow-shaped head in the soil. As the movable tube moves into a vertical position it lines up with the upper tube, triggering a mechanism holding the container and releasing the tree into the ground.

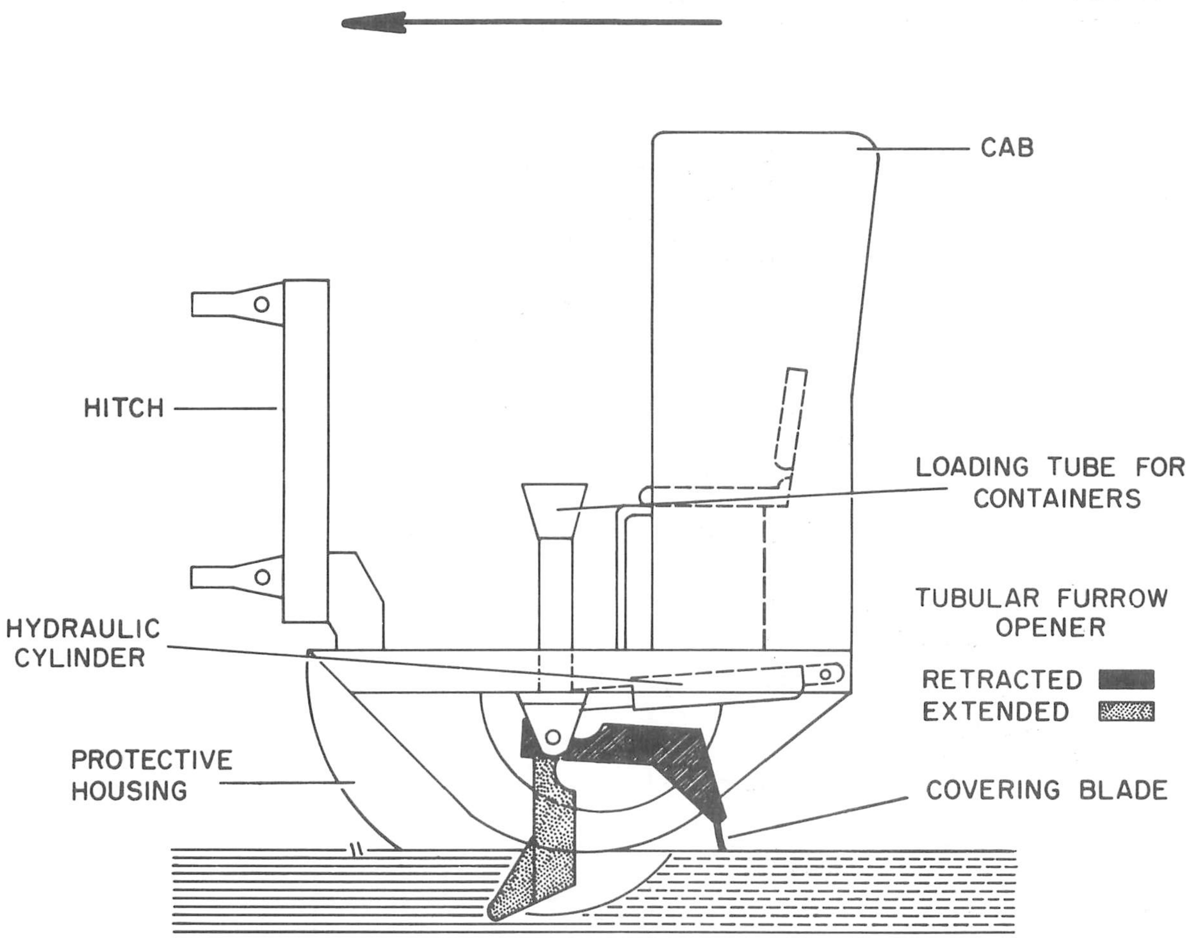

Fig. 3. Working principle of the Soviet Druzba planter for container stock.

One of the more significant developments in intermittent planting concepts was the rotating dibble mechanism used in the Timber Cat planters manufactured by the Forestry Equipment Company of Jacksonville, Florida (Fig. 4).

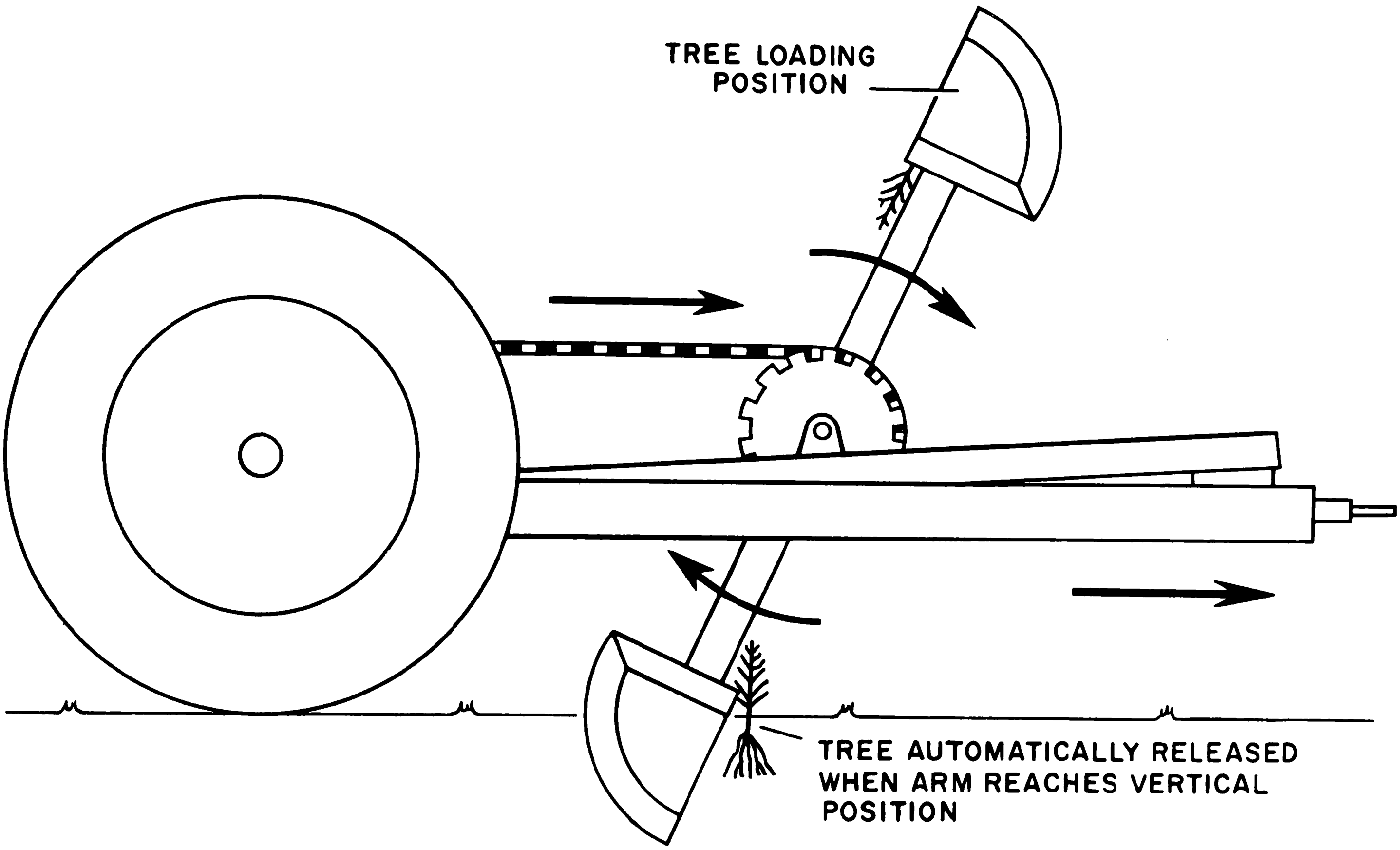

Fig. 4. Working principle of the rotating dibble used on the Timber Cat planter.

The Twin Cat planter was the first to use this principle, which is simply an arm with a dibble on each end connected to the inner side of the two rear wheels of a tractor. As the arms rotate, two operators, one on each side of the machine, load a tree into the dibble. When the dibble reaches a vertical position and penetrates the ground the tree is mechanically released.

A more advanced version employed a single rotating arm linked by a chain drive to the axle of the riding wheels of the planter. In this model the rotating arm and the operator are located in front of the riding wheels. The operator loads a tree into the dibble while it is moving past him. An injector, triggered by the action of a trigger arm as it passes a steel cam on the frame of the planter, releases the tree into the ground. A single weighted packing wheel packs the tree into the soil.

Although these machines performed successfully only on very easy, well-prepared sites, they were the first commercial planters to use an intermittent approach to opening the soil and planting bare-root seedlings in a single operation.

Another method of mechanized planting introduced during the 1960s utilized planters operating on the continuous chain principle. One machine of this design was the Whitfield Forest Land Tree Planter in which the tree was loaded between fingers on a vertically moving chain (Fig. 5). When the chain carried the tree into the furrow the fingers opened automatically, releasing the tree into the ground. The USSR and Germany also built machines using this principle (Fig. 6) (Bäckström 1970). An advantage of the chain method was that it permitted the operator to sit in a more natural position when loading the tree rather than being bent forward as in conventional planters.

Rising labor costs, coupled with the need for more versatile planting machines that would plant on sites occupied by obstacles such as rocks and stumps, have stimulated a renewed interest in mechanized planting.

Nowhere has the need for improved planting equipment been more urgent than in Ontario. With a tree planting program that is expected to double by 1984, over 95% of the current planting is done by hand. Furthermore, this percentage is not expected to change unless machines are available that can cope with the difficult terrain of the northern part of the province.

With mechanized planting rated top priority in the development of silviculture equipment, the Ontario Ministry of Natural Resources (OMNR) in 1970 initiated a program for developing a new planting machine specially designed for Boreal Forest conditions.

Personnel from OMNR, in cooperation with the Great Lakes Forest Research Centre (GLFRC) at Sault Ste. Marie, prepared a list of specifications as a guideline in the development of this machine. Some of the principal requirements of the proposed machine were that it:

1. be automatic or semiautomatic in operation
2. plant two or more rows simultaneously
3. operate efficiently without advance site preparation
4. plant in spots rather than in continuous furrows
5. scalp to mineral soil at time of planting with tree planted in center of scalp

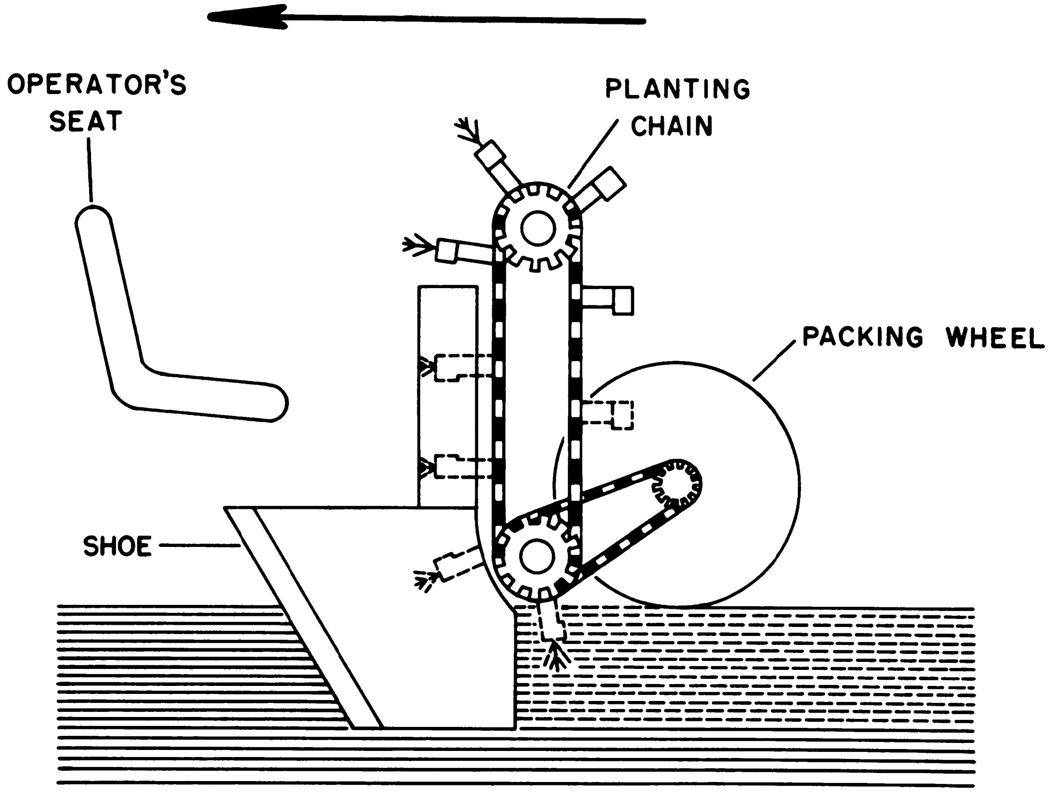

Fig. 5

Continuous chain planter with grip fingers (Whitfield planter)

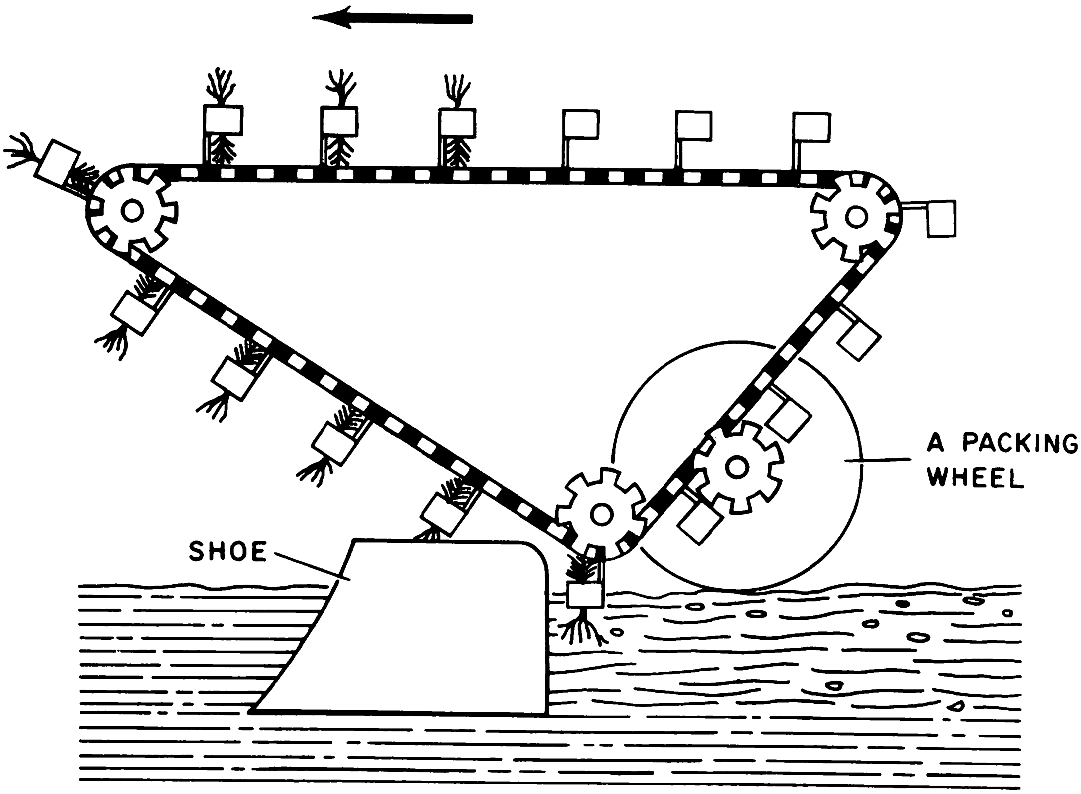

Fig. 6

Principle of German "Robot" planter.

6. plant trees at proper depth without mechanical damage and firm soil to eliminate air pockets

7. be capable of planting all commonly planted coniferous stock varying from 1 to 2 ft in total length with about 6-12 in. roots and 4-12 in. tops.

The first prototype planter resulting from this program, the Ontario Mark I Tree Planter, was completed and tested in September, 1971. Subsequent models, the Mark II and Mark III (see cover photo), were completed in the spring of 1972 and winter of 1974, respectively.

The principal components of the Ontario Mark III[1] are a frame or chassis mounted on two riding wheels, a planting beam, a sensing mechanism, packing wheels and a power unit (Fig. 7).

The frame of the planter is rectangular, of 1/4-in. boxed steel construction with the lower part of the hollow frame serving as an oil reservoir for the hydraulic system and the upper part as a fuel tank for the engine. A 22-hp diesel engine drives a 19-gpm pump, rated at 3000 psi, for powering the hydraulic components.

The planter rides on a pair of tractor wheels fitted with 14.9 x 24 pneumatic tires. These are mounted on a pair of trailing arms which may be independently raised and lowered by hydraulic cylinders. This permits the chassis to be elevated when the machine is being trailed or is operating on bedded land.

The planter is connected to a tractor by a pin-hitch arrangement, and is equipped with an extensible tubular steel telescoping hitch which can be raised and lowered hydraulically to compensate for variations in hitch positions on different tractors.

The dibble, which carries the tree into the ground, is mounted on the distal end of a planting beam that pivots vertically around an axis mounted toward the front of the machine. When in the raised position the tree is inserted in a slot in the dibble and held in place at the root collar between two flexible plastic fingers. When the dibble is in the lowered position and in the ground the tree is automatically released.

Along the bottom of the planting beam is a sensing mechanism which releases the tree only when the dibble has penetrated the ground to its maximum depth. The sensor consists of a plate connected to an arm which pivots around the same axis as the planting beam.

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[1] The Ontario Mark III-Model 2 version is described. Other Mark III planters may vary slightly.

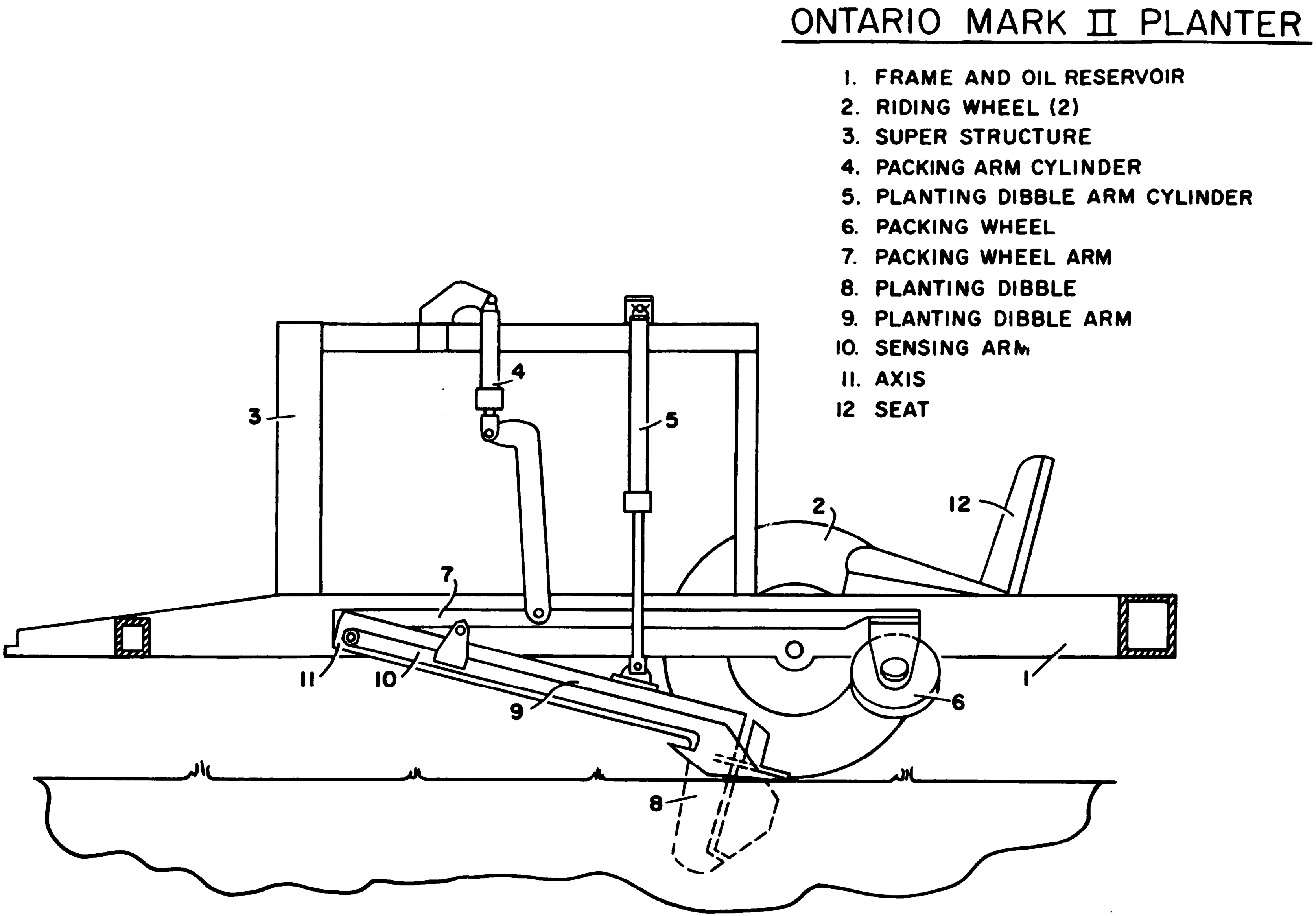

Fig. 7. Operating principle of the Ontario Mark II and Mark III planters.

The action of the sensor is as follows. The sensing plate is held in a position a few inches below the base of the planting beam. When the beam is lowered and the dibble has penetrated into the soil to its maximum depth the sensor plate contacts the ground forcing the sensing arm to pivot toward the beam. The movement of the sensing arm activates a hydraulic valve which in turn moves an ejector plate inside the dibble, releasing the tree.

The sensor plate must make contact with the ground surface for the tree to be released. Thus, if the dibble encounters an obstacle at the end of its downward stroke, the sensor plate is prevented from contacting the ground so that the tree-release mechanism will not be activated. The fingers will continue to hold the tree until the dibble rides over the obstacle.

A pair of packing wheels which operate intermittently are mounted on arms that pivot around the same axis as the planting and sensor arms. The action of the packing wheels is synchronized with that of the dibble so that the slit made by the dibble is closed and the tree packed firmly in place.

The action of the planting cycle, which includes the synchronized movement of the planting beam, the sensor and the packing wheels, is initiated by the operator depressing a foot pedal.

The packing wheel pressure, the dibble pressure and the movement of the tree ejector can be varied to suit specific operating conditions.

Future Needs and Trends

Less than 10 years ago the pulpwood industry in Ontario was still using traditional methods of logging based mainly on manual labor (Haig and Scott 1972); today practically all the harvesting methods are highly mechanized. It is not unreasonable to expect that within the next few years planting may experience similar changes.

It is almost certain that planting machines, like their counterparts in the pulpwood harvesting field, will be somewhat more complex than those with which we are now familiar. This will mean that agencies responsible for regeneration will require personnel with specialized training in mechanics. To meet this need it is hoped that both universities and community colleges will see fit to include courses in mechanics in their curriculum or expand on those already in existence. Likewise, OMNR will require in-service training programs to keep employees abreast of new developments in the field of mechanization.

It is generally assumed that the planter design most suitable for operating on difficult sites is one based on an intermittent principle (Siren 1970). It is therefore rather surprising that of the 43 planting machines tabulated on pages 71 and 72, only three employ the intermittent dibble principle (Appelroth 1974). The largest group includes the continuous furrow machines but with the exception of the Reynolds-Lowther Crank Axle Planter all the continuous furrow planters appear to be designed for operating on relatively easy, open conditions.

Of the three intermittent dibble-type planters, the Soviet LMB1 is designed for container stock while the other two, the Ontario Mark III and the Austrian Quickwood, are for planting bare-root stock.

Conspicuously absent from this list are the Swedish-designed SHS V, VI and VII planters and the Soviet Druzba-2 series described earlier (Bäckström 1970). Both series of machines were designed for container planting and were built during the 1960s.

Planting machines which are used for operating on open agricultural land are quite safe to operate and, for the most part, are relatively comfortable to ride. With machines that operate on rough site conditions special care must be taken to ensure that the machine is comfortable and safe for the operator.

Most continuous furrow planters operating on rocky or stumpy sites tend to be quite uncomfortable for the operator as the planting element will lift the machine when it encounters an obstacle. On some of the more recent continuous furrow machines the riding qualities have been improved by certain changes in the design.

The Crank Axle has a vertically articulating frame with the riding wheels mounted on crank axles. It is built so that the riding wheels will remain in contact with the ground even when the planting elements are forced out of the ground by obstacles.

The Taylor Drum Colter Planter smooths out the ride by having the drum colter, the planting shoe and packing wheel elements independently attached to a mounting plate at the front of the machine.

Most intermittent planters are designed so that when the dibble encounters an obstacle the dibble arm absorbs the impact, with relatively little discomfort felt by the operator. Riding qualities are further improved on intermittent machines when the planter is directly mounted on the tractor, as in the Quickwood machine, or when large wheels with low pressure tires are used as in the Ontario Mark III.

The rougher the area the greater the safety precautions that are necessary. Machines designed for wild land conditions such as the Crank Axle, the Taylor and the Ontario Mark III all have heavy-duty cabs. The Taylor cab is lined with foam rubber for further protection.

The question of container vs bare-root planting machines varies with different countries and even within countries. Sweden and Finland in the past few years have concentrated more on machines which will handle container stock rather than bare-root trees (Bäckström 1970). All the machine concepts described for planting by Bäckström and Wahlquist (1973) are for container stock.

In the USSR, at least as recently as 1969, the emphasis was on building machines for planting bare-root stock, and from most of the recent literature it appears that this trend is continuing (Siren 1971).

In Ontario, because our program is geared mainly to planting bare-root stock, planting machine development is still aimed in this direction whereas in British Columbia the trend appears to favor machines for planting container stock.

A marked advantage that machines for planting containers or plugs have over bare-root planters is their ability to carry stock easily and the fact that it is much simpler to automate the loading and planting of the tree when it is in a container or plug.

Although some work has been done on completely automating the Ontario Planter this work has been temporarily suspended because of the high development costs involved. Furthermore, there is reason to believe that it would increase the cost of the machine to the point at which any cost advantage to be gained by doing away with the operator would be lost (Bäckström and Wahlquist 1973).

The advantage of a fully automatic machine, whether for container stock or for bare-root stock, is that automation lends itself to faster loading than is possible using an operator, especially if the machine is for multirow planting. Also, on very rough sites it may not be feasible to use an operator to load trees.

Some authorities have expressed interest in a self-propelled planting unit in preference to equipment that must be pulled or mounted. While the advantage of self-propelled planting equipment is apparent in locations that have a long planting season (such as the southern United States) it is difficult to justify the economics of the capital outlay required for this equipment under Ontario conditions where the planting season is usually less than 6 weeks. If, however, a machine were designed that could be readily adapted for both bare-root and container-stock planting, the argument in favor of a self-propelled unit becomes stronger. A self-propelled planter becomes even more attractive if the basic machine can be used for other forestry activities such as herbicide and fertilizer spraying and mechanical or chemical precommercial thinning.

The designing of planting machines should, in future, combine expertise from at least three fields. The basic biological requirements should be specified by foresters and the design and development of the planter by engineers, with analysts to test the validity of the design before proceeding with development.

Bäckström and Wahlquist of the Swedish Logging Research Foundation prepared the first detailed systems analysis of artificial forest regeneration systems. In their report (Bäckström and Wahlquist 1973) 38 separate forest regeneration techniques were analyzed including four planting units and 10 combined scarification-planting units. Most of the equipment described has never been built, but the simulation models serve to compare several different design concepts.

The concepts analyzed include intermittent planters, both manual and automatic, and continuous furrow machines with one or two operators. Also compared are combination intermittent scarifier-planters with and without operators, some using dibbles, others using rotary-type planting elements.

The following conclusions were drawn from this analysis:

1. Mechanized planting requires less manpower than manual systems but the cost is either comparable or somewhat higher.

2. Mechanized planting and scarification in two separate operations require more manpower than when the two activities are combined but the costs are comparable with those of row scarifying. When more extensive scarifying is done the separate operations are more expensive.

3. Regeneration costs for mechanized planting systems are about the same whether a machine is automatic or manually operated.

4. Continuously advancing machines are more productive and require less manpower than intermittently advancing machines.

5. The differences in productivity, manpower requirements and acreage costs between two-row and three-row planter-scarifiers are small.

It is important to remember, however, that these conclusions were based mostly on assumed values for hypothetical machines.

MECHANIZED ROW SEEDING

C.R. Mattice, Forestry Officer
Canadian Forestry Service
Great Lakes Forest Research Centre
Sault Ste. Marie, Ontario

The concept of mechanized row seeding is defined and examined in relation to other seeding techniques used in Canada. The barrel seeder and agricultural-type seeder are described and compared. Development and testing of an agricultural-type seeder by the Canadian Forestry Service are described and initial survival results presented.

On a défini et examiné par rapport à d'autres techniques utilisées au Canada le concept de l'ensemencement par semoirs à grains en ligne. On a décrit et comparé le semoir "baril" et le semoir de type agricole. On a décrit la fabrication et l'essai d'un semoir de type agricole développé par le Service canadien des forêts et on a présenté des données initiales sur la survie.

Introduction

The concept of mechanized row seeding includes three elements: seed dispersal must be performed by a mechanical device, the seeding must progress in rows, and the scarification and seeding must be conducted in a single operation. Very few of the current operational techniques satisfy these three criteria. (In Canada, only the barrel seeder and the Canadian Forestry Service's (CFS) row seeder qualify as mechanized row seeders.) The original CFS row seeder was essentially identical to a seeding unit developed previously in Maine by the United States Forest Service. It is interesting to note that an aerial row seeding technique is being developed in the United States. Although it is obviously a mechanized row seeding technique, the scarification and seeding are conducted separately, and consequently, I would prefer to regard it as a hybrid concept.

The barrel seeder was developed by the Ontario Ministry of Natural Resources (OMNR) in Thunder Bay. In sequence it is an assemblage of V-blade frontal attachment, large-sized crawler tractor (150-200 net hp), drawbar, three sets of shark-fin scarifying barrels attached in tandem to the drawbar and three trailing seed barrels in tandem (Fig. 1). Each seed barrel is a 24-in. steel cylinder with a cone-shaped nose. There are five spiral fins welded onto the cylindrical part of the barrel. A seed chamber into which dispersal nozzles are screwed is bolted onto the rear of the seed barrel.

Figure 1. The barrel seeder with three scarifying barrels and three trailing seed barrels.

The CFS row seeder will be described in greater detail later but in sequence it is an assemblage comprised of a V-blade, small-sized crawler tractor (50-80 hp), floating hitch, modified fire suppression plow and modified agricultural seeder (Fig. 2 and 3).

Mechanized row seeding is only one of seven different seeding concepts. They are listed in Table 1 and compared in terms of the numbers of acres treated in Canada and the percentage this represents of the total area. The comparison is made for two different periods: 1900-1972 and 1967-1972. It is interesting to note that mechanized row seeding is less than 1% of the total.

Figure 2. The CFS seeding assemblage without the trailing seeder.

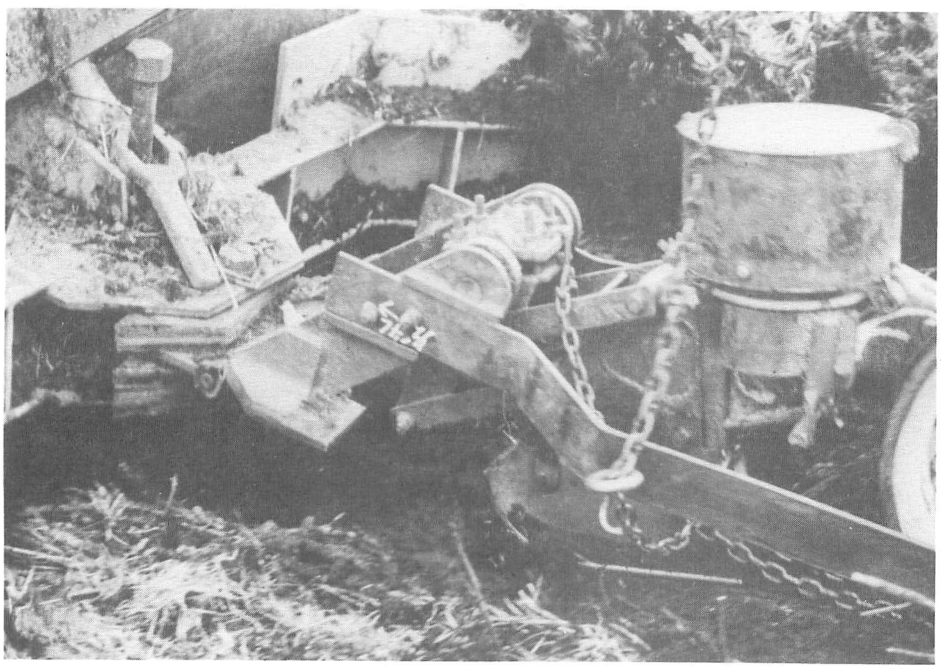

Figure 3. The modified agricultural-type seeder attached behind the fire plow with the trailing land wheel only partially visible.

Table 1. Area treated by class of seeding technique (Canada)

Class	1900-1972 (acreage)	1900-1972 (%)	1967-1972 (%)
1. aerial broadcast seeding by fixed-wing aircraft	60,967	18	19
2. aerial broadcast seeding by helicopter	71,092	21	29
3. aerial row seeding by fixed-wing aircraft	---	--	--
4. ground broadcast seeding by snowmobile	3,302	1	2
5. ground broadcast or spot seeding by hand, hand seeders or shakers	193,090	57	45
6. ground spot seeding by SFI, Bracke, Imsett	8,027	3	5
7. ground row seeding by mechanized seeding unit	500	--	--

NOTE: These figures are based on tables presented in Waldron, R.M. 1974. Direct seeding in Canada 1900-1972. *In* J.H. Cayford, *Ed.* Direct seeding symposium. Can. For. Serv., Ottawa. Publ. No. 1339. p. 11-27.

In comparing the different concepts it is apparent that the first three involve aerial seed dispersal, which means that they can seed large areas more quickly than any of the ground techniques. The first five classes are two-pass operations, whereas the latter two are one-pass. In general, the concepts closer to the top of the list are more wasteful of seed than those closer to the bottom. Classes 1, 2 and 4 all use the Brohm seeder as the seed-metering device. Finally it is apparent from the table that there has been a shift from hand seeding to aerial seeding.

Now that mechanized row seeding can be seen in context with the other concepts, let us examine the merits and drawbacks of this concept in relation to the others.

There are three merits worthy of discussion. First, there is a greater potential for reducing costs in the one-pass techniques. It should be possible to develop a relatively simple and highly reliable seeding mechanism. Such a mechanism would add little to the cost of scarification alone since the seeding is part of the same operation. This should be as cheap as, if not cheaper than, seeding separately, despite the low cost of aerial seeding. This one-pass feature is also a part of the spot scarifier seeders (class 6) which have proven economical on an operational scale.

The second merit is that both the barrel seeder and the CFS row seeder have a superior capability to direct seed to receptive seedbed. In broadcast seeding by aircraft or snowmobile the seed wastage is perhaps 80%. This is the percentage of ground surface that is left undisturbed by scarification and is consequently unreceptive as seedbed. On the other hand, spot scarifier-seeders are capable of dropping seed in the prepared seedbed with greater regularity than the barrel seeders but with less regularity than the CFS row seeder. However, the spot scarifier-seeders do not accurately meter tree seeds. They tend to drop from 5 to 15 seeds at a spot, whereas the mechanized row seeders tend to drop seeds singly. The third merit is that it should be possible to develop a capability to cover seeds mechanically as a part of the seeding operation with either row or spot seeders. This may allow the use of these techniques to seed those species with seeds that require covering. It may also be possible to integrate seeding with the application of herbicides, rodenticides, or fertilizers for both the row and spot seeders.

Next let us consider the drawbacks of this concept and the extent to which it may be possible to reduce their importance. There are two major drawbacks, one related to productivity and the second to the seasonality of seeding.

With respect to productivity, the agricultural-type seeder is drawn by a crawler-tractor in the 50-80 hp class and consequently is capable of productivity in the order of 1.5 acres per hour. In contrast, the seeding techniques which rely on scarification with the shark-fin drums--and this includes the barrel seeders as well as the spot scarifier-seeders--can scarify and seed at a rate of 2-3 acres per hour. The increased productivity is due to two factors: first, either the faster-moving wheeled skidders or the more powerful crawler-tractors in the 150-225 net hp class are used as prime movers, and second, all of these techniques scarify and/or seed more than one row at a time. The effect of this difference in productivity is diminished if not totally removed when the cost of seeding is considered. The increase in rental rate for the larger tractors and the wheeled skidders is a primary factor. In addition, where the seeding is a separate operation this cost must be added. The net effect is that, if productivity is a primary concern, the agricultural-type seeder is at a disadvantage, whereas if cost is an important factor, it is very competitive with, if not preferable to, the other techniques. If it is possible to develop the agricultural-type seeder into a multirow unit, its productivity may become comparable to that of the other techniques without a large sacrifice in terms of increased cost.

Next let us compare the two mechanical techniques which fall within the mechanized row seeding concept. The barrel seeder uses the rotation and the shaking provided by the drag action to disperse seed from small nozzles (Fig. 4). Because of the proximity of the nozzles to the ground surface they are susceptible to clogging on wetland sites and during wet or snowy weather. This can result in considerable downtime. None of the models of the agricultural-type seeder has suffered from this fouling problem. The metering of seed is also much more regular and positive with the latter. Although the seeding mechanism is currently actuated by a trailing land wheel and chain-sprocket wheel drive assembly, there is a good possibility that it can be actuated either hydraulically or electrically. This would improve metering capabilities even more. In the barrel seeder's favor, however, is the fact that it is already a multirow seeder capable of higher production, whereas the agricultural type may require considerable development before it can be considered operational or can eventually be twinned.

Although the CFS did not make an exhaustive comparison of the various seeding concepts and mechanical approaches, it chose to develop the agricultural-type seeder. Interest was originally prompted by a visit of one of our staff members to a trial in Maine in 1969. At that time it was felt that the particular merit of the unit was its seed-metering capability. The unit was also considered as a possible supplementary regeneration tool for treating small tracts of cutover. However, it may have potential as a cheap substitute for mechanical planting, especially on the easier sites.

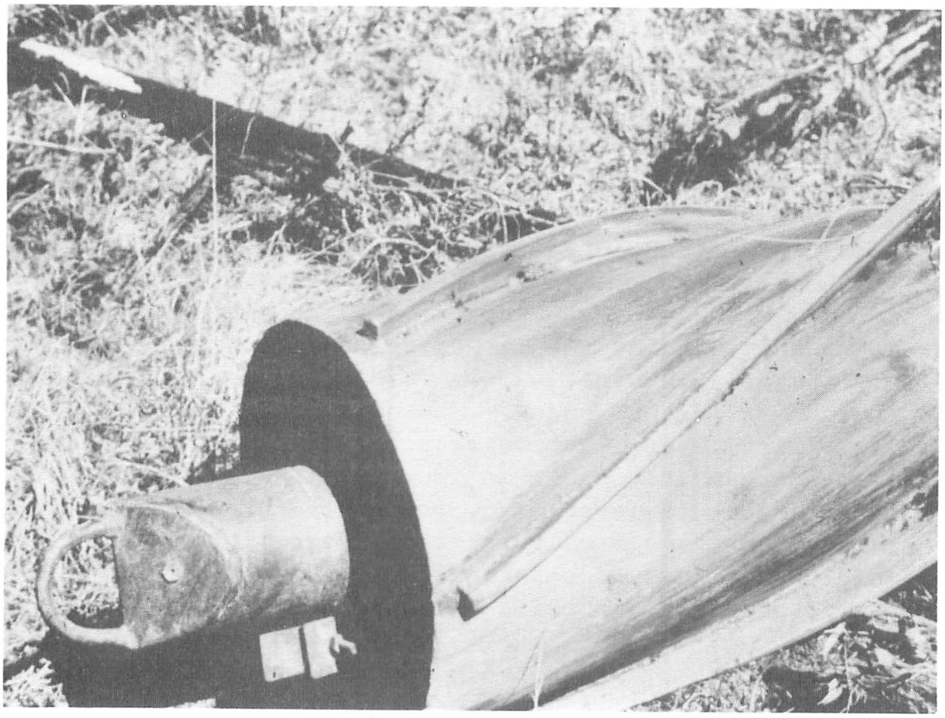

Figure 4. The seed barrel used in the barrel seeding technique.

During 1970 and 1971, the components for the row seeder were purchased and modified according to best-guess logic. The V-blade was purchased from Reynolds Research and Manufacturing Corporation in McAllen, Texas. It required the fabrication and incorporation of a pusher bar and a scalping foot. The pusher bar was needed so that residual standing trees could be leaned away from the bulldozer prior to contact and uprooting by the base edge of the blade or the scalping foot itself. In addition it was felt that the leaning action might partially expose or break some of the roots of the standing tree. The purpose of the scalping foot was to push stumps, rocks and both fine and coarse slash from the direct path of the trailing scarifier-seeder unit. The prime mover was rented locally when needed for field trials. The scarifying tool, referred to as a Sieco heavy duty fire suppression plow, was purchased from Southern Iron Equipment Company of Chamblee, Georgia. Although it required little initial modification, its two 26-in. steel scarifying discs were replaced with moldboards in 1972 (Fig. 5) because of excessive wear on the bearings in the hub of the disc and disc breakage resulting from the discs becoming lodged between stumps.

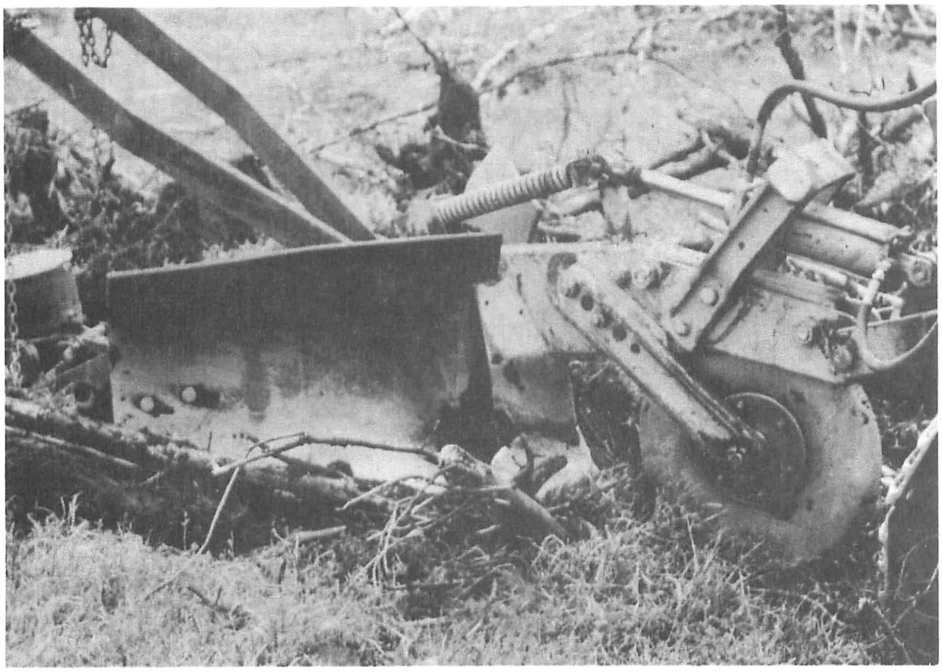

Figure 5. The modified Sieco heavy-duty fire suppression plow with moldboards incorporated.

The seeding unit itself which was basically an International 185 beet planter purchased through a dealer in the Sault Ste. Marie area required considerable modification, principally as follows (see Figure 3):

1. The tool bar hookup which attaches the seeder to the three-point hitches standard on agricultural rubber-tired tractors was replaced by a sandwich hitch which bolted onto the rear of the Sieco fire plow.

2. Two double opener discs which created the seed drill in the agricultural application were replaced by a steel ski on the bottom of which a raised steel "V" was welded. The ski both supported the seeder and compressed the specific site for seed drop so as to reduce the accelerated erosion in loose soil. The "V" merely loosened the surface in the immediate area of the seed drop.

3. The depth gauge bolt which fixed the drill depth was replaced by a bracket-spring device that acted as a shock absorber for the trailing land wheel.

4. A large fiberglass hopper was replaced by a smaller sturdier steel version.

5. Many of the cast iron components were replaced or buttressed with steel strapping or plate.

Three further developments were planned for the 1974 fiscal year. First, it was decided to purchase a Stan-Hay precision seeder for testing. The second innovation involved the fabrication of a Michigan floating parallelogram hitch to attach the fire-plow scarifier to the prime mover (Fig. 6). Third, it was decided to investigate the possibility of actuating the seed metering device electrically or hydraulically.

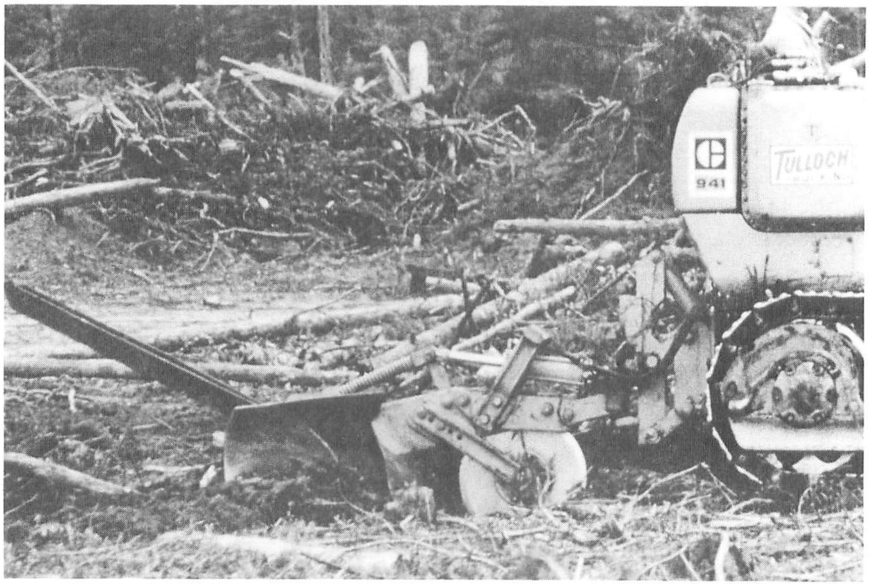

Figure 6. The Michigan floating parallelogram hitch attaches the fire plow to the bulldozer for use as a scarifying tool in this instance.

The working mechanism for the Stan-Hay is a rotating nylon or rubber belt into which holes of various sizes and spacings can be punched. A counter-rotating drum brushes excess seed from the holes just before ejection takes place. This basic seeder unit was bolted to a heavy-gauge steel box which was supported by a trailing land wheel. A chain-sprocket wheel assembly joining the axis of the land wheel to the input shaft of the seeder actuated the belt. It was felt that this might provide a better mechanism for metering small seeds (e.g., those of spruce). In addition it was anticipated that a belt seeder would be more flexible than a plate seeder in adjusting interdrop distances.

The Michigan floating parallelogram hitch consists of two steel plates, one which bolts onto the rear of the bulldozer and one to which the row seeder is attached in this instance. The upper and lower corners on each side of the two plates are joined by two steel arms which enable the two plates to remain parallel while moving vertically with respect to each other. A hydraulic piston linking the lower portion of the forward hitch plate with the upper portion of the hitch plate to which the seeder is attached provides positive control over the relative vertical positioning of the two plates (see Fig. 6). With the hydraulic circuit for this cylinder in a floating mode the two plates can also float freely. This is the actual operational mode for the hitch. It was felt that this hitching concept was superior to the normal sandwich hitch arrangement which permits no freedom of scarifier motion in the vertical direction with respect to the rear of the bulldozer. With the sandwich hitch the scarifying action of the fire plow could be best described as excessive scraping of microsite hillocks and skimming over minor depressions.

The last change currently being investigated is the possibility of actuating the seed-metering mechanism. All the models tested to date are actuated by a trailing land wheel connected to either the plate or the belt seeders by a chain-sprocket wheel drive. This is a good concept because it directly varies the seeding rate with the forward speed of the tractor. It is simple; it is positive. However, there are certain drawbacks associated with this arrangement. The drive mechanism is probably the major reason that the seeder itself has to be as large a unit as it has been in the past. The seeder trails the seeding assembly in a very vulnerable position; hence it needs considerable protection from physical damage. Because it is a long unit it is less maneuverable. Furthermore, it prevents the possible development of a front-mounted seeder. For these reasons, it was felt that there is considerable merit in trying to find a suitable, variable-speed, 12-volt, direct-current electric motor to actuate the seeder. Because of the problems associated with enclosing the motor to protect it from dust and moisture, the need to avoid overheating, and the possibility of burning out electric motors, hydraulic actuation is being considered.

Finally I would like to deal with the results of the twice-yearly operational trials undertaken since 1971. Although both white pine (*Pinus strobus* L.) and red pine (*P. resinosa* Ait.) were used in the 1971 trials, it was decided to use jack pine (*P. banksiana* Lamb.) as the test species thereafter because of its relatively reliable germination and survival. Once satisfactory success is obtained using this species, the technique will be adapted for use with other species. Because the emphasis has been on the development of a machine there was a minimum amount of data collection in terms of either machine work studies or biological results. However, with respect to the former it will be possible to determine overall costs and machine productivity for the trials. The biological assessments consisted of a measure of the percentage of 6.6-ft lengths of row with mineral-soil exposure, the percent stocking of these "milacre quadrats" and the density of seedlings on them. In addition, for the 1974 trials a measure was taken of seedling microsite and condition class.

Most of the trials to date have been conducted on flat to gently rolling sandy sites that are largely glacial outwash in origin. Basically they are relatively dry jack pine sites which were clearcut a few years prior to seeding.

The results of these trials in terms of stocking and density are presented in Table 2.

It is apparent from the stocking-density figures that mechanized row seeding is a promising operational regeneration technique for jack pine. Of course, various seeding techniques are successful with jack pine. But it must be remembered that mechanized row seeding has a number of superior characteristics which may eventually make it much more flexible, reliable, and inexpensive than other seeding techniques.

In summary, there are several points that merit discussion. First, mechanized seeding should not continue to be a poor relative of mechanized planting. Mechanized row seeding has already removed the operator from the regenerating unit. Mechanized planters have a long development road ahead before they reach this stage. It may require a relatively small investment of research and development dollars in mechanized seeding to produce survival and growth results as good as those produced by mechanized planting. There is strong evidence to show that the total cost of regeneration by mechanized seeders is only a fraction of that of mechanized planting. Second, the process of examining different principles and concepts is a vital first step in equipment development. This is a planning process and, consequently, it demands a comprehensive, integrated, and coordinated approach. It may be that there is no need to develop seven different concepts of seeding to produce a viable operational technique. It may be that the total real cost of researching and developing such a plethora of approaches is beyond our financial capability. Third, the mechanized row seeding concept is, in theory, inherently superior to many other seeding techniques. Consequently it may deserve more support from research and management.

Table 2. Density and stocking of row-seeded area, by year of trial and by year of assessment

Location	Time of seeding	Area (acres)	Species	Time of assessment	Percent stocking	Density
24 Range XI	Oct. 1971	31	wP	June 1972	11.5	1000
		15	rP	June 1972	64.1	1800
Fawn	May 1972	25	jP	July 1973	83.5	3300
				1974	92.8	N/A
Haughton	Oct. 1972	30	jP	Aug. 1973	94.4	5500
				1974	-	-
Haughton	June 1973	100	jP	Aug. 1973	100.0	6800
				May 1974	97.0	3190

BIOLOGICAL ASPECTS OF MECHANIZED REGENERATION

R. F. Sutton, Research Scientist
Canadian Forestry Service
Great Lakes Forest Research Centre
Sault Ste. Marie, Ontario

The biological basis of silviculture is stressed: problems are not essentially changed by mechanization. Discussion of biological materials available, preplanting treatment of those materials, and planting and seeding precedes an account of the biological studies undertaken in support of the Canada-Ontario Mechanized Reforestation Project.

L'auteur appuie sur les fondements biologiques de la sylviculture: les problèmes ne sont pas essentiellement changés par la mécanisation. Avant de rapporter les études biologiques en relation avec le projet Canada-Ontario Mechanized Reforestation, l'auteur discute des matériaux biologiques disponibles, du traitement pré-plantage de ces matériaux, et du plantage et de l'ensemencement.

Several speakers at this symposium have already addressed themselves to biological considerations that can be ignored only at our discomfiture. In fact, the biological aspects of silviculture are all-pervading, and they determine not only what is possible but also how readily it may be achieved. In this paper I should like to attempt some sort of unifying overview of those biological aspects that seem to me on the one hand to pose serious problems if ignored and, on the other hand, to enhance chances of success in achieving the results desired.

First I wish to stress that the biological problems associated with mechanized regeneration are the same problems that are associated with any sort of artificial regeneration (Sutton 1974). Some problems are accentuated by mechanization and some are diminished, but the essence of the problems and the principles involved remains the same whether or not mechanical assistance is adopted. Machines are merely extensions of the planter's spade in the same way that the planter's spade is an extension of his hands and fingernails.

My further remarks fall into three sections:

1. biological materials available

2. preplanting treatment of those materials

3. planting and seeding.

Biological Material Available for Regeneration

Let us first consider which species are available. On what basis are the species to be selected? Shall we try to regenerate an area with the species harvested from it? To do so would generally be reasonably safe, although we are immediately faced with the questions of race, variety, ecotype, etc. Also, although the amount of material harvested can hardly be bettered as a first approximation of productivity, one must remember that the harvested stand may have been the end product of many generations of slowly building productivity. This consideration may be particularly consequential for many relatively infertile outwash sands and gravels--the very sites that are providing the cutovers most amenable to mechanized reforestation.

Soil Fertility and Productivity

Intensification of forest management, with increased frequency of harvesting, and perhaps greater use of material such as small branches, roots, and even needles and bark formerly left in the forest as waste (but useful waste, containing nutrients), will also necessitate more consideration being given to soil fertility and nutrient requirements in relation to productivity. Morrison and Foster (cf. 1974) of the Great Lakes Forest Research Centre (GLFRC) in Sault Ste. Marie, Ontario have done useful work in this area, showing, for example, how nutrient cycling and the number of years' supply of nutrients varies for some nutrient elements and how these differ from soil to soil.

Soils and the gene pool are the basic forest resources. To manage our forests to maximum advantage we need to know a lot more about these resources.

Selection of Species

With respect to gene pool, we are not obliged, of course, to reforest with the species harvested. There are many notable examples of the successful use of exotic species: radiata pine (*Pinus radiata* D. Don) in New Zealand, where 30-year-old stands on the best sites have an average dbh of 20 in., and the mean annual increment is about 300 true cu. ft per acre on average sites (Poole 1969); Caribbean pine (*Pinus caribaea* Morelet) in Fiji, which commonly reaches a height of 20 ft in 4 years; *Hevea brasiliensis* Müll. Arg., an introduced species in Malaysia and Singapore, which produces more than 40% of the world's rubber. There is no a priori reason for regenerating only with the species native to the site. Of course, I am not suggesting that these species just mentioned are suitable for boreal Ontario, but I do suggest that there is every reason to search for and evaluate other possible exotic species.

It is true that our species options in boreal Ontario are not overwhelmingly large: the small number of tree species indigenous to the area is eloquent testimony to the harsh climate. The search for exotic supplements to (or replacements for) our indigenous species must be concentrated among northern, alpine, and cordilleran species of spruce, fir, pine, larch, and perhaps birch (*Picea, Abies, Pinus, Larix* and *Betula* spp., respectively).

Need for Reference Plantations

All species capable of withstanding our climate should be tested thoroughly to determine their potential in our conditions. Species with known undesirable features, such as Yeatman (1974) described recently for lodgepole pine (*Pinus contorta* Dougl.) when introduced into jack pine (*P. banksiana* Lamb.) regions, should be avoided. A range of provenances should be used in each species tested. Perhaps the likeliest exotic candidates for testing are Colorado spruce (*Picea pungens* Engelm.), Siberian larch (*Larix sibirica* Ledeb.) and European birch (*Betula verrucosa* Ehrh.). In my view, the only way to evaluate the potential of any species in our conditions is to establish long-term, full-rotation, fully stocked, intensively managed "reference plantations". We need desperately the information that only a grid of reference plantations can give. As Beckwith (1974) put it: "There is ... one major piece of information missing from the calculations of expected return on regeneration, particularly for white spruce. ... Yield tables which indicate how much wood volume to expect at any future date after planting *are not now available*" (italics in original). And: "Detailed management planning of lands planted to white spruce will not be possible until yield tables for plantations ... are made." The biological potentials of the various species can hardly be determined in any other way, and unless the biological potentials are quantified, the economic potentials are likewise incalculable. The reference plantations need to be large enough to avoid the island effect and they need to be established on a variety of representative sites throughout the merchantable forest area of Ontario. The man who creates this grid of reference plantations will walk straight into the foresters' hall of fame.

Short-rotation Shrub Wood Farming?

Up to this point there has been a tacit assumption that only tree species are to be considered for stand regeneration. After all, a silviculturist is by definition concerned with the culture of trees. But should we not also consider using shrub species in short-rotation wood farming? Farmed, short-rotation (5-10 years) willow (*Salix* spp.) under Scandinavian conditions may produce twice as much dry weight matter per unit area as the most rapidly growing spruce stands. Waldemar Jensen, President of the Finnish Pulp and Paper Research Institute, has stated that "...by the end of this century short-rotation wood-farming ... will assume importance, not only in countries where trees grow rapidly, but also in some districts of the North, the traditional softwood countries" (Jensen 1974). This is not just day-dreaming. Marks and Bormann (1972), for instance, have shown the importance of a fast-growing, shortlived, successional shrub species such as pin cherry (*Prunus pensylvanica* L.) in reducing nutrient losses after clearcutting. These workers determined rate of recovery in terms of amount of biomass, rate of biomass accumulation, rate of canopy closure, and rate of accumulation of nutrients (N, Ca, Mg, K, and Na) in plant tissues. Accretion of biomass was rapid in the young shrubs, and the 1650 g/m^2 amassed in the 6-year-old stand exceeded the usual range (1200-1500 g/m^2) for stands of temperate climax forest trees.

Tree Improvement

For the present, however, the biological material with which coniferous forest stands in boreal Ontario are being regenerated all derives from viable tree seeds.

Calvert (1974) states that "the procurement and handling of [suitable] seed is one of the most important steps in reforestation programs. Seed must ... be of the proper genetic make-up for [the] intended purposes. The question of seed source ... cannot be over-stressed." The tremendous contributions made by plant breeders and animal stock breeders towards increased productivity in agriculture are universally respected and applauded; are there not comparable gains to be won in forestry?

What sort of increase in yield are we talking about when we speak of genetic selection and tree improvement? Is it worth making a fuss about?

The evidence in respect to white spruce (*Picea glauca* [Moench] Voss), reviewed by Carlisle and Teich (1971), makes interesting reading. Nienstaedt (1969), for example, reported interim results from provenance trials of white spruce seedlings from 29 sources in the

United States and Canada, field planted at 14 locations from North Dakota to New Brunswick between latitudes 42° and 48°N: trees from seed collected in the Beachburg area of Ontario grew particularly well at all locations, giving height growth 35% better than average. In New Brunswick trees of this provenance were 25% taller than the overall average and 23% taller than a New Brunswick provenance. Some other provenances from Ontario and Quebec also performed consistently well. These were still young trees, planted between 1960 and 1962, but as Carlisle and Teich noted, Nienstaedt also referred to 29-year-old trials in northern Wisconsin in which white spruce from Douglas, Ontario (near Beachburg) maintained a height growth advantage of 22% above the trial average and 16% above local provenances. Again, there is a Canadian series of 8- to 15-year-old provenance trials with white spruce from 89 sources at 15 locations from Fredericton, New Brunswick, to Fort Frances in northwestern Ontario (Teich 1970): the best provenance at each location averaged 22% better height growth than the average, whereas the local provenance was only 3% better than the average. The provenance from Peterborough, Ontario not only grew consistently taller (mean 17%) than average at all locations, but on average was also 14% taller than the local populations. Carlisle and Teich emphasized the youthfulness of all these provenance trials but suggested that the findings indicate "considerable increases in height growth can be achieved by selecting white spruce genotypes".

Carlisle and Teich are not alone in arriving at this conclusion. The following news item appeared in the August, 1974 issue of Forest Industries: "White spruce seedlings from eastern Ontario grow about 15 per cent faster than the natural variety in the Lake States the [U.S.] Forest Service Institute of Forest Genetics has found. Accordingly, the University of Wisconsin, Madison, is propagating imported seedlings to produce seed for tree nurseries throughout the Lake States" (Anon. 1974a).

The evidence from the white spruce trials led Carlisle and Teich to the conclusion that the costs of producing genetically superior seed are more than offset by 2-5% increases in yield of merchantable timber and that the use of genotypes with superior wood qualities can profoundly affect mill profits.

With regard to jack pine, Yeatman (1974) states: "Important differences in growth and pest susceptibility have been found among populations originating from a single region or ecological zone. Gains up to 10 per cent can be expected if populations within regions are systematically sampled and tested and if seed collection is limited to the better sources as soon as they can be identified, i.e., after 10 to 20 years of testing".

A considerable effort is going into tree improvement research in Canada, especially Ontario. Carlisle (1970) estimated that the effort in this regard in 1969 was running at an annual rate of 30 professional man-years (14 supported by the federal government). The general aim is to improve species "by selection and hybridization, and produce trees of superior growth, form, wood quality and resistance to insects and diseases ..." (ibid.).

As Davey (1968) has pointed out: "Selection of trees which respond to fertilization in a specific manner could markedly increase the economic efficiency of fertilization, as well as increase the already considerable value of the tree improvement programs."

Thus, much depends on the seed chosen. Furthermore, once a stand has been established, the chance to change its genetic constitution will not recur for the best part of the next century. The long-term nature of forestry is all the more reason to take action as soon as possible to generate the basic data without which the various biological and economic options cannot be properly evaluated. I repeat: the *only* way to obtain these basic data is from properly designed, properly executed, and properly documented reference plantations. We can proceed on a hit and miss basis and in 100 years' time be little better able to evaluate our options, or we can build up systematically a store of knowledge that would pay for itself many times over. In the meantime, we must make maximum use of the evidence already available.

Management Intensity

As well as choosing the species, provenance, etc., to be used in regenerating an area, we must decide on what intensity of silvicultural management to apply. Given those particular trees and these particular sites, how much of the total growth potential are we going to try to harvest during the next rotation and in what form? If we accept stands that are less than fully stocked, we must accept that production will suffer in consequence. For example, weed growth in indigenous stands of pine in Wisconsin may reduce wood production by more than 15 cords per acre over a 40-year rotation (Wilde 1970).

Realization of growth potential can be approached only through intensive silviculture. In this regard, recent developments in eastern North America are very interesting: "Both New Brunswick and northern New England appear on the verge of a new era of intensive forest management according to information presented at the American Pulpwood Association Northeastern Technical Division meeting in St. Andrews, New Brunswick, June 11-13 [1974]" (Anon. 1974b). This report in the September, 1974 issue of Forest Industries continued: "A. Edison Stairs, Minister of Natural Resources for New Brunswick, explained that following an extensive study the province's legislature had authorized the recalling of licenses to private companies on Crown lands as the first step towards improved forest management. One conclusion of the study, according to informed sources, is that drain now equals growth in New Brunswick, hence any additional industrial expansion [in the forest industry] must be based on increased timber growth."

Ontario forestry must also become more intensive, if only because yield per unit area and haulage distance to mill strongly influence overhead and thus the cost and profitability of the unit product.

Preplanting Treatment of the Biological Material

Once the seed has been chosen, the treatment of that seed and of the seedlings produced from it can have a profound effect on field performance.

Seeds can be treated in a variety of ways that affect both viability and vigor (Fraser 1974). Seed costs money to obtain, of course, and the need to make the best use of it is obvious. This is especially true when we come to use, as we must, genetically superior seed.

Direct Seeding

The seed, however treated, can be sown directly, although for genetically superior seed, direct seeding will be too wasteful at least for a long time to come.

Direct seeding in Ontario has increased dramatically from the 80 acres so treated in 1956 to 11,135 acres in 1967 (Scott 1970) and 21,764 acres in 1973 (Anon. 1973). (For comparison, in 1973, 89,124 acres were regenerated with nursery stock, 6,034 acres with container stock, and 60,134 acres by modified harvest cut.) Seed is applied, from the air or the ground, to sites that are made receptive mainly by the use of mechanical equipment and hardware (such as finned drums, blades, teeth, tractor pads, and so on) designed to expose mineral soil.

Most seed is treated in attempts to reduce losses by birds and rodents and to facilitate sowing. About 90% of the area direct seeded is jack pine, and most of the remainder is white pine (*Pinus strobus* L.).

Scott (1970), after studying 22 areas aerially seeded with jack pine between 1962 and 1967 in north-central Ontario, concluded that the type and extent of site preparation largely determine the stocking achieved. Scott maintained that deciding after one growing season whether or not seeding had been adequate was "one of the most difficult decisions", and stated: "The problem stems from the difficulty in making a seedling count after only one growing season and the fact that delayed germination is not uncommon. A better method of determining the need for reseeding might be to work out a relationship between weather and seedling survival"--or in other words among weather, seedbed characteristics, germination, and seedling survival, such as reported by Riley and Mattice elsewhere in these Proceedings. The better these relationships are determined, the greater the control possible over the method.

Nursery Stock

The alternative to using seed directly is to raise stock in nurseries for outplanting. While what comes out of a nursery can be no better than what goes in, our concern must be for the best possible nursery product, whatever limitations, genetic or otherwise, are built in or accepted.

Whether we consider conventional bare-root, containerized or plug stock, the nursery regimes of seed treatment, nutrition, watering, and light, as well as such things as rooting medium and manipulation of root systems by containment or pruning, all affect not only the morphology of the plant but also the physiology. And they affect not only the current performance of the plant but also future performance. The possibilities here are much greater than are generally realized; the difficulty lies in assessing the potential of a seedling or transplant.

Stock Quality

Most of us have an intuitive idea of what constitutes a desirable seedling or transplant. Yet we have had the experience of seeing good-looking planting stock fail to live up to expectations and, conversely, we have seen poor-looking stock perform much better than expected. It was Wakeley (1948), of southern pines fame, who so well posed the question of physiological grades. One short paragraph from Wakeley's well-documented paper illustrates what is probably a general truth: "The most startling results appeared when the two slash pine [*Pinus elliottii* Engelm. var. *elliottii*] stocks [from one nursery] were considered separately. At the end of the first year, survival of the "inferior" stock averaged 18 percent better than that of the "superior" stock [based on morphological subgrades]. The survival of the "inferior" subgrades surpassed that of the corresponding "superior" subgrades in 11 out of 12 cases, in four of them by 20 to 34 percent. Five of the six "cull" subgrades from the "inferior" bed survived better than two of the six "plantable" subgrades from the "superior" bed, and one "inferior cull" survived better than the very best "superior" subgrade."

This is not to deny that good-looking stock can do well, or, especially, that poor-looking stock very often *is* poor. What it does underline is the difficulty of assessing by eye, measuring stick, or caliper the effective grade of nursery stock, despite the fact that there can be good relationships between morphology and performance within plant lots, as Mullin and Svaton (1972) have shown in their study of tenth-year survival and growth of white spruce which were highly correlated with initial top length and stem diameter. Incidentally, Finland has only this year changed over to a seedling grading system based on these two features (Leikola and Raulo 1973).

The essential weakness of morphological grading, however, is that the physiological and indeed the physical condition are not evaluated. Furthermore, the grade that a tree earns just after it has been lifted is the grade that it bears right up to the time the tree is planted or condemned and discarded. The *condition* of the stock *at the time of outplanting* is not revealed by current grading practices. Thus, Mullin's (1959) statement that "the study of physiological properties by laboratory tests and field planting offers the most direct means for quality control" remains as true today as when he made it 15 years ago.

Physiological characterization of planting stock is not an easy proposition for these very reasons. Relationships are complex, plant material highly variable, and environments difficult to control on anything but a growth chamber scale. Uncontrolled variation--experimental error--is enormous in studies of this sort and the truth is hard to pin down. Nevertheless, a good start has been made by workers such as Mullin in Ontario and Stone in California. The work must continue to the point at which planting stock potential is known at the time of outplanting.

As Wakeley (1948) pointed out, physiological grading can almost certainly be by batch or treelot, not by individual tree. This opens up the exciting possibility of tailoring stock in the nursery to suit particular environments.

Root regeneration potential is perhaps the first property we would like to understand fully and influence. Nutritional manipulations, e.g., the use of luxury consumption in the nursery to effect forest fertilization in outplanted trees, may also have important possibilities. The feasibility of this has already been demonstrated by Benzian in Britain (cf. Benzian and Freeman 1970): increased first-year shoot growth, obtained in Sitka spruce (*Picea sitchensis* [Bong.] Carr.) outplants by extra, late-season nursery fertilization, amounted to 70% in one trial and 85% in another.

Storage

Storage of planting stock is assuming increasing importance in the question of planting-stock supply and quality. Storage of planting stock offers independence from conventional limitations on times of nursery plant supply, a way of circumventing winter browning, and the chance of providing planting stock lifted at particular stages of physiological development. The Ontario Ministry of Natural Resources (OMNR) (and its forerunner, the Ontario Department of Lands and Forests) has been active in this field for many years. For example, the history of overwintering of bare-root planting stock in Ontario goes back 30 years or more (cf. Leslie 1945). In the late 1950s, Jorgensen and Stanek compared survival and growth of spring-lifted, spring-planted white spruce, black spruce (*Picea mariana* [Mill.] B.S.P.), and several pines with those of fall-lifted, spring-planted stock (cf. Jorgensen and Stanek 1962). Results with white spruce were particularly good: mortality of stored stock was low (5% or less, with one exception), while normal height increment was much better in stock that had been stored than in stock that had been freshly lifted and planted. The pines were more subject to desiccation during storage, and black spruce to loss of foliage, than was white spruce. The purpose of these studies was to determine whether use of fall-lifted stock over-wintered in storage close to northern planting sites could prevent spring frost damage of newly planted stock.

It was their interest in extending the planting season that led Burgar and Lyon (1968) to study the effect of storage on white spruce planting stock. They found that, although survival was not materially reduced, height development decreased progressively as the cold storage period approached or exceeded 3 months. In the same study the performance of trees that were stored after spring lifting as soon as the frost was out of the ground was compared with that of freshly lifted trees, with plantings conducted every 2 weeks until the end of September for stored stock or the end of October for fresh stock. Burgar and Lyon noted that several research workers had stressed the desirability of cold-storing only physiologically hardened stock or, in their words, "stock in which all growth processes are fully quiescent...as it survives and performs better than unhardened stock". This may be generally true. But the validity of their next statement is questionable: "Lifting trees as soon as the ground thaws in the spring would ensure their physiological hardiness." The dormancy of coniferous nursery stock in the spring is not true, physiological dormancy but a dormancy imposed by environmental conditions. The onset of root activity that occurs in the spring when soil temperatures reach about 42°F is preceded by (and may be dependent on) physiological activity in the shoots, although Lavender et al. (1973) claim, to the contrary, that spring shoot growth may be initiated by gibberellins exported from the roots. The physiological state of a tree entering true dormancy in the fall is certainly different from the physiological state of a tree leaving imposed dormancy in the spring.

Provided that problems associated with desiccation and molding can be overcome, fall-lifted stock cold-stored over winter seems to be a better biological bet for some species at least than spring-lifted, cold-stored stock (and, as we have seen from Jorgensen and Stanek's work, better even than fresh, spring-lifted stock in northern plantings) notwithstanding the extra months of storage.

The importance of physiological state derives from two main processes: root regeneration and shoot flushing. After a tree is outplanted, its initial survival depends mainly on whether enough water can be taken up to stave off desiccation to lethal levels. Newly flushed foliage transpires at about twice the rate of hardened-off foliage (cf. Christersson 1972), and if this extra moisture loss occurs before the root system can regenerate sufficiently to meet the additional demand, mortality will be high and shoot dieback will be common among survivors. The ideal physiological state for planting stock is one in which readiness to root rapidly is combined with delayed flushing.

A lot of work remains to be done on the physiological effects of nursery regime (nutrition, watering, shading, root pruning, and lifting time) and grading-storage practice (plant water balance, plant temperature, rate of cooling, degree of cooling, rate of warming, and perhaps daylength). However, there are possibilities of greatly reducing degrade among stored stock used in outplantings. The problem is urgent, for we cannot afford to use planting stock whose condition adds years to the rotation length.

Planting and Seeding

Not until forest managers regard regeneration as an integral part of the continuing life of the forest rather than as a separate, isolated episode can forestry be put on a fully rational basis. Harvesting and regeneration are not two independent operations. There is no logic in allowing the harvester uncontrolled freedom to minimize harvesting costs with little or no regard for the biological effects, not to mention the cost of regeneration and of subsequent operations. Surely the important consideration is maximizing efficiency and minimizing costs over all the operations that need to be carried out to fulfil management's objectives.

Whether or not to plant and how much to plant are policy decisions. How to plant has also been decided sometimes by policy, e.g., the adoption of hand-planting methods to create jobs in times of high unemployment. But increasingly this option is being denied us, and this is one of the main justifications for the joint OMNR-GLFRC large-scale, mechanized silviculture studies. Some of the results of these studies are being discussed here today.

The same forces determine the silvicultural options in preplanting site preparation and postplanting tending. The one-pass operation is expensive enough without adding unnecessarily to it.

Biological Studies

This was the starting point for the biological studies I have undertaken since 1971 in support of the mechanized silviculture project.

Mechanization becomes more attractive than labor-intensive practices as labor becomes increasingly scarce or expensive. It also has the desirable feature that machines will repeat untiringly the operation they are designed to do.

The philosophy behind the main biological studies was that only field machine plantings on a semioperational scale could provide *useful* operational information. Comparisons are being made between two provenances of each of three species (jack pine, black spruce, and white spruce), under three fertilizer x three herbicide treatments on a range of sites, the whole replicated for 3 years running. Replication in time is necessary to give some basis for evaluating the effect of weather which, of course, varies from year to year. To attempt predictive use of results from field experiments initiated in one year only is asking for trouble.

The bundle of 25 trees formed the basis of plot size, and there were five replications. The treatments chosen were of the type that could easily be applied by a future planting machine if they were found to be useful.

A succession of problems entirely beyond my control seriously affected the condition of the planting stock used in 1971 and 1972. The philosophy that had to be adopted was to accept that the results obtained in these trials would represent a lower limit of what might be achieved in excessively poor operational practice. The sort of thing involved included the use of overheated, rejected black spruce stock of exceptionally poor root:shoot ratio, underwater storage of bales of planting stock, a delay of 5½ weeks in the hot, dry spring of 1972 during which all field-stored stock flushed and the soil became extremely dry before a planting machine became operational, and the fact that only one make of planting machine became available for testing in 1971 and two became available in 1972.

Survival

Against this background, survival has been remarkably high (e.g., in the 1971 plantings, jack pine survival was about 80-90%, black spruce 65-80%, and white spruce 60-65%). In terms of height increment, jack pine has been by far the best. White spruce have begun to look like trees again. Some black spruce have recovered, but many are no taller now after four growing seasons in the field than they were when planted, and it may take another 2 years before recovery among black spruce reaches the stage attained by white spruce. Data are still being collected from all sites. Survival and growth data for the first 4 years will be analyzed during the coming winter.

Preliminary indications are that even unusually low-quality planting stock gave reasonably good survival when planted by the Reynolds-Lowther Crank Axle Planter in typical jack pine-black spruce cutovers in boreal Ontario. The main penalty to be paid (in addition to the mortality suffered) is the loss of growth momentum, especially in the spruces, which at a conservative estimate might lengthen the rotation by 3-5 years, perhaps more in the case of black spruce.

Age of Cutover

Though not included as an experimental variable in these studies, age of cutover has appeared to influence regeneration in several distinct ways. The sudden exposure and disturbance of the forest floor as a result of harvesting sets in motion significant changes in moisture, nutrient, and fertility relations. Soil temperatures rise under the influence of the increased radiation reaching the ground surface when snow cover is absent. Roots no longer supporting aerial parts and humus material break down under increased soil microbiological attack; some nutrients are lost by leaching after nutrient cycles are disrupted. The outward sign of this is the flush of development that takes place 1, 2, or 3 years after the harvest. If the regeneration operation is delayed until this stage, then the outplanted trees face more, better established, and more vigorous competition than would have been the case earlier.

A more mundane effect works in the opposite direction. The slash, roots, and residual stems left on cutovers pass from green resiliency to brittleness in about 3 years. Particularly during the first year after harvest, this material is apt to spring back after being pushed aside by the tractor and may bury as much as 10% of the trees, at least in the rather typical conditions represented in these studies.

Machine Planting

The machines that have been examined in detail--the Reynolds-Lowther Crank Axle Planter and Taylor Drum Colter Planter--have shown themselves fully able to plant trees without inflicting apparent damage. Machine-planted trees are no more poorly planted than are hand-planted trees; in fact, the superior packing achieved by wheels as compared with heels makes the difference between acceptable survival and virtually complete failure in conditions when the heel is unable to exert the force needed to pack soil and root together firmly enough to re-establish capillarity. Limited but convincing root studies among trees planted in sandy loam after a prolonged dry spell showed that machine-planted trees regenerated roots more rapidly and in greater numbers than did hand-planted trees. The soil moisture content in the root zone was significantly higher after machine planting than after hand planting, until the first heavy rain following planting repacked the soil, after which no significant difference remained.

However, when soil moisture is in good supply and hand planting is done well, as in my 1973 plantings, hand-planted and machine-planted trees survive equally well. Growth data have not yet been analyzed, but while there may be differences, none is obvious to the eye at this stage.

Manipulation of Fertility

Turning now to consider the fertilizer-herbicide treatments, the original idea had been to evaluate, as an alternative to fertilization, the use of herbicides to improve the nutrition of the newly planted stock. This can be very effective even when the amount of competition is quite small, as on some infertile sites, but only if there is vegetation within root-reach of the young trees to be benefited. The clearance of vegetation from the planter path and the isolation of the planted tree in a nutrient-poor, vegetation-free swath means that although soil moisture relations are improved, the option of fertilizing by using herbicides is closed. In any case, herbicides have not so far been used in the main studies because of the dearth of weed growth.

I must also mention that the 1971 and 1972 fertilizer treatments were applied, not by design but by necessity, too late to simulate fertilization at the time of planting. In 1973, color responses in the first growing season were obtained, but growth and survival data will not be available for analysis until next year.

Planting Season Extension

I should now like to outline the work being undertaken at GLFRC with the aim of seeing what can be done to extend the planting season. A long planting season is desirable so as to spread the heavy costs of mechanization over as broad a base as possible. Also, there are obvious advantages in reducing the seasonal nature of the workload.

The main study on this question is designed to permit the evaluation of comparisons among three species (only one provenance of each in this study, because of the impossibility of handling a greater workload) and three sites under three fertilizer treatments, with and without tilling. The study has been replicated in three consecutive years (1971-1973), and spring-lifted, cold-stored stock has been planted from June through mid-October.

Bearing in mind the striking influence of rooting medium fertility on root regeneration (cf. Björkman 1953), and the importance of root regeneration in securing survival of newly planted trees, I considered what might be done to improve the fertility of the rooting zone. Initially the aim was to mix the organic layer, where mineral nutrients are concentrated, with mineral soil, superimpose different levels of inorganic fertilization, and evaluate survival and growth of trees planted therein. Unfortunately, no machine was available that could operate on cutovers in the manner desired, and before the available tiller could be used the root mat and slash had to be removed. This preliminary site preparation pared off most of the organic material and thus most of the nutrients (cf. McMinn 1974). The Mang, a far superior machine, became available in 1972, but it was used on similarly prepared sites to preserve comparability. In all, 165,000 trees were planted in the 3 years of this planting-season extension study. Survival data have been collected; growth data will be gathered for several more years. Unfortunately, the cold storage facilities used in 1971 were totally inadequate, with temperatures rising to 60°F on occasion, and considerable mold developing. This, together with the initially poor stock, torture-tested as described in the machine planting study, made an almost irresistible combination. The cold storage facilities supplied by OMNR in 1972 and 1973 were very much superior, though still not devoid of problems.

Many of the data remain to be analyzed, but some preliminary indications may be given for some species and treatments. For example, the effect of site (Fig. 1), is not nearly as great as year of planting (Fig. 2), fertilization (Fig. 3), and tilling (Fig. 4) on the second-year survival of white spruce.

Root Regeneration

Concomitantly with the field plantings in the planting season extension study, samples of the planting stock were taken and tested in controlled growth chamber environments (with favorable levels of temperature and nutrient supply, etc.) to determine the amount of root regeneration developing in a standardized 3-week test period. The moisture status and morphological data were determined for each tree. The number and lengths of new roots were recorded, a not inconsiderable task when, exceptionally, a jack pine produced well over 2,000 new root tips in 3 weeks.

Root regeneration among trees randomly selected from stock at the site of outplanting is extremely variable. And here we return to the need to know how root regeneration and other expressions of physiological state are influenced by nursery and plant supply practices.

Data are still under analysis, but certain trends are nevertheless unmistakable, e.g., the pronounced decrease in root regeneration with increasing length of storage (Fig. 5). Also notable were the vigor of jack pine root regeneration and the better resistance of white spruce to storage as compared with black spruce and jack pine.

Scheme for Continuous Planting

Finally I should like to try to put everything together on this question of extending the planting season and suggest an idealized scheme for continuous planting through the growing season by making use of fresh and stored bare-root stock, plugs, and containerized plants in the following sequence (Fig. 6):

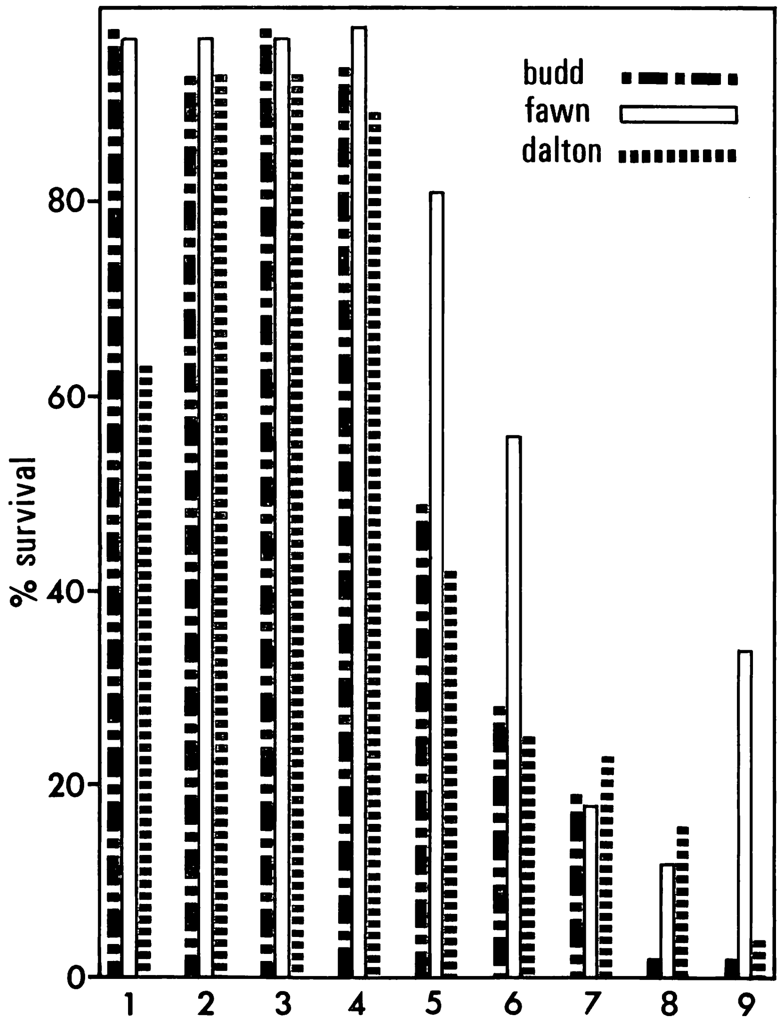

Fig. 1. Survival (September 1974) of control white spruce planted on three sites (Budd gravelly sand outwash, Fawn medium sand outwash, and Dalton loam till) on nine planting dates from June 29 through the 1973 growing season. Planting date on the x axis, percentage survival on the y axis.

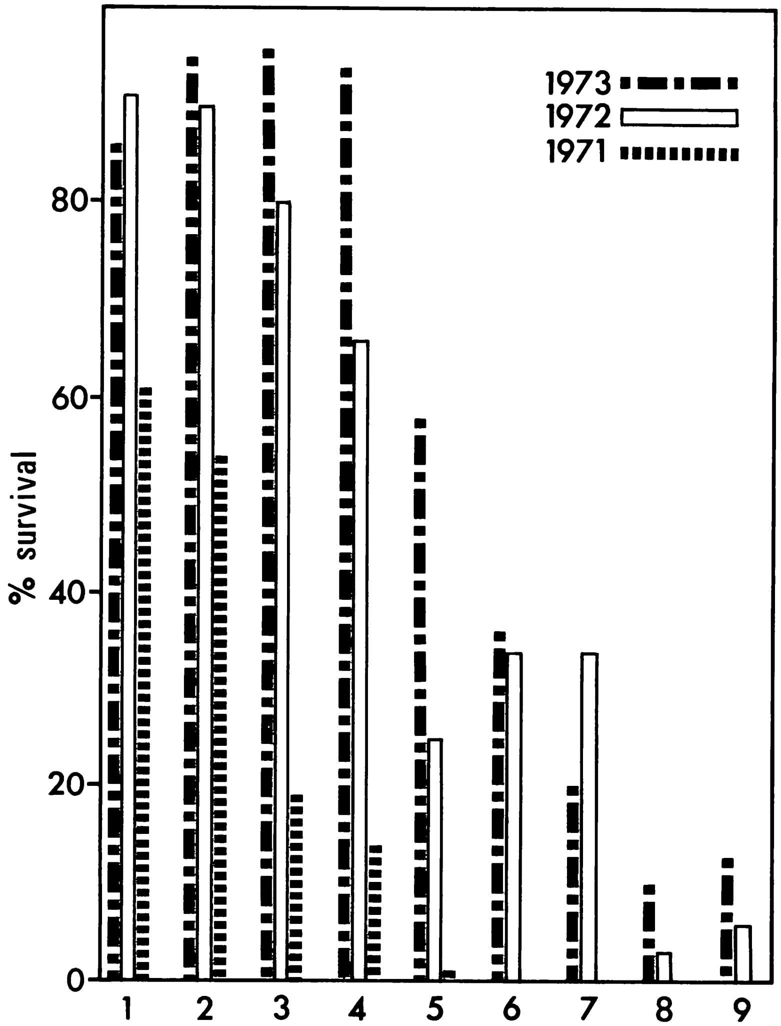

Fig. 2. Survival (September 1974) of control white spruce on three sites combined, planted on nine planting dates from June through the growing seasons of 1971, 1972, and 1973. Planting date on the x axis, percentage survival on the y axis.

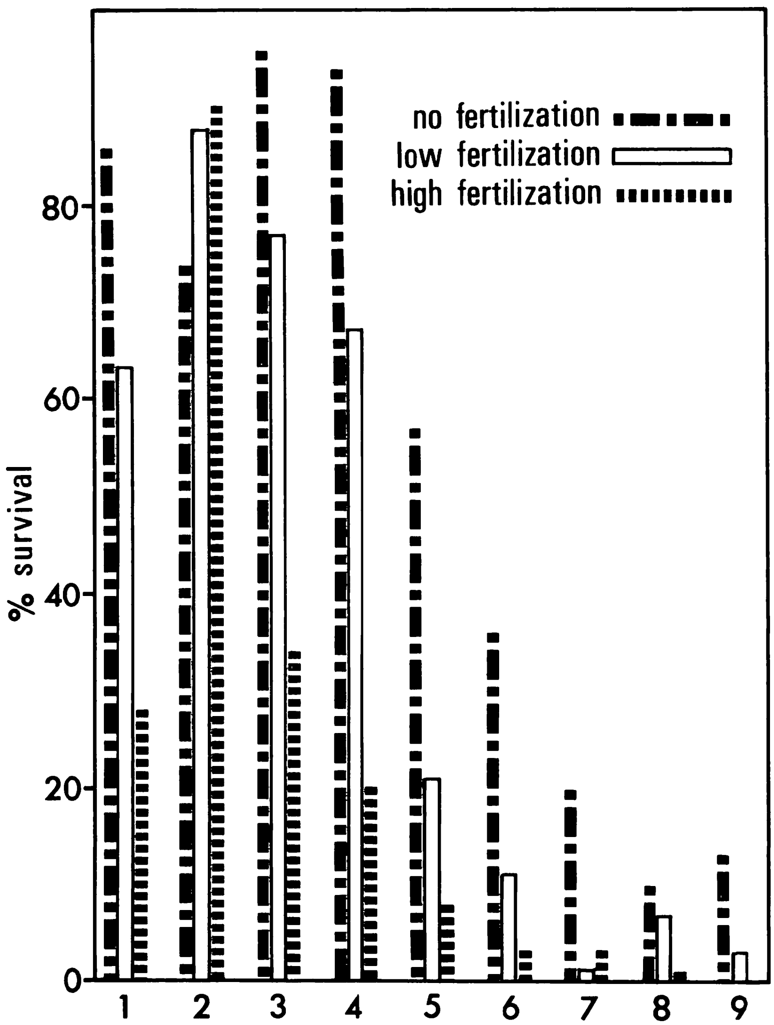

Fig. 3. Survival (September 1974) of white spruce, three sites combined, in the control, lightly fertilized, and heavily fertilized treatments, planted on nine planting dates from June through the 1973 growing season. Planting date on the x axis, percentage survival on the y axis.

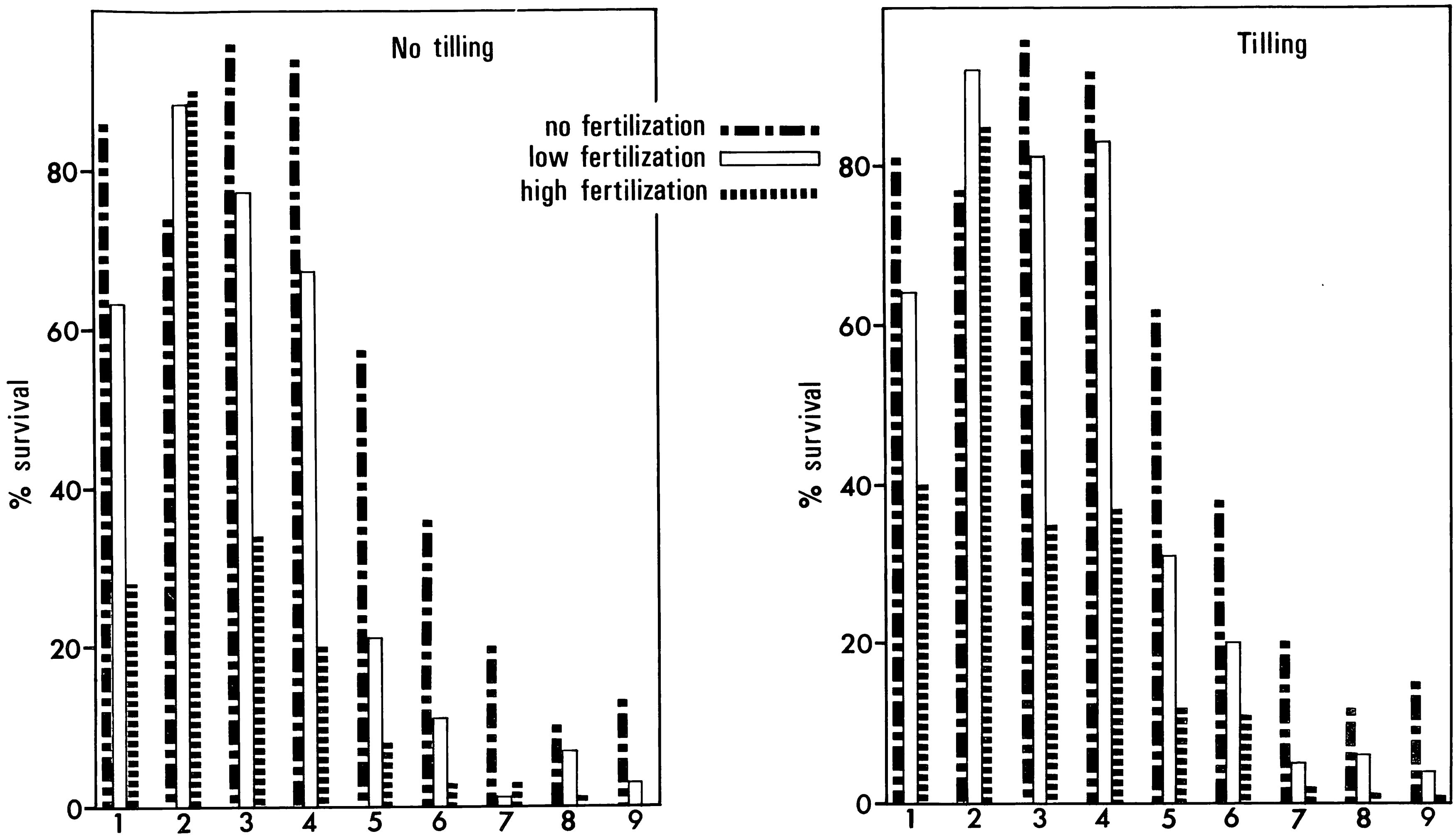

Fig. 4. Survival (September 1974) of white spruce, three sites combined in the control, lightly fertilized, and heavily fertilized treatments, with and without tilling, planted on nine planting dates from June through the 1973 growing season. Planting date on the x axis, percentage survival on the y axis.

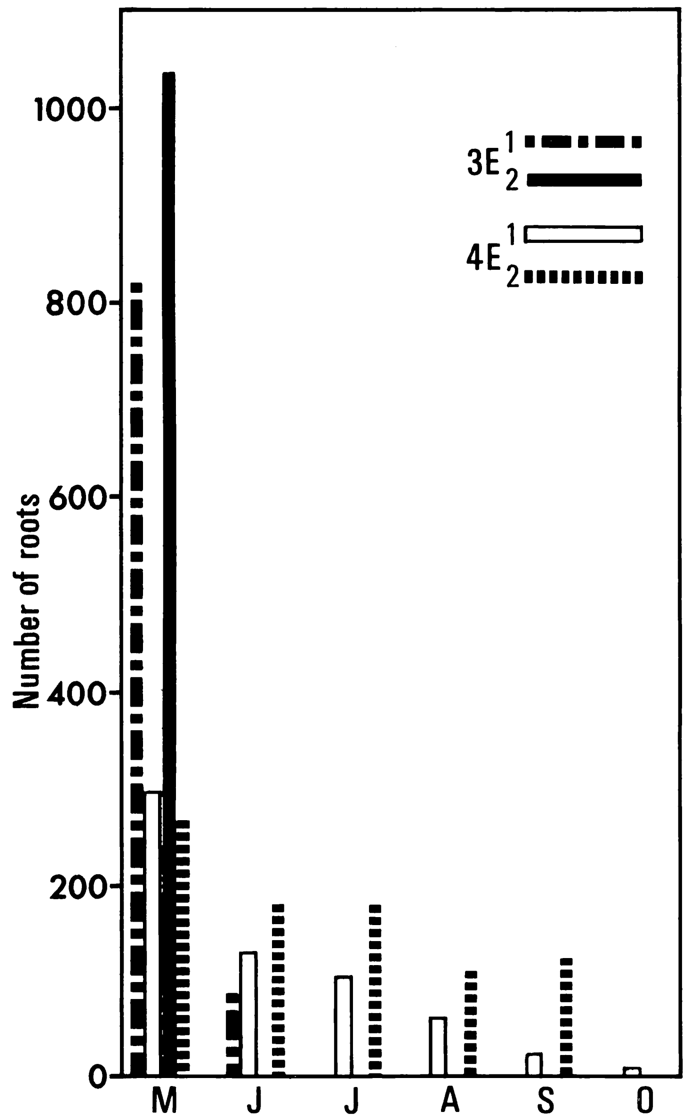

Fig. 5. New short roots produced during 21 days in controlled growth chamber environments by spring-lifted, 1972, 2+0 jack pine after different periods of storage through the 1972 growing season, excepting the May stock which was freshly lifted. Sampling date on the x axis, mean number of new short roots on the y axis.

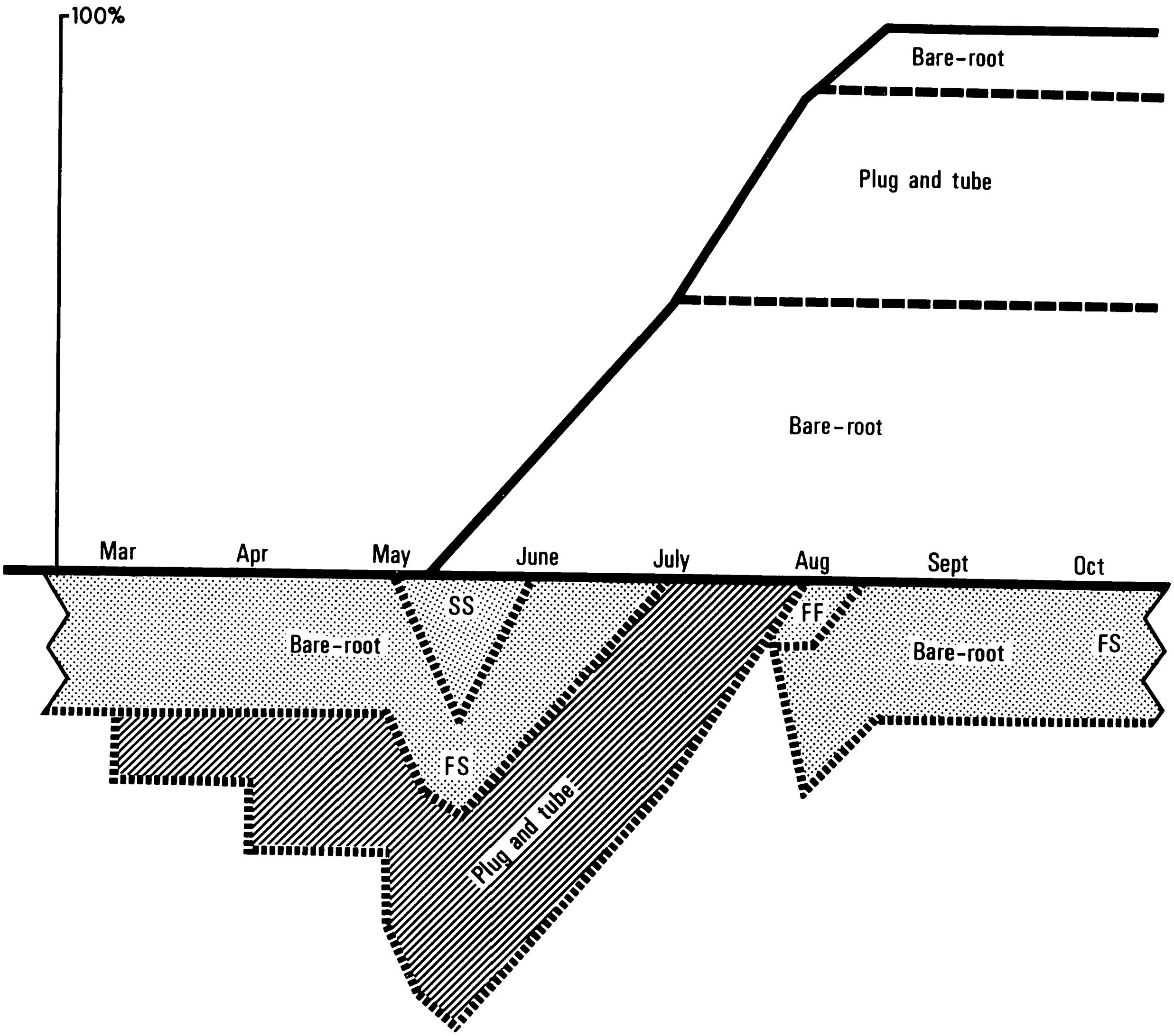

Fig. 6. Possible scheme for continuous planting through the growing season. In this idealized example, fall-lifted, bare-root stock in cold storage is overwintered for planting, together with some spring-lifted stock, during the first 6 weeks of the planting season. Plug stock and containerized stock that have been developing for an appropriate period beforehand (usually 12-20 weeks) may be planted for the next 4 weeks. Fall-lifted, bare-root stock can then be used in part for a period of fall planting and in part, after overwintering in cold storage, for planting the following spring. SS = Spring lifting, spring planting; FS = fall lifting, spring planting; FF = fall lifting, fall planting. Note: in this context, "fall" may in fact be late summer.

Stage 1 Planting begins on warmer, drier sites, as soon as soil temperatures reach 42°F in the spring, using bare-root jack pine and white spruce lifted in the previous fall and cold-stored over winter. Black spruce may be unsuitable in this regard. Planting continues on cooler, moister sites as the season progresses.

Stage 2 Planting continues, using conventional, fresh, spring-lifted, bare-root stock as necessary.

Stage 3 Planting continues with containerized stock 12 to 20 or more weeks old. The slope of the cumulative planting graph increases, reflecting the increased rates of planting possible with this stock.

Stage 4 Planting is done with fresh, late-summer lifted bare-root stock. Later lifted stock goes into cold storage for planting the following spring. Late plantings cease when soil temperature falls to 60°F after which root regeneration is inadequate to anchor the plant against frost lift and sustain it against desiccation.

In this way, planting in the Boreal Forest might progress at a fairly even rate from, say, late May until mid-September.

Mechanization accentuates the critical role of logistics in supplying planting stock to the outplanting site in the required quantity and quality. Mechanical breakdown can jeopardize large numbers of trees whose condition can deteriorate very rapidly in these circumstances. Refrigerated field storage is probably the answer to this problem.

Conclusion

Mechanical problems can be overcome: biological problems can be overcome as well, if we don't attempt to flout principles.

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MECHANIZED THINNING

J. D. Dunfield, Forestry Officer
Canadian Forestry Service
Forest Management Institute
Ottawa, Ontario

This paper presents an overview of mechanized thinning in Canada. Most of the experimental and ongoing work has been undertaken in the Atlantic and Pacific regions, where it has been given a fairly high silvicultural priority. Several prototype and production machines have been undergoing trials in Canada.

L'auteur analyse l'éclaircie mécanique telle que pratiquée au Canada. A ce sujet, les expériences et les travaux actuels ont surtout été entrepris dans les régions de l'Atlantique et du Pacifique, où cette technique de sylviculture a reçu une priorité assez élevée. On a entrepris des essais avec plusieurs prototypes et machines de production.

Introduction

In this paper I shall present an overview of mechanized thinning in Canada with some reference to foreign and regional conditions. I shall not attempt, in the allotted time, to explain or defend certain biological, ecological or economic aspects of thinning, but will confine my remarks to the hardware involved. In general, thinning will give more growing space to the residual trees and thus increase their increment and the average tree size at the final harvest. Through thinning, certain species can be removed or retained and an earlier return on capital investment can be secured.

The dictionary defines mechanization as a method of replacing manual or animal labor by a machine or tool. Automation can be defined as an evolution of mechanization whereby certain work functions may be undertaken by unmanned controls.

Many of the previous speakers have pointed out that mechanization has evolved in the woods because of a labor shortage and a desire to increase man-day productivity and to turn a somewhat tedious and laborious job into a more challenging effort. In some cases, mechanization can also produce more effective and consistent results.

While many developed countries have been undertaking thinning for decades, it is still a relatively new ball game in Canada on a commercial or production scale. Table 1 indicates the extent of manual and mechanized thinning in Canada as of 1974. Some regions consider thinning a high priority while other regions are more concerned with regeneration.

PRECOMMERCIAL THINNING

Table 2 indicates the methods and systems of precommercial thinning adopted or attempted in Canada. Many of the systems or machines were developed initially for land clearing or site preparation purposes. Although thinning is in its infant stage in Canada, we must remember that it usually requires at least 10 years to progress from the drawing board to production machine stages.

The Canadian Forestry Service (CFS) got involved in equipment development in 1970 after a certain pulp and paper company had become operational in precommercial thinning. Subsequently, the CFS built two prototype machines, using a wheeled skidder as the base or carrier vehicle. The results of the CFS thinner-mower were initially disappointing owing to engineering failures, inexperience and inadequate spare parts and service facilities. Isolation of the working sites also contributed to poor productivity.

From 1971 to 1974, a number of commercial brush cutters appeared on the scene, such as the Bombardier, Kershaw Klearway, Pettibone Hydro Ax and Nicolas Brush Cutter. The first three machines used a horizontal rotor principle similar to that of a large lawnmower, while the latter machine used the flail concept of hammerlike tynes.

The CFS in cooperation with the provincial authorities and logging companies field-tested these machines from 1971 to 1974 in eastern Canada. The results of these tests are shown in Table 3. A machine recording system and a field sampling procedure were developed to monitor the machines' performance and forestry conditions.

The tests were not all conclusive because of the limited time available and conditions which in many cases were not comparable. Productivity varied from 0.24 to 1.4 acres clearcut per hour and costs varied from $9 to $252 per acre. Machine availability ranged from 19% to 100% with the commercial machines averaging from 65% to 87% on the longer tests.

Table 1. Thinning programs in Canada

Precommercial thinning in Canada		
Location	Area thinned (acres)	Type of equipment or machine
Coastal British Columbia	13,000/year	brush hooks, chain saws and chemicals
Alberta	several thousand	drum choppers
Manitoba	5,000 (1960s)	drum choppers
Ontario	-	experimental
Quebec	40,000/year	brush hooks, chain saws, chemical and experimental mechanical methods
New Brunswick	-	experimental and operational in 1974
Nova Scotia	several thousand	hand tools on operational basis and experimental mechanical methods carried out
Newfoundland	less than 1,000	manual and experimental mechanical methods

Commercial thinning in Canada		
Location	Area thinned (acres)	Type of equipment or machine
British Columbia	1,800/year	manual cutting and mechanical skidding by skidders or cable yarders
Alberta and Manitoba	600	manual cutting and mechanical skidding
Ontario	-	operational in plantations only
Quebec	-	experimental only
Maritimes	-	experimental only

Table 2. Precommercial thinning methods and systems

- mechanical (carrier vehicle)
  - power-driven
    - rotary cutters (horizontal)
      - front-mounted
      - side-mounted
      - rear-mounted
    - rotary cutters (vertical)
      - front-mounted
      - rear-mounted
    - compactors
      - front-mounted
      - rear-mounted
    - saws
      - circular
      - chain-type
  - nonpowered
    - front-mounted
      - dozer blades
      - rakes
      - V-plow
    - rear-mounted
      - rollers or choppers
      - plows, discs, etc.
  - chemical
    - air-dispersed
    - ground-dispersed
- manual
  - chain or circular saws, axes
  - chemicals

Table 3. Summary of machine performance

Classification	FMI Prototypes		Kershaw Klearway	Pettibone Hydro Ax		Bombardier		Nicolas
	Nfld. (1971)	Quebec (1972)	Ont. (1973)	N.B. (1972)	N.B. (1973)	N.B. (1973)	Ont. (1973)	Nfld. (1973)
Scheduled operating time (hr)	445.4	173.5	--	112.1	15.0	42.0	--	95.3
Productive time (hr)	51.1	36.4	2.2	68.9	8.1	12.2	2.0	43.2
Mechanical delay time (hr)	361.6	128.4	--	13.6	2.0	10.9	--	51.2
Nonmechanical delay time (hr)	33.7	8.7	--	--	4.7	19.5	--	1.1
Machine availability (%)	19	26	100	87	86	74	100	65
Machine utilization (%)	12	21	--	62	54	29	--	--
Acres treated	30	70	5	43	12	16	5	17.5
Acres clearcut per productive machine hour	0.24	0.80	1.2	0.62	0.73	0.65	1.4	0.28
Estimated hourly operating cost ($)	20	20	25	25	25	20	20	20
Thinning costs per acre ($) (about 50% of area corridor-thinned)	252	48	13	24-39	14-20	15-19	9	37-70

Commercial Thinning

Most present-day logging equipment is too large and too costly to warrant its use in mechanized thinning, particularly in the stump area. Farm equipment is generally too fragile for continuous woods work. Consequently, mechanized thinning concepts and systems applicable to Canadian conditions are still to be developed from the stump to the landing area.

Recently some machines have been developed for small tree harvesting such as the Timberjack RW-30 (Fig. 1) which can fell, delimb and bunch trees up to a 12-in. stump (dib). This unit is basically a plantation or row thinner and achieved an average production of 102 trees per machine-hour on a test near Chapleau, Ontario in the late fall of 1973.

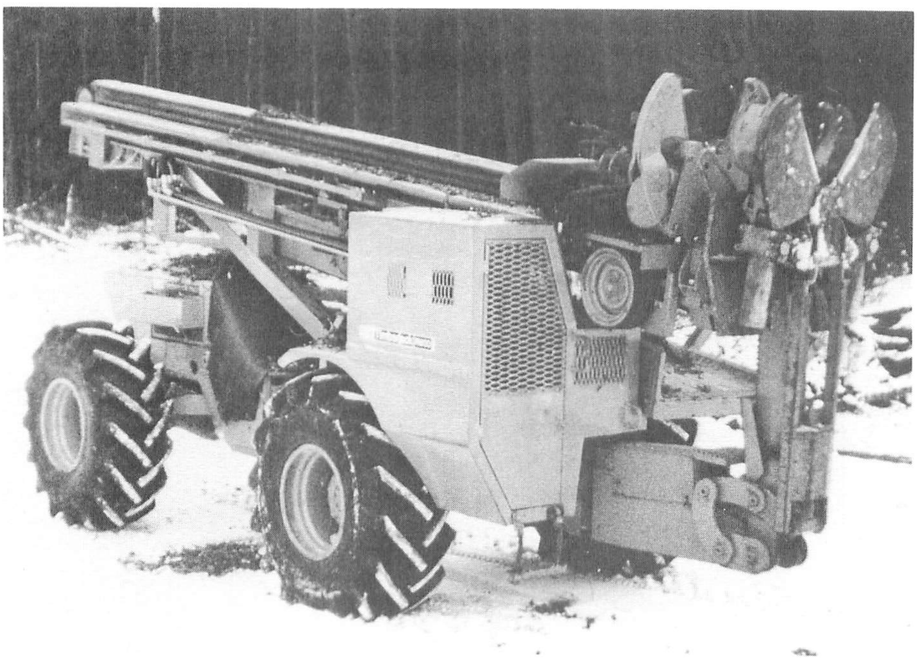

Figure 1. The Timberjack RW-30 has been developed in Canada as a final harvester but has also been successfully tested as a commercial strip thinner.

The Bobcat (M-174) feller-buncher may also be of use in selective, commercial thinning. This machine has an accumulator on its cutting boom whereby one to three trees can be cut and held.

The Timberline TH-100 is a shortwood harvester now used for thinning purposes in the southern United States. This unit has three wheels for maneuverability.

Commercial thinning in British Columbia has generally adopted the cable yarding system with manual felling because of topographic conditions on the coast. A Mini Alp cable yarder was purchased by the CFS and is now undergoing trials in coastal British Columbia. It is trailer-mounted and can be run from the power takeoff of a 45-75 hp farm tractor.

Two other experimental thinner yarders in British Columbia are the Iglund and the Pacific thinning systems with the former mounted on a farm tractor and the latter mounted on a truck.

Conclusions

Tree size and tree density appear to be the main factors that influence mechanical thinning if all other factors are equal. Slope and ground debris such as old stumps place constraints on mechanical equipment. Field tests indicated that manual labor and machine operators vary in their rate of production up to 100%.

In precommercial thinning, a suitable machine to cut individual trees selectively has not been developed to date, and row or corridor thinning must be considered only an initial step. For all-purpose use, the track-type carrier in precommercial thinning appears preferable, but roller choppers may be the most suitable row thinners in dry, rock-free areas. The tests were not conclusive as to the merits of a flail or rotary cutter head.

Further research is required before comprehensive conclusions can be reached regarding cost parameters for thinning, classification of sites requiring thinning, standards for machines, and the quality of operators and service facilities.

I would like to acknowledge the assistance and cooperation of the provincial and federal governments and equipment manufacturers who contributed to this paper.

SOME ECONOMIC IMPLICATIONS OF MECHANIZATION OF SILVICULTURE

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

Mechanization of silviculture offers some hope to the forest manager in relieving problems of rising costs and labor shortages. However, the benefits will not be achieved without adjustments being made in the manner in which forest management activity is carried out.

La mécanisation de la sylviculture permettra au gérant forestier d'espérer que les coûts d'exploitation soient baissés et que le problème de la rareté de main d'oeuvre soit résolu. Cependant, on ne pourra pas jouir des nouveaux avantages si l'on n'améliore pas les méthodes d'aménagement des forêts.

Introduction

Economic theory organizes its discussion of production around three basic factors: land, labor and capital. Production of any given product is attained through their combination. For instance, when we attempt to reforest an area we apply to land both labor in the form of planters, supervisors, etc., and capital in the form of tools, machines and planting stock to achieve our objective.

The theory of production goes on to say that any given level of output may be attained from more than one combination of the three factors of production. For instance, one acre of land plus two laborers and one planting machine may give the same output as one acre of land plus five laborers using shovels.

While a given output can be produced by several combinations of the factors of production, only one combination gives us the product at least cost. The cost of the product depends upon the quantity of the factors we use, their relative productivity in production and the price of the factors.

By now you are probably asking yourself what all of this economic "mumbo-jumbo" has to do with mechanized reforestation. The answer is--everything! Providing silvicultural workers with more complicated planting tools, anything from the *Pottiputki* to the Ontario Mark III Tree Planter, is in effect substituting capital for labor. An evaluation of the diversion of regeneration dollars from labor to equipment (i.e., capital) or vice versa, involves a recognition of the economic principles of production. If the goal is the most forest at the least cost, the concepts outlined above must be recognized.

The key point to be gleaned from the foregoing, and one that is too often overlooked, is that a change in the capital-labor combination may have varying effects on regeneration productivity and costs. We may get more or less output from an increase in the use of machines, or an increase in mechanization may either decrease or increase costs of regeneration per unit.

Obviously the goals of increased mechanization of regeneration activity are to increase the area regenerated for a given expenditure level and to increase manpower productivity. However, it should be recognized that we may not achieve one or both of these goals. The objectives of this paper are to consider the feasibility of achieving these goals through increased mechanization and to identify and discuss the management implications of this course of action. First we will deal briefly with the potential benefits of mechanization. Then we will turn to the costs involved. Finally we will attempt to identify some of the implications of changing regeneration technology and discuss briefly some policy implications.

Benefits

In a recent paper discussing the logging industry's reasons for turning to mechanization, C.R. Silversides stated that "the two major factors are a shortage of suitable woods labour and escalating wood costs." (Silversides 1974). If we substitute regeneration costs for wood costs this pretty well sums up the reasons for interest in increased mechanization of silviculture. Many of the activities associated with regeneration are labor intensive, and labor costs are rising rapidly as available labor supplies are shrinking. At the same time increasingly large areas of cutover land need treatment if existing cutting levels are to be maintained. Thus inflationary pressures on cost plus a shrinking labor supply are frustrating attempts to increase management capabilities. The concept of mechanization of silviculture offers some relief to the problem.

The potential benefits of increased mechanization appear to be as follows:

1. increased manpower productivity to help offset labor supply problems;

2. reduction in regeneration costs due to increased manpower productivity;

3. increased stability of the work force resulting in better job performance.

All of these items will help to alleviate the problems outlined above. The key question is, are the benefits really there?

Costs

Any discussion of the potential benefits of a new system necessarily involves a consideration of costs. Thus I will attempt to frame my discussion in terms of the benefits outlined above.

The first item to consider is the potential of mechanization in relieving manpower supply problems. There is little doubt that machines have the capability to increase manpower productivity in silviculture. How much is another question. Some areas such as scarification and planting of farmlands seem to offer little scope for further gain. On the other hand, planting in the Boreal Forest and production of nursery stock are both highly labor intensive and offer some potential for increased mechanization. The key then becomes the development of machines that can operate under the existing conditions. The range of types of mechanization that can affect manpower productivity is tremendous. In the nursery we can look at new machines for handling bare-root stock or at a container system which is essentially a different concept of growing trees. In the forest we may consider a new planting tool which allows the planter to achieve 10% greater productivity or a new planting system which may result in from 60 to 100% greater productivity. Alternatively we may look at a fully automated planter that requires only one tenth the manpower per unit area regenerated (Backstrom and Wahlqvist 1973). All of these options have potential for allowing better use of scarce labor resources. Which option the forest manager chooses should depend in large part on his existing labor supply situation and on the prospects for the future. It is obvious that, all other things being equal, the more difficult it is to obtain labor, the more attractive are the more highly mechanized alternatives, even though they probably involve a greater departure from existing operating procedures and thus greater implementation problems.

The second item on the list of potential benefits is the cost saving attributable to mechanization. In practice, whether or not cost savings are realized with a new system probably depends on the manner in which the system is implemented as much as the system itself. Thus generalizations become very risky. However, certain generalizations can be made. First, the simpler the innovation the greater the probability that the potential savings it embodies will be realized. It is much easier to capture the 10% increase in productivity attributable to a new planting tool than it is to go to a fully mechanical system. To cite another example, the planting cost savings associated with container planting are readily accepted, and there are indications that total regeneration costs will be less with container systems (Vyse and Ketcheson 1974). If we look at more complicated mechanized systems, the question of potential cost savings becomes murkier. A Swedish study of alternative regeneration systems has concluded that the most efficient mechanized system, a one-pass scarifier-planter, has an expected cost per acre that is higher than that of hand planting, even though man-hour productivity is greatly increased (Backstrom and Wahlqvist 1973). The offsetting cost factor is the capital cost of the machinery. While the results of this study are far from being the last word on the costs of mechanization, experience in the logging industry has tended to support these findings (Tucker and Ketcheson 1973).

As stated earlier, implementation of a new system is likely to affect costs as much as the system itself. Implementation covers everything from the planning stages through to the actual field application of the technique. Poor implementation can more than offset the potential benefits of a new system, whether the switch is from hand-planted bare-root stock to paperpots, or to a fully mechanized scarifier-planter. Therefore, when new approaches to silviculture are being considered, serious thought has to be given to the framework within which the new system is expected to perform. In terms of cost, there is one major difference between mechanized and manual planters. With mechanized planters a high proportion of the planting cost is incurred before the trees are planted. This is not so with hand planting. What this means is that, for costs to be kept to a minimum, the machine has to be worked as close to capacity as possible. If not, then costs will rise at an alarming rate. We know from the experience of other industries that a competent maintenance staff is required to achieve this. When we think of highly mechanized reforestation, we must also think about changing the nature of the work force. We are concerned not only with machine operators but with mechanics and welders as well. Unless this requirement is built into the implementation, the costs will probably be such as to make highly mechanized alternatives unacceptable.

A second major implementation consideration is the need for careful planning of mechanized operations. To achieve high availability and utilization the machines must be at the right place at the right time to do the job. Adequate numbers of machines must be available, but not too many. To ensure that these conditions are met, forest managers will have to plan and coordinate operations much more closely than in the past. The cost of having a machine sit idle in Swastika while stock is rotting in Dryden will be very high.

The third potential benefit outlined was the stabilization of the labor force. A highly mechanized reforestation program should mean a smaller, more stable labor force. The potential payoffs of this item are significant. For instance, in nursery work the quality of the final product, and therefore costs, are very sensitive to the quality of work performed. In the field stage, the quality of regeneration work will become even more sensitive to job performance as systems become more sophisticated. It should also be possible for existing technical and supervisory staff to put more effort into quality control as machines absorb more of the physical work load. However, at the same time as jobs stabilize and require greater skill, management will be required to adopt procedures that will attract and hold skilled labor as permanent staff. Thus the unit cost of labor will tend to rise as the skilled component of the work force grows.

Implications for Mechanized Reforestation

From the foregoing discussion of mechanization, several implications for future policy can be discerned. First, a discussion of mechanization tends to emphasize just how important existing labor supplies are to the silviculture program. Labor has to be regarded as a high-value, scarce resource, and policy has to recognize this fact. More effort should be made to maintain and expand existing labor supplies. Management procedures will have to be modified if we are to take advantage of available silviculture workers. Existing programs which are labor intensive should receive the highest level of supervision. A better appreciation of work performance, the development of flexible guidelines for work, and a greater emphasis on "people" management by experienced supervisors are essential for maintaining a satisfactory level of regeneration activity.

Forest managers should not shy away from adopting new labor-intensive programs in the expectation of possible breakthroughs in mechanization. Labor-intensive programs such as container regeneration systems offer significant cost savings, at least in the short run. While one expects the rate of mechanical development to increase at an increasing rate, it is not realistic to expect that the demand for unskilled silviculture labor will disappear. Thus programs that offer potential for increasing labor productivity through better use of existing labor supplies should receive the highest priority.

Second, one has to recognize that the cost of regeneration activity may not fall significantly as a result of mechanization. This does not mean that the search for more efficient systems should be curtailed. Some gains through increased capitalization of regeneration activity can be made and possibly the rate of increase of regeneration costs can be controlled. However, controlling regeneration costs depends upon more factors than simply the introduction of machines. In order to ensure satisfactory results from regeneration activity, a concept of satisfactory restocking at some specified point in stand development has to be combined with the least-cost method of achieving the desired goal (Vyse and Ketcheson 1974). Once the regeneration goal is established, developing the combination of production inputs to achieve the goal at the least cost becomes the challenge to forest managers. This means that the total regeneration system from seed collection through stand establishment will have to be considered. Optimizing our systems in terms of cost and performance, whether we are talking of planting or seeding, is essential to the efficient utilization of our regeneration dollars.

Third, increased mechanization is likely to require a significant change in the way silviculture operations are carried out. We have to think in terms of expanding the operating season. Better utilization of the available time through multiple-shift operations will help offset capital costs. Given the extension of operating hours to their outside limit, the key to acceptable costs is machine availability, and this requires an adequate maintenance system. For the maintenance system to be effective and not to be a drag on costs, serious consideration will have to be given to the scale of operations. How many machines and how many mechanics make up an efficient regeneration production unit? Failure to consider the scale of operations can destroy the mechanization concept.

Fourth, in light of potentially large capital investments required for mechanized silviculture, serious thought has to be given to who can best provide the service. Existing procedures have the forest manager buying a good portion of his power supply from private firms. I would expect that this practice will become even more intensive in the future. However, a suitable framework to support a silviculture industry will have to be developed. Items such as long-term contracts and expanded silviculture packages will have to be employed to attract the necessary capital investment.

A fifth implication is that managers are going to have to plan and coordinate activities. An assessment will have to be made of the potential demand for mechanical application on a province-wide basis. A system to coordinate available machinery with other regeneration inputs will have to be established. The costs of poor planning and poor management performance can be tremendous.

While mechanized silviculture offers great hope as an answer to some of the problems of forest management, without careful consideration of the questions raised in this discussion, mechanization of silviculture may end up as a graveyard for silviculture dollars.

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DEVELOPMENT AND IMPLICATIONS OF MECHANICAL SCARIFICATION IN THE NORTHWESTERN REGION

A.M. van Fraassen
Forest Management Supervisor
Ontario Ministry of Natural Resources
Dryden, Ontario

Between 1963 and 1972 mechanical scarification was established throughout the Northwestern Region. Site descriptions are given to indicate the operational feasibility of this method. The forest industry should help implement future scarification programs, which will have to consider both site factors and problems related to equipment.

Entre 1963 et 1972, le scarifiage mécanique a été établi d'un bout à l'autre de la Région nord-ouest. L'auteur décrit des stations pour illustrer les possibilités pratiques de cette méthode. L'industrie forestière devrait aider à réaliser de futurs programmes de scarifiage, qui devront tenir compte des facteurs de station et des problèmes relatifs à l'équipement.

Introduction

My remarks on mechanical silviculture in the Northwestern Region (OMNR) will be limited to mechanical scarification, first because mechanical scarification is an essential part of site preparation for either natural or artificial regeneration, and second because, in the development of mechanical silvicultural methods, scarification represents more than 85% in terms of area.

Developments During the Decade 1963-1972

In the Northwestern Region mechanical scarification was initiated in the early 1960s on the jack pine (*Pinus banksiana* Lamb.) sand flats north of Dryden by Dryden Paper Company Ltd. by dragging a combination of tractor pads and anchor chains across the fresh jack pine cut-overs, with the objective of promoting natural regeneration.

When these early attempts proved successful scarification became established throughout the Region and increased considerably in terms of area (Table 1).

Table 1. Mechanical scarification, Northwestern Region (1963-1972)

Year	Total area (acres)	District					
		Fort Frances	Kenora	Dryden	Ignace	Sioux Lookout	Red Lake
1963	745	136	-	349	260	-	-
1964	2,044	277	130	1,459	58	120	-
1965	4,029	-	809	2,060	1,060	-	-
1966	9,265	603	1,624	4,656	1,098	1,054	230
1967	10,038	225	2,263	4,863	2,200	150	337
1968	9,826	-	2,165	4,099	2,641	35	886
1969	10,282	1,035	1,408	4,177	3,025	544	93
1970	14,396	861	1,984	6,022	3,866	510	1,153
1971	15,093	803	2,460	5,578	4,679	180	1,393
1972	12,585	1,094	1,312	4,569	3,907	193	1,510
Total:	88,303	5,034	14,155	37,832	22,794	2,786	5,602

The districts of Dryden and Ignace carried out more than 70% of the total scarification in the Region, largely because cutting operations and the better sites were concentrated there.

Site descriptions in relation to scarification attempt primarily to indicate the operational feasibility of scarification rather than its capacity for improving vegetative growth. Therefore, a good site is one which offers the least constraint and a poor site is one which offers the greatest constraint to scarification. As a result, site description will contain topography, depth over bedrock, stoniness and soil textures as its major components. Further constraints such as stumps, logging debris, residual vegetation, etc., can be considered when applicable but can occur on any site.

The Northwestern Region has four major sites ranging from good to very poor. These are described on the following page.

Site	Topography	Depth over bedrock	Stoniness	Soil texture	Major working group
sand flats	gentle, 0-8%	3 ft plus	scattered or frequent stones and boulders	coarse, medium or fine sands	jack pine
clay flats	gentle, 0-8%	3 ft plus	scattered rock outcrops	clays or silts	spruce, poplar (jack pine)
rolling tills	moderate, 8-25%	shallow to very shallow (6 in.-3 ft)	frequent rock outcrops, stones and boulders	clays or sands	jack pine, spruce (poplar)
extreme broken tills	steep, 25% plus	shallow to very shallow (0 in.-1 ft)	frequent rock outcrops, steep rock ridges, boulder pavement	clays or sands	jack pine, spruce (poplar)

Wet lowland sites, eskers and marines are frequently encountered; however, they are minimal in area.

Site descriptions, where available, cover only the south half of the Region, excluding the northern portions of the Red Lake and Sioux Lookout districts. In this limited area extreme broken tills represent 10%, rolling till 63%, clay flats 20% and sand flats 7%.

When the development of mechanical scarification is considered in relation to site (Table 2) it appears that scarification was concentrated on the better sites until 1969, when scarification on the rolling tills increased rapidly to exceed 50% of the total area treated. This change in conditions brought about a change in objectives and methods (Tables 3 and 4).

Table 2. Mechanical scarification, Northwestern Region (1963-1972)

Year	Total area (acres)	Site		
		Clay	Sand	Till
1963	745	-	609	136
1964	2,044	407	1,537	100
1965	4,029	183	2,640	1,206
1966	9,265	2,375	4,832	2,058
1967	10,038	2,395	4,063	3,580
1968	9,826	3,265	3,573	2,988
1969	10,282	1,855	3,220	5,207
1970	14,396	4,085	4,284	6,027
1971	15,093	2,825	5,985	6,283
1972	12,585	3,930	2,388	6,267
Total:	88,303	21,320	33,131	33,852

Table 3. Mechanical scarification, Northwestern Region (1963-1972)

Year	Total area (acres)	Objective		
		Planting	Seeding	Natural
1963	745	-	-	745
1964	2,044	407	-	1,637
1965	4,029	73	200	3,756
1966	9,265	1,838	1,104	6,323
1967	10,038	2,643	968	6,427
1968	9,826	3,454	430	5,942
1969	10,282	3,676	901	5,705
1970	14,396	4,875	3,401	6,120
1971	15,093	5,854	2,226	7,013
1972	12,585	4,557	3,665	4,363
Total:	88,303	27,377	12,895	48,031

Table 4. Mechanical scarification, Northwestern Region (1963-1972)

Year	Total area (acres)	Pads and chains	Barrels and chains	Blade
1963	745	745	-	-
1964	2,044	1,867	177	-
1965	4,029	4,029	-	-
1966	9,265	6,164	3,101	-
1967	10,038	2,882	5,035	2,121
1968	9,826	3,847	3,450	2,529
1969	10,282	4,016	3,568	2,698
1970	14,396	3,358	8,988	2,050
1971	15,093	1,989	9,809	3,295
1972	12,585	1,459	9,382	1,744
Total:	88,303	30,356	43,510	14,437

As mentioned before, scarification on the jack pine flats was carried out using pads and chains to promote natural regeneration. Its success was due largely to the abundance of seed available from the pure pine stands and to sufficient mineral soil exposure by the pads and chains because of the thin duff layer. Neither of these conditions was prevalent on the tills. Not only were spruce (*Picea* spp.) and poplar (*Populus* spp.) content much higher but also deep layers of duff prevented adequate mineral soil exposure by using pads and chains, thereby preventing germination of the available seeds. Subsequent assessments indicated insufficient seedlings in numbers and distribution. As a result, scarification using shark-fin barrels and chains with subsequent aerial seeding or hand planting came into practice. To date it has proven the most successful and versatile method. It offers a multiple choice in barrels of different shapes and sizes, loaded and empty and in chains of different lengths and weights. A variety of combinations can be chosen for different site conditions and can be matched to different power requirements.

The development of scarification on the gentle, deep clay sites in the Wabigoon River and Rainy River basins followed a different pattern. Hand planting nursery stock was and is the major regeneration method on these rich sites. However, it was found that excessive slash on fresh cutovers and excessive shrub competition on the older cutovers were deterrents to proper distribution of the planted stock and added to the operational difficulty of handling large planting crews. Scarification by barrels and chains on fresh cutovers to break down slash piles and arrange a pattern of narrow lanes or troughs approximately 6 ft apart did result in better distribution, easier handling of crews and increased planting production. On the older cutovers with excessive vegetation of shrubs and poplar suckers, a front-mounted angle blade or V-blade was used to bulldoze tunnels 8-14 ft wide at varying distances apart depending on the density of the residual vegetation for subsequent planting.

It should be noted that on the majority of these sites the duff layers were extremely thin (not more than 6 in.) and that maintenance of this moisture-retaining layer was critical to the survival of the planted stock. Consequently, empty shark-fin barrels are used and blading is carried out in winter after the ground is frozen to keep mineral-soil exposure to a minimum.

In summary the following scarification and regeneration pattern has been developed in the Northwestern Region over the last decade:

> *On sandflats:* scarification with pads and chains for natural regeneration or subsequent broadcast seeding when seed source is insufficient

On clays: light scarification with shark-fin barrels and chains for subsequent planting of nursery stock

On tills: scarification with shark-fin barrels and chains for subsequent broadcast seeding or planting of nursery stock.

It should be noted that total scarification never exceeded 25% of the area cut over. This can be attributed to small regeneration budgets during the first half of the past decade: most of our funds were allocated to the planting of nursery stock and to a gradual change of the cutovers to poorer sites during the second half of the decade. The rolling tills, interlaced with numerous rocky ridges, steep precipices and excessive wet pockets, proved to be a real constraint on the tractors dragging the scarification equipment.

Future Development 1973-1982

The forest production policy now in effect in Ontario recognizes the fact that future demand for forest products is directly related to present silvicultural investment and that the relationship can be expressed in quantitative terms. Definite "output targets" are set for the province, regions and districts in terms of cunits of wood to meet wood demand forecasts in the year 2020. The output targets are directly related to silvicultural input expressed in acres to be annually regenerated by a variety of methods. A 10-year "phase in" period allows for annual increases in budget, manpower and equipment. Mechanical scarification will play an important part in this silvicultural input. In the Northwestern Region scarification will increase by 180% over the next 10 years to reach 54,000 acres annually by 1982 (Tables 5 and 6). Annual cutover area treated will increase from 25% to 50% (Table 7).

No major change is anticipated in size and location of the future cuts; therefore, the bulk of scarification will still be carried out by the Dryden and Ignace districts. It is interesting to note that this may change toward the end of the decade in light of the recently announced pulpmill and sawmill expansion in the Northwestern Region. Most of this expansion will result in large increases of cutover area in the Red Lake and Sioux Lookout districts. Major revisions in output targets and silvicultural inputs must be made to keep pace with industrial expansion.

Future developments in mechanical scarification will undoubtedly have to take into consideration both site factors and problems related to equipment.

At present our knowledge of sites is concentrated in the southern half of the Region--the north half is a blank map. Since future development will be concentrated there it is extremely important that we embark on a program to widen our knowledge in that respect. I would expect that such a program must be completed in the next 5 years to be of any use as a planning tool.

Table 5. Mechanical scarification, Northwestern Region (1973-1982)

Year	Total area (acres)	District					
		Fort Frances	Kenora	Dryden	Ignace	Sioux Lookout	Red Lake
1973	19,354	1,470	3,310	5,600	6,850	424	1,700
1974	27,132	2,600	4,200	6,000	9,700	2,532	2,100
1975	31,995	2,800	4,580	6,600	11,050	4,465	2,500
1976	35,300	2,900	4,460	7,400	12,960	4,840	2,740
1977	37,650	3,600	4,640	7,900	12,960	5,110	3,440
1978	41,028	4,400	5,603	8,900	12,960	5,325	3,840
1979	44,676	5,050	6,566	10,200	12,960	5,610	4,290
1980	48,970	6,586	7,204	11,600	12,960	5,930	4,690
1981	52,155	7,986	7,409	12,860	12,960	6,100	4,840
1982	54,033	9,180	7,553	12,960	12,960	6,480	4,900
Total:	392,293	46,572	55,525	90,020	118,320	46,816	35,040

Table 6. Mechanical scarification, Northwestern Region (1973-1982)

Year	Total area (acres)	Objective			
		Planting	Seeding	Other	Natural
1973	19,354	5,260	5,930	2,550	5,614
1974	27,132	5,460	9,655	5,092	6,925
1975	31,995	5,760	10,215	7,770	8,250
1976	35,300	6,260	10,615	9,385	9,040
1977	37,650	6,680	11,015	10,115	9,840
1978	41,028	6,890	11,660	11,535	10,943
1979	44,676	7,196	12,277	13,359	11,844
1980	48,970	7,549	13,018	15,324	13,079
1981	52,155	7,820	13,597	16,970	13,768
1982	54,033	8,120	14,146	17,151	14,616
Total:	392,293	66,995	112,128	109,251	103,919

Table 7. Percent of cutover area to be scarified, Northwestern Region (1973-1982)

Year	Dryden	Fort Frances	Ignace	Kenora	Red Lake	Sioux Lookout	Region
1973	30	14	37	24	27	5	25
1974	32	25	51	30	27	20	31
1975	35	27	58	27	28	29	36
1976	40	28	68	26	25	25	37
1977	42	35	68	26	26	27	38
1978	48	43	68	29	25	28	41
1979	55	49	68	33	25	29	43
1980	62	64	68	34	24	31	46
1981	69	78	68	35	23	32	48
1982	69	89	68	36	23	34	50

In the southern half, treatment areas on good sites (clays and sands) are rapidly decreasing as wood harvests, out of necessity, are concentrated on the rolling, rocky tills and even on extremely broken tills which are termed by the industry "logging nightmares". The term "nightmare" is just as applicable to scarification. From past experience it is estimated that on clays and sands 70% of the cutover can be scarified, on rolling tills 50%, on extremely broken tills 30%.

Conventional power-propelled machines such as D7s and D8s have been found inefficient in rolling and extremely broken tills in terms of total cutover scarified and production. Wheeled skidders used in 1973 and 1974 have shown promise in both respects, owing to greater flexibility in adverse terrain and to greater speeds which offset lower drawbar horsepower. However, it should be recognized that the wheeled skidder is designed for an entirely different type of work. Excessive tire wear, insufficient horsepower and weight are the major disadvantages of the wheeled skidder used in scarification.

Research in this field is badly needed. Within a few years scarification budgets in the Northwestern Region will be in excess of $1 million annually. It would be to our advantage to develop the proper machine to do a proper job to ensure that this money is efficiently used. After all we have spent considerable effort and money to develop the Ontario Mark III Tree Planter which in the Northwestern Region could be used only for about 12% of the total treatable area.

The major problems encountered in the use of tractors and skidders for scarification are as follows:

1. scarcity of machinery

   Owing to the economic boom in forestry, mining and construction there is a lack of interest on the part of equipment owners in committing machinery for a relatively short period each year (maximum of 30 weeks) to a program which has proven to be hard on machinery.

2. lack of proper equipment maintenance and management

   The small-equipment owners who have traditionally carried out the districts' scarification programs lack proper maintenance facilities and management expertise. The result is loss of production due to lack of spare parts and transportation facilities needed for the frequent moves between treatment areas. For example, an equipment owner in the Dryden area frequently exceeded 2.5 acres/hr production with his machines. However, he completed the total 4,000-acre program with three machines in 25 weeks, which at 50 hr/wk per machine resulted in an average of 1.6 acres/hr. The reason: only 60% availability per machine.

3. lack of trained operators

   Owing to a general scarcity of skilled labor there is a definite lack of tractor and skidder operators experienced in scarification. This results in lost time, poor quality and inefficient use of machine and scarification equipment. After all, a machine is only as good as its operator.

To alleviate these problems we need equipment owners sufficiently interested and able to make necessary capital investments in machines for scarification, power-propelled machines in sufficient numbers to complete the program within the allotted time (maximum 30 weeks) (Table 8), mobile maintenance facilities to carry out minor repairs on the job, sufficient transportation equipment (floats) to facilitate efficient moving of the equipment between areas, trained operators with interest in scarification, and sufficient spare parts and/or machines to achieve 80% availability.

The obvious way to achieve these objectives is to engage the forest industry in implementing the scarification program. The forest industry has the greatest interest in maintaining the yields on limit areas through prompt and successful regeneration, especially since annual cuts on the developed limit areas have reached the allowable cut and the demand for expanded limit area is increasing.

Table 8. Mechanical scarification, Northwestern Region (1973-1982). Estimated equipment requirements

Year	Area (acres)	Avg production (acres/hr)	Required machine hours	Available hours per machine	Required no. of machines
1973	19,354	2.0	9,677	1440	7
1974	27,132	2.0	13,566	1440	9
1975	31,995	2.0	15,998	1440	11
1976	35,300	2.0	17,675	1440	12
1977	37,650	2.0	18,825	1440	13
1978	41,028	2.0	20,514	1440	14
1979	44,676	2.0	22,338	1440	16
1980	48,970	2.0	24,485	1440	17
1981	52,155	2.0	26,078	1440	18
1982	54,033	2.0	27,017	1440	19

NOTE: Mechanical scarification is expected to be carried out in 30 weeks of each year beginning May 1.

Required machine hours = Area (acres) ÷ Average production

Available hours per machine during the scarification period = 30 weeks x 5 days x 12 hours x 80% availability

Required number of machines = Required machine hours ÷ Available hours per machine.

The forest industry has a proven record of excellent equipment management and maintenance. The opportunity to use maintenance facilities and management expertise for both harvest operations and scarification will result in lower unit cost. Moreover, most of these facililities are in existence so that no time need be lost in their development.

However, the trend seems to be for the forest industry to get out of the silvicultural field, leaving the implementation of this aspect of forest management more and more to small equipment owners under annual contract with OMNR. It is outside the scope of this paper to examine the phenomenon in detail; suffice it to say that forest harvest and reforestation programs cannot be implemented in isolation from each other.

In conclusion, I would like to make a few observations about quality. Successful scarification will ultimately be measured in terms of adequate numbers and distribution of seedlings regardless of whether they are regenerated naturally or artificially. We cannot wait five or more years after scarification to term it successful, because if it is not successful there is little we can do about it at that time. Therefore, a relationship between adequate stocking and adequate scarification must be developed and translated into minimum scarification standards which are measurable when scarification is in progress and when it is completed. At present, scarification methods seem to be based on individual observations without any attempt to standardize them.

The scarification program in the Northwestern Region is a great challenge. Its success will depend on the concentrated effort of all of us.

So let's get on with it.

IMPLICATIONS OF AND POSSIBILITIES FOR MECHANIZATION IN THE NORTH CENTRAL REGION

H.P.G. van Bers, Regional Forestry Specialist
Ontario Ministry of Natural Resources
Thunder Bay, Ontario

By 1982 the North Central Region's annual planting program will reach 31,000 acres, of which 60% could be planted by machines capable of operating in a wide range of conditions. Power units to pull site-preparation equipment should be flexible enough to operate in various ground conditions. Increased demand for wood fiber, higher costs and a declining labor force require an accelerated mechanization rate.

Vers 1982, le programme de plantage annuel de la Région nord centrale devrait atteindre 31000 acres, dont 60% par des machines capables de travailler dans toutes sortes de terrains, avec des tracteurs à équipement de préparation du sol. On doit augmenter le taux de mécanisation pour satisfaire la demande toujours plus grande de fibre de bois, considérant les coûts plus élevés et la réduction de main d'oeuvre.

The North Central Region of the Ontario Ministry of Natural Resources (OMNR) (Fig. 1) is comprised of six districts: Atikokan, Thunder Bay, Nipigon, Geraldton, Terrace Bay and White River. Except for a small area in the southwest end, the North Central Region falls within the Boreal Forest Region, having as its principal tree species black spruce (*Picea mariana* [Mill.] B.S.P.), balsam fir (*Abies balsamea* [L.] Mill.), jack pine (*Pinus banksiana* Lamb.), aspen poplar (*Populus* spp.) and white birch (*Betula papyrifera* Marsh.).

The 1968 forest production policy for Ontario states: "We are to produce and maintain growing stock on the productive forest lands to yield a continuous supply of at least 9.1 million cunits of fibre annually for the wood-using industries." The regional share of the provincial objective is 1.7 million cunits of fiber annually for which we need an estimated 93,000 acres. The policy further states: "Inefficient

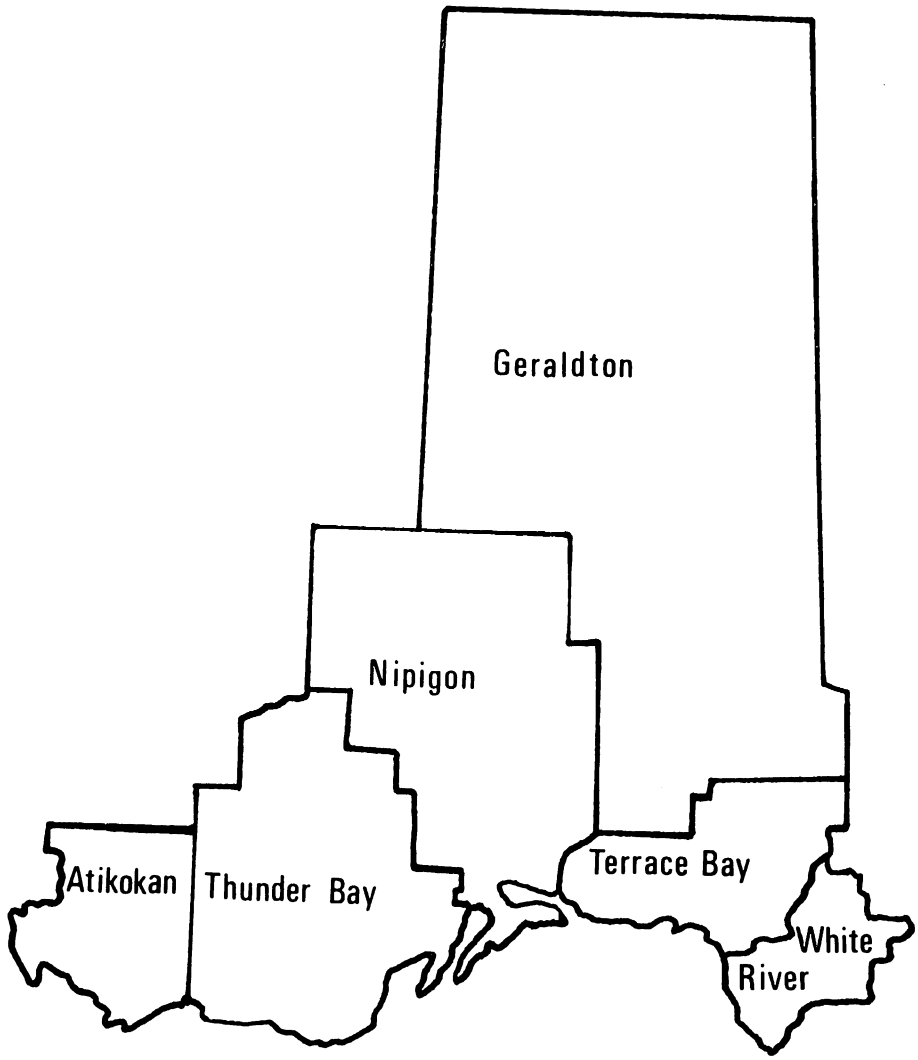

Figure 1. Administrative districts and forest regions of the North Central Region (OMNR).

use of forest land cannot be further tolerated; we must *immediately regenerate* the estimated 90% of cut-over area that will not be satisfactorily stocked within five years by natural means". We believe that 90% is too high and that it is closer to 70 or 75% for the North Central Region.

Large expansions of existing wood-using industries and the establishment of new industries are taking place, resulting in larger areas which will require immediate regeneration.

From the implementation of the regional production policy, we project that 64,000 acres will be regenerated in 1982-1983. This would be an increase of 90% over the 1974-1975 program. The *annual* site preparation requirements (not including prescribed burning) will more than double from 17,000 to 40,000 acres within the next 10 years. However, in spite of all these aforementioned anticipated increases, the fact remains that the total acreage we will be regenerating is far from sufficient using present methods and technology. During the 1973-1974 fiscal year, the total cutover area was 110,000 acres, of which approximately 80,000 acres would have required some form of treatment to regenerate. We treated only 28,000 acres, leaving 65% unregenerated.

Towards the end of this decade (1980-1981), the estimated annual cutover will be in the neighborhood of 200,000 acres. If 25% regenerates naturally, 90,000 acres or 60% of the area requiring regeneration will be neglected.

Not only do we disagree with the level of regeneration we are scheduled to carry out but we wish to emphasize the urgent need for more mechanization of our silvicultural techniques if this will reduce the cost and increase the acreage that we can treat successfully.

It is also our opinion in the North Central Region that the need for mechanization is immediate. The development of *specialized* machinery has not kept pace with the requirements and must be speeded up.

We will always attempt to adapt logging equipment to our needs or rebuild farm machinery. These procedures served our purposes very well up to a couple of years ago when only 55% of the provincial allowable cut was utilized. Now, however, over 75% is being cut even though better utilization may account for part of the increase.

With the high demand for timber, companies are operating in less desirable areas. Industry has equipment for harvesting but we have very little for regenerating these areas.

Increased use of mechanical equipment for silviculture may well be the key to expanding our silviculture program.

There are two principal areas of immediate concern where mechanization or improvement of it must take place. The first is tree planting. In 1973-1974, our planting program covered approximately 17,000 acres. In 1982-1983, we expect to do close to 31,000 acres, an increase of 80%. We estimate that 60% of our annual tree planting could be done by machine. This represents an average of 10,000 acres per year in the first 3-4 years, increasing to 15,000-16,000 acres or 12 million trees annually after that. However, it is extremely important that the machine be designed to meet our special northern Ontario conditions. It should be operable in a wide range of conditions such as heavy slash and rock-strewn areas, which are beyond the capability of conventional planting machines. Sufficient machines and people who can maintain them should be available to make the fullest use of our short planting season. For the last 3 weeks we have had a planting machine (the Ontario Mark III Tree Planter) on trial in the Region but have not been able to assess it.

The second area of concern is the type and design of the unit pulling our scarification and site-preparation equipment. We have made good progress in developing some unique drag units that fit northern conditions and requirements. The main units now used are flanged barrels, ringed barrels, anchor chains, V-blades and tractor pads. As tree planting of nursery stock is one of the most expensive methods of regeneration ($48 per acre), more emphasis has been placed on other systems, particularly natural regeneration with modified harvest cutting, seed tree system, seeding, and scarification for natural regeneration. Site preparation is usually associated with all techniques. The type of drag, arrangement and number of units are determined from the site conditions, species requirements, method of harvesting and, last but not least, for now anyway, the tractor one can obtain. The latter may lack drawbar horsepower or may not be suited to the ground conditions. This can greatly affect the quantity, quality and cost of the work. A compromise is the only solution, but it is not very desirable. Within the next 10 years, scarification will increase from 5,000 to 10,000 acres per year and site preparation from 17,000 to 40,000 acres per year. However, some districts will not be able to do more than 20% of this using conventional equipment tractors.

To increase our acreage, we either increase the length of drawbars from 8 ft to 24 ft or use wheeled skidders or all-terrain vehicles. We need to develop machines that are flexible enough to operate under a variety of conditions, and we need trained people who are familiar with their operation.

This year, the Nipigon District is using two 880 Clark Ranger (Fig. 1) wheeled skidders that have met some of the specific requirements mentioned earlier. The machines have the power to pull the necessary drag units; they will operate under a variety of site conditions, especially on difficult terrain such as shallow sites and wet areas, treating 2-8 acres per hour per machine depending upon ground conditions.

Another very important and desirable aspect of the Clark Rangers is that they are under a multiyear contract. This way, we have specialized equipment committed to *our needs alone* and we are able to plan our work as necessary. Too often, machines cannot be obtained because of other commitments and we often get inexperienced operators. As a result, too much downtime is spent on repairs and maintenance. We need more specialized equipment for treating the ever-increasing cutover areas.

Figure 1. Large skidders, such as the Clark Ranger 880 shown above, are being given increased consideration for site-preparation operations.

Thus far, I have mentioned only the regeneration part of forest management. As for tending, we may, in the future, require a mechanical unit for cleaning or thinning the dense and overstocked stands of jack pine, balsam fir and poplar. We may be required to manage these stands in the future.

At the present time we know of machines that are on the market: a mulching machine, the Nicolas Brush Cutter, made in France and the Hawthorne Tree Eater, Model 8000, manufactured by the Triumph Machinery Co. in New Jersey. We had the latter in our region a couple of years ago and it showed definite promise. You may have seen the Kershaw Klearway Cutter and Bombardier mowers during the Gogama field trip in conjunction with the Direct Seeding Symposium held in Timmins in September, 1973. Mechanization is essential if precommercial thinning is to be carried out on a large scale.

Another field of activity where mechanization is recommended is our seed collection program. Records for the last couple of years clearly show that we have not been able to collect sufficient quantities efficiently. At present we have only a cone stripper for jack pine--with limited results--and nothing for either black spruce or white spruce (*Picea glauca* [Moench] Voss), for which the cost of collecting is too great.

As the last item on the subject of mechanization, we would like to propose the initiation or reinstatement of an information system for the field staff, perhaps in the form of a silvicultural leaflet originating at the field level.

NORTHERN REGION VIEWPOINT

J.T. Rudolph, Forest Management Supervisor
Ontario Ministry of Natural Resources
Kapuskasing, Ontario

Current site-preparation problems in the Northern Region (OMNR) can be solved by applying improved techniques to available machinery. Planting machines are being developed to offset forecasted tree planter labor shortages: the dibble principle of the Ontario Mark III Tree Planter has potential for planting on dry sites. Training of machine operators and mechanics is essential.

Les problèmes de préparation de la station actuellement confrontés dans le nord de l'Ontario (OMNR) peuvent être résolus par l'application des techniques améliorées à l'outillage disponible. Des machines à planter sont à l'étude en vue de parer aux carences de main d'oeuvre prévues dans ce domaine: le principe sur lequel fonctionne la Planteuse Mark III Ontario rend possible la plantation sur les stations sèches. La formation d'opérateurs et de mécaniciens pour de telles machines s'avère essentielle.

Introduction

I believe it is safe to say that the mechanical stage of regeneration which has historically received the most attention in the Northern Region of the Ontario Ministry of Natural Resources (OMNR) is site preparation. On the other hand, mechanization of tree planting has only recently received the attention it warrants, with the initiation of formal test trials.

Site Preparation

Initial advances in site-preparing cutovers prior to tree planting were mainly on jack pine (*Pinus banksiana* Lamb.) sites. Much success has been had with the simple shark-fin barrel drag arrangement, which still receives the widest use in the Region, including use on upland spruce (*Picea* spp.) sites. Other machines, such as the V-plow, Young

Teeth, KLM-240 Marttiini Reforestation Plow and Rome disc, have also become standard in many districts.

Existing machinery, however, has not solved all of our site-preparation problems. For example, on jack pine and upland spruce sites, we have two problems:

1. inconsistent quality of site preparation due to the effect of fresh slash (1-3 years) on the site

2. the need to expose more mineral soil at roughly the same cost to permit the use of less expensive broadcast seeding.

The solution to these two problems does not necessarily mean the development of new equipment but perhaps an improvement in techniques using existing machinery.

A more serious problem arises when one considers the preparation of poorly drained peat sites on black spruce (*Picea mariana* [Mill.] B.S.P.) lowland. These areas have taditionally remained untreated owing to their wetness as it was impossible to operate heavy machinery on them.

Recent development work in the Kapuskasing District (1973-1974) using wheeled skidders one year and a high flotation (wide-track) D6C tractor (Fig. 1) another year on lowland black spruce sites has provided needed and valuable information for the forest manager. The skidder did not operate well on the wet lowland but proved satisfactory for the most part on the slopes and upland sites. One problem with the skidder is the creation of ruts resulting in pools of water on the site even when the machine is operated with no attachments. The wide-track tractor did not produce ruts to any significant degree, even when operated with a drag attachment; the ground site-prepared with this tractor has proven excellent for planting nursery stock and tubes, and there is apparent potential for direct seeding. Kapuskasing District is now prepared to put this machine to work on a regular operational basis as a result of its development trials, and I understand other districts are interested in a similar machine.

Escalating Costs

There is no easy answer to the escalating cost of renting heavy equipment from contractors each year. The question remains: what can we do about it? One possibility is to place tenders earlier in the year (January-February), particularly with the large contractors, rather than wait until March-April. The larger operators book their machines early and are usually in a better position than small operators to offer lower rates. It might help if we were more specific in what they would and would not be required to do in the tender description. Some of these fellows may have got "burnt" once, perhaps on their first contract with OMNR, and may have tended to carry this over in subsequent bids in the form of a rate possibly higher than necessary. If some explanation of the method to be used, site conditions to be encountered, and downtime payments were included in the tenders, contractors might be willing to offer lower machine rental rates. This all seems very simple, but it is all too often forgotten.

If it is possible for one district to coordinate the use of a particular machine with another district and get all the work done, the contractor should be able to offer a lower rate. This may mean that one district received the machine later in the operating season, but if the contractor is dependable, an arrangement of this kind should be acceptable to the districts.

Figure 1. High-flotation crawler tractor of the kind necessary for traversing wet or soft-soiled areas during site-preparation operations.

Mechanized Tree Planting

Machines for placing nursery stock in the ground have not been used extensively in the Northern Region. Most machines that have been available commercially to date were more suited to reclaiming abandoned agricultural land than reforesting Boreal Forest sites. The Lowther Wildland Tree Planter was used for a few years on the better jack pine sites in the early 1960s, but has since fallen out of use. The reasons for this are varied, depending on the user; however, it would be sufficient to say that the machine was not capable of handling our typical Boreal Forest cutovers.

Since 1971 the federal and provincial governments under a joint agreement have been undertaking operational trials of various commercial planting machines in the Northern Region, e.g., the Reynolds-Lowther Crank Axle Planter, the Reynolds-Lowther Dual Colter Planter, and the Taylor Drum Colter Planter. These trials have taken place on some of our easiest and most difficult jack pine and spruce sites. Formal reports and conclusions on the results of this work are not, to my knowledge, available yet. However, on the basis of my personal involvement, witness and reading of some preliminary results, I am pessimistic about seeing any of the machines now being tested placed on a regular production basis on the sites in the Northern Region. Boreal Forest sites are just too rough for these machines! Terrain, fresh stumps, residual trees, slash, rocks and wetness make it impossible to plant the required number of trees per acre when some form of plow shoe is the avenue through which trees are placed in the ground. The dibble principle of the Ontario Mark III Tree Planter would seem to have the greatest potential for northern sites.

The machines now being tested under joint agreement represent in various degrees a safety risk to the tree planter-operator. I suspect there would be a high rate of turnover in operators as there is a great deal of shaking and bouncing when riding the machines. Rates per thousand trees could be equal to or worse than existing costs for site preparation and hand planting. I predict that for as long as adequate numbers of fairly dependable tree planters are available, forest managers will shy away from planting machines. However, if and when their hand is forced by a lack of tree planters, machines like the Ontario Planter may be the only alternative. I rule out almost completely those planting machines with a fixed position plow shoe. My comments on planting machines have been in reference to jack pine sites. In my opinion, until there is some major advancement in mechanical planting on jack pine sites, no progress will be made on the low, wet black spruce sites, and little or none on clay hardpan.

Labor Shortage for Tree Planting

The potential problem of a shortage of labor for tree planting is a real possibility in the Northern Region. Many districts have not been able to recruit enough local labor and are now transporting James Bay Indians to fill their camps. How long this limited source of manpower will last is uncertain now, but we run the risk of having this supply reduced significantly, or cut off completely if some economic activity should develop for these people close to home. For this reason, if for no other, it is important for us to find alternative methods of planting trees and alternatives to planting trees. With this latter point in mind, a technique such as modified harvest cutting of spruce should be given increased emphasis in the districts.

Thinning

Precommercial and commercial thinning are not yet carried out on a regular basis in the Northern Region. Successful trials have been conducted by the Canadian Forestry Service (CFS) using a special Eaton and Yale (Timberjack) machine equipped with a shear blade in a strip thinning of 40- to 45-year-old jack pine; in addition, manually operated motorized brush saws have been tried in 9- to 10-year-old jack pine. Reports have been, or will be, published on both projects.

Apparently benefit:cost ratios for thinning have not been high enough, so far, to warrant bidding for the funds already committed to crop establishment. Perhaps the benefits from thinning the stands close to the point of consumption will some day be greater than those of establishing a stand of trees many miles from the mill.

Machine Development

There is bound to be new and increased use of machinery on the silviculture side of forestry. I think that some specialized commercial machines currently available might be adapted to site preparation. Development work in this area, particularly on black spruce slopes and lowland sites, must continue. The high flotation D6C Caterpillar tractor looks as if it has good potential for treatments on our wet sites. We may even be able to run this machine over winter haul roads into winter cutovers which until now have received no silviculture treatment.

Rubber-tracked all-terrain vehicles may deserve more attention than we have been giving them for on-the-site transport of men, trees and equipment in the Clay Belt. This would apply to our prescribed burn operations as well as to tree planting.

Another possible future development is extensive use of mobile truck refrigerator vans to transport and hold nursery stock for planting. Cochrane District has received funds this year to purchase a secondhand refrigerator van in order to conduct feasibility trials on the possible use of such units on a region-wide basis.

Training

It would appear that the Northern Region is developing, renting and purchasing more and more mechanical equipment each year in its effort to achieve its output target for the year 2020. Some of this equipment is highly sophisticated, and if we are not prepared to operate and maintain it properly this could mean costly trouble. What I am saying is that hand in hand with the rental or purchase of machines should go formal training in their operation and maintenance. At present, it is not uncommon for us to place our own staff on rented skidders without training. Some districts are even considering the purchase of skidders. It has been proven time and time again that untrained drivers cause more machine downtime than those with training. The same might be said in regard to safe operation. In addition to training the operator, staff mechanics should be educated in the care and maintenance of every different silviculture machine purchased, and at least be able to offer advice on the most common types rented. Districts may help the situation somewhat by taking advantage of courses offered in their locale. For example, the wood industry and manufacturers sponsor skidder-operator training courses in which OMNR might become involved. It is hoped that the Region will anticipate this growing need for training in the field, and take the appropriate action soon.

Summary

1. We need to use existing equipment and technology on jack pine sites to prepare better seedbeds by exposing more mineral soil for relatively cheap broadcast seeding.

2. Wet black spruce sites present a problem as far as vehicle mobility is concerned (i.e., for transporting men and trees, scarifying or pulling a planting machine). Equipment that will help solve this mobility problem may now be available. Further investigations and trials must be conducted by OMNR.

3. Mechanized tree-planting machines of the "drag" type with colter and plow shoe will probably receive little production use in the Boreal Forest. The Ontario Planter's dibble concept looks as if it may have potential.

4. A possible shortage of labor for tree planting in the near future dictates that we find an alternative method of planting nursery stock and, where possible, an alternative to planting nursery stock.

5. Machine operation and maintenance training are important aspects of the process of mechanization. Failure to keep pace in this area will mean costly mistakes in terms of dollars and possibly lives.

IMPLICATIONS OF AND POSSIBILITIES FOR MECHANIZATION OF SILVICULTURE IN THE NORTHEASTERN REGION

J.F. Christian, Forest Management Supervisor
Ontario Ministry of Natural Resources
Blind River, Ontario

The percentage breakdown of different silvicultural treatments in 1973 and that proposed for 1982 to meet the Northeastern Region's (OMNR) output target are illustrated. The possibility that target levels will not be attained using traditional techniques is raised. The Region must look to more efficient and effective silvicultural practice.

L'auteur fournit les pourcentages d'existence des différents traitements sylvicoles en 1973 et ceux proposés pour 1982 afin d'atteindre les objectifs de rendement de la Région du Nord-Est (OMNR). Il mentionne la possibilité de ne pas atteindre les objectifs fixés si on utilise les techniques traditionnelles. La Région devra rechercher des pratiques sylvicoles plus efficaces et effectives.

Because I am the last of the four [OMNR] regional speakers and because, in preparing my talk, I expected that many of the implications and possibilities presented by the preceding speakers would apply to the Northeastern Region as well as to their own, I do not plan to go into great detail. I do hope that the little I will say along with what you have already heard will allow you to infer the implications and possibilities for mechanization in the Northeastern Region.

I would like to say something about the forests of the Northeastern Region, where the Region is now in its silviculture program and where the staff of the seven districts within the Region have proposed that we be in 1982 to meet the target assigned under Ontario's Forest Production Policy. Finally I would like to say a little on what I see as the implications and possibilities for silviculture in the Northeastern Region.

The Forests of the Region

As many of you know, the Northeastern Region is one of great variety and is in effect a transition zone. Here the hardwoods of the Huron-Ontario and Algoma sections meld into the pine-aspen-white birch sections of the Great Lakes Forest Region. These meld into the fringe or transition sections of the Boreal Forest Region.

This complexity presents problems to the forest manager: the range of species and sites which occur, the species mixtures, the stand sizes, the difficulties in determining the species for which to manage a site and, often, once a decision has been made, the tending required to promote the species.

Where is the Northeastern Region in its Silviculture Program?

In this presentation I have chosen to deal with percentages rather than with numbers of acres and so on. This I did partly because I want to show the relation between the activities in which we involve ourselves and the changes we predict, not the numbers themselves. Mostly, though, I chose to do so because I can read small numbers more easily than large ones.

Figure 1 shows the percentage breakdown in 1973 of the broad types of silvicultural treatments. Of the total area reported, 18% was site-prepared for planting and seeding, 31% was regenerated naturally with no money invested, 15% was planted with both bare-root and container stock, 10% was direct-seeded, 9% was subjected to other regeneration treatments, including modified harvest cutting, seed-tree cutting, scarification, etc., 4% received mechanical or chemical tending treatments, and 13% received hand tending treatments.

Where does the Northeastern Region Propose to be in 1982 in its Silviculture Program?

Figure 2 shows the percentage breakdown proposed for 1982 for the broad types of silvicultural treatment.

Of the total area to be treated, the proposed percentage breakdown for types of silvicultural treatment are: 18% site preparation for planting and seeding, 28% natural regeneration (down from 31% in 1973), 13% planting (down from 15%), 7% direct seeding (down from 10%), 10% other regeneration treatments (up from 9%), 8% mechanical and chemical tending treatments (up from 4%), and 16% hand tending treatments (up from 13%).

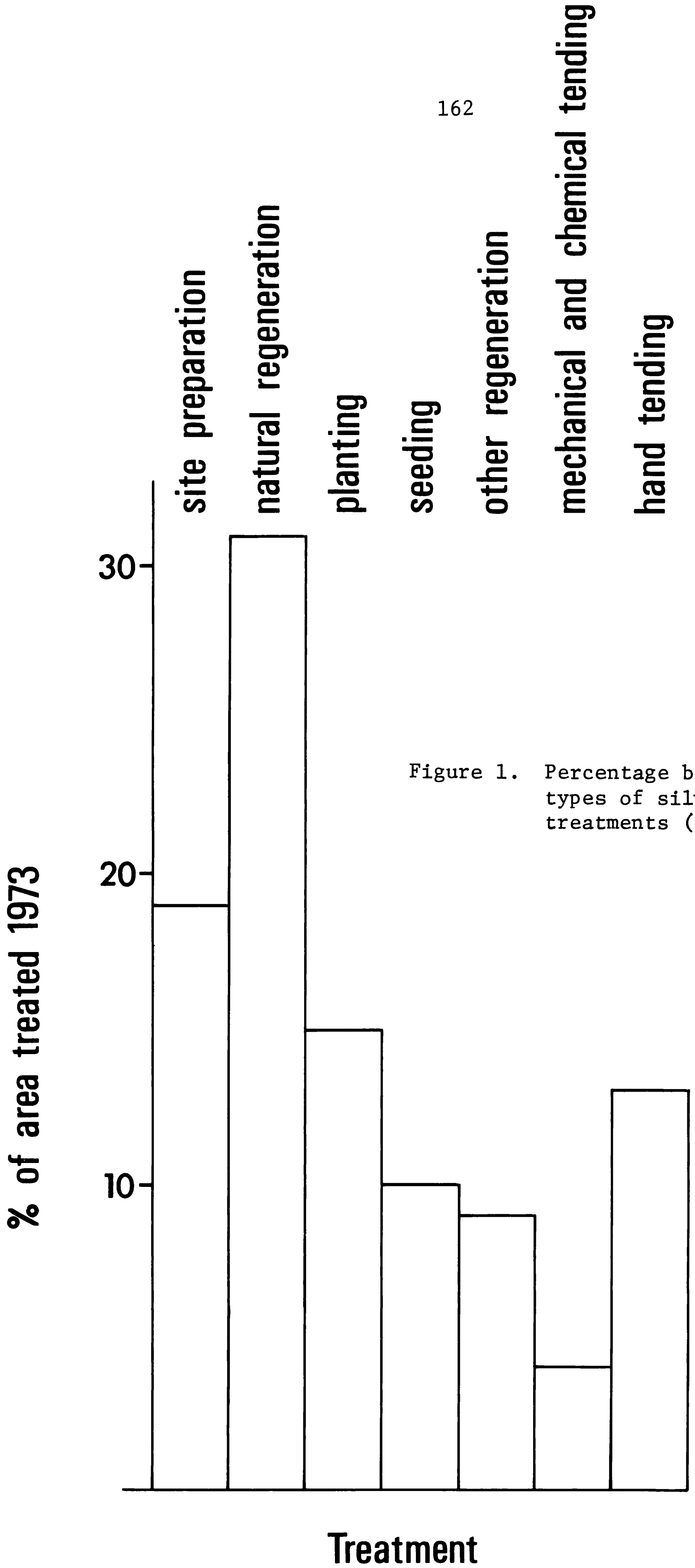

Figure 1. Percentage breakdown of broad types of silvicultural treatments (1973).

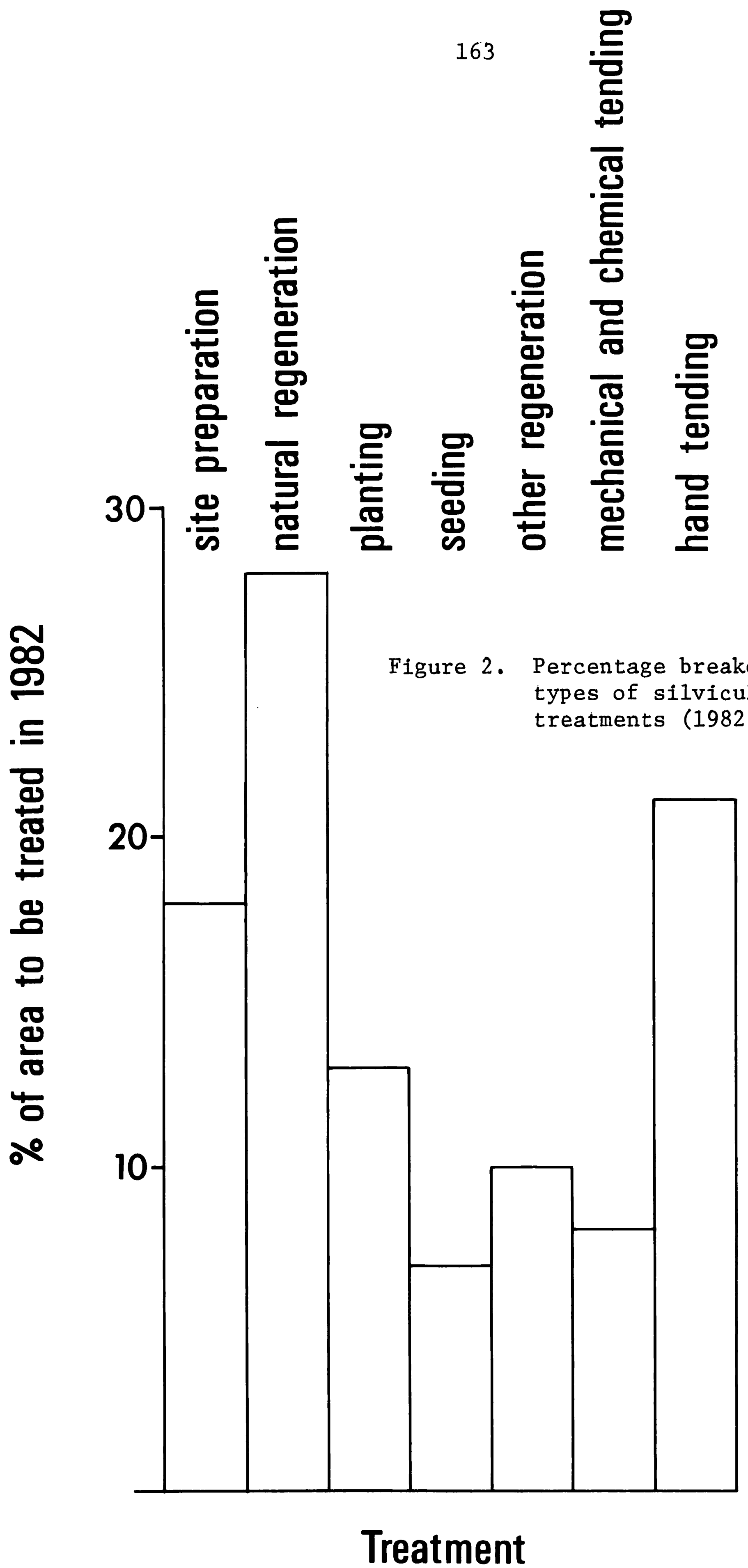

Figure 2. Percentage breakdown of broad types of silvicultural treatments (1982).

The total area treated is expected to increase by 77% but the changes in treatments themselves vary.

Figure 3 shows both the 1973 and the proposed 1982 treatment areas expressed as a percentage of the total area reported in 1973.

Between 1973 and 1982, the area of site preparation for planting and seed is to increase by 84%, the natural regeneration area by 58%, the planted area by 46%, and the seeding area by 22%. The area of other regeneration treatments will be 2.13 times greater than that of 1973, mechanical and chemical tending treatment will be 3.17 times greater, and hand tending will be 2.22 times greater.

What Does This Mean in the Context of This Symposium?

Let's look at our projections again.

site preparation	1.8 times 1973 level
natural regeneration	1.6 times 1973 level
planting	1.5 times 1973 level
seeding	1.2 times 1973 level
other regeneration treatments	2.1 times 1973 level
mechanical and chemical tending	3.2 times 1973 level
hand tending	2.2 times 1973 level

Already difficulties are being encountered in meeting the Region's schedules. In some districts sufficient manpower has been hard to find and sometimes, even when it has been found, the quality of work has not been acceptable. The required number of tractors could not be hired this year. Equipment which some districts expected to be using is not yet available to them.

The projections I have been using were developed almost 3 years ago and were done rather hurriedly. We realize that unassisted natural regeneration may not provide what we had hoped for and that more tending than we had forecast will be necessary.

I feel that, to meet the production policy, the annual area to be regenerated will remain about the same after 1982, but the annual area requiring tending treatments will continue to increase.

Figure 4 is a graphic illustration of the proportions in which the districts' staff have projected that the working group will be treated to meet the Region's output target. This, with what you have already heard, may give you an idea of the degree to which the techniques now under development may be adapted to the Northeastern Region.

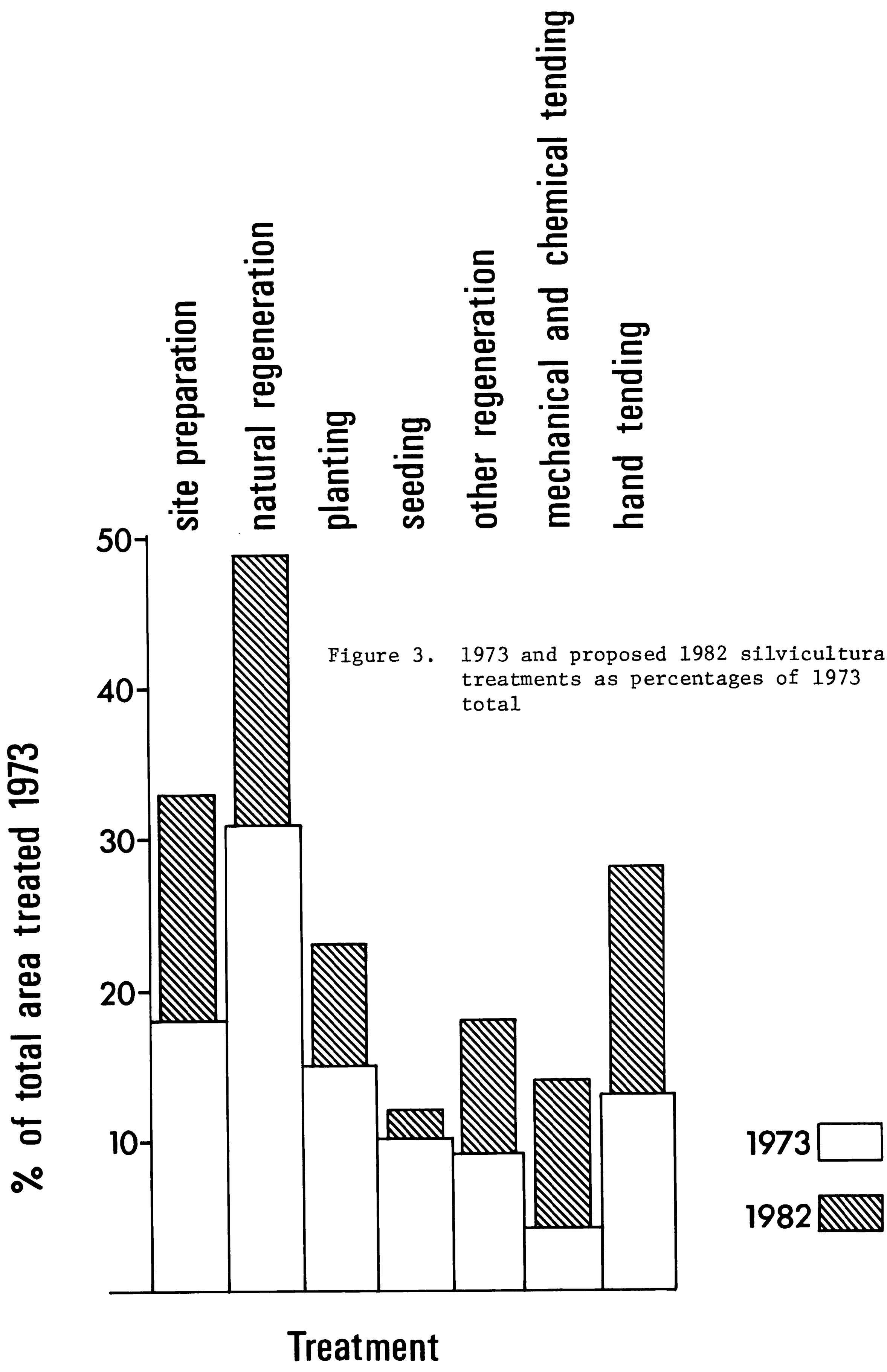

Figure 3. 1973 and proposed 1982 silvicultural treatments as percentages of 1973 total

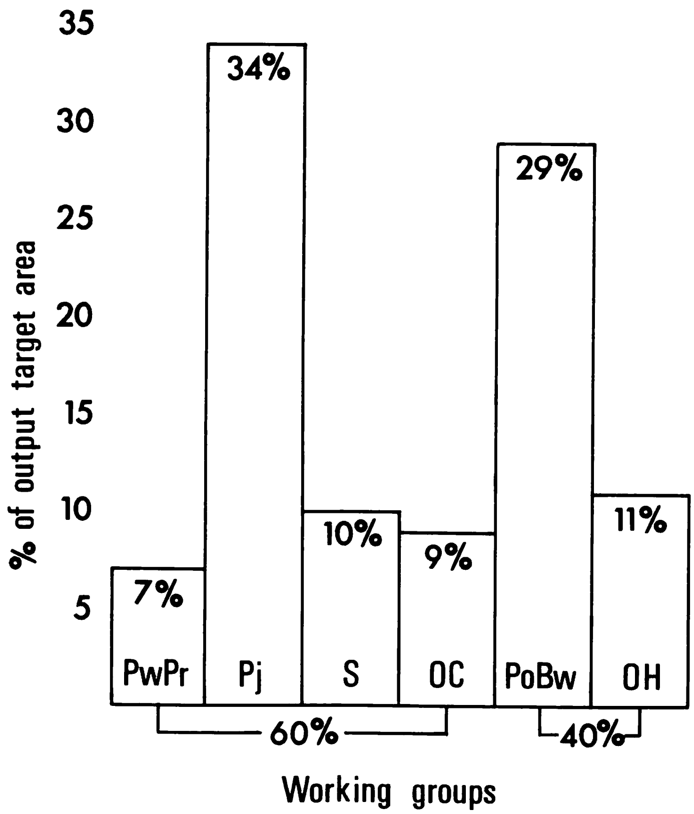

Figure 4. Proportions in which working groups will be treated to meet the Region's output target.

My prediction is that if we think and practise cutting, site preparation, planting and perhaps a little tending we will fail to reach the level of silvicultural effort required for 1982 and beyond. Even if we modify this to cutting, mechanized planting and perhaps a little tending I think we will still fail.

Consider that if the area proposed for planting in 1982 is all done by machine, if a machine can plant 500 trees per hour or per half acre, and if each machine works six 10-hour days per week over a 5-week planting season, the Northeastern Region alone will require 88 planting machines and tractors. Even if two shifts per day are worked (i.e., 16 hours per day) 55 machines will be needed.

Of course, I have suggested that all the planting be done with single-row machines and that the production be 1/2 acre per machine hour. Machines capable of better production will be developed. However, can the Northeastern Region take full advantage of them?

The nature of the forests combined with the size of harvesting operations involved makes it seem unlikely to me. In 1973, 46% of the regeneration projects carried out were less than 100 acres in size and 81% were less than 300 acres.

We in the Northeastern Region are now taking another look at our silviculture program. We must look at and for silviculture systems, not site preparation, regeneration and tending projects. We must look for silviculture systems which minimize the labor input or at least maximize its effectiveness, minimize the need for highly specialized and/or hard-to-get tractors and equipment or, again, maximize their effectiveness, and maximize the period of the year over which the individual phases of the system can be applied.

We will be looking hard at modified harvest cutting, preparation of receptive seedbeds for natural seed fall and direct seeding, preparation of planting sites, and planting, seeding and tending techniques which effectively and as efficiently as possible bring the crop trees to rotation age.

To close, I would like to reiterate that the Northeastern Region cannot only look to mechanization of the more common techniques but must also develop more efficient and, at the same time, more effective silviculture systems. Certainly, we need some new and improved tree planters, scarifiers, and planting, seeding and tending techniques. Mechanization is necessary, probably essential, to the Northeastern Region, but the treatments we apply must continue to develop. Other approaches to silviculture and other ways of using equipment already in use and under development will be undertaken.

SUMMARY

R. A. Haig
Research Manager
Canadian Forestry Service
Great Lakes Forest Research Centre
Sault Ste. Marie, Ontario

Introduction

Mechanization of silviculture is a must! The participants in this symposium viewed the problem in many different lights, and offered many different suggestions for its solution. However, there was a consensus on the central issue that effective mechanization of the major silvicultural operations must be achieved very quickly if our forests are to meet the rapidly increasing demands placed upon them. Some of the factors that point to the need for mechanization are the magnitude of the job to be done, an inadequate labor supply, high unit costs, and a short operating season.

This symposium provided a good overview of the silvicultural problem, focussing particularly on the massive regeneration program required in northern Ontario. It also presented an up-to-date report on recent progress in mechanization, and an outline of plans for the future. It is expected that this exchange of information will stimulate further development of the techniques and equipment required to mechanize silvicultural operations in Ontario.

Production of Planting Stock

A higher level of mechanization has been achieved in the production of planting stock than in most other silvicultural operations. In the nursery, tilling, seeding, mulching, fertilizing, herbicide spraying, and root pruning have all been mechanized, largely by modification of agricultural equipment. Harvesting of seedlings is one labor-intensive operation that is only partially mechanized, but satisfactory progress is being made in this area. Current efforts are concentrated on the development of a six-row belt harvester that will harvest seedlings in a manner that will permit them to be packaged at the rear of the machine. Such packages of seedlings (which have yet to be developed) are expected to be compatible with the requirements of the new Ontario Planter, and could conceivably be shipped directly to the planting site without further handling. This will place a premium on the production of uniform, good-quality stock, as there will be no counting or culling of stock in the packing shed. This in turn will call for improvements in the precision of seeding, and work on this problem is under way.

Container stock must play a part in Ontario's reforestation program, primarily to increase the length of the planting season. Research studies and operational experience have indicated that container stock should be restricted to easier, drier sites supporting light vegetation. Although such sites may not be the most productive, they are certainly the most amenable to mechanized operations. Because of the demonstrated importance of stock size, tentative minimum specifications have been set for container stock produced and planted in Ontario. Similarly, the performance objective set for container stock is that it should be equivalent to bare-root stock in survival and growth 3 years after planting. Both production and planting of container stock are amenable to mechanization, and for some systems (e.g., Japanese paperpot) loading and seeding are already mechanized. Mechanization of container planting is somewhat less urgent, because hand planting is considerably faster with containers than with bare-root stock, and this reduces the potential gain to be achieved by mechanization. Assessment of the paperpot container system is under way in northern Ontario, and if the present schedule can be maintained, a reasonably complete biological and economic evaluation should be available within about 2 years. Assuming the results of this evaluation are positive, rapid implementation of the paperpot system is expected.

Site Preparation

In northern Ontario, site preparation, for natural or artificial seeding or for planting, is the biggest silvicultural operation in terms of area, power requirements, and cost. There is a wide range of size and power in both crawler and wheel-type tractors, and there would appear to be little need to develop specialized prime movers for silvicultural purposes. Obviously, the selection of the size and type of prime mover will be governed by factors such as the size of the job, the power required, and the site conditions. Although small machines are easily transported and their operating costs are low, it is worth noting that production efficiency tends to increase with the increasing size of the prime mover.

To a limited extent, a variety of commercially available land-clearing or agricultural equipment is used for site preparation, including shearing blades, rakes, choppers and discs. However, these have not adequately met the requirements in the Boreal Forest. The urgent need for more rugged and versatile site preparation tools led to the development of devices such as the shark-fin barrels, tractor pads and anchor chains. These tools, products of the ingenuity of individual field foresters, are currently the mainstays of site-preparation operations in northern Ontario.

The heavy accumulation of slash and/or the brush conditions on many planting sites require the clearing action of a front-mounted V-blade. Although V-blades are commercially available, probably most of those in use in Ontario are manufactured or at least modified in local machine shops, to meet the specifications of individual foresters. One of the problems with these devices is that they may be limited to one size or even one make of tractor. Another limitation is that a change in site conditions (e.g., a difference in the depth of the duff layer) may also require a trip to the machine shop for modification.

A promising new entry in this field is the prototype V-blade developed in 1974 as part of the joint OMNR—CFS mechanization project. It is adaptable to a range of tractors, readily adjustable for varying site conditions, and because of the rolling drum under the scalping shoe, it can operate very effectively in the "float" position. This last feature is most desirable, as it increases the uniformity of site preparation and reduces the effort and skill required by the operator.

Another new entry in the site preparation field is the flail scarifier, of which two prototypes are being developed. The total weight and horsepower requirements of these "powered" site-preparation tools are much less than those of the more common types of nonpowered equipment such as shark-fin barrels. Thus, even though their productivity per hour might not be as great, in theory the cost per acre of site preparation with powered equipment should be less than with nonpowered equipment. The flails also have a biological advantage: they have a mixing action which creates a better and more fertile seedbed than that usually produced by the deep-plowing action of most scarifiers. The major disadvantage of powered equipment is that it is more complex and hence more prone to breakage. However, this disadvantage could be overcome by good engineering. The development of flail scarifiers or other types of powered site preparation equipment should be pursued, as it could add valuable new weapons to the forest manager's arsenal.

Because of obvious economies that would result, site preparation should be integrated with regeneration operations wherever this is feasible. Site preparation for natural seeding represents one such integration. The Bracke cultivator, the CFS row seeder and the various planting machines represent additional efforts to integrate site preparation and regeneration, and each of these will be discussed further.

Direct Seeding

For the regeneration of jack pine, direct seeding offers a low-cost alternative to planting, and the variety of seeding techniques provides even greater choice. In addition to their low cost, all seeding techniques have the advantage of being less labor-intensive than planting. In view of the critical labor situation, this advantage alone should promote the increased use of direct seeding.

In Ontario, aerial broadcast seeding on sites previously scarified by shark-fin barrels is the technique most commonly employed. It has the great advantage that site preparation can be carried out throughout most of the snow-free season, and the extensive scarified areas can be seeded very rapidly during the short favorable periods in spring or fall. A variant of this technique is broadcast seeding from a snowmobile, which employs a modification of the Brohm aerial seeding unit, and is usually carried out in late winter when snow conditions are favorable.

Operational trials have clearly shown that in broadcast seeding of jack pine, the most critical factor affecting success is the degree of mineral-soil exposure achieved by scarification. Trial results suggest that 80% stocking (by milli-acre quadrats) can be obtained one year after treatment by sowing 10,000 seeds per acre on an area with 58% mineral-soil exposure, 20,000 seeds per acre where exposure is 23%, or 30,000 seeds per acre where exposure is 15%. Assuming this relationship is confirmed by further work, the forest manager can choose either to increase the degree of site preparation and sow less seed, or vice versa, depending on the cost (and availability) of seed relative to the cost of site preparation.

Mechanized row seeding appears to have a number of potential advantages over broadcast seeding. Site preparation and sowing are carried out simultaneously, the seed is distributed more accurately in relation to the prepared seedbed, and the number of seeds sown per acre is much reduced. The increasing scale of regeneration operations makes the latter point significant. Furthermore, because of better control over the distribution and placement of seed, the resulting stands resemble plantations in terms of density and uniformity of stocking. The most obvious disadvantage of mechanized row seeding is that because it is carried out at the same time as site preparation, the operation is limited to that portion of the growing season which is favorable to seeding (perhaps one month in the spring, and another in the fall). However, even this disadvantage may be overcome by new developments in seed pelleting or encapsulating, which show promise of being able to control the time at which germination begins.

Two row-seeding devices are currently under trial in Ontario. The barrel seeder (developed by OMNR) consists of a steel cylinder with spiral fins, a cone-shaped nose, and a number of nozzles through which seed escapes as the cylinder moves along in the track of the shark-fin barrel to which it is attached by a short length of chain. This device is simple and rugged, and its performance should be adequately assessed. The CFS row seeder is patterned after one developed in Maine, and consists, basically, of a fire plow and a modified agricultural seeder. This device is attached by means of a floating hitch to a small crawler tractor with a front-mounted V-blade. The first prototype was developed and tested in 1971, and modification and testing have continued since then. The trials have been encouraging in terms of rate of treatment (about 1.5 acres per hour on jack pine cutovers) and in terms of stocking and density of regeneration. Although further improvements might be made to achieve greater precision in seed metering and to permit the sowing of smaller seed (i.e., spruce), the current prototype would appear to be adequate for jack pine. In view of the cost advantages of seeding over planting, this development should be exploited as quickly as possible.

The Bracke cultivator has some of the features of row seeders: site preparation and seeding are simultaneous, and little seed is wasted on unprepared ground. This commercially available machine is quite rugged and reliable, and it is already being employed on an operational scale in Ontario. A thorough evaluation of the performance of this machine is urgently required, as it appears to have considerable potential.

Mechanized Planting

Three of the more promising commercial planting machines have been tested quite intensively. In addition to determining the capabilities and limitations of these machines, the test program has developed standardized test procedures, and provided baseline data against which the performance of the new Ontario Planter may be compared.

One general conclusion is that all planting machines required slash and debris removal for effective operation. In these trials a front-mounted V-blade was used, and because of the volume of slash, tractors in the D-6 class were required. Uniform planting stock improved the performance of all machines, and regular servicing proved essential. The quality and cost of machine planting were generally comparable with those of hand planting plus site preparation, on "easy" to "moderately difficult" sites on which these machines are capable of operating.

Recognizing the limitations of conventional planting machines that operate on the continuous-furrow principle, the joint OMNR-CFS committee has given top priority to the development of a totally new type of planting machine with an intermittent or spot planting action. Work got under way in 1970, and the first prototype, the Ontario Mark I Planting Machine, was produced in September, 1971. Subsequent models, the Mark II and Mark III, were completed in the spring of 1972 and the spring of 1974, respectively.

Testing in the 1974 season indicated that the basic planting action of the Mark III is satisfactory. In the summer of 1975 three units of the Mark III will undergo intensive testing in northern Ontario. When the test results are evaluated (and the necessary modifications made) it is expected that an operationally reliable, single-row semi-automatic planting machine will be available.

Although such a machine could be produced commercially and employed on an operational scale, it would not meet all the initial specifications. These call for automatic operation, and the planting of more than one row of seedlings at a time. Other desirable features include the capability of planting container stock as well as bare-root stock, with minor modification of the same basic machine. Work on these phases is in the planning stage, and is expected to move forward quickly when the basic planting unit is adequately proven.

Biological Considerations

Notwithstanding the urgent need to mechanize silvicultural operations, it must be remembered that basic biological problems remain the same with or without mechanization. Soils and the gene pool are the basic forest resources. To achieve maximum growth potential from a particular area, it will be necessary to establish the right provenance of the right species, and then manage it intensively throughout the complete rotation. At present we must admit that we don't know the full biological potential of such a widely planted species as white spruce, but indications are that it is much greater than that recorded in the normal yield tables. Stock quality is of paramount importance, and present grading rules based on morphological features are not adequate. A means of physiological grading is required, and we must be able to determine the physiological state of stock right up to the time of planting (i.e., as affected by storage and handling). The ideal physiological state for planting is one in which readiness to root rapidly is combined with delayed flushing.

The mechanization program includes studies of those factors (such as tilling, fertilization, and herbicide application) that could conceivably be incorporated into a mechanized planting system. Possibilities for extension of the planting season (through the use of cold-stored stock) are also being investigated. The rationale is that the feasibility of planting with expensive machines will be enhanced if a larger proportion of the frost-free season can be utilized. Preliminary indications from these studies are that root regeneration potential is extremely variable but decreases sharply with length of storage, and that white spruce shows better capability for cold storage than black spruce and jack pine. Other indications are that the performance of machine-planted trees is superior to that of hand-planted trees (largely because of better packing) and that tilling has a greater effect on survival than does site. So far, fertilization of new plantations has not shown promising results, and herbicides have not been necessary because of the scalping action of the V-blades employed in conjunction with all machine plantings carried out to date.

On the basis of available information it is possible to suggest an idealized scheme for planting throughout the full frost-free season. Such a scheme would begin in the early spring with cold-stored bare-root stock, progress to fresh-lifted bare-root stock later in the spring, then to containers in early summer, then back to fresh-lifted bare-root stock in late summer and early fall.

Economic Implications

Economic theory states that production of any given item is attained through the combination of three basic factors: land, labor and capital, and that a given level of production may be attained from more than one combination of these factors. Silvicultural operations, such as tree planting, are no exception to this theory. Mechanization of tree planting substitutes capital for labor, in the hope of increasing man-day productivity and reducing cost per acre. Other potential benefits are an increase in the stability of the work force, and a resulting improvement in the quality of work. However, it will not be easy to realize these benefits, and the greater the departure from existing practices the more difficult (and expensive) the change will be. Another hazard to be borne in mind is that poor implementation of the new (i.e., mechanized) system can more than offset the potential benefits.

In order to achieve cost savings, machines must be worked close to their capacity. This means that advance planning must be effective to ensure that the right machines are in the right place at the right time. It also means that a well-trained and well-equipped maintenance staff must become part of the work force. It should be recognized that the greater the skill required of such a silvicultural work force the higher will be the pay demanded.

Managers should begin to treat labor as the scarce commodity that it is. Such treatment could produce substantial benefits even with existing labor-intensive methods, and will be essential to the efficient implementation of mechanized methods.

Because of the high capital investment in machines, it will be necessary to expand the operating season and make better use of available time. Multiple-shift operations would appear to be one partial solution to this problem.

In summary, we should not expect any miracles from mechanization, particularly in terms of a reduction in overall costs. The potential benefits are realizable, but to obtain them will require clearheaded planning, and optimization of the total system from seed collection through to harvesting.

Mechanized Thinning

Although not considered such a high-priority problem as reforestation, the mechanization of both precommercial and commercial thinning merits attention. Reforestation can do little to alleviate a fiber shortage that may occur as early as the year 2000, because all stands that could be harvested by that date must already be established. The merchantable growth rate of some of these stands could be enhanced by thinning, but current labor rates suggest that thinning will need to be mechanized before it is widely applied.

For precommercial thinning a variety of machines are available for mowing or crushing swathes in dense young stands in the 8-20 ft height class. These machines, used in conjunction with hand thinning or power-saw thinning of the residual strips, have reduced the cost of precommercial thinning in the very dense stands that occur typically in the Maritimes. However, this type of treatment has had limited application in Ontario, as extensive stands of such high density are not common.

Commercial thinning in semi-mature stands, either natural or in plantations, has considerable potential, but to reduce the difficulty of controlling the operation, and the cost of thinning itself, cutting in strips or rows seems almost essential. A number of small feller-bunchers are commercially available, and these appear well suited to this type of application. Small cable yarders have also shown promise for commercial thinning in semi-mature stands in British Columbia.

As the present surplus of mature and over-mature stands is consumed, harvesting of younger stands will be necessary. In this event, mechanization of commercial thinning may be an economically viable operation that could alleviate some potentially serious fiber shortages.

Regional Perspectives

Spokesmen for all four northern regions indicated that there was difficulty in reaching current regeneration objectives, and that the very much higher production targets to be reached by 1982 represent a most formidable challenge. They also agree that although mechanization alone will not solve the problem, it will be an essential part of the solution.

Site preparation is generally conceded to be the biggest problem. By 1982 the percentage of the annual cutover area requiring treatment is expected to rise from the current level of about 25% to 50%. For the Northwestern Region alone this means scarification of about 54,000 acres per year, at an estimated cost in excess of $1 million. Cost is not the only problem; a shortage of power units is an added difficulty. Proven techniques are also lacking for some difficult site types such as black spruce peatlands and rough upland tills. Current trials with high-flotation tractors on the former and large skidders on the latter should be closely watched to determine whether they represent a breakthrough.

Offering longer term contracts and calling tenders earlier in the year might make more tractors available, and greater effort should be made to involve the forest industry in the regeneration program.

Implementation of the latter suggestion would take advantage of the expertise and maintenance facilities of the forest industry, as well as their equipment and operators. One regional spokesman also suggested the need to relate the degree of scarification to the subsequent success of regeneration (a relationship that is being investigated in the direct seeding trials noted earlier). Establishment of this relationship would permit managers to set clear specifications for site preparation, and this would facilitate the contracting process.

At present, machine planting plays little part in the reforestation program of any of the northern regions. Estimates of the potential for mechanized planting vary widely, from 12% of the total cutover in the Northwestern Region to 60% in the North Central Region. However, it is agreed that the higher percentages can be achieved only by a new type of planting machine capable of operating efficiently under a wide range of conditions, including heavy slash, stumps, and rocks.

A need for precommercial thinning is noted in at least one region, and it would appear that little will be done unless the operation can be mechanized.

The scale of the artificial regeneration program requires large quantitities of seed, and these are increasingly difficult to obtain. Mechanization of cone collection is seen as a partial solution, and a prototype machine has been developed which removes jack pine cones from slash. A similar machine for harvesting black spruce cones appears both feasible and necessary.

The very large number of power units that would be required for full mechanization of regeneration activities suggests that other approaches must be explored. In the Northeastern Region alone it is estimated that 55 to 88 tractors would be necessary to meet the 1982 regeneration objectives. The obvious conclusion is that other silvicultural techniques must be employed to the fullest possible extent. These will include modified cutting, and preparation of seedbeds for natural or artificial seeding.

In short, the general consensus is that mechanization of silvicultural operations must be developed and put into practice as quickly as possible. However, the forest manager cannot expect to rely solely on mechanization, but must employ all his silvicultural skill in the selection and application of the most appropriate technique for each situation.

Conclusions

1. New forest production targets call for a major increase in the scale of silvicultural operations conducted in Ontario. Using current labor-intensive methods it will not be possible to carry out the

silvicultural program on the scale required. Mechanization of silvicultural operations represents an indispensable element of the strategy and tactics to be employed in meeting Ontario's forest production targets.

2. Large numbers of prime movers (both crawler tractors and wheeled skidders) are required to implement the regeneration program. Although the development of new types of prime movers is not required, new organizational, administrative, and financial arrangements will be necessary to ensure that the required units are available and that they are worked to their full capacity.

3. Necessity has led to the invention of a number of simple and rugged site preparation devices (such as shark-fin drums) but the power requirements of this type of equipment are high, and for both biological and economic reasons there is a need to develop powered site preparation tools such as flail scarifiers.

4. Direct seeding is a low-cost alternative to planting, it is not labor-intensive and, for jack pine at least, the probability of success seems more than adequate to warrant increasing application. Recently, new techniques and equipment have improved the precision of seed distribution, reduced the quantity of seed required, and raised the level of success obtained. These new developments should be exploited promptly.

5. The capabilities and limitations of conventional planting machines in the Boreal Forest of Ontario appear to have been established. On cutover or brushy sites these machines require a front-mounted V-blade and they appear to be limited to use on deep, boulder-free soils of sand or clay texture. On such sites their planting quality has been found superior to hand planting, at a cost equivalent to the cost of hand planting plus site preparation.

6. Uniform stock of high genetic potential must be available at each planting site in the proper physiological condition for planting. This truism is particularly significant in view of the large scale and the high costs of mechanized planting operations.

7. Satisfactory progress has been made on the number one priority item in Ontario's mechanization program, the development of a new planting machine operating on the spot-planting principle. Currently, the major objective is to test the prototype (Mark III), modify it as necessary, and put this machine into operational use. Meanwhile, work should proceed on the development of a machine with multiple planting heads, automatic feeding of planting stock, and the ability to operate on a wide range of sites.

8. Assuming that the current trials of the Japanese paperpot show it to be a biologically and economically sound approach to container production and planting in Ontario, the system should be implemented as rapidly as possible. The development of production facilities will be the first requirement, but modifications of the Ontario Planter should also be made to permit machine planting of paperpots.

9. Mechanized silviculture offers a number of potential benefits, but to capture these benefits requires a major departure from existing practices, and this must be done very carefully. Obviously it will be necessary to develop a systems approach to silviculture, from seed collection through to harvest, rotation through rotation. Only in this way can we ensure that optimization of each phase of the system is compatible with optimization of the total system.

APPENDIX

Basic conversion factors for all measurements used in the text of these Proceedings are given below:

1 inch = 2.54 centimeters

1 foot = 30.48 centimeters

1 chain = 20.12 meters

1 acre = 0.40 hectares

1 milacre = 4.05 square meters

1 pound = 0.45 kilograms

1 short ton = 0.91 metric tons

1 cunit = 2.83 cubic meters

1 cord = 3.62 cubic meters
(stacked or piled wood)

t °Fahrenheit = 5(t − 32)/9° Celsius