PROCEEDINGS OF A WORKSHOP ON CONTAINER PLANTING IN CANADA

DIRECTORATE OF PROGRAM COORDINATION
OTTAWA, ONTARIO
INFORMATION REPORT DPC-X-2

JANUARY, 1972

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Forestry Service / Service des Forêts

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EDITED BY

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DEPARTMENT OF THE ENVIRONMENT
CANADIAN FORESTRY SERVICE
JANUARY, 1972

FOREWORD

Canadian forest land managers are currently faced with rapidly expanding demands for planting stock arising from increasing acreages of cut-over lands and with rapidly increasing costs of producing and planting conventional bare-root nursery stock. Because of these trends considerable interest has been shown during the last decade in the development of mechanized container planting systems which have the potential to increase planting productivity, to reduce costs, and to provide the technology required to more completely mechanize the tree planting operation. In 1968 the Forestry Branch, the predecessor of the Canadian Forestry Service, held a container planting workshop in British Columbia to review the then current programs and to discuss container planting research. Between September 28-30, 1971, the Canadian Forestry Service of the Department of the Environment sponsored a second workshop on container planting at the Kananaskis Forest Experiment Station in Alberta. The workshop was held to review current operational and research-development programs in Canada, to discuss various problems associated with producing and planting container-grown stock, and to identify further research and development needs. In addition to Canadian Forestry Service personnel, the workshop was attended by representatives of all provinces from Quebec westwards, the Alberta Research Council, Saskatchewan Pulpwood Ltd., and Laval University.

Papers presented at the workshop are included in this volume. In addition, and to provide for somewhat broader coverage, two additional papers are included — one dealing with the container planting program in Nova Scotia by D. Levy, and the other describing the program of North Western Pulp and Power Limited, by I.S. Ferdinand.

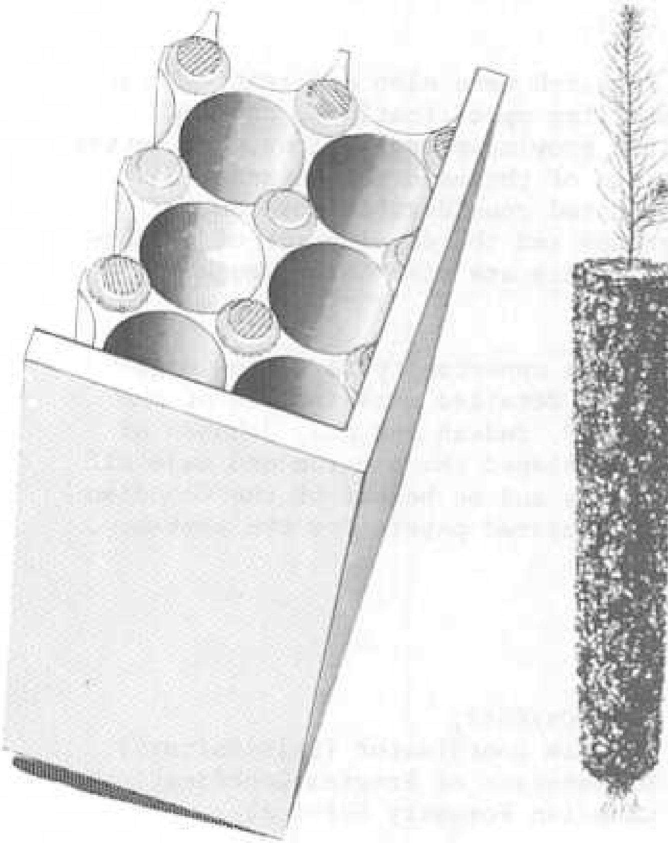
These papers indicate that the evolution of container planting systems in Canada is proceeding rapidly; it is also apparent that a number of different systems are currently being tested or developed across the country. However, in spite of these system differences there are certain commonalities among current programs. Firstly, it is now apparent that results of field plantings of seedlings grown in rigid containers of small diameters, as for example the 9/16-inch Ontario tube, the 3/4-inch Ontario-type tube and Walters' bullet, have not always yielded satisfactory survival and growth and in several instances bare-root stock has outperformed the container stock. Accordingly, there are several current trends: the use of larger containers (minimum rooting volume of 2.5 cubic inches or a container approximately 1 inch in diameter x 3 inches in length) for growing seedlings; the development of systems that involve the removal of the container prior to planting, such as the BC/CFS Styroblock, the Spencer-Lemaire fold-up plug tray, the R.C.A. "peat sausage" and the Swedish Multipot; and the use of biodegradable materials such as the Japanese paperpots. Techniques for rearing seedlings in containers are also undergoing change. These include a trend towards lengthening the growing period in order to obtain larger seedlings, the overwintering of spruce, the curtailment of late summer planting and, in the light of current knowledge, the improvement of growing media, fertilization treatments, root pruning techniques, seed selection and light, temperature and moisture conditions during the rearing stage.

Certain areas requiring further research were also apparent. These include the determination of optimum seedling specifications, rooting volumes, shoot/root ratios, more specific growing prescriptions, and better hardening off procedures. The realization of the need to integrate both seedling production and planting has prompted considerable work on the mechanization of container planting systems and the development of production and tree planting machines. Improvements are also being sought in packaging and transportation systems.

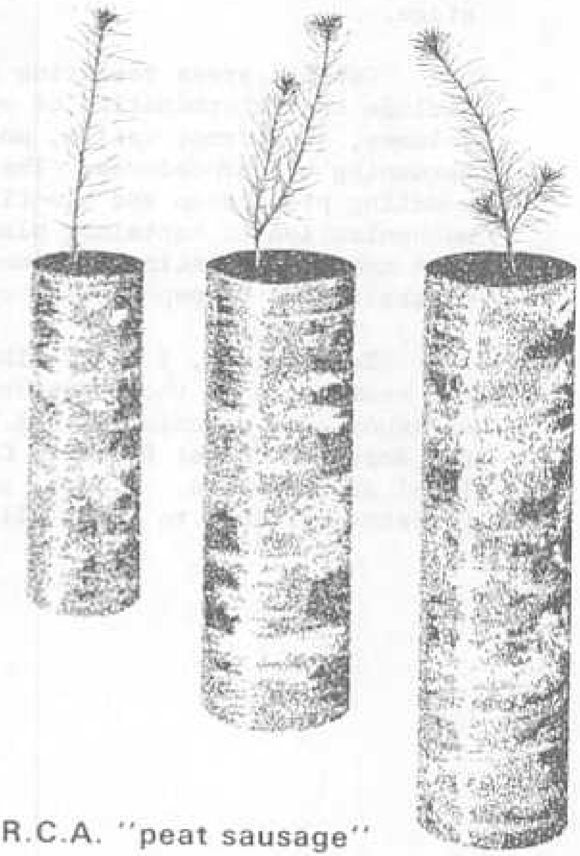
To conclude, I would like to take this opportunity to acknowledge the assistance of those responsible for the detailed organization of the workshop, and especially to R.F. Ackerman, F. Endean and H.J. Johnson of the Northern Forest Research Centre who developed the program and made all local arrangements. I wish, both personally and on behalf of the Canadian Forestry Service, to thank all those who prepared papers for the workshop.

J.H. Cayford,
Program Coordinator (Silviculture),
Directorate of Program Coordination,
Canadian Forestry Service.

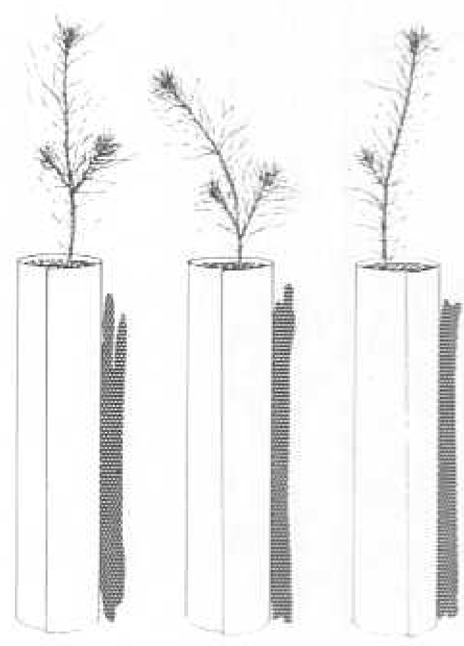
Containers currently in common use in Canada



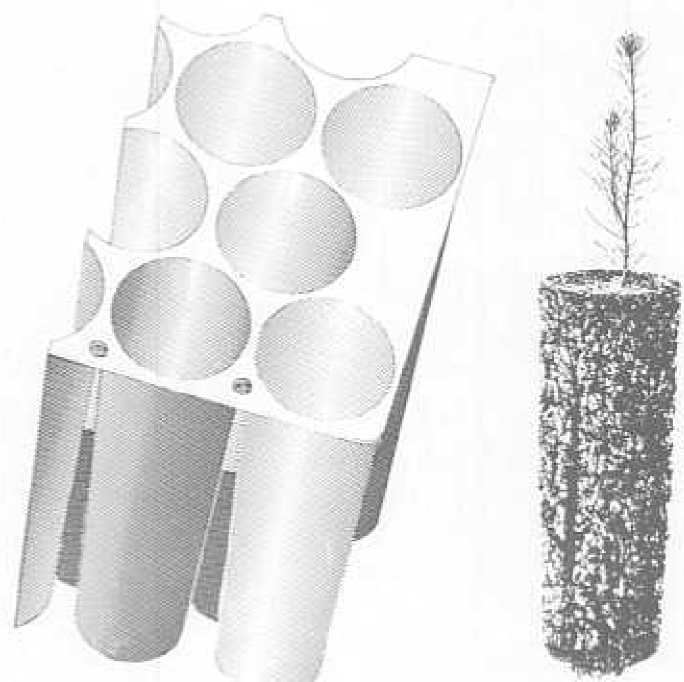
BC/CFS Styroblock



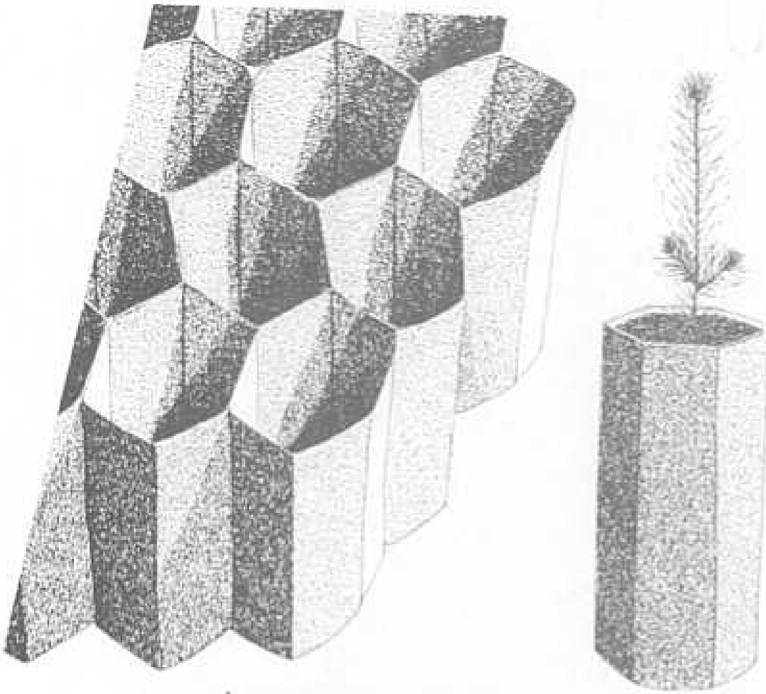
R.C.A. "peat sausage"



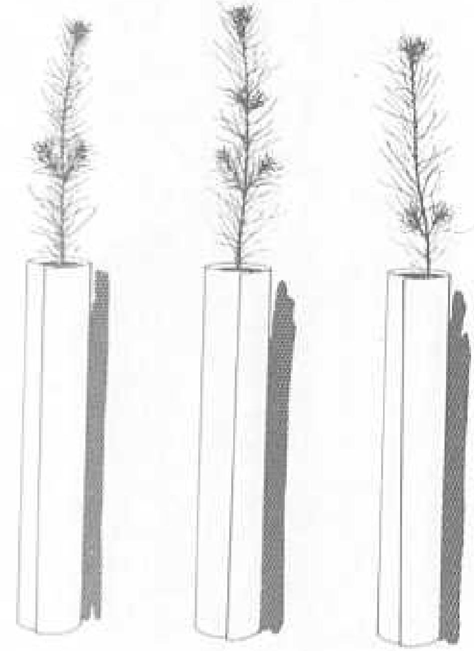
Ontario-type tube



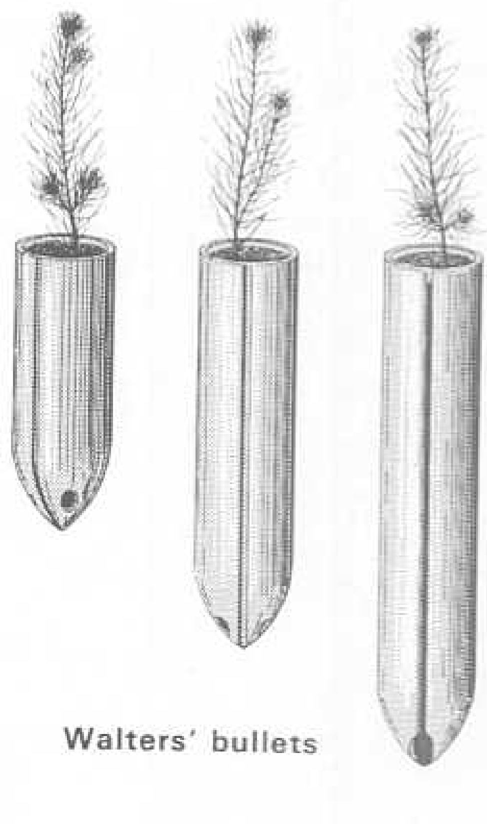
Swedish Multipot



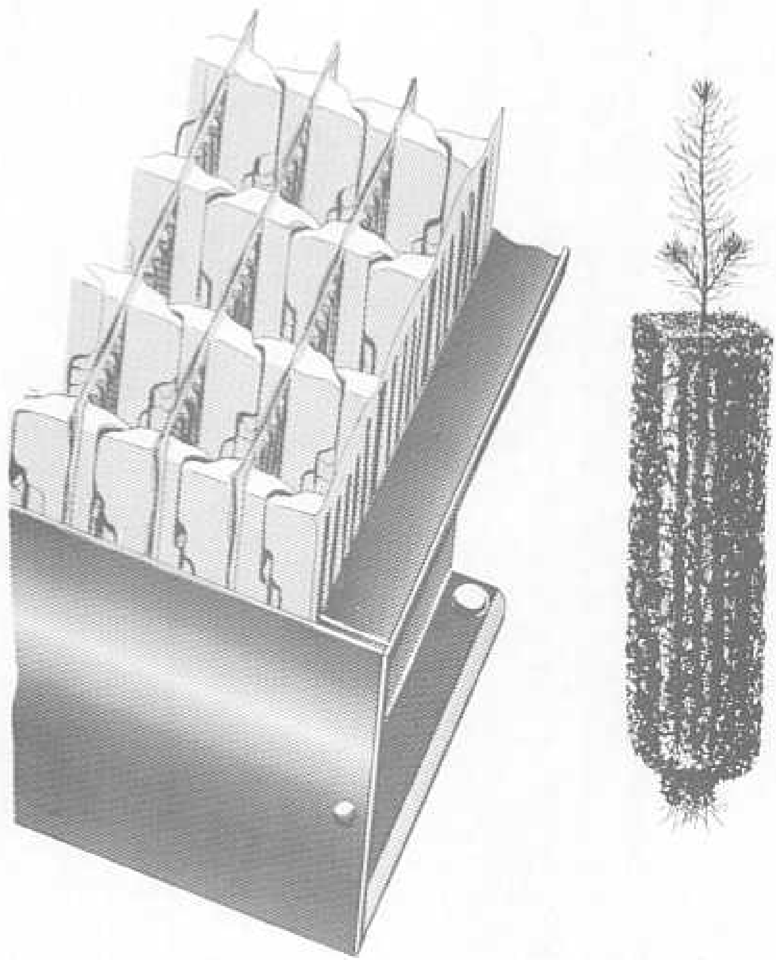
Japanese paperpots



Ontario tube



Walters' bullets



Spencer-Lemaire fold-up plug tray

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IN BRITISH COLUMBIA

N.E. Sjoberg[1]

INTRODUCTION

The production of 75 million bare-root seedlings by 1975 is the target set for British Columbia forest nurseries. This objective will be met, if not exceeded, by that time. The manpower required to plant these seedlings can be conservatively estimated at 100,000 man-days, based on a season of approximately three months and on current planting methods. Will there be a sufficient quantity of qualified labour to insure a high degree of plantation success? We are not overly optimistic.

The Reforestation Division of the BC Forest Service began examining new planting techniques in 1968 on a cooperative basis with the Canadian Forestry Service. The object of this cooperation was to reduce manpower requirements in the planting process and to improve the field performance of planted seedlings. The program can be described in terms of the following phases:

- Phase I - exploratory research and testing to demonstrate the potential of new systems and to define objectives for refined experimentation and development.
- Phase II - experimentation and development with pilot production of the most promising system.
- Phase III - production with continued experimentation and development.

In general, the Canadian Forestry Service is responsible for basic research, development and technical direction of the program, whereas the BC Forest Service is concerned with such operational aspects as nursery construction and production, plus some mutually agreed upon supplementary test work.

PRODUCTION OF CONTAINER SEEDLINGS

Container seedlings have been produced in British Columbia by the Forest Service (Table 1), by the Canadian Forestry Service at Victoria, by the University of BC Research Forest at Haney, and by Pelton Reforestation Co. at Haney.

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[1]Reforestation Division, British Columbia Forest Service, Victoria, British Columbia.

Table 1. Container seedling production at Duncan and Surrey nurseries by container type (1968-1971)

Year	Nursery	Number of containers by type and nursery design		
		Walters' bullet in sub-irrigation tank unit	Walters' bullet in overhead irrigation unit	BC/CFS Styro-block in over-head irrigation unit
1968	Duncan	100,000		
1969	Duncan	200,000		
1970	Duncan	200,000		800,000
1971	Duncan	230,000	280,000	420,000
1971	Surrey		470,000	6,000,000

Seedlings grown during 1968 and 1969 by the BC Forest Service (Table 1) were primarily for demonstration purposes and field testing. Pilot production for reforestation outplanting by companies and the Provincial Government began in 1970 at the Duncan Forest Nursery. This production was expanded during 1971 with the development of the Surrey Container Nursery.

NURSERY METHODS

The long growing season in the coastal region of British Columbia permits the production of container seedlings outdoors in a minimum-cost facility in contrast to greenhouse production that is necessary elsewhere. Methods are designed for early seeding, rapid germination, and controlled nutrition to provide plantable quality seedlings in one growing season.

Nursery Design

The Surrey Container Nursery covers 128,000 square feet or approximately 2.9 acres not including a 20 foot perimeter access road. Its potential capacity is approximately 8.1 million seedlings grown in Styroblocks on pallets at ground level. Asphalt, gravel and native soil ground surfaces are being tested.

Saran shade cloth covers five of the eight units for optimum growth and for protection from birds, wind, frost and weed seed. Three levels of actual shade are applied - 46% for hemlock and spruce, 30% for Douglas-fir, and 20% for pine. The cloth is supported by link fence post and rail components, and two gauges of galvanized wire.

The irrigation system is semi-permanent with a buried permanent 4-inch PVC main line and portable one-inch PVC lateral lines. Rain Bird sprinkler heads spaced 20 feet by 20 feet provide water from six directions for uniform

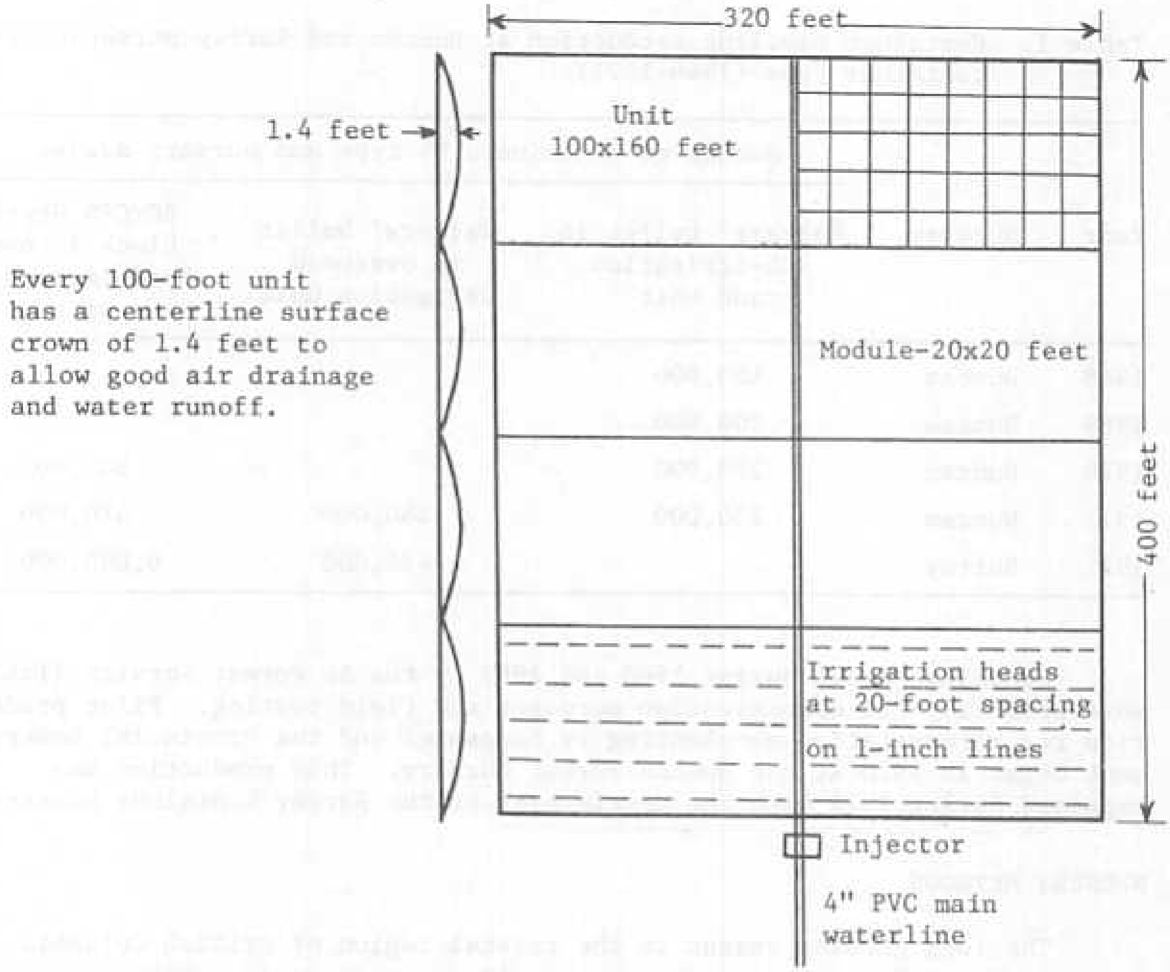

Figure 1. Surrey nursery section.

application. The output per head is 0.76 US gpm at 45 psi. Fertilizer is injected into the system by a Fert-O-Ject 500 on a normal 2-inch line installation. It is capable of fertilizing approximately 1.5 million seedlings at one time. The irrigation system provides total area frost protection at recommended precipitation rates when alternate lateral lines are closed. The quantity of water, fertilizer injection schedule, and frost protection requirements were the main factors that determined the nursery size (Figure 1).

Soil Medium and Mixing

The soil medium consists of three parts commercial fine peat moss to one part vermiculite. Dolomite lime is added (7.5 - 10.0 lb. per cu yd) to adjust acidity to the desired pH. A modified manure spreader coupled with a silage blower was used in 1971 to mix the soil. One man was able to mix 20 yards per day with this equipment.

Loading

A mechanical box dropping vertically on cams was used for impact loading of two Styroblocks at one time. The desired compaction was obtained by operator experience. A maximum production of 100,000 cavities per man-day can be obtained with this machine.

Seed Treatment and Seeding

Seed sown in 1971 was selected on the basis of weight and stratified by standard wet and cold treatment. Light stratification was not employed. Final cleaning prior to seeding was done with a Dakota blower to improve seeding efficiency.

The seeding machine was designed by the Department of Agricultural Engineering at the University of British Columbia. Its principle is one of vacuum pickup and air ejection. A revolving drum is geared to a feeding conveyor for continuous operation at a rate of 35,000 cavities per hour. This rate was not achieved due to seed quality and cleanliness.

About half an inch of granite grit was applied after sowing to improve the conditions for germination, to prevent the germinants from being displaced, to inhibit the growth of moss, and to assist penetration by the radicle.

Germination

Douglas-fir, because of its relatively fast growth rate was seeded first and placed outside in the nursery to germinate. All other species were pregerminated in a germination room having a capacity of 1.4 million cavities. The average germination period outside was five weeks, whereas in the germinator, it was five days.

Heat was supplied to the germinator by a Modine propane-fired unit which continuously circulates air and moisture through polyethylene distribution tubes, thus preventing air stratification. High humidity was maintained by three misting lines with TEE-Jet nozzles. Very even germination rates were attained with this system.

Stock Maintenance

Stock maintenance during the growing season included fertilizing, water cooling, weeding, and clipping.

Fertilizer application and rate varied with the species treated and the amount of natural precipitation. In general, high nitrogen (28-14-14) was applied two or three times a week throughout the growing season.

Water cooling was necessary during the hot weather in August.

Clipping of excess seedlings in each cavity commenced as soon as dominance was indicated.

A small crew was required almost all summer to keep down weeds.

Nursery Monitoring

Monitoring procedures included: costing and job time studies; soil and air temperature measurements with bridge meters and thermographs; soil moisture measurements by block weight; and random growth measurements. All data collected are to be analysed this coming winter.

FIELD TESTING

Since 1968, the BC Forest Service has outplanted approximately 150,000 containerized seedlings in test plots to assess survival and growth rates of various types of stock. Preliminary results indicate that good quality container seedlings have a significant survival and initial growth advantage over conventional bare-root seedlings.

PLANS FOR 1972

Further expansion of container seedling production is not planned for 1972. Evaluation of present methods and further test and development work is considered necessary.

The feasibility of growing container stock in the interior of the province rather than growing it at the coast and transporting it to the interior is to be examined. Pilot nurseries have been established at three locations — Vernon, Prince George, and Telkwa. Each nursery contains three levels of environment

1) controlled greenhouses;
2) semi-controlled structure with plastic or shade cover as required; and
3) uncontrolled, open environment treatments at each pilot nursery will be compared to replications at the Surrey Nursery.

In conjunction with interior nursery testing, 48 field test plots have been established to compare coast grown stock moved direct to interior British Columbia test sites versus stock acclimatized for varying periods in the interior prior to planting.

The possibility of cold storing repackaged container stock to allow handling flexibility is to be assessed. If container stock can be extracted from its container, repackaged and put into cold storage at the time of maximum hardiness, the nursery area will thus be cleared, permitting early spring sowing. Field performance may also be improved.

CONCLUSION

Technology of a container system is advancing rapidly in British Columbia. Large-scale production with confidence will be a reality in the near future, provided the basic research, testing, and development work is continued at an accelerated rate.

CONTAINER PLANTING PROGRAM

AT THE PACIFIC FOREST RESEARCH CENTRE

J.M. Kinghorn[1]

The container planting research and development program of the Pacific Forest Research Centre may be divided into 3 distinct phases[2], each requiring differing kinds and quantities of resource inputs (Fig. 1). Duration of each phase depends on technical progress and user acceptance.

Phase I, which began in 1967, consisted of demonstrating the container planting technique, testing container nursery and planting methods, and developing container methods with the potential of higher degrees of biological success and user acceptability. In order to field test container seedlings, large numbers of plants have had to be grown using combinations of the best presently known, yet practical, cultural methods. Problems have been solved on an *ad hoc* basis as encountered. Although appraisal of test plantations will be continued for several years, the initial objective of demonstrating the viability of containerization has been reached. Phase I has required the efforts of several generalists covering all phases of containerized growing and planting. Nature and objectives of the program has precluded the necessity of, or opportunity for, in-depth research.

With the British Columbia Forest Service now seriously embarking upon operational production of container stock, the Canadian Forestry Service program is being adjusted to ensure that containerized technology is applied in the most effective manner. Whereas Phase I may be described as a demonstration and rudimentary development program, Phase II should be a development and service venture, requiring coordination by generalists of the expertise of specialists in various fields to solve production problems as they arise and, through in-depth research, devising improved prescriptions for growing and planting container stock. The effort should be comprehensive and intensive to ensure that Provincial nurserymen and planters continue to apply the best up-to-date techniques, and that production methods continue to evolve until the principal advantages of containerization are fully exploited.

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[1]Canadian Forestry Service, Pacific Forest Research Centre, Victoria, British Columbia.

[2]All phases of the program have and will be undertaken in close cooperation with the British Columbia Forest Service. The attached schematic activity diagram (Fig. 1) displays past, current, and forecast responsibilities of the British Columbia Forest and Canadian Forestry Services and their interrelationships.

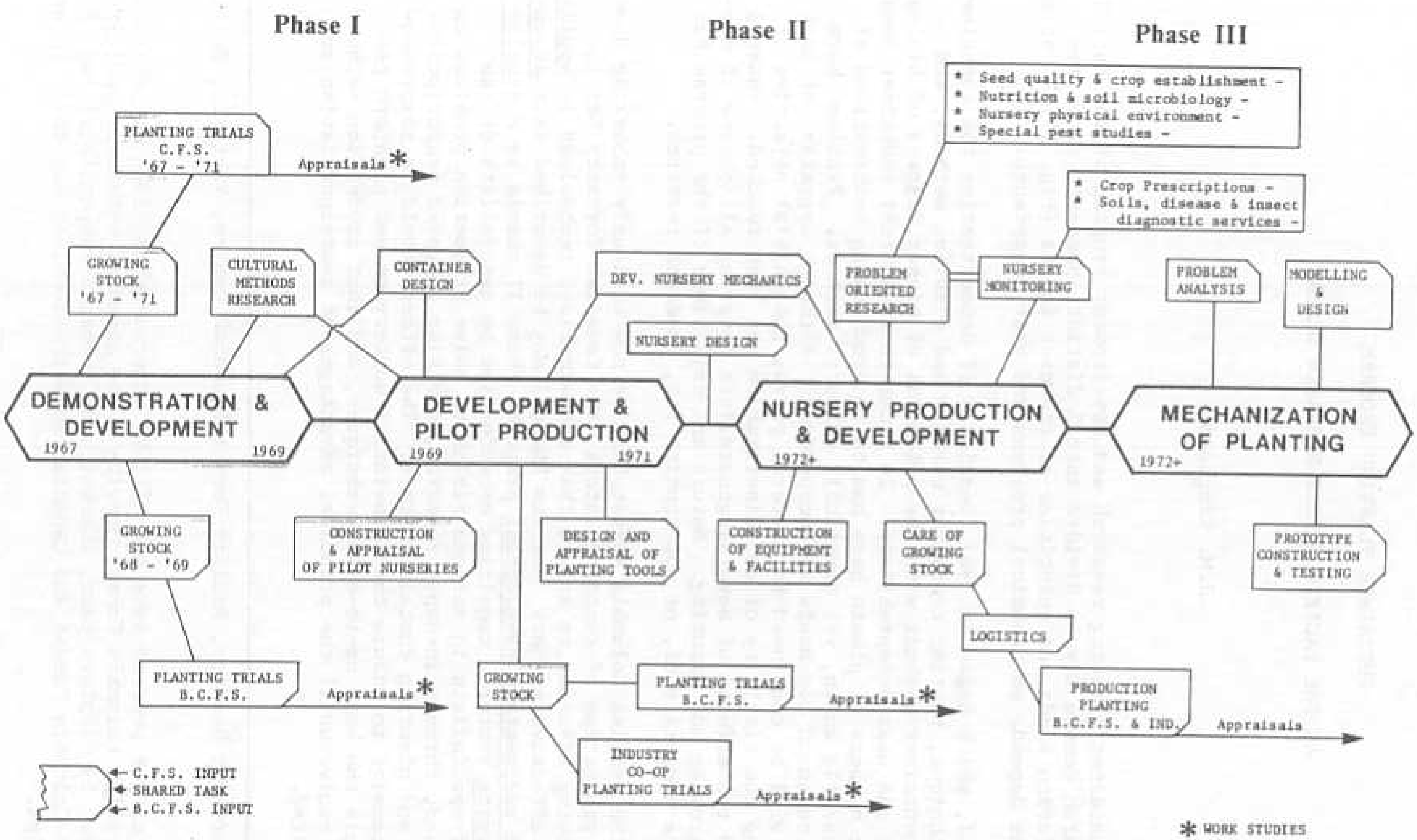

Figure 1. Schematic illustration of the cooperative container planting research and development program of the Pacific Forest Research Centre and the British Columbia Forest Service.

At the outset, the objective was to demonstrate a container method that showed the greatest potential for maximizing mechanization of the planting process. Walters' bullet container-system was selected as the approach most likely to fulfil this objective. It soon became evident that the bullet system, whilst yielding very significant gains in planting productivity, was unfavorably influencing seedling survival under certain field conditions. Bullet container trials were continued, but simultaneously an alternative method was investigated. Seedlings grown in bullets were removed immediately before planting. This modified ball planting approach has been described as plug planting. The firm and shaped root-plug retains a reasonably high planting productivity potential without the root constricting characteristic of most containers. A container especially designed for growing plug seedlings was manufactured of foamed polystyrene and named the BC/CFS Styroblock[3]. Although the plugs grown in Styroblocks may not satisfy the requirements of mechanical handling, they will be quite adequate for demonstrating a biologically acceptable system, and for developing reliable production nursery methods. Later, as mechanical considerations are given higher priority (Phase III), a skeletal and/or decomposable bullet-like container will probably be devised for assisting mechanical handling and planting.

During the first two phases of the program, several nursery designs have been examined on a pilot scale. Relatively simple shadehouses have been tested, and appear adequate for growing seedlings in the mild coastal climate. Greenhouse schedules have also been examined. During 1971, small greenhouses have been built by the BC Forest Service at three locations in the interior Forest Districts of the Province. Type and location of future production nurseries will be based on experience gained in these test units during the next 2 or 3 years.

Development of nursery equipment is being undertaken by the Canadian Forestry Service through provision of research contract funds. It is anticipated that this support program will accelerate as biological studies define mechanical requirements of the system. Phase III, the mechanical planting objective, if not solved elsewhere, will probably be supported on a similar contractual basis.

Throughout the program, economic analysis of several reforestation systems have been undertaken to determine the cost effectiveness of innovations, and to provide guidance for further development work.

At this juncture, Pacific Forest Research Centre staff are preparing progress reports detailing much of the work undertaken during Phase I. Two reports have been issued and another two are approaching completion.

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[3]Parenthetically, it is interesting to note that the Styroblock method was developed almost simultaneously with, but quite independently of two other systems, viz. the Multipot system designed for reforestation in Sweden, and Todd's Speedling system developed for growing transplants of agricultural crops in Florida. The concept of all three methods is identical; only cavity sizes and shapes differ.

CONTAINER PLANTING PROGRAM

IN ALBERTA

L. Glade[1]

INTRODUCTION

This paper describes the present container planting program in Alberta, its relationship to the total reforestation program and some current economic considerations. Recent improvements in production techniques are discussed in relation to the current container planting program and potential effects on future developments indicated. Significant research by the Canadian Forestry Service and the Research Council of Alberta has helped to bring the container planting program to its present level of development. Additional research will be required if further improvements in techniques are to be achieved; foreseeable research needs are briefly outlined. The Alberta Forest Service is prepared to cooperate in all research necessary to the advancement of the program.

CURRENT REFORESTATION PROGRAM

Current planting stock requirements range from 7 million seedlings (to plant 25% of the areas harvested annually) to 70 million seedlings (to plant 25% of the area harvested, burned, lost to exploitation clearing, and potentially productive land known to be unstocked). The restocking of potentially productive land alone would require a 20-year reforestation program. These figures are based on a planting density of 500 seedlings per acre. Container seedlings would necessarily play a large part in fulfilling any part or all of these requirements.

In terms of planting stock the present program consists of approximately 5 million seedlings; the container portion of this total is 1.5 million seedlings. Currently there are four container types in use: R.C.A. "peat sausage", 0.3 million; BC/CFS Styroblock "plugs", 0.5 million; Spencer-Lemaire "plugs", 0.5 million and Japanese paperpots, 0.2 million.

As the end of the time period (7-years) allowed for natural regeneration of cut-overs under Alberta's Timber Quota System approaches an increase in planting stock requirements is anticipated. There is little doubt that an increase in both conventional and container seedlings will be necessary to meet the needs. However, due to long term planning requirements for conventional 3-0 stock, container seedlings may be better suited to satisfy the immediate reforestation needs of areas cut-over under the Timber Quota

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[1]Alberta Forest Service, Department of Lands and Forests, Edmonton, Alberta.

System. The ratio of conventional to container seedlings should be determined by cost and, seedling survival and growth. To date, operational-scale plantings of conventional seedlings have had the edge over container (principally the Ontario-type 3/4-inch tube) planted seedlings in all respects, especially survival and growth. Early results with test plantings of the more recently developed containers - 1-inch R.C.A. sausage, Styro-plugs, Spencer-Lemaire plugs and Japanese paperpots - indicate that survival and growth will equal conventional planting stock.

ECONOMIC CONSIDERATIONS

Economic considerations dictate that growing and planting 5 million seedlings annually is the maximum production possible without upsetting the balance with scarification, seed procurement, stand improvement, etc. This situation coupled with the increase in size of the container from 3/4 inch to 1 inch has magnified the production problems even more. The larger containers increase the growing area requirements by at least 33%. For example; a tray in 1968 held 210, 9/16-inch Ontario tubes. The same tray holds only 94, 1-inch R.C.A. sausages, or 72 Spencer-Lemaire plugs. A Styroblock containing 192, 1-inch plugs covers more than three times the area of one tray.

This increase in size increases the cost of growing and handling. The cost of growing and handling 9/16- and 3/4-inch containers ranges from $11.00 to $13.00 per thousand. The cost of the 1-inch containers is approximately $15.00 per thousand. However these costs include only the Styroblock and the R.C.A. sausage. The Spencer-Lemaire and paperpot containers have to be hand seeded since no vacuum seeder has been developed. Hand seeding will increase the cost even more. Unless the use of the paperpot is totally mechanized, it is unwieldy and impractical.

The larger containers have increased the volume of the rooting medium to approximately 2.5 cubic inches. Although results from field trials under Alberta conditions are not available at this time, it is quite certain that the increase in rooting medium and planting the seedling as a plug, will increase survival and growth. It is hoped that these two factors coupled with an improved planting efficiency will offset the disadvantage of higher costs.

PRESENT AND FUTURE DEVELOPMENTS

Container planting of seedlings has been abandoned in favor of the "plug" concept. In this way the seedling with the rooting medium is removed from a mold, or the container is removed from the seedling and rooting medium, just prior to planting. Three types of plugs are in use by the Alberta Forest Service (Styroblock, Spencer-Lemaire, and R.C.A. sausage). The fourth (paperpots) may be considered a plug, but it would also have to be classified as a biodegradable container. Unfortunately there is no control, at this time, over the length of time it takes for the container to decompose.

The decision must and soon will be made to devote our efforts to one production container. During the past 10 years, more than 20 different types of containers have been tried. Fortunately, during that time no effort was made toward all out development of one type of container. With the introduction of the plug the time has come to devote our efforts to one production container. Experimentation on a production basis is no longer practical, economical, or necessary. That is not to say that trial and experimentation with new types of containers should be terminated. However, the time, effort, and money devoted to techniques for rearing, handling, transportation and tooling for four types of containers could be better spent on one production design and technique.

Several factors already mentioned will have to be considered when deciding on a production model. Container size and volume in relation to optimum survival and growth will have to be determined. The logistics of handling and transportation must be considered. What are optimum costs in relation to optimum survival and growth? It is generally agreed that no container is presently available that is ideal for all sites and conditions. Some compromises will be necessary.

When a decision on the production container is made the next step will be, mechanization, both in the nursery and in the field. An intensive effort to mechanize nursery operations in relation to containers has only been discussed. The Alberta Forest Service has purchased a mechanical planter that has potential for adaptation to container planting. Much more work has to be done before this potential can be realised.

The original intention of growing seedlings in containers was to achieve increased production by raising seedlings in artificial environments. The original growing period was 8 - 10 weeks. This period has been expanded to 12 - 16 weeks in order to increase growth and to improve the overall vigor of the seedlings prior to planting. Container seedlings could be germinated in early spring, summer and fall; excluding a 6-week period from approximately July 1st to August 15th. Experience has shown that germination and growth is unsatisfactory during this period.

Consideration is now being given to overwintering all container seedlings. Seedlings reared during the spring, summer, and fall of one year would not be planted until the following year. The result would be a 1-0 container seedling substantially larger than a 1-0 seedling in a conventional seedbed. An overwintered seedling should be more vigorous and better able to withstand the elements after planting. It is possible that an overwintered container seedling may also require a larger container.

RESEARCH REQUIREMENTS

Due to the changes in growing practices as a result of increased size of containers, overwintering, etc., additional research must be undertaken. The Alberta Forest Service intends to cooperate on container research to the fullest extent possible. The following research priorities are suggested

1) the study of the physiology of seedlings in relation to growth initiation, balanced growth (optimum root-shoot ratio), hardening off, and dormancy under intensive semi-controlled culture;
2) rooting medium density;
3) starch reserves;
4) determination of optimum time for pruning, lifting, and planting (both conventional and container seedlings);
5) determination of optimum storage and handling techniques;
6) methods to stimulate root growth.

Results from any of the areas mentioned will aid the container program substantially.

TRAINING AND SUPERVISION

Research and development by itself is not enough. Optimum containers and conditions previously mentioned are of little significance if the seedlings are not planted properly. In an infinite number of cases training and supervision relative to handling and planting have been lacking. We cannot afford to ignore this factor in the future. Field personnel must be made more aware of the time, effort and money involved up to the time seedlings are delivered to the planting site. An understanding must be reached with fire control personnel to prevent total abandonment of silviculture projects for fire suppression. Finally, planting crews must be more intensively trained and supervised to insure the best results possible. To date, no program has been initiated in this respect but it is under discussion.

SUMMARY

The Alberta Forest Service would like to move forward with an improved and expanded container seedling program for reasons mentioned previously and summarized as follows:

1) The annual allocation of funds is not increasing proportionate to our needs. The potentially lower cost of container seedlings should be fully exploited.
2) On-the-ground unit costs are increasing while survival and growth remain static.
3) Conventional seedbed attrition at the Provincial Nursery due to soil type, irrigation, and biological problems is restricting production of 3-0 stock.
4) Adequate training and supervision to insure satisfactory planted results has not materialized.

Research in the areas mentioned integrated with more intensive direction, training and supervision in our own area should bring about a marked improvement.

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CONTAINER PLANTING PROGRAM

IN SASKATCHEWAN

F. Flavelle[1]

The first attempts at producing container-grown seedlings were made in 1966. Two species were used - jack pine and white spruce. The container used was the 9/16 inch split styrene container 3 inches long (Ontario tube). About everything that could go wrong in growing trees in containers went wrong - seed dormancy, slow and poor germination, and damping off, resulting in nil production. However, after sending two representatives to study methods used at North Western Pulp and Power, and reading the Ontario Department of Lands and Forests' manual on tubed seedlings, our results were much better, and, considering the type of container, we were satisfied with the seedlings produced.

In 1967, some plantable container seedlings were grown and the first plants were set out in May. A total of 3,900 jack pine seedlings in containers were planted. One thousand were planted on a dry sandy soil, and 2,900 in furrows in an area that was devoid of trees and had reverted to prairie. Conditions in 1967 were very dry and only 17% of the 1,000 trees survived, but 75% of the 2,900 containers planted in the furrows survived.

A larger number (45,000) white spruce containers were also planted in May 1967. These were planted in an area that had been severely burned in 1961. The debris from the fire was windrowed and the containers planted in the cleared strips. Again, due to the dry conditions, this planting was a complete failure. (Even the conventional 2-2 stock planted at the same time and in the same area perished).

A fall container planting of jack pine was done in furrows in an open untreed area. A total of 44,600 containers were planted and approximately 75% survival has been realized to 1971.

In the spring of 1968, 41,000 jack pine seedlings were container planted in furrows. To date survival is approximately 65%. A total of 17,600 white spruce were container planted in the fail area of 1967 and to date survival is 80%.

In the fall of 1968, some 36,000 white spruce were container planted in an untreated cut-over. The site is very rolling with clay and sandy clay soils. Survival in 1971 was approximately 30%.

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[1]Forestry Branch, Saskatchewan Department of Natural Resources, Prince Albert, Saskatchewan.

In 1969, a total of 100,000 white spruce were container planted. On a recent cut-over area 60,000 were planted, while 40,000 were planted on a cleared, burnt area - a continuation of the 1967 project. Survival counts in the fall of 1968 indicated a survival of 70% but it is considered that, at this date, survival will be only 50%.

A container planting of 80,000 jack pine was also done in 1969. These were planted in small trenches that had been prepared in grass areas of an old burn. Survival to date is about 35%.

In 1970 our planting program was concentrated on jack pine production - only 12,000 white spruce were container planted. A total of 87,000 jack pine in containers were set out in the remainder of the prepared area of 1969. Overall survival is somewhat less than 50%.

In 1971 we again grew a small number of white spruce and jack pine in the same split container and outplanted them. Survival figures were not available at this time, but possibly better survival will be realized as moisture conditions were favorable.

It is evident from the foregoing, we have experienced some frustrations. Survival has been the main problem due to such things as the smothering of pine seedlings by drifting sand, rabbits and grasshoppers cutting off newly planted seedlings, frost heaving, and containers being pulled out by birds.

As a result of continued poor survival, and progress made in the field of new containers, we are currently trying containers that produce a "plug". We grew several thousand seedlings in BC/CFS Styroblocks and will plant some this fall and in the spring of 1972. We are also trying the new Spencer-Lemaire fold-up plug tray and will be attempting to produce some 50,000 plantable plugs in 1972.

At our nursery, just north of Prince Albert, we have a small plastic greenhouse where all our seedlings in containers are grown. This facility was adequate for the number of containers we were producing. However, these facilities would not be adequate for the production of a large number of plugs.

Our operations for the split plastic container (Ontario tube) were mechanized to some extent. However, since we have been experimenting with the newer types of containers, all operations have been done by hand.

Container planting is done using "stand up" dibbles. In some cases, these dibbles have a hoe blade attached for preparing mineral soil scalps by clearing away vegetational and other debris. Our planters average 1,000 to 1,100 containers per 8-hour day.

In summary, I would say we are definitely through with split styrene containers. We are experimenting with plugs and closely watching developments in the types and sizes of containers used elsewhere, and the techniques of getting them into the ground.

As you are no doubt aware, Saskatchewan has entered the pulpwood era and the cut-over area is increasing. If containers have a place in our reforestation program, we should be deciding on a plug type container and getting into production now.

CONTAINER PLANTING PROGRAM

IN MANITOBA

B. Gilmore[1]

Manitoba started container planting in 1969 with seedlings grown in the 9/16 x 3-inch plastic (Ontario) tubes. The material was grown in a 24 x 32 feet corrugated plastic greenhouse. For 1969 and 1970, 120,000 seedlings were produced in tubes, of which approximately 70% were jack pine, 15% white spruce and 15% red pine. In 1971, the quantity of plastic containers was reduced to provide space in the greenhouse for a trial planting using 80,000 Japanese paperpots (3/4 x 5 inch) and 5,000 white spruce in 1 x 5 inch BC/CFS Styroblocks.

A second greenhouse was opened in the summer of 1971 and both buildings modified to carry a second deck of seedlings giving a capacity for 300,000 Japanese paperpots (Bh-213) or 90,000 Styroblocks of the sizes used at present.

Operation of the greenhouse in 1969 and 1970 was started at the end of March; the indoor growing period was 2½ months. This year seeding was done February 20, and stock kept in the greenhouse slightly over 3 months to increase the height and stem strength of the plants. Sixteen hours of light per day was maintained with supplementary artificial light. Plans for 1972 are to start the operation by February 1 and to grow a second crop for fall or spring planting.

Sites for planting were in areas scarified by barrel scarifiers, bulldozers or anchor chains preparatory to planting bare-root stock. A number of plots have also been established in unprepared ground with cover density varying from weed growth and light brush to thick poplar regeneration 15 feet high.

A variety of soil types were selected for each species to assess planting problems and to compare survival and growth rates under as many conditions as possible.

All plastic tube planting has been done by two man teams using weeding hoes with a 9/16 x 3-inch dibble; one used the hoe and the other carried trays and planted the tubes. A shoulder harness with a carrier for a single tray to enable men to work individually did not prove satisfactory. Planters found the latter method tiring and it did not increase production per man day. Planting rates varied from a high of 160 per man-

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[1]Operations Division, Manitoba Department of Mines, Resources and Environmental Management, Winnipeg, Manitoba.

hour on ideal sites with a minimum of debris and moisture conditions that allowed for light scalping, to a low of 75 per man-hour on unprepared sites with heavy weed and brush cover. Making holes of proper depth for the tubes was difficult in loose, sandy soils if the surface had dried. In such soils it was necessary to scalp the surface down to moisture and plant the seedling in a depression where it would very likely be buried by erosion by rain or wind.

For this first year of planting paperpot containers, holes were made with planting shovels. Close supervision was required to assure that seedlings were planted at the proper depth. Planting stock was piled flat in light plywood boxes with a metal handle. A box 9 inches wide, 16 inches long, and 7 inches deep will hold approximately 250 paperpots 3/4 inch in size. Rate of planting was slightly slower than for planting bare-root stock in similar ground.

In 1971 seedlings grown in paperpots were set out on 1/4-inch plywood, 2 feet x 4 feet; each flat carrying a total of 2,800 seedlings. Drying at the edges of these flats caused considerable loss in the greenhouse. Roots penetrated through the side of the paperpots 3 months after seeding. This did not hinder separating the seedlings, and from recent observation it appears possible that planting could be delayed to the end of a 5 month growing period. At this time the paper in the Bh-213 containers still had sufficient strength to permit separation of the seedlings and handling as required for planting. For 1972, three sided boxes holding 1,400 seedlings will be used and an automatic mist system installed to assure even germination. These will be easier to handle in transport and the open side is expected to expedite separation of the seedlings for planting.

In 1969, experiments with plastic (Ontario) tubes showed good survival for the first season. In a few locations ravens or rodents were suspected of pulling tubes and some loss was noted from erosion by rain on a freshly barreled site. Some frost heaving occurred on all sites, but was of more importance on loose sand and gravel type soils than in clay or loam. In some locations, greater loss from frost heaving was noted during the second winter after planting than from the first winter.

In 1970, high mortality of red pine and jack pine in Ontario tubes was observed shortly after planting. Grasshoppers were cutting the stem near the tops of the containers, and eating most of the stem. Previously planted 1-year-old seedlings on the same area were not touched. Test plots were planted at these same locations in 1971 to determine differences, if any, between paper and plastic containers where grasshoppers were prevalent. A count 1 month after planting showed almost twice the survival in paperpots as compared with plastic tubes.

Three years' experiments with plastic (Ontario) tubes indicates this method has several disadvantages; restriction of growth, slow development of a root system, frost heaving, feeding by grasshoppers and damage by birds or rodents. Average survival after 2 years, excluding areas killed by grasshoppers, runs from 40% to 60%.

In 1971, experiments with paperpots shows some promise for this method. Its apparent advantages over plastic tubes are: the quantity that may be grown in limited space, the extended planting period, the tailoring of production to field requirements, the improvement of root growth and the lack of specialized equipment for transport or planting.

Planting loss outside grasshopper infested areas have been very light to date. Weather conditions have been more favorable than average. Present indications are that we may have 80% or better survival for this first season.

CONTAINER PLANTING PROGRAM

AT NORTH WESTERN PULP AND POWER LTD.[1]

I.S. Ferdinand[2]

BACKGROUND

North Western Pulp and Power Ltd. is entrusted with the management of some 3,000 square miles of forest land for the purpose of producing pulpwood. The land is leased from the Crown under a 20-year, renewable, Forest Management Agreement. Under the terms of the Agreement the Company enjoys exclusive harvesting rights to all coniferous timber and also has total responsibility for the prompt reforestation of all cutover areas. The maximum time allowed by the agreement for the reforestation of cutover areas is 10 years following cutting.

The Forest Management Area is located in the eastern foothills region of the Rocky Mountains with manufacturing facilities at Hinton, Alberta. In terms of floral classification, the bulk of the area is located in the Boreal Forest Region, Lower (B.19a) and Upper (B.19c) Foothills Sections, and a smaller portion in the East Slopes Rockies Section (SA.1), Subalpine Forest Region (Rowe, 1959). Commercial species present by percent of productive area are: lodgepole pine - 51%, black spruce - 17%, white spruce - 12%, alpine fir - 2%, hardwoods (trembling aspen and balsam poplar) - 11%. Reproduction and recently burned over areas occupy 7% of the total area. A large percentage (94%) of the productive land is covered by even-aged, fire origin stands. A lesser portion (6%) is covered by multi-aged, near-climax or climax stands of white spruce and alpine fir.

Because of the above factors, and because of economic considerations, the Company has adopted an even-aged, sustained-yield management system. Such a program prescribes some form of clear-cutting with prompt regeneration. Rotation age, as calculated for maximum pulpwood yield, is 80 years. A reforestation period of about 5 years is included in this rotation.

For management and administration purposes the Management Area is divided into relatively small, manageable units called Compartments. The average size of a Compartment is between 25,000 and 30,000 acres, and is

[1]Extracted from "Reforestation of cutover lands at North Western Pulp and Power Ltd." - a paper presented at the 53rd Annual Meeting of the Woodlands Section, Canadian Pulp and Paper Association and reproduced here through the courtesy of the Woodlands Section. A supplemental section "Summary of 1971 container planting program at North Western" prepared by the author in November 1971 provides an up-to-date account of recent changes in the container planting program.

[2]North Western Pulp and Power Ltd., Hinton, Alberta.

designed to be cut-over in a twenty-year period. Each Compartment is assigned to one of four 20-year cutting cycles, depending on age class distribution and urgency for harvesting. Overmature and decadent stands are given priority in harvesting and are assigned to the first cutting cycle whenever possible. It is expected that systematic and orderly clear cutting will result in an improved distribution of age classes by the end of the first rotation.

One-half of the wood volume from roughly half of the area is removed in alternating strips or patches during the first half of the 20-year cutting cycle in each operating Compartment. The remaining half is harvested during the second ten-year period following successful regeneration of the initial cutovers. Provincial regulations limit the average size of the individual cutover areas to 40 acres in spruce and to 60 acres in pine.

Strip cutting is usually practiced in spruce and spruce-fir type stands. The width of the strips usually does not exceed 10 chains in order to accommodate natural seeding from adjacent uncut areas. Block or patch cutting is practiced in most pine-types. Cut layout in this case accommodates efficient extraction and erosion control considerations and, because of the serotinous nature of the slash-born cones, is not circumscribed by strip widths.

The size of the annual cutover program varies from year-to-year due to the fluctuation in the volume of purchased wood. Recent annual cutover areas total in the neighborhood of 10,000 acres.

CONTAINER PLANTING PROGRAM

Experimentation with container planting commenced in 1962 in cooperation with the Canadian Forestry Service. A number of types and sizes of containers were tested in both the nursery and field. By 1965, the Ontario-type, split plastic tube 3/4-inch diameter by 3 1/4-inch long, was adopted for large scale field trials as the best suited to our needs and has been in use since.

The present seedling production facilities have an annual capacity of 1.5 million 10-week-old seedlings in the 3/4-inch containers. The actual net production depends on the culturing success which has been around 90 percent for the last four years. The seedlings are produced in weekly batches of 100,000 to 110,000. The number of batches that can normally be produced is fourteen. With overwintering the production capacity can be increased by 20 to 25 percent.

The seedling culturing technique has changed little from that reported by R. Carman in 1966. The changes worth mentioning include the increase in the outside hardening off period from four to six weeks and the treatment of the growing media with an inert wetting agent.

The technique of field planting has also remained essentially the same during the past few years. The size of the basic planting crew has increased from three to four. One man carries and supplies the seedlings to the other three who do the actual planting. The increase in crew size resulted in increased efficiency and flexibility. Average production rates of 1,655 seedlings per man-day were accomplished during 1970 at a 9 by 9 feet spacing. The production of the best crew averaged 2,156 seedlings per man per day for a five-week period. The planters are paid piece work rates which are set between 1.4 and 2.2 cents per tree, depending on the planting site.

Survival and Growth

Monitoring of survival and growth on the container planted area has been undertaken by the Canadian Forestry Service as a research project. Their reports indicate that the average first-year survival has been in the 70 to 80 percent range for both lodgepole pine and white spruce. By the third year, survival declines to around 60 percent on the majority of the planted areas.

After five years experience with container planting it can be stated that most of the advantages attributed to the system by both, researchers and industrial foresters (McLean 1959, Walters 1961, Ackerman 1965, Carman 1966) are true. However, expectations regarding establishment and initial growth following planting appear to have been somewhat optimistic. Physical restriction on lateral root development and the small rooting volume afforded by the 3/4-inch containers are believed to be the most important limiting factors for lodgepole pine and white spruce.

Current Developments

The shortcomings in the present container planting system are directly related to insufficient basic knowledge of the physiological requirements of young seedlings. Lacking this knowledge, we, as so many others, simply proceeded to produce planting stock that best fitted our idea of good seedlings. Little was known about their chances for establishment under the extremes of field conditions. The gap in basic research into the physiology of juvenile growth is gradually being closed, mostly by federal research efforts. Industry has acquired valuable experience in rearing and planting techniques. Important developments have also taken place in container planting design during the past year. All these factors combined, indicated to us that the chance for improvements in the containerized system may be at hand. As a first step towards improvement, we have prepared initial specifications for greenhouse-cultured seedling quality and field performance in cooperation with members of the Canadian Forestry Service research team. These are listed below:

1) rooting volume of container: minimum 2 cubic inches,
   diameter of container: minimum 1 inch,
   length of container: minimum 3½ inches;
2) total dry weight: 200-300 mgs at time of planting;
3) top to root ratio: between 1.0 and 2.0 at time of planting;
4) hardening off to take place to woody stem stage;
5) no physical restriction on root development following planting;
6) resistance to frost heaving;
7) survival 80 percent or better after two years;
8) growth rates to equal or better those of natural seedlings of same age.

An attempt will be made during 1971 to produce seedlings that conform to specifications 1 to 5 above and it is expected that the results will satisfy items 6, 7 and 8. The desired improvements are to be accomplished through the following modification in the present culturing and planting technique:

1) increase the size of container to 1 inch diameter x 4 inches in length (estimated rooting volume 2.3 cubic inches);
2) increase nursery period to 14 weeks for pine and longer if necessary for spruce;
3) abandon the use of high-nitrogen fertilizers and replace with one of low nitrogen content;
4) reduce frequency of watering, especially during the last 3 weeks in the nursery;
5) remove containers during field planting and plant seedlings as bare-root plugs.

Modifications to 1 to 4 should result in the production of relatively large, hardy and well-balanced seedlings. Particular attention will be paid to keeping top-to-root ratios within the specified limits. This aspect of seedling culturing has often been neglected in the past and resulted in planting of seriously unbalanced seedlings.

Perhaps the most important change proposed is the discarding of containers during the planting operation. This will allow the roots to penetrate into the surrounding soil immediately after planting. Establishment should take place within a 2 to 3 week period. The removal of the containers is also expected to reduce the incidence of frost heaving and may permit planting on bare mineral soil where growth rates appear to be best.

Recent developments in container design make plug planting economically and practically feasible. There are two containers presently on the market worthy of consideration. The BC/CFS Styroblock, is one, the other is a folding container unit marketed by Spencer-Lemaire Industries of Edmonton. Both containers offer similar environments for culturing. For logistic reasons we have decided to adopt the Spencer-Lemaire fold-up plug tray for operational use. With minor modifications in the existing planting equipment and technique, speed of planting should not be significantly reduced.

Further research efforts should concentrate on establishing the relationships between survival and growth, site conditions and seedling characteristics such as top-to-root ratios, size, hardiness, etc.

SUMMARY OF 1971 CONTAINER PLANTING PROGRAM AT NORTH WESTERN

The 1971 seedling production totalled 514,000 seedlings of which 66,000 were grown in Styroblocks and the balance of 448,000 were cultured in the Spencer-Lemaire fold-up plug tray. Growth rates of the early spring seedlings fell short of expectations in both types of containers due to the exceptionally cool and wet weather during May and June. Those seedlings that missed the cool weather grew satisfactorily.

There is room for improvement in both the Styroblocks and the Spencer-Lemaire containers. Small pores due to faults during forming permit some roots to penetrate into the walls of the Styroblocks, making extraction of the plugs somewhat difficult. In order to ensure trouble free extraction, the seedlings require at least two weeks longer culturing period than is required in the Spencer-Lemaire containers. The Spencer-Lemaire containers, in their present form, are not satisfactory as they permit root egress from one cell into another. The resultant root binding also hampers extraction and causes the break-up of the plugs during the planting operation. Efforts are presently under way to correct the short comings of this container.

The Styroblocks produce seedlings with a pronounced spiraling in the root system, due to lack of guiding grooves in the walls of the growing chambers. The serrated walls of the Spencer-Lemaire containers effectively prevent spiraling of the root system.

Whether or not spiraling of the roots in the early stages of the seedling's development is detrimental or not is not known. Just to be on the safe side, it would be desirable to produce seedlings with root systems approximating that of the open grown natural seedlings, that is, with minimal spiraling.

Experience during planting of the plug type seedlings indicated that the dibble is only suitable for planting in bare mineral soil. Satisfactory planting was accomplished with a light mattock only, on areas of duff and sod. While planting with a mattock is more difficult physically, as compared to the dibble, planting rates of 1,200 to 1,500 seedlings per man per day can be obtained from an experienced crew under normal circumstances.

Greenhouse facilities are presently being expanded to give an annual productive capacity of 1.3 to 1.5 million seedlings in one inch diameter containers.

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CONTAINER PLANTING PROGRAM

AT THE NORTHERN FOREST RESEARCH CENTRE

F. Endean[1]

The first work on container planting was started in 1962 with cooperative field experiments between the Alberta Forest Service, North Western Pulp and Power Co. Ltd. (N.W.P.P.) and the Canadian Forestry Service. The first experiment was based on the 7/8- x 2½-inch Walters' bullet and incorporated age of seedling x site x season of planting x seed bed treatment; this experiment was repeated in 1963. In 1964, a further experiment was initiated using different types of containers including tar paper, Kraft paper, and the 3/4-inch rolled polystyrene (Ontario-type) tube and incorporating the planting parameters already mentioned (Ackerman, *et. al.* 1965). Based on early results containerized planting of seedlings was pronounced as promising and further work recommended; however, concern was expressed about root restriction, rooting volume and seedling size and condition.

In 1965 the cooperating agencies tended to go their own separate ways. N.W.P.P. began pilot plantings and became fully operational in 1967 using the 3/4-inch Ontario-type tube and 8-week-old seedlings. The Alberta Forest Service started operational planting with the same system a year or so later. Results of monitoring the N.W.P.P. plantings from 1965-69 have been reported by Johnson and Marsh (1967), Johnson and Dixon (1968), and Dixon and Johnson (1969).

Between 1965 and 1968 the Canadian Forestry Service initiated a further set of trials, centred mainly on rearing problems. These were

1) effects of seed size (Ackerman and Gorman 1969);
2) effects of soil mix in greenhouse and field;
3) effects of greenhouse tiering (Ackerman 1967);
4) root temperature studies;
5) frost tolerance studies;
6) effects of container types on growth;
7) effects of cold frame treatments.

Unfortunately, operational programs by the province and N.W.P.P. gathered momentum and started to generate their own particular problems before these CFS initiated trials could provide useable information.

In 1969, in view of the obvious need for greater input into container planting research a three-man team was set up to investigate container types,

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[1]Canadian Forestry Service, Northern Forest Research Centre, Edmonton, Alberta.

and seedling condition as affected by rearing treatment including nutrition. This work has been almost completed, and some of the results will be reported at this meeting. Our current program stems from these and previous findings.

Results from our research and development programs clearly indicate

1) that the 3/4-inch Ontario-type tube container and Walters' bullets with 8-week-old seedlings are unsatisfactory for Alberta field conditions;
2) that as a result of these trials, the CFS is convinced that a plug form of container-grown seedling promises to be the best basis for developing a containerized planting system and thus all future research and development work will be based on this assumption;
3) that the rearing environment, including temperature and nutrients, have a pronounced effect on the condition of the seedling produced and its field performance. Generalized growing conditions can be prescribed at this time but these prescriptions need to be further refined through research;
4) that there is a need to determine adequate rooting volume for individual tree species if maximum seedling growth is to be obtained during the rearing period;
5) that there is a need for larger and more vigorous seedlings and this need will require longer rearing periods. At present, rearing periods can only be defined in general terms.

Future research and development work will be conducted on multidisciplinary lines and will take the following form:

1) refinement of rearing techniques to produce seedlings which will be in suitable physiological condition for rapid field establishment during the first year following out planting;
2) refinement of rooting volume prescriptions;
3) pilot plantings in different climatic regions.

As soon as a physiologically adequate seedling has been achieved which can be used as a testing device, we intend to re-examine the planting method and its mechanization, site preparation (which we consider inadequate, and possibly inappropriate as currently practised), basic organization and logistics of the "plug" containerized planting system.

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CONTAINER PLANTING PROGRAM

IN ONTARIO

K.H. Reese[1]

INTRODUCTION

In our operational-scale container planting program[2] we, in Ontario, have now cycled through one complete revolution. First, it was production problems, then establishment problems. We have now reached a phase where we know the critical ecological, silvicultural and operational aspects of field survival for our more difficult species; we are ready to adopt a new container planting system; ready to rebuild our old equipment and facilities; and launch our container planting program on a new plateau. We are currently in low key, in a redesigning phase - both in operations and in our research. For this reason I will discuss our current thinking rather than our current methodology.

We know tubed seedlings can be used successfully in our northern planting system. We are now in the process of integrating containers with our bare-root nursery stock production and want our nursery production targets to reflect demand for container stock. Containerized seedlings will no longer be a project on the side, but will function as a legitimate method of supplying planting stock. Our current annual production of eight million container-grown seedlings will probably drop for a short time until the problems associated with planning a longer range objective of container seedlings and bare-root stock can be worked through; current nursery inventory levels are around 100 million bare-root stock.

Seven Forest Districts of the original 15 are still producing container-grown stock, and the results they have obtained, while not always optimum, have been sufficiently encouraging to maintain their interest. For the Forest Districts with inconsistent results, it is now a production problem - to get their container-grown seedlings up to quality standards that have been achieved by the leaders, that is seedlings 3 to 5 inches in height, not less than 75 days old, and with most being overwintered.

Our research efforts, which led to the development of operational tubed-seedling planting programs, have in more recent years been concerned with short-term problem-orientated projects. Further field-orientated

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[1]Timber Management Branch, Ontario Department of Lands and Forests, Toronto, Ontario.

[2]Principally using the 9/16- x 3-inch split plastic tube; maximum production reached 20 million seedlings annually.

research will not be undertaken until a new system is defined and its implications studied. Development of equipment and automated gear is awaiting a decision on a new tube size and a new soil mix; this program has been static for the past two seasons now (1969-70).

Following is a brief description of our present techniques and our current thoughts for modifying our system.

PRESENT TECHNIQUES

Greenhouses

Many of our early troubles were due to our inability to maintain an optimum environment during the critical germination phase. We still want greenhouses and are currently rebuilding two installations. The new houses are aluminum arch with fiberglass covering. Greenhouses, 160 by 32 feet were arbitrarily chosen as a size that could produce one million shippable 9/16-inch tubes. Automated ventilation and heating and semi-automatic watering are included. Controlling light and CO_2 are only possibilities at this stage.

Tube Size

The 9/16-inch tube is inadequate for growing the 3- to 5-inch seedlings which our conditions require, and the trend to overwintering means our container must support a larger root system. Root systems in our initial 9/16-inch plastic tube show much less distortion than in our planted bare-root stock. Large jack pine or white spruce may require an even larger tube since these species tend to retain their initial root system after establishment. Black spruce tends to grow an entirely new root system following outplanting so that container root distortions are not a permanent feature. With 8 to 10 inch tall stock, 9/16-inch tubes in the centre of trays tend to develop a restricted root system due to the abnormal elongation of the tops of seedlings. Jack pine requires more growing space per seedling than our 9/16-inch tubes with some 300 seedlings per square foot have allowed. Tube size is the key to our new system and a 3/4-inch to 1-inch tube is being considered.

Type of Container

This is still an open question. Given an adequate size of plant, our current system can give 95% survival after one winter. The possibilities of post establishment growth are an unknown since in most cases we have only 2 years growth data on our adequately grown seedlings.

The cost of the proposed 1-inch plastic tube will open other container possibilities; only a few of the more recently developed containers have been superficially tested in the greenhouse and fewer have been outplanted. We know there are containers we do not want, but many alternatives exist. Air pruning instead of using copper bottom trays and consideration of containerless planting await further study.

Growing Medium

In our attempts to automate the loading of tubes, we became aware that there were 'peats' and 'other peats'. The very earthy peats or muck peats tended to pack too tightly — even with hand loading — for roots to readily develop. Mechanical loading with these fine peats proved almost impossible and resulted in insufficient density and slumping when initially watered. Fiber content is important, particularly when containerless or plug planting is done, since mucks do not hold together as a unit unless root-bound.

Fertilization

Fertilizers have been a major key to our ability to grow larger plants and increase our success in the field. We have done considerable work with fertilizers, but there are gaps in our knowledge.

Our research level fertilizer trials have been carried out in elaborate greenhouses at Maple, Ontario and have yet to be superimposed on the operational greenhouse benches. We have demonstrated that we can grow much larger plants than we now do; we know our phosphorus levels are critically low in our soils; and we know previous recommendations for nitrogen have been, generally, too low. Fertilizers can be watered into peats and our pre-mixing of phosphorus and potassium into the soil before seeding is not essential.

The more successful fertilizer innovations have supplemented our previous prescription with ammonium nitrate. These old formulae often carried seedlings on the verge of hunger or even in the yellow phase. With overwintering or outside growth on racks with a reasonable hardening off period, this increased nutrient regime has improved survival in field plantings.

Our current level of soil monitoring suffers due to the lack of a standard or a nutrient working level for peats. All of our background is with nursery or mineral soils. Developing this standard is of high priority so that we can move out of the "squirt and peak" period.

We want to duplicate the annual nursery soil and plant analysis work in our container system. Prior to shipping, plants and soils would be sampled to rate the physical size of the seedlings and the nutrient regime under which it was grown. The grower will have defined the size of seedling he wants to ship; the assessment should tell him how close his schedule came to meeting his standard. In fact, he can sample his crop as the growing season develops and determine how close the seedling is to his standard growth curve. This can be called programmed growth, if you wish.

IMPACT OF CONTAINERS ON BARE-ROOT STOCK

To say that containers have had an impact on conventional nursery planting stock would be an understatement. Annual budgeting by governments does not mesh with 3 to 5 year time lags between demand and supply in the production of nursery stock. The role of greenhouses in extending the growing season and developing larger stock faster is a serious consideration. In the growing of black spruce, our nursery system requires 8 seeds for one shippable tree. In an era with expensive genetically improved seed, a system which can produce one tree from two seeds is an attractive alternative.

We have reached a point in many areas where available labor limits reforestation program. Containers offer an opportunity to reduce labor input and allow for the necessary tending or follow-up work. There is also an opportunity to take the peak off the spring work load by extending the planting period into the summer.

CONCLUSION

Six years ago we adopted, operationally, a container package called tubed seedlings. To date, some 90 million tubes have been planted with some good results and some bad results. We are generally satisfied with the concept and believe we know what we want in terms of a type of seedling. Our temporary equipment and greenhouses are worn out and we will rebuild these around a new system and modified container, the exact parameters of which are yet to be determined.

CONTAINER PLANTING PROGRAM

AT THE GREAT LAKES FOREST RESEARCH CENTRE

R.A. Haig[1]

HISTORY

As you probably all know by now, the Research Branch of the Ontario Department of Lands and Forests began experimenting with small container-grown seedlings in the mid-fifties. Work was confined largely to one species (red pine) and the projects were carried out on a small scale, using the now-familiar 9/16- x 3-inch plastic (Ontario) tube. The results were quite promising, and the potential for increasing the rate and reducing the cost of reforestation looked attractive.

Suddenly, in 1966, the decision was made to develop an operational program, and a production target of 20 million tubelings was set for the first year. This target included all the commonly planted conifers, most of which had not previously been produced in containers even on an experimental scale. This meant that at least 20 Forest Management Unit foresters had to become greenhouse experts overnight.

The difficulties in launching the program were enormous, but somehow most of the production problems were overcome, and surprisingly 17 million seedlings were container-grown and planted. As might be expected, field performance of the tubelings was extremely variable, and of course, every forester had his own theories to explain the variations. Although the standard Lands and Forests plantation assessment system was being applied to tubeling plantations, it was obvious that this was not intensive enough to quickly pinpoint the factors responsible for success or failure.

It was decided that an intensive assessment should be carried out on one season's planting program in one Forest District. The objective of this project was to identify the problems and provide a basis for research aimed at solving them. It was also thought that information arising from the assessment could be put to immediate use by forest managers. Such an assessment was carried out and the results were made available on a confidential basis to the Ontario Department of Lands and Forests.

CURRENT PROGRAM

In 1968, Dr. J.B. Scarratt began a project to evaluate the importance of factors influencing the survival and establishment of tubelings on spruce-

[1]Canadian Forestry Service, Great Lakes Forest Research Centre, Sault Ste. Marie, Ontario.

fir sites, and the potential value of the technique for regenerating this forest type. (This project was based at least in part on early information provided by the assessment.) Specifically, the studies were designed to determine the effects of seedling age and size, date of planting, and vegetation control on the survival and growth of tubelings on a variety of typical site and microsite conditions. Shorter term studies were aimed at determining the influence of various production variables (such as tube size and overwintering) on survival and growth.

These studies produced useful interim results which Dr. Scarratt has reported more or less informally to the Department of Lands and Forests on a number of occasions. Recently he conducted a field tour of his study plots which provided a clear demonstration of his major findings, without the aid of detailed statistical analysis. Most of this work is nearing completion, and it is expected that the results will be published in the near future. Already the information has been taken into consideration by those responsible for Ontario's reforestation program.

FUTURE WORK

In 1970, discussions with the Department of Lands and Forests led to the development of a cooperative Canada-Ontario program aimed at developing the necessary equipment and techniques to mechanize the Province's reforestation operations. The overall objective of this program is to reduce costs and improve efficiency but it is obvious that such a program must have a sound biological foundation.

As most of you probably know, our first priority is the development of a new type of planting machine capable of efficiently planting bare-root stock on recent cutovers in the boreal forest. Among other considerations, this choice was influenced by the progress being made elsewhere in the mechanization of container systems. It was also influenced by uncertainty as to the future direction of Ontario's container planting program. However, there is little doubt that there will be a container planting program of some kind.

Basic to the success of any container system is seed that will germinate rapidly and produce a high percentage of seedlings with vigorous early growth and good survival potential. The emphasis of Dr. Scarratt's work will be to provide the biological information that will make it possible to obtain the best possible performance from the seed available. The specific objectives, primarily with respect to white spruce are

1) to determine the relationships between seed origin, seed size and seed treatment, and the parameters of germination and seedling development;
2) to determine the relationships of seed size, germination rate, initial germinate size, and the growth pattern of young seedlings of differing origin;
3) to determine the influence of the duration of cold stratification on the germination of different seed sources and on the minimum temperature requirements for germination;

4) to determine the extent to which germination behaviour and response to seed pretreatment are influenced by seed age, maturity and storage conditions.

An essential aim of this study is to develop specific techniques for increasing the uniformity of germination and seedling growth in white spruce under nursery conditions.

A second study has as its general objective the provision of background information necessary for the culture of containerized planting stock, of acceptable biological performance, in a form suited to mechanization of the production and planting operations. However, due in part to the current state of uncertainty with respect to Ontario's container planting program, and in part to developments taking place elsewhere in Canada and abroad, no major new work is planned in this area at present. Instead, an evaluation will be made to determine the most critical factors in the production-planting sequence requiring further study. A continuing evaluation will also be maintained with respect to container systems being developed elsewhere, and further work may be initiated as a result of continuing consultations with the Ontario Department of Lands and Forests. I also hope and expect that what we learn at this workshop will assist us in shaping our future program of container planting research.

REPORTS AND PUBLICATIONS

The following publications are in manuscript form:

Scarratt, J.B. Effect of size at planting on the growth of white spruce and jack pine tubed seedlings (for Can. J. Forest Res.).

Scarratt, J.B. Effect of size at planting on the dimensions of white spruce and jack pine tubed-seedling planting stock (for Tree Planters' Notes).

The following report is included in these proceedings:

Scarratt, J.B. Tubed seedling research in northern Ontario.

CONTAINER PLANTING PROGRAM
AT THE PETAWAWA FOREST EXPERIMENT STATION

W.M. Stiell[1]

No container planting research as such is being carried out at Petawawa. However, physiologists of the Tree Biology Section are using containers in studies aimed at accelerating the growth rate of seedlings prior to field planting. Following initial research to define optimum environments for seedling growth, an automatic irrigation and feeding system[2] was devised for material being raised in containers in growth cabinets or in the greenhouse. Very large increases in the growth rate of white spruce and jack pine seedlings were achieved by these means, and results were improved further through the use of appropriate rooting media; a commercial product "Turface" was most effective for the spruce, while a vermiculite-peat mixture seemed best for the pine. It is hoped that still additional gains in performance can be made through the manipulation of temperature and photoperiod.

These cultural methods have been developed specifically for growing seedlings in lots of not more than 2,000 for forest genetics experiments. Enlarging the scale for operational production of container stock is considered mainly an engineering problem.

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[1]Canadian Forestry Service, Petawawa Forest Experiment Station, Chalk River, Ontario.

[2]Pollard, D.F.W. 1971. Automatic watering and feeding of seedlings in controlled environments. Can. Dep. Fish. Forest., Can. For. Serv., Information Report PS-X-28.

PROPOSED CONTAINER PLANTING PROGRAM

FOR QUEBEC

P. Bonin[1]

INTRODUCTION

Because Quebec, at present, is neither producing nor planting containerized seedlings, this report presents the results of a detailed analysis of current efforts in this field. The analysis is based on a review of the literature, observations on the programs and methods of Ontario, Alberta and British Columbia, and our own greenhouse trials. For this work, which is continuing, we hope to develop a program suited to our own field conditions and provincial needs.

Eleven different containers have been considered for possible use in Quebec (Table 1). A brief summary of our assessment of each follows. They were all rejected, mostly on the basis of the cost of the container and the anticipated restriction of seedling growth.

CONTAINER ANALYSIS

Wooden Tube

Due to the heterogeneous composition of the walls we think it would be hazardous to keep the tubes in the trays for more than 12 months, whereas we would expect to keep them in trays for approximately 15 months. The cost is also very high, at least $10.00 per thousand.

Cardboard Tube (Domtar)

Two types were tested; one coated with resin and one without. Bench tests proved that the first type induced nitrogen deficiency. The walls of the second type seem to be much too thick for the roots to penetrate within a reasonable period of time. We have no precise figure for the cost, but it would be around $10.00 per thousand.

Fibre Tube (Canadian Can)

This tube's main advantage is that no additional growth medium is needed. It is fertilized and ready for use, but it is very expensive, more than $10.00 per thousand. The sowing operation must be very precise, and the roots may spread to adjacent tubes.

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[1]Quebec Department of Lands and Forests, Quebec City, Quebec.

Table 1. Comparison of 11 containers and the proposed "Quebec system"

Type of container	Initial investment		Facilities to adapt different sizes of tube	Handling Operations					Container	
	Tube	Tray		Tube in trays	Filling of the tubes	Transportation facility to the planting site	Need to split the tray for the planter	Trays recovery	Presence	East of removal
Wooden	high	mod.	mod.	yes	yes	cumbersome	may not	yes	yes	yes
Cardboard (Domtar)	high	mod.	mod.	yes	yes	"	may not	yes	yes	no
Fibre (Canadian Can)	high	nil	high	no	no	"	obligatory	no	no	–
Swedish Multipot	ext. high	nil	very low	no	yes	"	impossible	yes	no	–
American tomato	ext. high	nil	very low	no	yes	"	impossible	yes	no	–
Spencer-Lemaire	high	mod.	mod.	yes	yes	"	may not	yes	no	–
Walters' bullets	high	high	very low	yes	yes	"	no	yes	yes	no
Japanese paperpots	low	mod.	mod.	yes	yes	"	obligatory	yes	yes	yes
BC/CFS Styroblock	mod.	nil	low	no	yes	"	obligatory	no	no	–
R.C.A. "peat sausage"	low	mod.	very high	yes	yes	"	may not	yes	yes	no
Ontario tube	high	mod.	mod.	yes	yes	"	may not	yes	yes	no
Quebec's system[1]	very low	mod.	very high	yes	yes	very easy	readily done	no	yes	yes

[1]Now being developed

Swedish Multipot

The major problem with this container is the need to determine the correct volume of soil required for optimum seedling growth before a mould of the correct dimensions can be ordered from a manufacturer; the cost of such a mould might be in the order of $150,000.

American Tomato Plastic Tube

The main reason for rejecting this container is its low soil capacity. It contains less than a cubic inch of soil and a full tray would be too cumbersome to carry easily to the planting site.

Spencer-Lemaire Fold-up Plug Tray

This is a very good approach to the container planting technique. This six-tube hinged container is reinforced with grooves which induce the roots to grow down instead of around the container. Unfortuntely, its disadvantages are too important for us to adopt it. Its high cost, around $10.00 per thousand, and the possibility of the roots spreading to the adjacent tubes outweigh its advantages.

Walters' Plastic Bullet

This styrene bullet-shaped container is split down one side. When it is introduced into the ground it is cut on the other side. These slits are supposed to enable the roots to escape from the container, but most field trials have not borne out this expectation. The cost is also very high, more than $10.00 per thousand, and the need for expensive, specially perforated trays is an additional deterent to their acceptance.

Japanese Paperpots

This type of container is intermediate between systems wherein a non-biodegradable (generally plastic) container is planted and systems wherein "plugs" of soil removed from the container are planted. Results obtained elsewhere are very promising, but inconclusive. One advantage is that the "honeycomb" can be manufactured in a variety of diameters and lengths at low cost; approximately $5.00 per thousand. At present the big disadvantage is that only an unacceptably large size of "honeycomb" is readily available on the market.

BC/CFS Styroblock

This is one of the best containers on the market today, as the seedling is planted as a "plug" without its container. The survival of seedlings is very high. The cost ($7.00 per thousand) is moderate, and the container can be taken to the planting site without disturbing the seedling. With the Styroblock concept handling is minimized, but, as this container is not readily biodegradable and will be discarded at the planting site, littering will be a very important factor related to its use.

R.C.A. "peat sausage"

This extrusion system may have a brilliant future as it may be easily adapted to a highly automated system without a large capital investment. The cost of the tube is very low approximately $3.00 per thousand, and there is a large degree of flexibility in producing containers of varying lengths and diameters. This flexibility is impossible to obtain with rigid wall containers. Removal and disposal of the polyethylene film before planting is a problem but this system seems to be the best one to work with. Another disadvantage, at least in the samples we have seen, is that the soil is so firmly packed that the roots have a tendency to grow between the envelope and the soil core.

Ontario Tube

The many tests undertaken by the foresters of Ontario and elsewhere prove that the volume of soil contained in this tube (9/16- x 3-inch) is much too small. Because of the rigid plastic tube wall root egress is very slow and thus seedling establishment is difficult. We estimate the cost of a 1-inch diameter tube at about $10.00 per thousand.

QUEBEC'S PROGRAM

This winter (1971/72) we will try to determine the "recipe" for growing container seedlings in our three greenhouses. For this purpose we will use the BC/CFS Styroblock. We consider this container to be the best for laboratory purposes.

Ultimately we hope to develop a paper tube for use in a continuous, extrusion method. To get to this we will

1) Develop a machine, using a centrifugal pump, to extrude a saturated slush of bark fine particles. To this pump a compressor will be added in order to vary the density of the mix as required. In this way we hope to overcome the high density encountered with the current screw extrusion method.
2) Develop a paper film sufficiently resistant to moisture to contain the roots for a little more than a year. It would cost approximately $1.00 per 1000 tubes.
3) Make small bales of approximately 200 seedlings for shipment from the nursery to the planting site. Tubed seedlings in trays take too much space for efficient transportation to the planting site.
4) Use Gro-Lux illumination to extend the daily photoperiod. Gro-Lux was chosen on the basis of a cost comparison with incandescent light (Table 2). Artificial light will provide approximately 60 lumens per square foot.
5) Develop a planting tool so that the planter will not have to bend down to perform his duties. This tool should not compress the soil, but cut a removable plug.

Table 2. Comparison of incandescent and Gro-Lux lighting for greenhouses

Type of bulb	Cost/ bulb ($)	Number of bulbs per greenhouse	Total power/ hour per greenhouse	Life of bulb	Lumens per greenhouse	Cost/million lumens per hour ($)	
						lamp	power
150R/FL	1.20	72	10,800	2,000 hrs	144,000	.30	.75
F40-GRO	3.50	96	3,840	18,000 hrs	192,000	.10	.20

CONTAINER PLANTING PROGRAM

IN NOVA SCOTIA

D.M. Levy[1]

The planting of greenhouse-grown containerized forest tree seedlings began in Nova Scotia in October 1968. At this time the Canadian Forestry Service supplied about 2,000 seedlings in Ontario 9/16-inch plastic tubes to each of Scott Paper Company and Nova Scotia Pulp Co., Ltd. Survival information for these plantings are not available to me but the growth of surviving black spruce planted by Nova Scotia Pulp Co. has been encouraging. Mortality was assessed as being due to crows, frost heaving, girdling due to wind whipping, and the inquisitiveness of man.

In 1968, the Nova Scotia Department of Lands and Forests decided to go into the production of containerized stock. But, perhaps because it was our first attempt, the results, both in the greenhouse and the field, were not encouraging. Of 314,000 containers seeded, only 45,000 germinated and survived to be outplanted. This was a mere 14%. Field survival figures are not available but, since most of the containers planted were 3/4-inch Ontario-type tubes, frost heaving was severe.

We also produced a few Swedish Multipots and a few Walters' bullets. The former showed real promise and the latter were deemed a complete failure.

In 1970 many of our mistakes of the previous year were corrected and of the 656,000 containers seeded, 406,000 or 62% were outplanted.

In 1970 our main production was again of 3/4-inch plastic tubes but we also increased our production of Multipots and experimented with the Domtar Tretube.

With the Tretubes, germination was poor and top growth of the surviving germinants was retarded. A few trays of these were overwintered and good top growth was obtained in the spring of 1971.

Planting was carried out until mid-August and frost heaving, soil (clay) heaving and mortality due to drowning or drought were again the main causes of mortality with the plastic tubes. Some frost heaving was predestined due to poor (shallow) planting, but unforeseen problems arose in another area.

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[1]Manager of Reforestation, Nova Scotia Department of Lands and Forests, Lawrencetown, Nova Scotia.

The planting tool used with these tubes is a dibble which compacts the soil to a depth sufficient to allow the tube to be inserted so that the top is level with, or slightly below, ground level. In the case where the soil is heavy, i.e., clay or clay loam, the clay swells with the autumn rains and does two things. One, it begins the heaving process by pushing the tube up above the soil surface level. Two, the clay plugs the bottom of the tube which during a prolonged rainy period does not allow the water to drain out freely, and the roots die. If the converse is the case, i.e., a prolonged dry spell after the tube bottom has become plugged, the roots cannot make contact with sufficient soil to obtain moisture and therefore the seedlings succumb to drought.

Even with the use of Multipots some frost heaving occurs but we do not expect it will pose serious problems.

In 1971, after what we felt was a successful season last year, we again encountered greenhouse problems. Although we are not yet sure (the Canadian Forestry Service, Forest Insect and Disease personnel are still working on it), it appears as if our soil was somehow contaminated with Simazine. Germination was good but shortly thereafter the germinants threw their seed caps and they began to die back. The symptoms were similar to root rot but root rot did not occur until after the dieback had reached the soil surface. Surprisingly, this mortality occurred in white and Norway spruce but not in red pine.

Production was reduced voluntarily in 1971 due to lack of demand. Two sizes of plastic tubes were used in 1971, 9/16-inch and 3/4-inch; the Swedish Multipot trays were again used and we tried a limited quantity of BC/CFS Styroblocks.

Because of greenhouse problems in 1971, of the 284,000 containers sown we only have 168,000 plantable seedlings, some of which will have to be overwintered in order to get them to a size suitable for outplanting.

In Nova Scotia we still consider the production of containerized stock experimental and the main use we plan for this type of stock at the present time is for making up non-scheduled demands (e.g. after a wildfire) that we could not supply with our normal bare-root stock. Containerized stock is the nearest thing we have to an instant tree.

The container we plan to use in the immediate future is the Swedish Multipot tray. Using this tray we hope to semi-automate our production so that costs can be brought down to a reasonable level.

From the above you can see we still have not established any standards of production but hope to do some work on this in 1972.

I have dwelt mostly on production of container-grown seedlings because we do not have too much to offer on planting, except that some type of site preparation is essential before planting and that the planting tool should remove a plug of soil which will be replaced by a similar-sized plug containing a seedling.

Table 1. Overall survival in 1971 of all species planted in 1968 in various containers

Container type	Container Dimensions				Percentage Survival	
	Diameter		Length			
	inch	cm	inch	cm	1965 Burn	1967 Scarified
Bare-root 2-0 stock					50	84
Walters' bullet	7/8	2.2	4 1/2	11.5	45	32
Ontario plastic tube (white)	9/16	1.4	3	7.6	25	32
Ontario-type plastic tube (blue)	3/4	2.0	4	10.2	23	15
Polyethelene bag	2 3/8	6.0	4 3/4	12.0	70	50
Polyethelene bag	2 3/8	6.0	7 1/8	18.0	33	32
Jiffy 7 pellet	2 3/4	7.0	3 1/3	8.5	40	62
Peat pot	4 3/8	11.1	3 1/2	8.9	70	62

Basis - 28,800 seedlings.

peat pots, and biscuit containers have been used with more or less success. The plastic tubes did not decompose over the 6 years and caused damage which resulted in branchy growth to the stem of red pine trees in areas exposed to winds. The Nova Scotia Department of Lands and Forests is conducting a large-scale trial of container planting methods in the nursery at Lawrencetown.

In Nova Scotia, the Canadian Forestry Service has introduced a reforestation program in cooperation with the Department of Lands and Forests which includes the use of containers. Over the past decades, there has been a loss of productive forest acreage in the Clyde River - Halifax Ecoregion of western Nova Scotia. This loss is being extended as disturbed areas are allowed to revert to scrub or to shrubs. The prevention of further losses of productive forest lands through successful reforestation is an important problem. Mechanical control of ericaceous weeds, scarification and site preparation methods and follow-up planting or seeding and subsequent plantation maintenance will support the re-establishment of productive forest. The rockiness of much of the region militates against any widespread mechanical site preparation but it will be practical in certain areas. In the coming few years, it will be necessary to make informed guesses about the most suitable planting methods in the region and about the proper species to plant.

At present we are assessing existing plantations by collecting data on species planted, methods of site preparation, planting techniques and maintenance, age class and type of planting stock. In addition, we are selecting superior seed sources of red and black spruce to develop and improve seedling production for future demands. However, a concurrent species and provenance-testing study is necessary to supplement and refine information presently available. In addition, trials on direct seeding, planting with bare-root and tubed seedlings should be carried out. It is unlikely that any one technique will be universally suitable and careful attention must be paid to site quality and site variations in all restocking trials.

Three kinds of containerized seedlings will be considered for inclusion in the forthcoming trials:

1) Japanese paperpots - seedlings will be grown and outplanted in "honeycombed" pots constructed of specially prepared, biodegradable paper.
2) Polyethelene bags and jiffy pots - seedlings are lifted from either greenhouse or nursery seedbeds, planted into these containers and given intensive care until they are planted in the areas to be reforested; these containers are especially suitable for planting under severe conditions.
3) Swedish Multipots or BC/CFS Styroblocks - seedlings are grown in a honeycomb-like container. When the seedlings reach the proper size they are pulled from the moulds and outplanted as "plugs".

Mechanization of the above paperpot containers will be investigated. Anticipated time before all plantations are established in the field is 3 years.

REARING CONTAINER STOCK

CURRENT REARING KNOWLEDGE

D. Hocking[1]

INTRODUCTION

When I was invited to prepare a paper on current rearing techniques, I was a little reluctant because I don't think we have any widely accepted or regularly practiced rearing techniques. I suggested a few alternative titles: perhaps it should be current rearing practice or current rearing recommendations or maybe current rearing questions. Finally I settled on current rearing knowledge. The reason for that is because there are really no simplistic answers; no blanket recommendations which can be made regarding the rearing process for container seedlings.

Earlier papers discussed different systems for pilot or operational production. That was good because you have to have a system, but I think I'd like to turn the discussion back towards the seedling, which is after all, our ultimate objective.

To optimize the rearing process, we must, first, understand and then control all aspects of all phases of seedling growth. Second, we need an objective in terms of the type of seedling we want. It may be that we need several objectives; that is, the specifications of the seedlings we want, could, and probably will vary for species, for sites and for weather conditions at time of planting. But we need to know something about the type of seedling we want. Third, we need to monitor operational production of the seedlings in order to maintain control of the rearing process.

With those three points, I would like to present and discuss some of the data which I and my colleagues gathered over the last few years for meeting the first objective and partly the second one.

Our previous research and present knowledge has been based on or developed from the assumption that seedlings have to be big and tough and have to have a low shoot to root ratio in order to survive. This is, I think, the conventional assumption: the seedlings need to be balanced shoot to root and they need to be reasonably big. With this as a working objective, I will discuss, in turn, the various aspects to be considered in the rearing process.

Seed

We cannot over-emphasize the importance of the seed. We need to select seed from a source that is appropriate for the planned planting site.

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[1]Canadian Forestry Service, Northern Forest Research Centre, Edmonton, Alberta.

The seed should be of high quality: of high germinative capacity and clean, otherwise we may have root diseases and/or empty containers.

We must know the effects of stratification on germinative capacity of the selected seed. Blanket assumptions may be incorrect. To illustrate this, Table 1 shows the emergence and survival of stratified and non-stratified seed in irrigated seedbeds in the Alberta Tree Nursery at Oliver, near Edmonton. We sowed unstratified seed ourselves for every seedlot that the nursery stratified, and vice versa. During the course of the summer we assessed emergence rate and the final seedling stand. Over the whole range of seedlots, there were eight superior stands after stratification and 11 superior stands without stratification. There is no correlation to species or to geographic origin.

Table 1. Emergence and survival[1] of stratified and non-stratified seed in an irrigated seedbed (Hocking unpublished)

Seedlot (AFS[2] No.)	Stratified	Unstratified
White spruce		
DW.5-3-68	20.2*[3]	6.0
DS.7-1-68	6.7	10.2*
DS.5-2-68	12.3	20.2*
DS.4-1-68	7.3	20.3*
DS.2-2-68	14.2	12.8
DP.7-2-68	5.7	11.8*
DP.5-1-68	21.2*	17.0
DL.3-1-68	29.3*	10.0
DG.2-3-68	17.8*	7.0
DF.67-51	2.0	4.7*
DF.67-31	18.5*	3.8
DF.3-1-68	5.2	9.7*
DE.60-35	0	2.0*
DA.67-67	1.8	5.2*
DA.67-35	22.3*	2.7
DA.67-34	22.3*	5.7
DA.67-33	25.0*	2.8
Lodgepole pine		
DP.60-79	6.6	5.5
DP.64-32	2.7	8.0*
DE.67-69	2.8	2.5
DE.67-65	2.7	5.0*
Douglas-fir		
CR.61-154	1.8	3.2*

[1]Figures are seedlings per lineal foot, means of six permanent sample plots.
[2]AFS - Alberta Forest Service.
[3]*indicates significantly better stands P = .05.

Without some testing for stratification response of each seedlot, it is foolish to make a blanket recommendation that we should stratify them all or vice versa. The important point is that we need to test each seedlot to determine its response before using it to a large extent, particularly in such an intensive program as container seedling production.

Seed Cover

Grit is widely used and has some advantages as a seed cover. With it the hypocotl of the germinating seedling reaches the substratum easily and the grit suppresses moss growth. Two points should be considered. Firstly, the seedling should not have to compete with moss if growth conditions are adequate; the seedling will take off much faster than the moss. Secondly, if the rooting medium is appropriate there should be little need to weight the seed down to force the hypocotl in; a situation that seems to be necessary when the density of the rooting medium is greater than about 0.08 to 0.1. However, a more uniform emergence seems to occur when a grit cover is used than when it is omitted.

Sand is not suitable for covering seed because it tends to crust and inhibit emergence.

Rooting Medium

Composition, volume, and density are necessary considerations in choosing the rooting medium. We have run experiments in cooperation with the Research Council of Alberta, using cylinders of extruded peat (R.C.A. "peat sausages") with densities from just over 0.1 to almost 0.3. There was a negative correlation between growth and shoot to root ratio and substratum density (Table 2).

In our laboratory, we have found that nothing has given better results than straight peat, and several years ago we settled on peat as our rooting medium for experiments.

Table 2. Growth[1] of lodgepole pine seedlings on substrate of differing density (after Mitchell, Hocking and Kay unpublished)

Density of rooting medium[2]	Total wt[3] (mgs)	Shoot to root ratio	No. of white root tips[4]
0.156	109.1	3.16	13.5
0.185	68.9	3.04	9.4
0.224	52.9	2.86	9.2

[1]Assessed at 12 weeks after emergence.
[2]Rooting media were extruded R.C.A. "peat sausages".
[3]Figures are means of at least 100 seedlings, and differ significantly at the 1% level.
[4]White root tips visible against the (transparent) container wall.

The volume of the rooting medium is discussed in detail in papers by Mr. Endean and Mr. Boudoux. In general, volume of the rooting medium should be at least equal to the air volume occupied by the top when the seedling is of a size appropriate to its intended use.

Root Pruning

Whether or not the roots should be pruned is an important question. Roots which grow out of containers and across the bottom of the tray are of no value in planting as they will only be distorted when set in the ground. These roots must be removed, manually if necessary; but it would be better if their development was prevented. This has been done in the past by spraying copper paint or placing a sheet of copper foil in the bottom of the tray that holds the containers. This stops the roots from growing out of the container, but the total result is not completely desirable. Table 3 shows an interaction of two fertilizers with a copper and non-copper substratum. The effect on growth is that the presence of copper reduced height growth and total weight by 16 and 18%. Columns 7 and 8, Table 3, clearly indicate the effect of copper on roots and shoots. Copper content of treated roots is very very high and that is the reason, I suspect, for the reduced growth. The seedlings are suffering from mild copper toxicity.

A more desirable method of root pruning than poisoning them with copper, is permitting them to grow in the hostile environment: dry air. This has been termed "air root pruning" and is achieved by suspending containers above circulating air. Better still is to use containers with root permeable materials (such as peat) and having the containers sufficiently separated for air circulation.

Table 3. Influence of copper flat-lining on growth of tubed lodgepole pine seedlings (Hocking unpublished)

Treatment	Seedling parameters					Copper (ppm)	
	Height (cm)	Total wt (mgs)	Inside tube root wt (mgs)	Outside tube root wt (mgs)	Total root wt (mgs)	Roots	Shoots
½N, copper	7.16	123.2	25.2	-	25.2	106	6
½N, no copper	7.63	142.3[1]	20.8	8.3	28.3	9	4
RX - 30, copper	5.76	82.4	19.5	-	19.5	219	13
RX - 30, no copper	6.15	100.3[2]	14.1	9.2	23.3	12	8

[1]Difference from copper-treated: 16%.
[2]Difference from copper-treated: 18%.

Hardening Off

We should look at how we handle seedlings before they go to the forest: i.e. hardening off. I will discuss later what this term means with respect to the rearing process and to seedling parameters.

Ackerman laid out an early experiment, with lodgepole pine and white spruce that shows the effect of hardening off upon the size of the seedling and upon its survival in the field (Table 4). Seedlings were put in a cold frame 4 weeks prior to planting and controls were retained in the greenhouse. There was no significant effect upon total weight of lodgepole pine, but there was a large effect upon the shoot to root ratio. Root growth continued while shoot growth was depressed. For white spruce there was a large effect upon both total weight and shoot to root ratio. Survival of hardened seedlings in the third year was about 50% better than the controls.

Table 5 illustrates another experiment in hardening off. We tried to simulate outdoor hardening off in the greenhouse by using a treatment of low nutrients and increased potassium. Seedlings were "hardened" by treating them with KCl solution while withdrawing nutrients and maintaining them in the greenhouse. Controls were hardened off in cold frames, and received standard fertilizer treatment. "Hardening" treatments involved seedlings reared with different proportions of nitrogen and phosphorus in the fertilizer.

Seedlings that had received the KCl treatment survived and grew better than those hardened off in the normal way, in cold frames. But this might have been because they were very significantly larger overall. The previously observed effect of cold frame hardening off, reduced growth and shoot/root ratios, was confirmed here. There were no consistent differences relatable to the nutrient treatment.

Table 4. Influence of hardening off in a cold frame on seedling size and field survival (Ackerman unpublished)

	Lodgepole pine		White spruce	
	Greenhouse	Cold frame[1]	Greenhouse	Cold frame[1]
Total weight (mgs)[2]	47.5	46.3	20.1	9.7
Top weight (mgs)	40.8	35.5	16.7	7.4
Root weight (mgs)	6.8	10.8	3.4	2.3
Shoot/root ratio	6.1	3.8	4.9	3.6
Percent survival (3 years)	46.0	62.0	42.0	60.0
Mean height in inches (3 years)	4.1	4.4	2.2	2.2

[1]Hardened 4 weeks in cold frames.
[2]After 8 weeks total growing time.

Table 5. Influence of method of hardening off and nutrient regime on survival and growth of white spruce seedlings (Hocking unpublished)

Treatment[1]	Total weight at time of planting (mgs)	Shoot to root ratio at time of planting	Wet site		Dry site	
			Survival[2] (%)	Mean height (cm)	Survival (%)	Mean height (cm)
KCl N:P	85.6	5.0	86.9	3.7	83.8	2.2
KCl 2N:P	76.1	4.1	77.2	4.2	63.8	2.4
KCl N:2P	77.8	4.8	92.6	3.7	89.9	4.2
KCl 2N:2P	84.6	4.7	88.4	4.1	68.4	3.6
Mean KCl treatments	81.0	4.7	86.3	3.9	76.5	3.1
Cold Frame N:P	57.5	3.2	79.9	2.9	32.2	1.7
Cold Frame 2N:P	60.7	3.5	72.9	2.5	75.6	2.9
Cold Frame N:2P	59.7	3.1	44.2	2.0	40.6	1.9
Cold Frame 2N:2P	61.7	3.3	67.4	2.8	74.7	2.4
Mean, cold frame treatments	59.9	3.3	66.1	2.5	55.6	2.2

[1]Grown for 8 weeks from emergence in the greenhouse, then 2 weeks of "hardening" treatment.
[2]Assessments made after two growing seasons in the field.

With regard to cold frame hardening off, it definitely has an effect on growth and on survival; but the reasons for the effect are not at all clear. Without knowing clearly what "hardening off" is, we can't really use it in a rational way. For example, later in the summer we can't put seedlings out in the cold frames and get the same effect that we do in the spring. We need to analyze further what we mean by "hardening off". What are the influences of the environment in the cold frame (and what is the physiological effect of a KCl treatment) that bring about changes in the seedling which result in differences in survival?

Influence of Light

Light is one of the main environmental factors that we can control in the rearing of seedlings. One of the most important aspects of light is the photoperiod; or hours of light per day. Growth rates and cycles of many plants respond to day length changes. Table 6 illustrates such responses of five provenances of white spruce and five of lodgepole pine from Alberta. There is almost a full degree of latitude differences between the most northerly and the most southerly spruce provenances, not quite as much for the pine.

The southerly seedlots tend to have a greater weight than the northerly ones under a short photoperiod. However, northerly provenances respond much more to increased photoperiods, both in terms of dry weight and in height. The message here is: tailor the photoperiod to the provenance, within practical and economic limits.

There are other questions regarding light which I won't discuss in detail but which must be borne in mind. They are: Should the light be intermittent or should it be continuous? What sort of fluctuations are necessary? What intensity? What sort of threshold level is necessary to bring about a response? What are the critical wave lengths, and how may they be delivered economically?

Temperature Effects

Temperature is one of the easiest things to control in raising seedlings. Figure 1 shows a generalized diagram of response to temperature of roots and shoots separately. Response in this instance is similar for lodgepole pine and for white spruce. There is a greater response to increased day temperature in the shoot than there is in the root. So if, and this is a big "if", your objective is to get the shoot/root ratio down, you have to lower the day temperatures to suppress shoot growth while root growth continues. Figure 2 illustrates the same principle in terms of shoot/root ratio. The shoot/root ratio increases faster at a high temperature than it does at a low temperature for spruce and for pine. The response is more marked for white spruce than for lodgepole pine.

Temperature has an even more marked effect if you can control independently the shoot and root temperatures. Figure 3 shows the responses to different soil temperatures at a constant air temperature of 80° during the day and 60° during the night. At 40°F root temperature, it doesn't matter how warm the air is, the seedlings are not going to grow much at all. But as you increase the soil temperature you get progressively greater growth. That can be expressed again in shoot/root ratios as in Figure 4. The three lines represent different provenances, but the trends are the same for all provenances. Shoot/root ratio for lodgepole pine seems to be levelling off at a root temperature of about 70; for white spruce it has a minimum at 50 and then starts to go up again.

These observations help to explain the changes that occur in seedlings' growth during cold frame hardening off. You can go a long way toward controlling growth rates and shoot/root balance through temperature control.

Table 6. Clinal response to photoperiod, Alberta white spruce and lodgepole pine (Hocking unpublished)

Latitude of seed source (°)	Total dry wt (mgs) (14 hr)	Growth response (% of 14 hr value)				Shoot to root ratio (by wt) at		
		Dry weight (mgs)		Height (cm)				
		18 hr	22 hr	18 hr	22 hr	14 hr	18 hr	22 hr
White spruce								
1. 58.35	107.2	244	400	157	171	1.21	2.18	3.25
2. 56.45	138.2	206	345	132	143	1.94	2.23	2.81
3. 54.15	176.3	141	256	135	143	1.63	2.14	2.16
4. 52.30	224.8	139	242	98	99	2.41	2.59	2.85
5. 49.20	178.9	136	144	89	88	2.65	2.49	2.45
Lodgepole pine								
1. 56.30	407.0	134	371	111	113	3.28	3.98	2.59
2. 55.15	338.0	196	293	102	109	2.97	2.94	2.69
3. 53.40	360.5	158	271	108	110	3.10	3.23	2.67
4. 52.20	657.6	152	240	104	102	3.42	2.96	2.18
5. 49.35	695.6	144	231	94	83	2.22	2.21	2.99

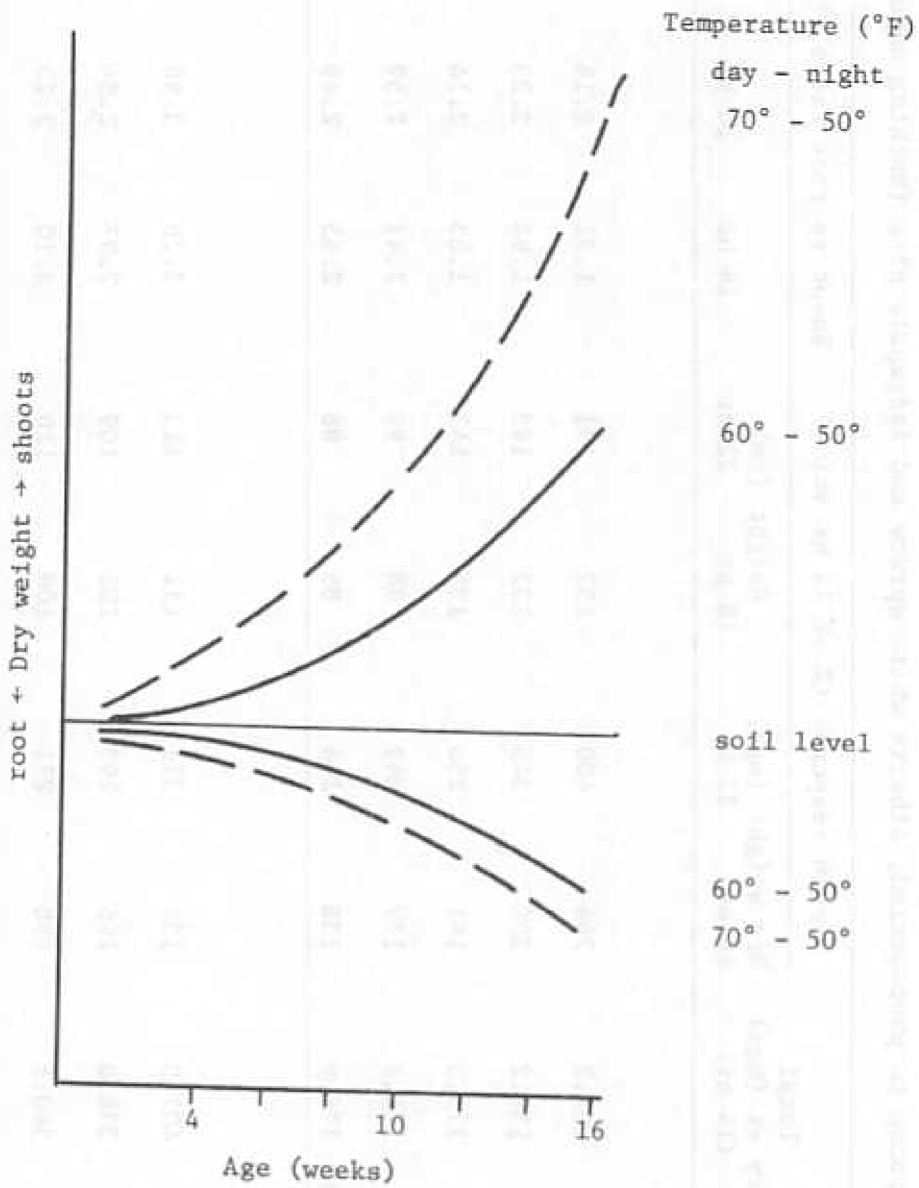

Figure 1. Influence of air temperature on shoot and root growth; generalized for white spruce and lodgepole pine (Hellum unpublished).

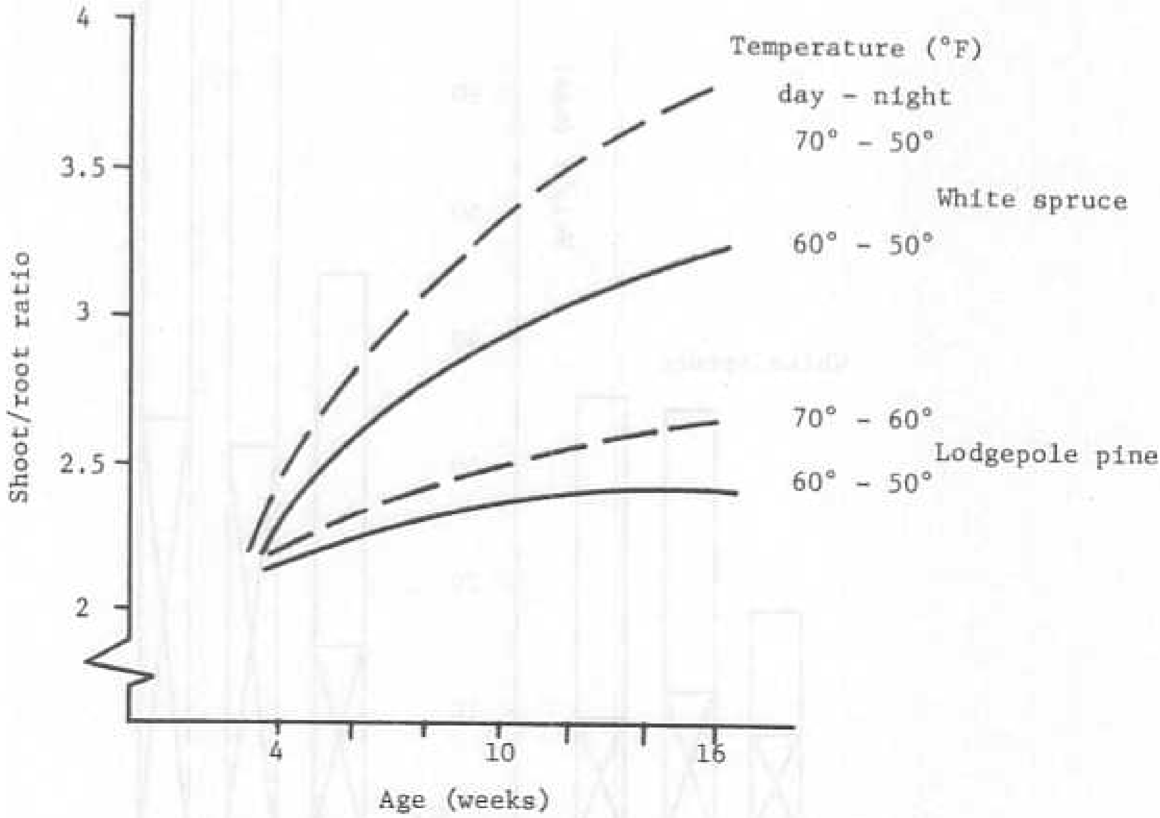

Figure 2. *Influence of air temperature on shoot/root ratio of white spruce and lodgepole pine (Hellum unpublished).*

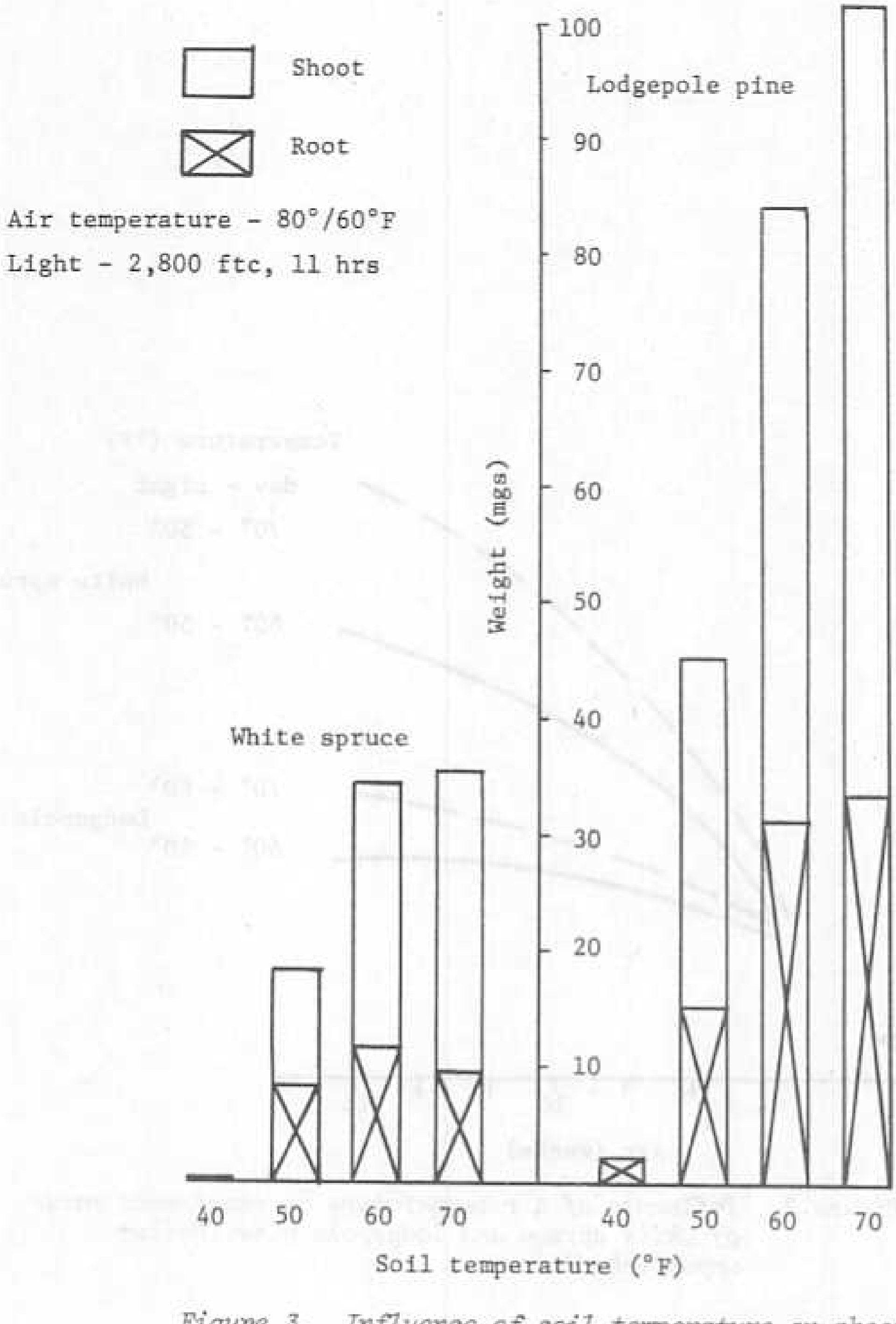

Figure 3. Influence of soil temperature on shoot and root growth of white spruce and lodgepole pine (Ackerman unpublished).

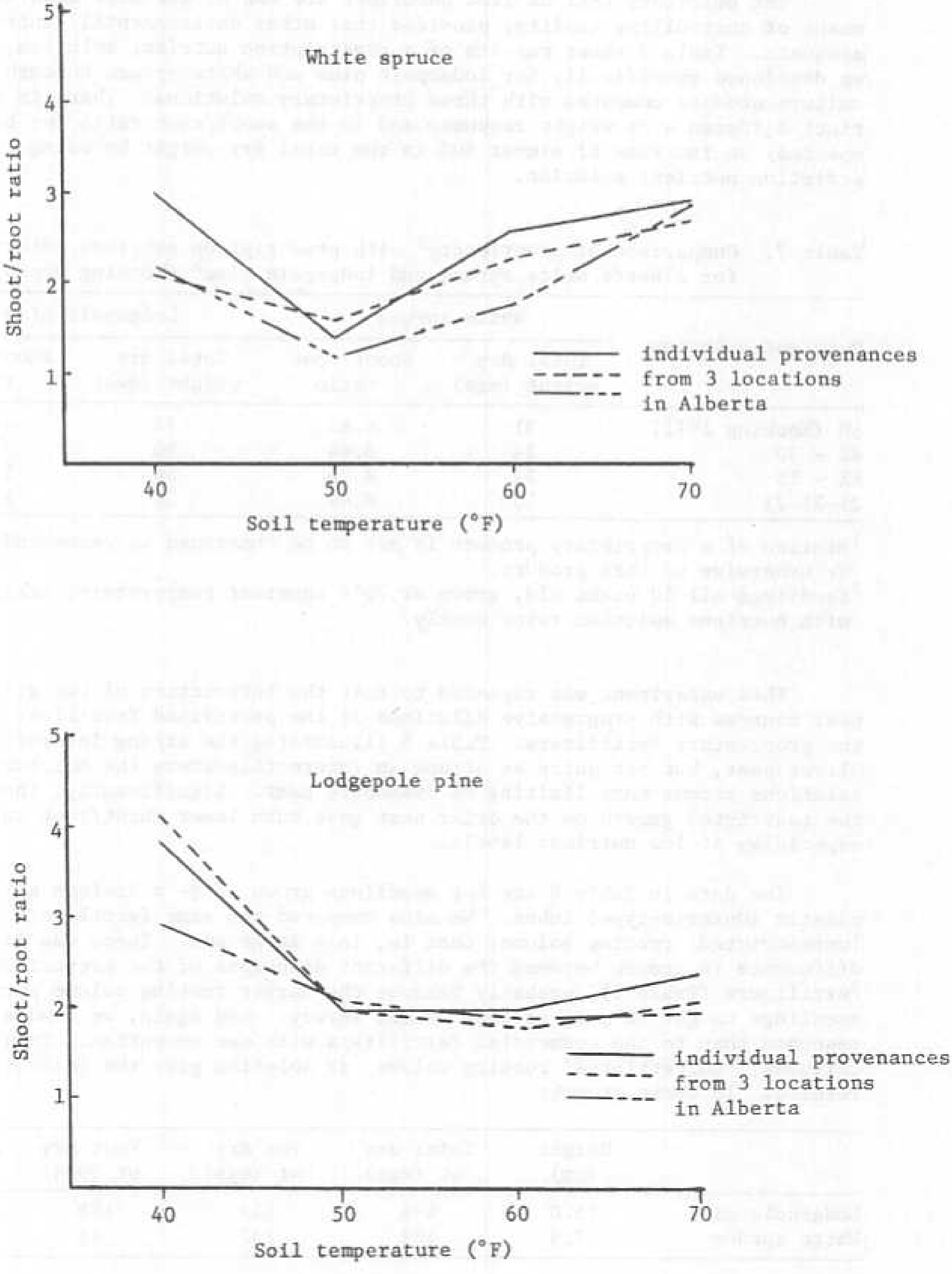

Figure 4. Influence of soil temperature on shoot/root ratio of white spruce and lodgepole pine (Ackerman unpublished).

Nutrition

The nutrients that we feed seedlings are one of the most important means of controlling quality, provided that other environmental controls are adequate. Table 7 shows results of a prescription nutrient solution, which we developed specifically for lodgepole pine and white spruce through sand culture studies compared with three proprietary solutions. There is a distinct difference in weight response and in the shoot/root ratio for both species: an increase of almost 50% in the total dry weight by using a prescription nutrient solution.

Table 7. Comparison of proprietary[1] with prescription nutrient solutions for Alberta white spruce and lodgepole pine[2] (Hocking unpublished)

Nutrient solution	White spruce		Lodgepole pine	
	Total dry weight (mgs)	Shoot/root ratio	Total dry weight (mgs)	Shoot/root ratio
½N (Hocking 1971)	31	6.65	73	4.03
RX - 30	24	8.64	50	5.70
RX - 15	22	8.25	54	5.97
21-21-21	20	8.44	32	5.00

[1]Mention of a proprietary product is not to be construed as recommendation or otherwise of that product.

[2]Seedlings all 10 weeks old, grown at 70°F constant temperature, irrigated with nutrient solution twice weekly.

This experiment was repeated to test the interaction of two different peat sources with progressive dilutions of the prescribed fertilizer and the proprietary fertilizers. Table 8 illustrates the strong interaction on Oliver peat, but not quite as strong an interaction where the moisture relations become more limiting on Evansburg peat. Significantly, though, the restricted growth on the drier peat gave much lower shoot/root ratios, especially at low nutrient levels.

The data in Table 8 are for seedlings grown in ¾- x 3½-inch split plastic (Ontario-type) tubes. We also compared the same fertilizers in an 'unrestricted' rooting volume; that is, in a large pot. There was little difference in growth between the different dilutions of the prescribed fertilizers (Table 9), probably because the larger rooting volume permitted seedlings to get as much as they needed anyway. And again, we find a better response than to the commercial fertilizers with one exception. In sand cultures, 'unrestricted' rooting volume; ½N solution gave the following results: 16 weeks growth:

	Height (cm)	Total dry wt (mgs)	Top dry wt (mgs)	Root dry wt (mgs)	Shoot/root
Lodgepole pine	15.0	496	337	159	2.12
White spruce	7.9	183	137	46	3.00

Table 8. Interaction between nutrient solutions and substratum on growth of lodgepole pine in $\frac{3}{4}$- x $3\frac{1}{4}$-inch split plastic (Ontario-type) tubes[1] (Hocking unpublished)

Fertilizer	Oliver peat[2]					Evansburg peat[2]				
	Height (cm)	Total dry wt (mgs)	Shoot wt (mgs)	Root wt (mgs)	Shoot/ root	Height (cm)	Total wt (mgs)	Shoot wt (mgs)	Root wt (mgs)	Shoot/ root
$\frac{1}{2}$N[3]	6.8	102	81	21	3.88	5.6	75	57	18	3.18
$\frac{1}{2}$N/2	5.4	82	62	20	3.12	4.5	68	49	20	2.47
$\frac{1}{2}$N/4	5.1	73	56	18	3.10	3.7	55	37	19	1.94
RX-15 ($\frac{1}{4}$ tbsp/gal)	4.9	73	57	16	3.64	4.7	75	48	16	2.95
RX-30 "	5.7	81	67	14	4.79	5.8	70	56	14	4.04
21-21-21 "	5.2	68	54	14	3.92	4.5	71	52	18	2.85
Example for white spruce, 10 weeks on $\frac{1}{2}$N	5.3	35			6.5					

[1]Age: 10 weeks from emergence. Irrigation: fertilizer solution once a week; 1 gal/10 ft^2 of tubes; no additional water. Environment: plastic greenhouse; 65-70°F day (peak 90°F at noon), 50°F night; relative humidity 35-40% (trough 20% at noon).

[2]Oliver peat is freshly-dug near the nursery. Evansburg peat is commercially dug, steam-dried and compressed for shipping. The main difference between the two is in moisture-relations. Evansburg peat is difficult to wet and retains only little moisture.

[3]This represents one of the fertilizer solutions found excellent in sand culture studies. The next two lines are respectively $\frac{1}{2}$ and $\frac{1}{4}$ dilutions.

Table 9. Influence of proprietary and prescribed nutrient solutions on potted lodgepole pine and white spruce[1] seedlings with unrestricted[2] rooting volume (Hocking unpublished)

Fertilizer	Height (cm)	Total dry wt (mgs)	Shoot wt (mgs)	Root wt (mgs)	Shoot/ root
½N	7.1	247.2	170.4	76.8	2.22
½N/2	6.7	242.8	166.2	76.6	2.17
½N/4	6.3	244.7	160.3	84.4	1.90
RX-15	7.2	295.5	207.5	87.9	2.36
RX-30	6.8	159.6	116.8	42.8	2.73
21-21-21	5.6	152.9	111.7	41.2	2.71

[1]See footnote 1, Table 8.
[2]Large pots containing peat.

In practical fertilization, apart from using a balanced solution, there are two problems to be aware of: nutrient deficiencies through under-application or leaching, and toxic excesses that might arise through concentration by evapotranspiration.

Moisture

A valuable controlling element is moisture. Our experience has shown that high moisture levels tend to lead to more rapid growth, especially of shoots. Low moisture conditions (not severe stress) tend to restrict shoot growth more than root growth. This is suggested by the data in Table 9. Again extremes of moisture, as with nutrition, lead to problems: excesses to diseases or stunting, deficiency to wilting or death.

Seedling Specifications

The data presented earlier illustrate how we can control to a nice degree, the size and proportions of the seedlings we rear. We have used this information to try to develop some knowledge of desirable seedling specifications. We have done some work on growing what we call different seedling types, for want of a better word. Table 10 illustrates four seedling types resulting from nutrient, moisture and age differences. The first type, A, is a big seedling almost ½ gram in total weight, with a high shoot/root ratio. Seedling B is only about ¼ of the size but it has a much lower shoot/root ratio. Seedling C is smaller yet and has a high shoot/root ratio. Seedling D is a very small seedling in our terms but it is still quite big compared to the ones which go out to the field at 8 weeks of age, and it has a very suitable shoot to root ratio.

We planted these four seedling types in a simulated field condition in which we froze the soil at a depth of 10 inches and permitted it to warm up to a normal air temperature at the surface. The resulting gradient of soil temperature approximated that of the boreal forest. Air temperature

Table 10. Influence of seedling "type" on initial establishment and growth (Hocking and Endean unpublished)

A. Seedling parameters at time of planting.

Seedling type	Shoot wt (mgs)	Root wt (mgs)	Total wt (mgs)	Shoot/root ratio	Rearing conditions Nutrient	Age (wk)
A	440.6	130.0	570.6	3.39	½N	16
B	119.6	70.7	190.4	1.69	½N/4	16
C	114.2	41.2	155.4	2.77	½N	12
D	46.6	26.9	73.5	1.73	½N/4	12

B. Seedling responses after 12 weeks in simulated field conditions.

1. In dry clay.

Seedling type	Total wt (mgs)	Shoot/ root ratio	Shoot wt increment (mgs)	%	Proportion of same age type	Root wt increment (mgs)	%	Proportion of same age type
A	1006.8	3.12	322.6	73	96	114.6	88	115
B	335.9	1.67	90.7	76		54.9	78	
C	411.3	3.04	185.2	162	100	60.7	147	113
D	184.0	2.00	76.1	163		34.4	128	

2. In moist loam.

Seedling type	Total wt (mgs)	Shoot/ root ratio	Shoot wt increment (mgs)	%	Proportion of same age type	Root wt increment (mgs)	%	Proportion of same age type
A	1299.9	2.69	507.1	115	83	222.2	171	151
B	434.6	1.89	1164.7	138		79.6	113	
C	546.6	2.54	278.8	244	140	113.4	275	138
D	207.4	1.60	81.3	174		53.6	199	

was varied, day to night, to approximate field conditions. We planted in two different soil types at two different soil moistures. I have given in Table 10 only data for the two extremes: the dry clay soil and the moist loam soil.

After the equivalent of one field season, 12 weeks, seedlings were assessed and the growth increments were expressed in absolute quantities and as percentages of the original weights. The interesting comparison here is between the two seedling age groups. The first group, of seedling types A and B, were 16 weeks old and were grown on a rich nutrient and a dilute nutrient. Group C and D were 12 weeks old and were grown on a rich nutrient and a dilute nutrient. Between age groups, proportionate shoot growth is about the same: 96 and 100%. But the seedlings with the rich nutrient regime, both the old ones and the young ones, put on more root growth than the ones on the low nutrient regime: 115% and 113%. Interestingly, the younger seedlings put on proportionately more shoot and root growth than the older ones. This is for dry conditions, i.e., within 5% of wilting point moisture, for the whole period of growth.

Seedlings in moist loam grew a great deal more. The root growth of the seedlings reared on rich nutrients is very much more than for those reared on dilute nutrients. The shoot growth is a little bit less between the big seedlings but much more for the small seedlings.

One thing I'd like to point out here is that even though the rich nutrient seedling in moist loam only put on 83% as much in proportionate growth as the little seedling, 115% of 507 milligrams, is still quite a lot more than 138% of 164 milligrams. In short, the big seedlings increased their advantage in absolute terms during this growth period. The differences between them and the small ones were increased; they out performed them.

Table 11 shows the results of a droughting experiment. Seedlings were planted into moist sandy loam and were given no more water for a period of 12 weeks. The final soil moisture content was 7.45%; 45% of the seedlings were wilted or dead. We then watered the seedlings and left them for 2 weeks; finally we excavated them washed them, and determined root and shoot increments. Seedlings which did not exhibit new white root tips were classified as being dead.

In this extreme drought condition, the majority of the seedlings' energy went into root growth. Seedling type A put on 192% shoot increment but 750% root increment. Increments of similar proportions were noted for all types. This result is observable also in the trend of all the seedling types towards a lower and nearly uniform shoot/root ratio. There are no really important differences in mortality.

The important point, then, is that the seedling type in terms of total weight and shoot/root ratio, gave no important differences in survival either in drought conditions or in normal conditions, but did give very important differences in growth response.

Table 11. Influence of seedling "type" on tolerance of extreme drought (Hocking unpublished)

A. Seedling parameters at time of planting.

Seedling type	Shoot wt (mgs)	Root wt (mgs)	Total wt (mgs)	Shoot/ root ratio	Rearing conditions[1]
A	88.0	25.2	113.2	3.51	01
B	67.4	22.3	89.7	3.02	02
C	59.4	23.3	83.7	2.55	04
D	87.0	24.1	111.1	3.61	E1
E	62.6	24.4	87.0	2.56	E2
F	55.1	25.2	80.3	2.18	E4

B. Seedling responses after 12 weeks with no watering: final soil moisture content 7.45%; 45% wilted or dead.

Seedling type	Total wt (mgs)	Shoot/ root ratio	Shoot wt increment (mgs)	%	Root wt increment (mgs)	%	Mortality %
A	469.8	1.21	169.0	192	187.6	750	33
B	389.7	1.08	134.7	200	165.3	740	31
C	313.0	1.27	116.1	195	115.2	495	29
D	391.0	1.13	121.1	139	159.7	665	29
E	262.0	1.11	75.4	120	99.6	408	27
F	196.8	1.08	46.9	85	69.6	277	23

[1]Seedling types were grown in differed substratum (0 indicates Oliver peat; E - Evansburg peat) and subjected to 3 different nutrient treatments. (1,2 and 4 indicate progressive dilutions.)

Seedling Age and Quality

Age is really not a suitable criterion by which we can specify seedling quality. We must use such parameters as seedling weight and the ratio of shoot to root. Another expression I've considered and which seems to give a correlation is the ratio of shoot length to the total weight of the seedling; the length in millimeters and the weight in milligrams.

There are other parameters as well: bud activity and whether or not there are active white root tips. But the outcome of our experiments so far with seedling types suggests simply that the bigger the seedling the better it does in good or extreme site conditions. Our experiments have been replicated in the field, and we hope to have results from these worked out this winter.

CONCLUSION

In conclusion, I would emphasize again that in order to rationalize the rearing process we have to understand and control all aspects of growth. Secondly, we have to have an objective - we have to know what we are trying to grow. And thirdly, we need to monitor operational production to maintain control and achieve our objective.

REFERENCES

Hocking, D. 1971 Preparation and use of a nutrient solution for culturing seedlings of lodgepole pine and white spruce; with selected bibliography. Can. Dep. Fish. Forest., Forest Res. Br., Northern Forest Research Centre. Information Report NOR-X-1.

ACKNOWLEDGEMENTS

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PHYSIOLOGICAL BASIS FOR THE MANIPULATION

OF SEEDLING CHARACTERISTICS

H.M. Etter[1]

INTRODUCTION

Container planting systems offer many opportunities, and dilemmas, in the selection of the correct growth conditions during the rearing phase. Most rearing programs allow for the selection and control of physical factors such as temperatures, moistures, lighting conditions and container design; of chemical factors such as nutrition and rooting medium pH; and of biological factors such as seed source, age at planting and hardening off requirements. Many of these quantitative and qualitative choices, within the potential range of each factor, are made without a basic philosophy against which they can be weighed. I would like to present such a rearing philosophy based upon several studies (Etter 1969, 1971, Gietych and Farrar 1961) and upon general physiological and ecological principles (Kozlowski 1971, Teeri 1971, Vegis 1964) that I think will be of interest to those who must determine and improve upon current rearing techniques.

SPECIES AND ECOTYPE SELECTION

The first way in which seedling characteristics can be determined is by selection of specific species and ecotypes from among those plants that grow in a given planting region or are to be introduced into it. This selection should be done in relation to the environmental gradients that will be encountered by the plant in the field among which moisture and temperature are perhaps the most important. Physiological information can assist in making these selections by choosing drought resistant types for very dry sites, and plants that can carry on anaerobic respiration for sites that may be flooded. Recent studies with arctic plants (Teeri 1971) have indicated the importance of these two physiological processes in the distribution of tundra vegetation along moisture gradients. Selections based upon the effects of temperature on photosynthesis or on root growth would also be important. Once the appropriate species and ecotypes have been selected, much can still be done to manipulate their characteristics during rearing, but only within their defined genetic potentials.

HETEROTROPHIC GROWTH

The first physiological stage that occurs during rearing is the period from water uptake by the seed until the seedling begins to respond

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[1]Canadian Forestry Service, Northern Forest Research Centre, Edmonton, Alberta.

to external light and nutrient conditions. This growth period is termed the heterotrophic growth phase, and usually extends for 2-3 weeks after germination for lodgepole pine or white spruce. During this period the plant's growth requirements, and our ability to alter its growth, are limited mainly to variations in temperature, moisture and substratum oxygen conditions. Fertilization and high light intensities are not required since the nutrient and carbohydrate reserves in the seed and cotyledons are used for growth. A transition from this growth phase to the next appears first in the leaves in response to increased rates of photosynthesis. Roots do not respond to nutrients until after the shoots, and no response to nitrogen fertilization has been found in the roots of white spruce until 5-6 weeks after germination (Etter 1971). Table 1 further describes the responses of white spruce seedlings to nitrogen nutrition during their heterotrophic to autotrophic transition.

Table 1. Dry weights (mg/plant) and root-to-leaf ratios of 5-week-old (from germination) white spruce grown under various nitrogen regimes.

		Nitrogen level (ppm N)		
Plant part	Nitrogen form	5.6	56	112
Leaf	Nitrate	5.4 a[1]	9.0 b	8.3 b
	Ammonium	5.1 a	8.2 b	9.1 b
	Ammonium nitrate	6.0 a	8.6 b	9.1 b
Stem	Nitrate	1.1 a	0.9 a	0.9 a
	Ammonium	0.8 a	0.8 a	0.8 a
	Ammonium nitrate	0.9 a	1.0 a	1.0 a
Root	Nitrate	2.6 a	2.7 a	2.3 a
	Ammonium	2.7 a	2.3 a	2.2 a
	Ammonium nitrate	3.1 a	3.0 a	2.9 a
Whole plant	Nitrate	9.1 a	12.6 b	11.5 b
	Ammonium	8.6 a	11.3 b	12.1 b
	Ammonium nitrate	10.0 a	12.6 b	13.0 b
Root/leaf	Nitrate	0.48 a	0.38 b	0.28 c
	Ammonium	0.53 a	0.28 b	0.24 c
	Ammonium nitrate	0.52 a	0.35 b	0.32 b

[1]Values are the mean of four replications each consisting of 40 plants. Values in the same row that are followed by the same letter do not differ significantly at the 95% level.

AUTOTROPHIC GROWTH

The second physiological state that is encountered during rearing is autotrophic growth. Photosynthesis and mineral nutrient utilization begin to determine the rate of growth of the plant as it develops; additional light intensity and mineral nutrient supplies must be supplied along with optimal temperature and moisture conditions. At this point all of these environmental conditions can be optimized to speed growth to the desired size until the rooting volume becomes limiting. The nitrogen level and light intensity have a strong influence on the root/leaf ratio, with maximum root/leaf ratios obtained by low nitrogen nutrition, high light intensity, adequate spacing between plants and an adequate rooting volume. Most higher plants cannot be continuously maintained in a rapid growth phase, and enter a quiescent or dormant condition unless they are exposed to special environmental conditions such as a broken night period (Gietych and Farrar 1961). If growth is to occur soon after the seedlings are planted out, they must not be entering a dormant state. This planting requirement will in turn influence the length of the autotrophic period. As the plant approaches its normal dormancy period, exposure to cold temperatures or short days will induce dormant bud development. The phenological state of the plant at the end of the assisted growth period is related to its immediate growth potential in the field. Thus planting out should be programmed well before or immediately after its normal dormancy period. While we know less about root dormancy and growth than shoot dormancy and growth, consideration has to be given to the fact that roots and shoots do not show their greatest growth at the same time, or in response to the same environmental conditions. For example, root growth can occur in the spring or fall when the shoots are not actively growing.

On the other hand, planting a seedling in the middle of its most active growth phase can present survival problems since the plant's resistance to frost, drought and heat are low in this phase; also, the plant is growing at a rate that probably cannot be maintained in the field due to lower availability of nutrients, moisture and light or to lower temperatures. The physiological state of the plant must therefore be altered before it is planted out or overwintered. This leads to the third physiological state that I would like to identify, i.e., dormancy.

IMPOSED AND TRUE DORMANCY

If a plant is exposed to unfavourable growing conditions such as low temperatures or nitrogen deficiency at an age when it does not normally become dormant, an imposed dormancy results (Vegis 1964). The main differences between an imposed dormancy and a true dormancy are the conditions required to reactivate growth. Plants in an imposed dormancy will grow as soon as unfavorable environmental conditions are removed; whereas plants in true dormancy usually have special requirements, such as an extended cold period, before they will break dormancy.

An imposed dormancy should follow the rapid autotrophic growth period to increase the plant's resistance to adverse environmental conditions, to more closely match its growth rate with the capabilities of the field location, and to foster the establishment of a symbiotic relationship with mycorrhizal fungi in an attempt to reduce planting check and increase first year survival.

SUMMARY

This rearing philosophy for a hypothetical rearing system is summarized in Table 2 by listing the critical environmental factors that exist during the heterotrophic, autotrophic, dormant or field establishment phases.

Table 2. Hypothetical rearing system and field establishment for lodgepole pine or white spruce first year seedlings.

Growth phase	Approx age in weeks	Critical environmental factors				
		temp	light	moisture	nutrition	other
Hetertrophic	0-4	high-low alternating	low short day	high frequent	none	substratum oxygen high
Autotrophic	4-10	high continuous	high long day	moderate	high	adequate rooting volume
Imposed dormancy	10-12	low continuous	moderate shorter day	moderate	none	
(True dormancy overwinter can be inserted)						
Field establishment	12-18	moderate-low alternating	high	moderate	moderate	contact between roots and soil

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A LOOK AT SHOOTS'N ROOTS IN THE NURSERY

R.G. Matthews[1]

AIR ROOT PRUNING

The BC/CFS Styroblock 2 cavity is designed with a taper of 70 thousandths per inch of length to facilitate the extraction process. The lower portion of the cavity is rounded to guide roots to the drainage holes where air root pruning is achieved. A more recent design employs a conical shape in this area to eliminate some tendency to root spiraling at the bottom of the cavity.

In order for the air pruning principle to work, adequate ventilation must be supplied under the Styroblocks. If Styroblocks are placed on gravel or asphalt surfaces, seedling roots will soon extend into these surfaces. Styroblocks at Surrey and Duncan nurseries (BC) are supported on pallets constructed with 2 x 4's on edge.

Even with this method, ventilation near the center of the pallet is sometimes inadequate and roots will grow out onto the moist surface of the pallet boards. Walters' bullets in plastic trays may also lack adequate ventilation as the bullets are normally suspended within ½-inch of moist pallet boards. This is a poor nursery practice as seedling roots can come in contact with disease organisms. This practice also results in a poor root system as most of the growing tips are outside the container and will be lost prior to planting.

Problems can also arise with some shallow rooting species if the cavities in the Styroblock are filled too full. Sitka spruce has extended surface roots into adjacent blank cavities, forming two root plugs.

Examples of white spruce, interior Douglas-fir and lodgepole pine extracted at Surrey nursery in mid-September show good air root pruning. White spruce and Douglas-fir, sown April 29 and May 12 respectively, have shown poorly developed root systems due to their late start. Another problem with Douglas-fir is its tendency not to proliferate roots in the upper portion of the soil, making the formation of a complete plug difficult.

Lodgepole pine sown April 14 has formed a good plug by mid-September. It probably should be planted at this stage to avoid root spiraling, which is common with this species in Styroblocks.

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[1]Canadian Forestry Service, Pacific Forest Research Centre, Victoria, British Columbia.

CONTAINER SIZE

Seedlings have been grown in containers of many shapes and sizes. In Victoria, a prototype plug container was constructed of toothbrush containers having a rectangular cross section. The root systems produced had a similar shape. Containers were also constructed of various diameters and lengths of PVC pipe and from plastic drinking straws. The PVC containers were fitted with a styrene cone to similate the root pruning effect achieved in bullets. The PVC containers varied in diameter from 1.5 cm to 8 cm and in length from 6 cm to 41 cm. Only the seedlings in the drinking straws were obviously restricted. Other root systems exploited the shape and size of the container, demonstrating their enormous adaptability.

GROWING MEDIA

Figure 1 illustrates the influence of soil media on shoot and root development and shoot-root ratios. The seedlings were grown in the Styroblock 2 and received the same fertilizer treatment.

White Spruce

Equal shoot-root ratios (3.6 and 3.5) are achieved in pure peat or in three parts peat to one part vermiculite. However, pure peat did produce larger shoot and root weights. Pure peat has not been used on a production basis because of the difficulty of loading it into bullets. With the increased use of the larger diameter Styroblock, perhaps its use should be reconsidered.

Interior Douglas-fir

One part peat to one part sand compares favorably in shoot-root ratio to pure peat (2.8 vs 2.5), however the absolute weights of shoots and roots are higher in peat or the 3:1 peat-vermiculite mix. Again, pure peat would be preferable, but caution must be exercised since the water holding capacity of peat or peat-vermiculite may be involved in root-rot problems with coastal Douglas-fir.

Lodgepole Pine

The 3:1 peat-sand mix results in a preferred shoot-root ratio (3.4) - when compared to peat or 3:1 peat-vermiculite - even considering the slight reduction in root weight. However, the additional weight of a soil mix containing sand would not be justified. For this reason peat or 3 peat to 1 vermiculite are the preferred mixes for lodgepole pine.

NUTRIENT ADDITIONS

Figure 2 shows the relationship of shoot and root weights which result from increasing fertilizer rates. This test was conducted in a growth chamber from January to June 1970; a replication in a greenhouse gave similar results. The soil medium was a 3:1 peat-vermiculite mix; the container was the Styroblock 2.

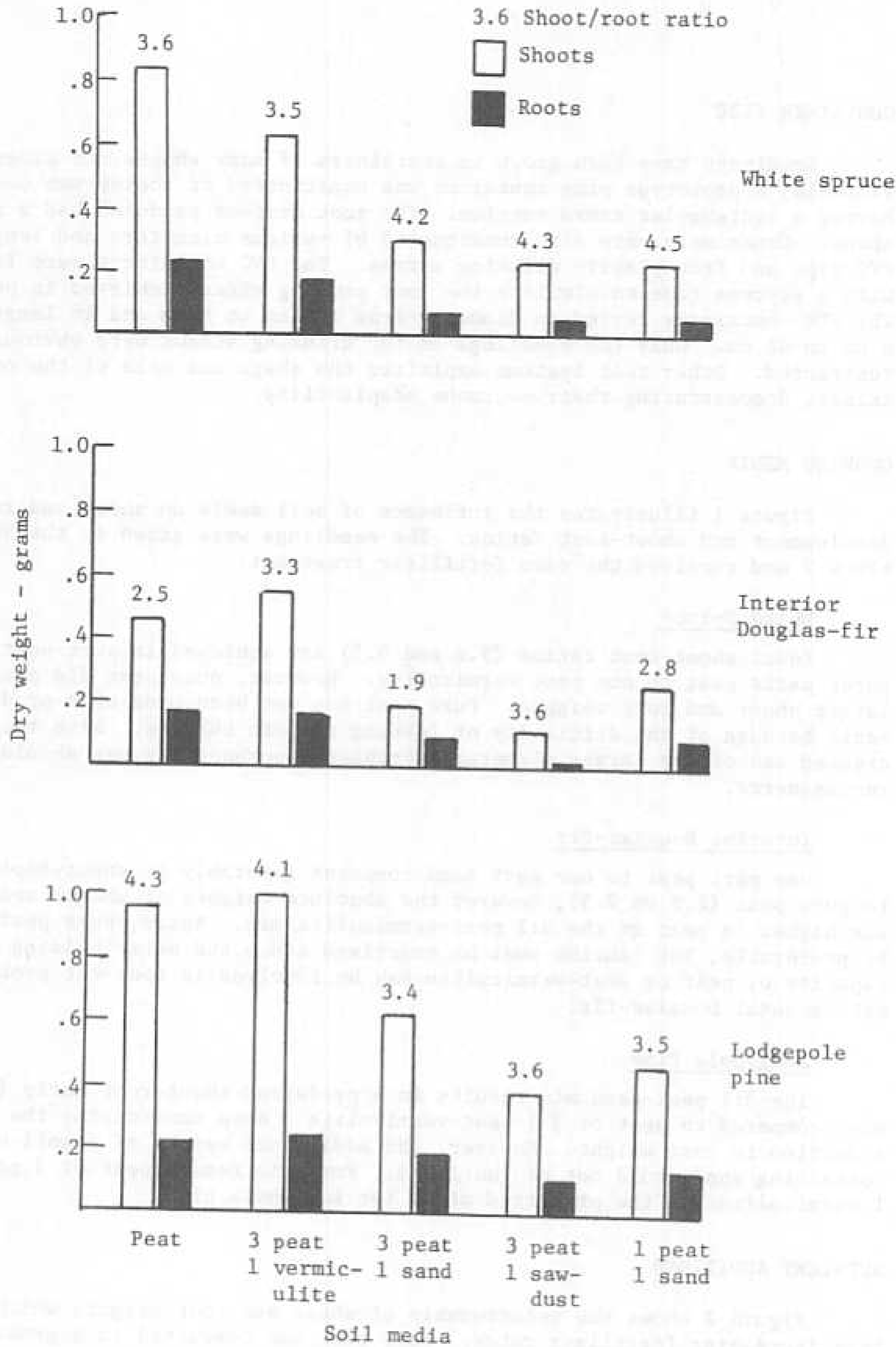

Figure 1. The effect of soil media on the dry weight of shoots and roots and on shoot/root ratio of white spruce, interior Douglas-fir and lodgepole pine seedlings grown 6 months in a growth chamber.

Fertilization treatments:

A - 2 applications of 34-0-0,
1 application of 28-14-14.

B - 2 applications of 21-0-0,
1 application of 28-14-14.

C - applications of 28-14-14 only.

Rates of application are given below.

——— Shoots

------- Roots

1.5 Shoot/root ratio

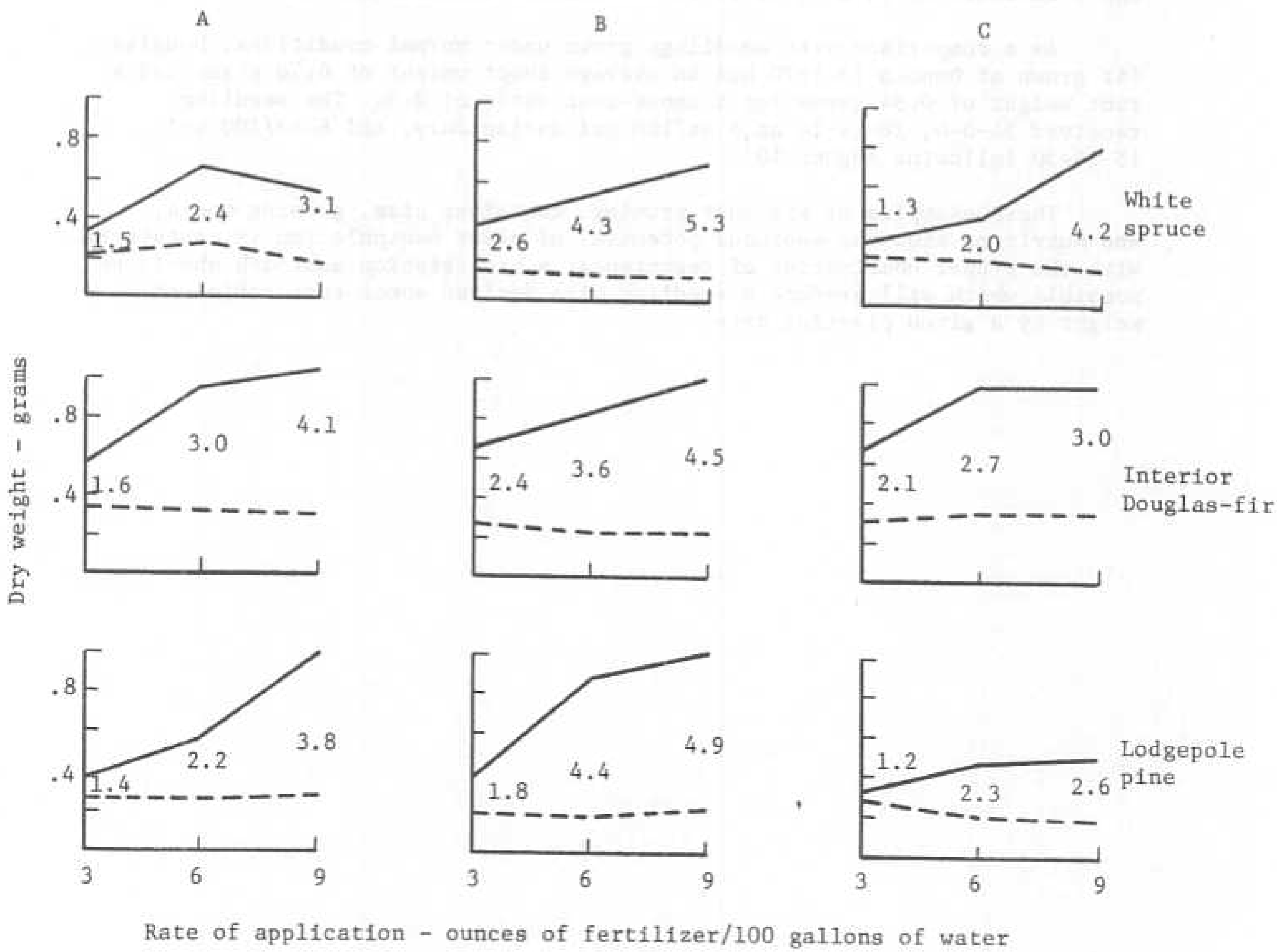

Figure 2. The effect of 3 fertilization treatments on the dry weight of shoots and roots and on shoot/root ratio of white spruce, interior Douglas-fir and lodgepole pine seedlings grown 6 months in a growth chamber.

The fertilizer treatments were:

1) two applications of ammonium nitrate (34-0-0) and 1 application of 28-14-14;
2) two applications of ammonium sulphate (21-1-0) and 1 application of 28-14-14;
3) applications of 28-14-14 only.

The graphs show that increasing the fertilizer rate from 3 oz/100 gal to 6 and 9 oz/100 gals increases shoot weights without a corresponding increase in root weight. In many cases, root weights at higher fertilizer levels are smaller, resulting in unbalanced shoot-root ratios at these levels.

Shoot-root ratios must be balanced with absolute weights to achieve a reasonable standard. This means a higher shoot-root ratio could be preferable if the absolute weights of shoots and roots are higher, e.g., the 6 oz level of 34-0-0, 28-14-14 combination on white spruce.

As a comparison with seedlings grown under normal conditions, Douglas-fir grown at Duncan in 1970 had an average shoot weight of 0.78 grams and a root weight of 0.34 grams for a shoot-root ratio of 2.3. The seedlings received 34-0-0, 28-14-14 at 6 oz/100 gal during July, and 6 oz/100 gal 15-15-30 following August 10.

These examples of air root pruning, container size, growing media, and nutrition show the enormous potential of plant manipulation in containers. With the proper combination of techniques, a prescription approach should be possible which will produce a seedling of a desired shoot-root ratio and weight by a given planting date.

THE POTENTIAL USE OF MYCORRHIZAL INOCULATION IN THE PRODUCTION OF FOREST TREES

J.A. Fortin[1]

INTRODUCTION

The term mycorrhiza designates a structure which results from a symbiotic association between certain fungi and the rootlets of plants. This association, which significantly affects the biological functioning of the roots, was first observed in the boreal forest where it is ubiquitous. In the southern hemisphere, foresters have been widely interested in this phenomenon and have developed many useful applications (Mikola 1969). In Australia and Rhodesia, as examples, inoculating the soil with mycorrhiza fungi is absolutely essential if significant growth of exotic trees, especially the pines, is to be obtained.

In the boreal forest of Canada, the usefulness of mycorrhizal fungi is much more subtle. But even here foresters should have some interest in this symbiotic relationship and they should learn how to use it for the production of forest tree seedlings in sterilized soils.

EFFECTS OF MYCORRHIZAE ON THE GROWTH OF TREES

The mycorrhizal association influences the biological functioning of tree roots and hence the morphology, physiology and ecology of the whole tree.

Morphological Modification

Due to the action of mycorrhizal fungi, the shape of tree rootlets is modified; the rootlets lose their root hairs and these are replaced, so to speak, by the mycelium of the fungus; the hyphae grow between the living cortical cells and form a mantle over the rootlet thus producing the "Hartig net".

The rootlets, invaded by the fungus, branch in different ways according to the species of tree. In the invaded roots, the formation of secondary structures is delayed thus increasing the relative amount of absorbing tissues at the rootlet-soil interface. These effects on the rootlets themselves are followed by a change in the shoot/root ratio which is generally better balanced in mycorrhizal seedlings (Table 1).

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Table 1. Growth characteristics of mycorrhizal and non-mycorrhizal seedlings of red pine cultivated aseptically *in vitro* for 3 months[1]

Treatment	Green weight (mgs)		Shoot/ root ratio	Dry weight (mgs) shoots	Number of mycorrhizal meristems per seedling	Number of seedlings
	Shoots	Roots				
Inoculated	2400	1450	1.6	524	573	12
Non-inoculated	1320	260	5.1	267	0	13

[1]All data presented are significantly different at the 0.1% level.

These morphological changes are induced by plant hormones - auxin (Ulrich 1960) and Kinetin (Miller 1971) - produced by the mycorrhizal fungi.

Physiological Modifications

Mycorrhizal rootlets function differently from those without this association. They absorb minerals from the soil more efficiently than non-mycorrhizal rootlets. This relationship has been demonstrated many times (Harley 1969). Particular attention has been given to the absorption of phosphorous but the absorption of other elements, nitrogen, potassium, and magnesium is affected. Water is also more easily absorbed and thus trees with mycorrhiza are more resistant to dessication (Mikola 1969).

Ecological Modifications

The relationships between rootlets and soil microorganisms are completely transformed by the presence of mycorrhizal fungi. Marx (1969) showed that mycorrhizal rootlets are resistant to pathogenic fungi and nematodes. An antibiotic, diatretyne nitrile, has been detected in mycorrhizal tissues.

PRACTICAL CONSEQUENCES

It is possible to apply this knowledge to the production of forest tree seedlings in the nursery and, as well, to the container-growing of seedlings in greenhouses.

In the nursery, a mycorrhizal seedling would utilize soil nutrients more efficiently and would not suffer from unbalanced nutrition. Such seedlings would require less irrigation as the mycorrhizal fungi would help in holding moisture around the rootlets; seedlings, through antibiotic substances, could be more resistant to pathogenic fungi. An increased growth rate could be anticipated (Figures 1 and 2). At the time of planting the seedlings would have a low shoot/root and a pool of minerals, especially phosphorus, would be trapped in the fungal mantle of each rootlet. These seedlings would be in a position to cope immediately with the microbial environment of the forest floor.

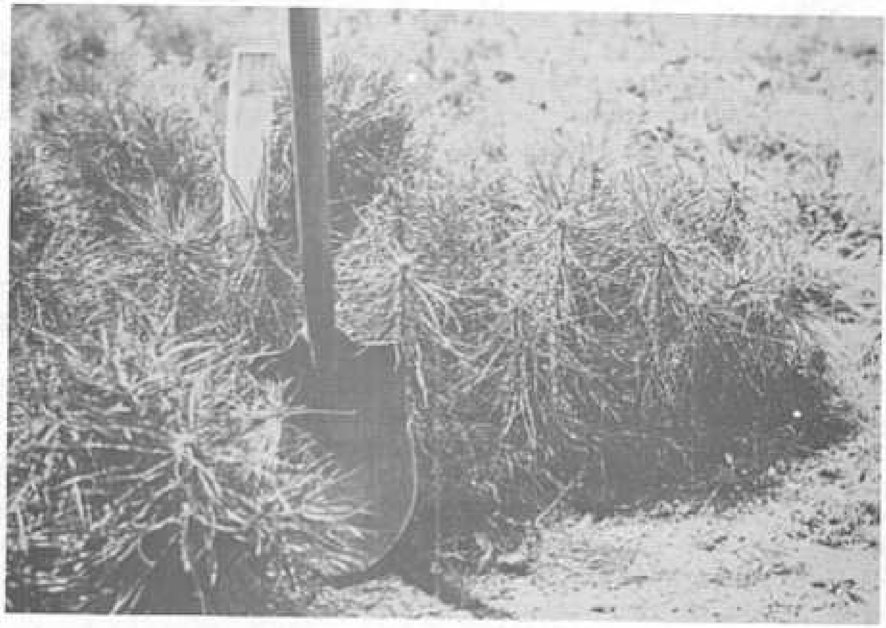

Figure 1. Mycorrhizal red pine seedlings in their second year of growth in a previously sterilized nursery soil.

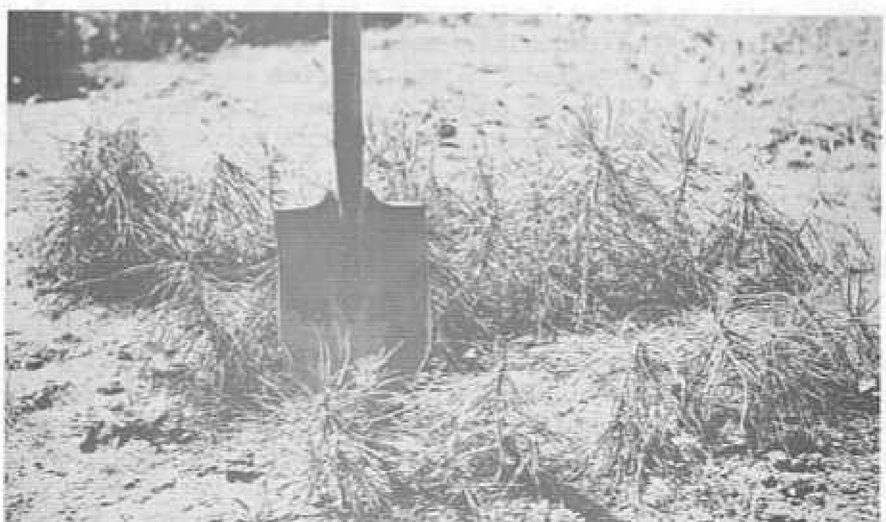

Figure 2. Non-mycorrhizal red pine seedlings in their second year of growth in a previously sterilized nursery soil.

It could be argued that mycorrhizal fungi are present in all soils of the boreal forest and that seedlings could become mycorrhizal shortly after planting. But it should be stressed that seedlings could also come in contact with weak pathogenic fungi (e.g. *Mycelium radicis atrovirens* also ubiquitous in boreal forest soils) thus retarding or preventing their implantation with beneficial fungi.

INOCULATION

How can we make sure that seedlings will have healthy and efficient mycorrhizae when leaving the nursery without unduly increasing the cost?

Natural infection from nursery soils, which often begins during the second growing season, is too weak and unreliable. In certain circumstances infection can take place only after the third growing season (Trappe and Strand 1969). The production of fruiting bodies is widely different from year to year and the species of fungi contributing to this spontaneous inoculation are not necessarily the best ones for the tree species involved. The inoculation of sterilized nursery soil with specific fungi should be attempted. Even in the presence of fertilizers, the growth of seedlings can be greatly stimulated. Similar results can be obtained by introducing duff from natural stands, but there is danger of introducing nematodes and phytopathogenic fungi along with the mycorrhizal fungi.

Inoculating the container-grown seedlings with pure culture of fungi is most promising. Three ways of doing this are under experimentation: with spores, with mycelium homogenate, and by inoculation of the peat moss substratum itself. The inoculate must be selected carefully to ensure that the fungus used is best suited to the species of tree and the soil conditions under which it is being grown. Figure 3 shows the different steps that must be followed in selecting a mycorrhizal fungus for inoculation.

Isolation of the fungus can be made from spores, from mycorrhizal roots or from a sporophore; the latter is the most practical. The culture thus obtained must be checked for purity to ascertain that there is no other organism that could, sooner or later, cause problems. The identity of the organism must be well established to permit the utilization of known knowledge about the fungus species. Physiological investigations will establish the optimum and the limiting temperatures and pH of the strain. The fungus should be tested for its aggressiveness, its viability, its efficiency in absorbing minerals and in protecting seedlings from phytopathogenic organisms. Then, and only then, can one select a fungus as an inoculation which will have a good chance of success.

Thereafter, mass cultivation can be made in a mixture of vermiculite and peat moss (Vozzo and Hacskaylo 1971) or in a liquid medium (Fortin 1967). Inoculation could be made through irrigation systems or by incorporation of the inoculation into the peat-vermiculite substrate. Of course, appraisal will be essential in order to improve the selection of the best mycorrhizal fungi.

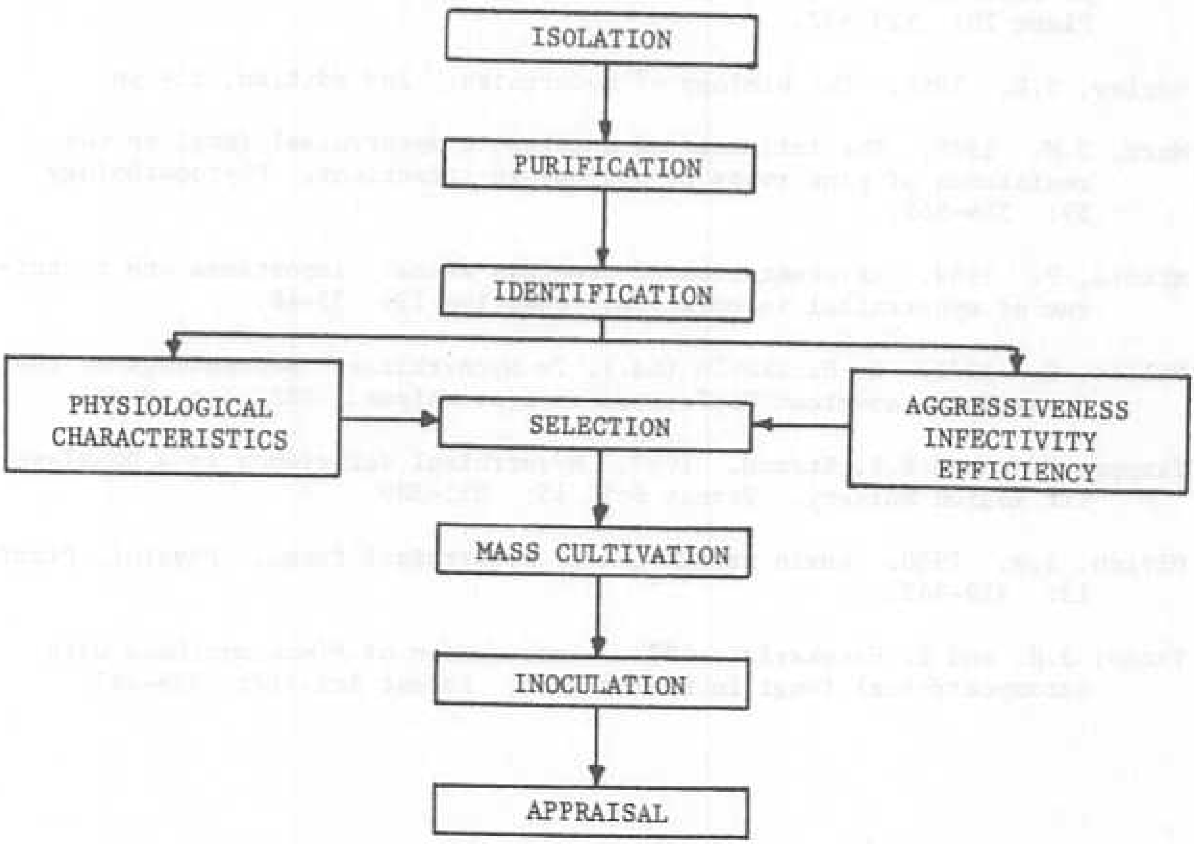

Figure 3. Main steps in a selection program aimed at the inoculation of forest tree seedlings with mycorrhizal fungi.

CONCLUSIONS

In the boreal forest trees are naturally associated with mycorrhizal fungi. This association, which was evident as early as the carboniferous era, is deeply inscribed genetically in tree species. I feel that it would be a mistake to try to work with tree seedlings without taking this association into account. The amount of knowledge available on this subject is impressive but it is time that we used it for practical purposes.

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BIOLOGICAL AND PHYSICAL FACTORS

AFFECTING ESTABLISHMENT AND SUBSEQUENT GROWTH

INFLUENCES AFFECTING CONTAINER SEEDLING PERFORMANCE

ON VANCOUVER ISLAND, BRITISH COLUMBIA

J.T. Arnott[1]

INTRODUCTION

Since 1967, the Liaison and Development section of the Pacific Forest Research Centre has been field testing the bullet, plug and bare-root reforestation systems over a range of forest site types in the coastal region of British Columbia, principally on southern Vancouver Island. Assessing and comparing the biological performance of these three systems has been one of the primary objectives of the study. The bare-root system has been used as a "control" because of its widespread use and because it has proven satisfactory for certain tree species. However, this system is labor intensive, and offers much less potential for mechanization than several container systems which can provide trees at a much lower cost.

The ultimate success of a reforestation system depends on the cost per established seedling. Many factors can affect the establishment, and ultimate performance, of the containerized seedling and these factors will be the subject of this report.

CONTAINERIZATION

Container shape and size and their subsequent effects on seedling performance have been primary objectives in much of the research work. At the initiation of the container research program, the 2 1/2-inch and 4 1/2-inch Walters' bullet were tested together with the 9/16-inch Ontario tube. In the nursery phase, the larger volume of the 4 1/2-inch bullet produced a correspondingly larger seedling than the other two container sizes. However, once planted on high sites, these initial height differences tended to be masked as roots egressed from the containers. Survival differences between these three container types have generally been non-significant for Douglas-fir and western hemlock 3 years after planting.

Results from the coastal trials indicate that the single, most important factor affecting seedling mortality and early growth rate is the removal of the container at the time of planting. Planting of a containerless seedling (i.e. plug) resulted in much improved survival rates and slightly increased growth (Tables 1 and 2). These data are based on a minimum of 7 plots per species at each location. Each plot had 350 trees arranged in a completely random design.

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[1]Canadian Forestry Service, Pacific Forest Research Centre, Victoria, British Columbia.

Table 1. Percent survival and average height of Douglas-fir bullet, bullet-plug and bare-root seedlings, 3 years after planting on Vancouver Island.

(i) West Coast (Franklin River)

Container type	Planting season					
	Fall - 1967[1]		Early spring - 1968		Late spring - 1968	
	Survival (%)	Avg ht (cm)	Survival (%)	Avg ht (cm)	Survival (%)	Avg ht (cm)
4½-inch bullet[3]	68	46	71	38	58	28
4½-inch bullet-plug[4]	--[2]	--	86	46	77	30
2 + 0 bare-root	79	89	92	82	93	81

(ii) East Coast (Copper Canyon)

4½-inch bullet	74	20	71	18	66	21
4½-inch bullet-plug	--	--	87	20	86	25
2 + 0 bare-root	59	37	71	41	83	41

[1]Approx. planting dates: Fall - October 20.
Early spring - March 20.
Late spring - June 20.

[2]Not planted.

[3]Seedlings grown and planted in Walters' bullets.

[4]Seedlings grown in Walters' bullets then removed and planted as plugs.

Table 2. Percent survival and average height of western hemlock bullet, bullet-plug and bare-root seedlings, 3 years after planting on Vancouver Island

Container type	Fall - 1967[1] Survival (%)	Fall - 1967[1] Avg ht (cm)	Early spring - 1968 Survival (%)	Early spring - 1968 Avg ht (cm)	Late spring - 1968 Survival (%)	Late spring - 1968 Avg ht (cm)
(i) West Coast (Franklin River)						
4½-inch bullet[3]	48	49	56	46	7	32
4½-inch bullet-plug[4]	--[2]	--	60	56	8	30
2 + 0 bare-root	35	79	15	72	--	--
(ii) East Coast (Copper Canyon)						
4½-inch bullet	59	23	59	24	17	21
4½-inch bullet-plug	--	--	71	26	24	23
2 + 0 bare-root	36	32	30	33	18	33

[1]Approx. planting dates: Fall - October 20.
Early spring - March 20.
Late spring - June 20.

[2]Not planted.

[3]Seedlings grown and planted in Walters' bullets.

[4]Seedlings grown in Walters' bullets then removed and planted as plugs.

CONTAINER INFLUENCE ON ROOT DEVELOPMENT

With Walters' bullet, root systems egress from the side slit - or slits - and the base of the container. With the plug, on the other hand, root systems develop uniformly from the original container root mass. Due to fewer restrictions on their development, the individual components of the root systems in plugs are much larger and more numerous.

Roots emerge from the Ontario tube principally from the bottom and lower portion of the vertical slit. Subsequent root growth slowly opens this slit although in most cases the tube remains closely attached to the root mass.

Vigorously growing seedlings soon shed themselves of any restrictions placed on their root system by bullet containers.

Although fairly distinct root patterns are developing from each of the container types planted in 1967/68, these differences are not discernible from mere observation of the growth of the seedling itself. Thus forecasting possible future effects of the container on the ultimate performance of the seedlings is a matter of conjecture at this time.

STOCK SIZE AND QUALITY

The influence of stock size on seedling survival was amply demonstrated in the first series of experimental plantations established during 1967/68. In these, two stock sizes were planted in paired comparisons; "small" and "regular". At the time of planting, the mean heights of the small and regular stock in the 4 1/2-inch bullets were 6 and 9 cm, respectively, for Douglas-fir, and 3 and 7 cm, respectively, for western hemlock. The effect of the smaller stock size on subsequent survival is clearly illustrated in Table 3. Although these results reflect the effect of stock size on survival 3 years after planting, the trend was evident from the beginning of the field trial. Thus, during the years that followed, every attempt was made in the container nursery to improve stock size and quality through modification of the cultural techniques. Improvements were realized through use of earlier sowing dates, modifications of the soil mix, together with changes in the rates and frequency of fertilizer applications. As a result, western hemlock survival was much improved in the second and third year replications. Some of the best field results were obtained from stock 12-14 cm in height with a 3:1 shoot/root ratio.

SEASON OF PLANTING

For Douglas-fir, planted during the fall and spring of 1967/68, survival rates for seedlings planted in 4 1/2-inch bullets and as bullet-plugs for the three planting seasons were quite similar (Table 1). Best survival was obtained from the early spring planting. These results also apply to western hemlock planted in the fall and early spring (Table 2). Late spring planting results for western hemlock were extremely low due to stock deterioration in the nursery before planting. Early spring is not conclusively

Table 3. Percent survival of Douglas-fir and western hemlock 3 years after planting in 4½-inch Walters' bullets using two sizes of stock

(i) West Coast (Franklin River)

Stock size	Planting season					
	Fall - 1967[1]		Early spring - 1968		Late spring - 1968	
	Douglas-fir	Western hemlock	Douglas-fir	Western hemlock	Douglas-fir	Western hemlock
Small	46	22	44	27	40	19
Regular	68	48	71	56	58	7

(ii) East Coast (Copper Canyon)

Stock size	Fall - 1967[1] Douglas-fir	Fall - 1967[1] Western hemlock	Early spring - 1968 Douglas-fir	Early spring - 1968 Western hemlock	Late spring - 1968 Douglas-fir	Late spring - 1968 Western hemlock
Small	47	19	29	14	58	29
Regular	74	59	71	59	66	17

[1]Approx. planting dates: Fall - October 20.
Early spring - March 20.
Late spring - June 20.

the best planting season for container stock. In subsequent replications of these field trials, from 1967-70, maximum survival rates generally resulted from fall and/or early spring planting (Arnott 1971).

SITE QUALITY

Two distinct geographic regions were chosen for the container field trials at the low-medium elevations on Vancouver Island. Although both fall within the Southern Pacific Coast Section (C.2), Coast Forest Region (Rowe 1959), one is located on the cool, wet, west coast while the other is situated within the rain shadow on the drier east coast of the Island. In addition to much more favorable climatic conditions on the west coast, sites are also superior, with deeper, more granular soils. Although these differences in site quality are not reflected in survival data, they are most evident in their effect on seedling growth (Tables 1 and 2).

VEGETATIVE COMPETITION

To date, the incidence of seedling mortality due to vegetation competition has been low on the British Columbia coast. Container seedlings have been planted on freshly burned sites and so, initially, competition is negligible. Provided seedling growth progresses at a satisfactory rate with little or no plantation check, re-invasion of the site by natural vegetation is rarely a problem. In fact, the shade from re-established natural vegetation is often beneficial to the seedlings, particularly on the more severe southern exposures.

ANIMAL DAMAGE

The most prevalent form of animal damage encountered in these plantations is deer browsing. Of the two tree species tested in the field trials, Douglas-fir is most seriously affected.

Browsing is not necessarily fatal but it does adversely affect seedling growth in the critical phase of establishment. In most of the experimental plantations on the coast browsing has not seriously affected survival. Where it has, the deer population has been unusually high. A classic example of this can be found in our plantations on the Victoria Water Board Forest. Here the difference in survival between fenced and unfenced areas was as high as 60% for Douglas-fir in bullets.

FERTILIZATION

Fertilizer applications to container stock at the time of planting on alluvial deposits in the Coastal Forest Region have resulted in substantially increased height growth of Sitka spruce, Douglas-fir and western hemlock (Table 4). The fertilizer used was hoof and horn which was placed in Walters' bullets and planted uphill and as close to the seedling as possible.

Container plantings of western hemlock on the degraded acid-brown soils of the east and west coasts of Vancouver Island indicated only a small positive fertilizer effect on height growth. In addition, preliminary fertilizer trials of Douglas-fir on rapidly drained sites of shallow sandy loam soils at high elevations showed no beneficial effects of such fertilizer application.

Fertilization at the time of planting will be feasible in a container system when a satisfactory mechanical planter has been developed. The results of this exploratory trial indicate a potential for achieving rapid early growth of fertilized container seedlings and as such warrant further study.

SUMMARY

1. Survival and growth rate of seedlings as plugs at the medium elevations on Vancouver Island, BC, has been consistently better than that of seedlings in bullets.

Table 4. The effect of fertilizer application at time of planting on the survival and height growth of Sitka spruce, western hemlock and Douglas-fir after three growing seasons

Sitka spruce				Western hemlock				Douglas-fir			
bullet[1]		plug[2]		bullet		plug		bullet		plug	
F.[3]	No F.	F.	No F.	F.	No F.	F.	No F.	F.	No F.	F.	No F.
percent survival											
79	96	100	92	50	20	42	52	95	86	100	100
average height (cm)											
45	41	58	45	36	35	52	20	47	35	61	35

[1]Seedlings grown and planted in Walters' bullets.
[2]Seedlings grown in Walters' bullets then removed and planted as plugs.
[3]F. = fertilizer treatment.
No F. = no fertilizer treatment.

2. Stock of low quality and small size will not provide acceptable results in the field. Minimum acceptable height of Douglas-fir and western hemlock is 12 cm and 9 cm, respectively.

3. In the first year's field trials, seasonal differences were rarely substantial. In subsequent replications between 1968-70, highly significant seasonal differences were encountered. Generally, fall and/or early spring planting provided the best survival rates.

4. Site quality differences were not reflected in container planted seedling survival data but they were most evident in their effect on seedlings growth.

5. Light vegetative competition favors container-planted seedling survival on the British Columbia coast.

6. Deer browsing can reduce survival of container-planted trees by as much as 60 per cent in areas with very high population density.

7. Fertilization at planting has the potential for achieving rapid early growth of container seedlings.

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Arnott, J.T. 1971. A progress report on the field performance of Douglas-fir and western hemlock container seedlings on Vancouver Island, British Columbia. Can. Dep. Environ., Pacific Forest Research Centre, Can. Forest. Serv., Victoria, B.C. Inform. Report BC-X-63.

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INFLUENCES AFFECTING CONTAINER SEEDLING PERFORMANCE NEAR PRINCE GEORGE, BRITISH COLUMBIA

E. Van Eerden[1]

INTRODUCTION

Although cost per established seedling will ultimately determine the relative degrees of success of one reforestation system versus another, reliable estimates of biological performance are essential requisites to a fair comparison of the cost-effectiveness of all systems. On the basis of this premise we formulated a number of specific questions relative to container seedling performance under coastal and interior conditions. Field testing commenced in 1967 and is continuing. Coastal plantations include mainly Douglas-fir and western hemlock, while interior field tests are concerned with the performance of white spruce, lodgepole pine and interior Douglas-fir.

CONTAINERIZATION

The effects of a container on the establishment of a seedling may be a reflection of two conditions. First, the size and type of container and, second, the presence or absence of the container at planting time.

Survival, 3 years after planting, of a preliminary trial established on two sites near Prince George, B.C. during 1967, shows that the type and size of container influence the survival rates of the three species to a different degree (Table 1). Survival of lodgepole pine and white spruce is highly correlated with container size. The largest container, 4½-inch Walters' bullets, gave the highest survival. With Douglas-fir, however, the mortality of seedlings in the 4½-inch bullet is considerably higher than of those in 2½-inch bullets. This is attributed to poor root quality, as is demonstrated by a greater incidence of fatal frost heaving in 4½-inch bullets. In all other cases fatal frost heaving is highest for 9/16-inch Ontario tubes, intermediate for 2½-inch bullets, and least for 4½-inch bullets. From later trials it is evident that the incidence of frost heaving for plugs is negligible.

Recent root excavations in these plantations show that, to date, root development from 2½-inch bullets is superior to that of 9/16-inch tubes, which in turn is better than root growth from 4½-inch bullets. Nonetheless,

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[1]Canadian Forestry Service, Pacific Forest Research Centre, Victoria, British Columbia.

Table 1. Survival, 3 years after planting, of seedlings of Douglas-fir, lodgepole pine and white spruce in four containers

Container	Percent survival[1]		
	Douglas-fir	Lodgepole pine	White spruce
2½-inch bullet	76	72	46
4½-inch bullet	58	78	58
9/16-inch Ontario tube	51	59	39
3/4-inch Ontario-type tube	–	58	43

[1]Means of two age classes and two sites.

general survival and early growth is highest for 4½-inch bullets, probably because of greater growing space within the container when moisture is not limiting.

Paired comparisons of bullets and bullet-plugs in other trials indicate that root development may be impeded by the container. Irrespective of site, age of stock, and planting season, removal of the container yields improved survival and somewhat faster growth rates (Tables 2 and 3 and Figure 1).

Survival and growth of cold-stored, bare-root seedlings planted in spring and of freshly lifted nursery stock planted in summer and autumn is comparable with that of the best container seedling stock.

The combined effect of increased soil volume and removal of the container is demonstrated by comparisons between 4½-inch bullet seedlings and Styro-plugs grown in the Styroblock 2. It is apparent that plugs have superior first year survival (Table 3) and growth rates.

Table 2. Survival, 2 years after planting, of bullet and bullet-plug seedlings on three sites near Prince George, BC.

Sites	Percent survival[1]					
	Douglas-fir		Lodgepole pine		White spruce	
	bullets	plugs	bullets	plugs	bullets	plugs
Site 1	70	79	88	95	68	85
Site 2	68	86	86	90	81	90
Site 3	71	79	84	97	82	91
Average	70	81	86	94	77	89

[1]Means of four planting dates.

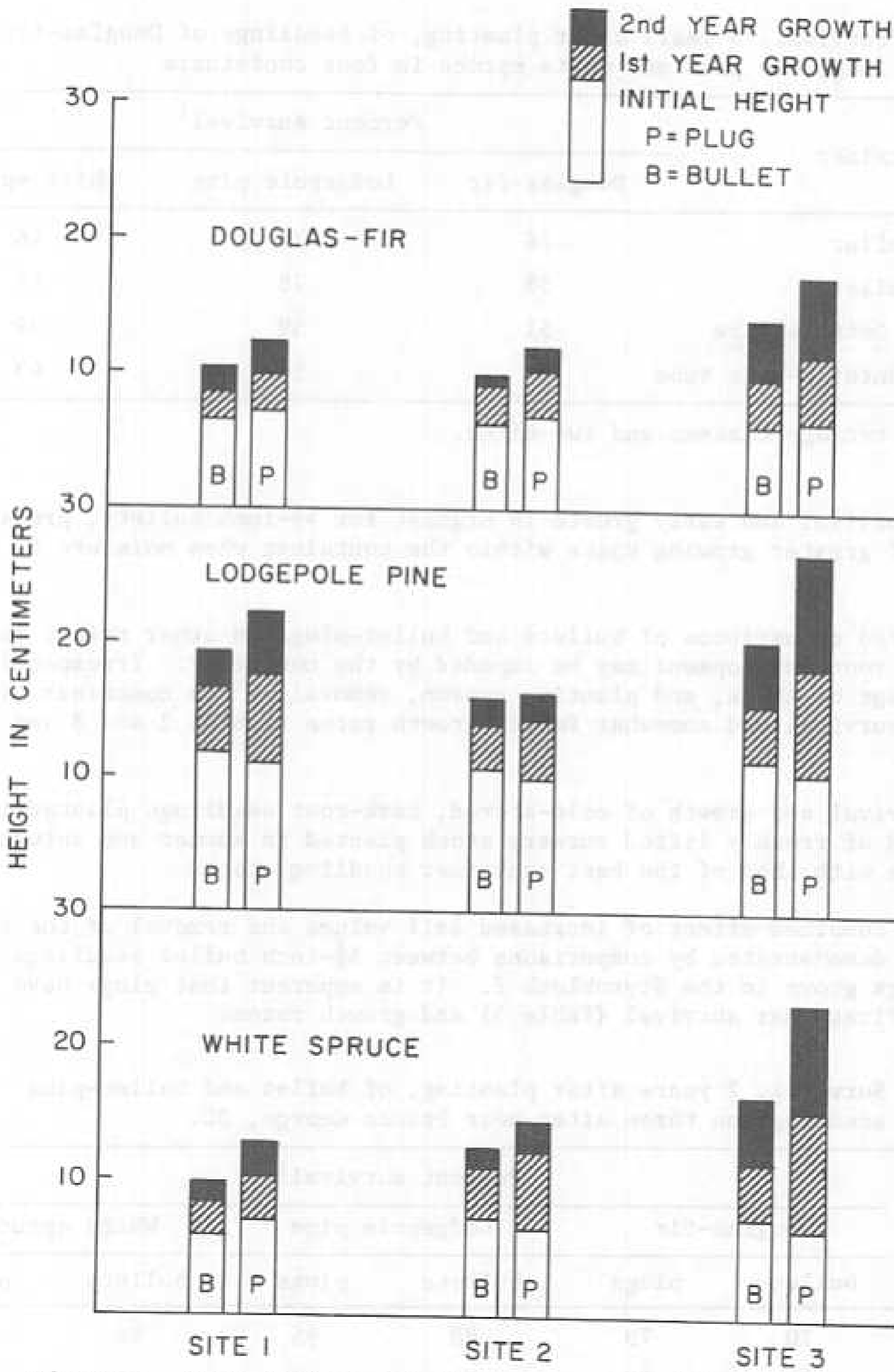

Figure 1. Mean initial height and annual height growth of surviving bullet and bullet-plug seedlings of Douglas-fir, lodgepole pine and white spruce, 2 years after outplanting on three sites.

Table 3. Survival, 1 year after planting, of Styro-plug 2 and 4½-inch bullet seedlings planted on two sites near Prince George, BC

Sites	Percent survival[1]					
	Douglas-fir		Lodgepole pine		White spruce	
	Styro-plugs	bullets	Styro-plugs	bullets	Styro-plugs	bullets
Site 2	78	70	89	70	89	76
Site 3	90	77	96	87	97	91
Mean	84	73	92	78	93	83

[1]Means of four planting dates.

STOCK SIZE AND QUALITY

Plantations of container-grown seedlings in the montane and subalpine forest regions near Prince George, BC, convincingly show the influence of size and age of planting stock on seedling establishment, particularly for lodgepole pine and white spruce. Three years after planting, a 6-week increase in age resulted in an improvement in survival rates of 24 and 36 percent for lodgepole pine and white spruce, respectively (Data not presented). Although smaller in magnitude due to overall improvements in container seedling quality, a similar trend in survival differences between age classes is evident in other plantations (Table 4 and Figure 2). Growth, also, is strongly influenced by seedling age and size at time of planting (Table 5 and Figure 3).

In bullets, the older age classes of lodgepole pine and white spruce have statistically significant higher survival than the younger age class (Table 4 and Figure 2). However, it is also apparent, that matching species with site will partly offset the deficiency in size, especially for lodgepole pine, as indicated by a significant site - age interaction for this species. For white spruce differences in survival due to age were significant only for the two sites best suited to spruce. Survival of the young age class of white spruce seedlings gradually improved as their age increased. It is clear that white spruce seedlings in containers must reach a threshold size before they can be successfully outplanted.

Survival of Douglas-fir seedlings in bullets is not significantly different for the two age classes (Table 4 and Figure 2). In part this may be due to poor adaptation of the species to the general area, which is near the northern range limit of Douglas-fir. A more likely explanation, at least for these trials, is that low survival is strongly related to our inability to prevent root deterioration of older Douglas-fir seedlings in containers. We suspect, and have some evidence to show, that roots of this species die back at some point in the growing cycle. The older stock gradually deteriorates with a concomitant decrease in survival, while survival of the younger stock improves as it gains in quality and size until it reaches the same critical point.

Table 4. Survival of two age classes of bullet seedlings of Douglas-fir, lodgepole pine and white spruce, 2 years after outplanting on three sites

Sites	Percent survival[1]					
	Douglas-fir		Lodgepole pine		White spruce	
	young	old	young	old	young	old
Site 1	75	76	86	87	60	69
Site 2	68	68	77	86	60	79
Site 3	58	65	72	83	61	78
Mean	67	70	78	85	60	75

[1]Means of three planting dates.

Table 5. Initial and current heights of two age classes of bullet seedlings of Douglas-fir, lodgepole pine and white spruce, 2 years after outplanting on three sites.

Sites		Height in centimeters[1]					
		Douglas-fir		Lodgepole pine		White spruce	
		young	old	young	old	young	old
Site 1	Initial height	5.0	6.9	5.4	11.6	3.2	6.1
	Height at 2 yrs	7.3	10.9	11.3	18.9	5.3	10.0
Site 2	Initial height	4.8	7.0	5.0	11.4	3.2	7.2
	Height at 2 yrs	7.0	10.9	9.6	15.2	5.7	12.2
Site 3	Initial height	4.6	7.0	4.6	11.9	3.1	7.5
	Height at 2 yrs	10.1	14.2	14.6	18.9	8.1	17.8

[1]Means of three planting dates.

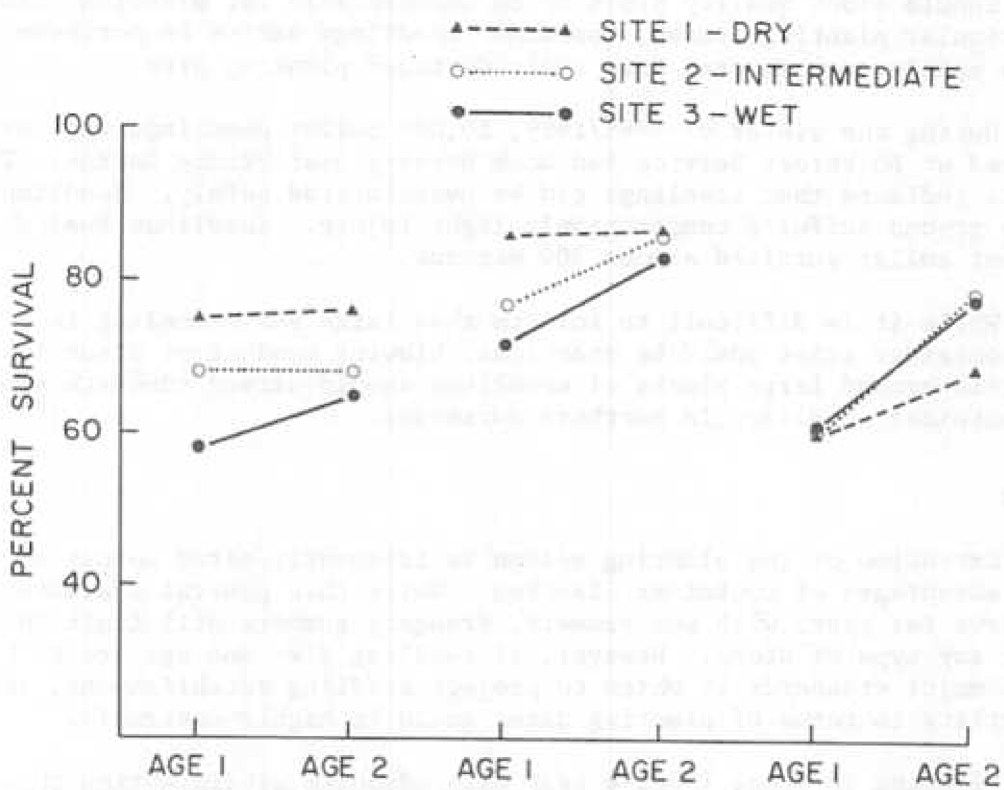

Figure 2. Survival of two age classes of bullet seedlings of Douglas-fir, lodgepole pine and white spruce, 2 years after outplanting on three sites.

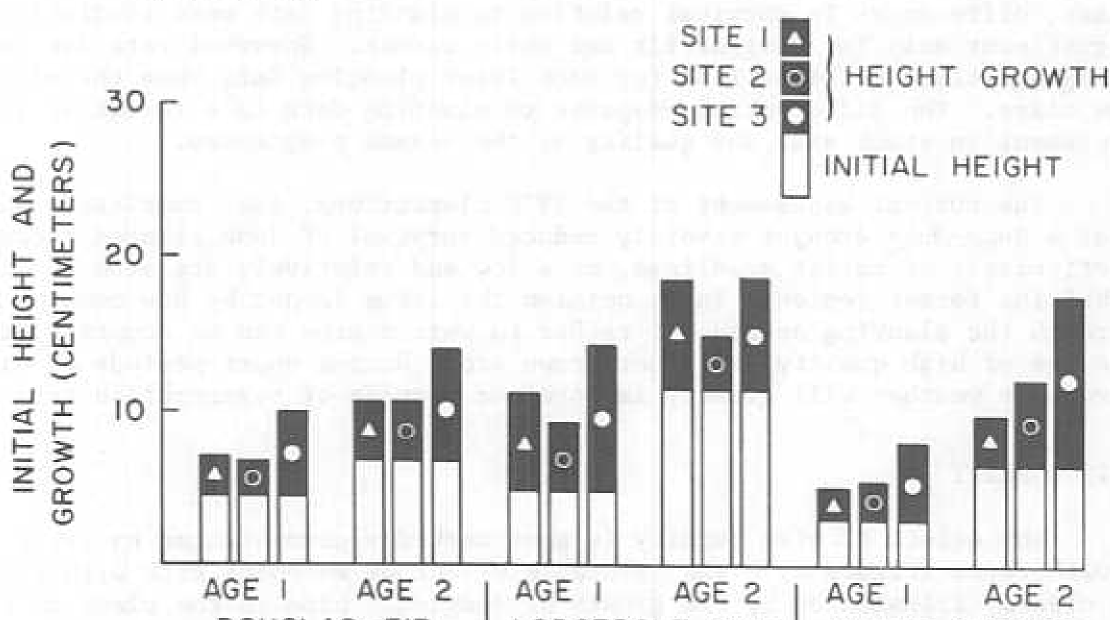

Figure 3. Mean initial height and current height of two age classes of bullet seedlings of Douglas-fir, lodgepole pine and white spruce, 2 years after outplanting on three sites.

Should stock quality prove to be unacceptable for planting throughout a particular planting season, container seedlings native to northern forests can be safely overwintered near their destined planting site.

During the winter of 1968/1969, 10,000 bullet seedlings were overwintered at BC Forest Service Red Rock Nursery near Prince George. The results indicate that seedlings can be overwintered safely. Seedlings stored on the ground suffered comparatively light injury. Seedlings heeled in to the root collar survived almost 100 percent.

While it is difficult to foresee that large scale heeling in of individual container trays would be practical, blowing sawdust or other insulating materials around large blocks of seedlings should afford adequate protection for container seedlings in northern nurseries.

SEASON

Extension of the planting season is frequently cited as one of the major advantages of container planting. While this general statement may hold true for years with wet summers, droughty summers will limit the planting of any type of stock. However, if seedling size and age are to be two of the major standards by which to project seedling establishment, some flexibility in terms of planting dates would be highly desirable.

Planting in June, 1968, a year with adequate precipitation throughout the summer, resulted in the highest survival 2 years after planting (Figures 4 and 5). For the older age class there is a general and steady decline in survival for each progressively later planting date. Within the older age class, differences in survival relative to planting date were statistically significant only for Douglas-fir and white spruce. Survival rate for the young age class declined less for each later planting date than the older age class. The differential response to planting date is a result of improvement in stock size and quality as the season progressed.

The current assessment of the 1970 plantations, just completed, shows that a June-July drought severely reduced survival of June planted stock, particularly of bullet seedlings, on a low and relatively dry site in the subalpine forest region. In my opinion the issue is not by how much we can stretch the planting season but rather to what degree can we compress it. The use of high quality container-grown stock during short periods of highly favorable weather will greatly improve our chances of regeneration success.

SITE QUALITY

The effect of site quality is most markedly demonstrated by early growth rates (Figure 1). The favorable effect of matching site with species is clearly illustrated by the growth of lodgepole pine in the plots in the montane forest region. Similarly, the spruce on the wet site is outgrowing identical stock on the poorer sites. Although growth rates of all three species are highest on the high quality wet sites, survival of lodgepole

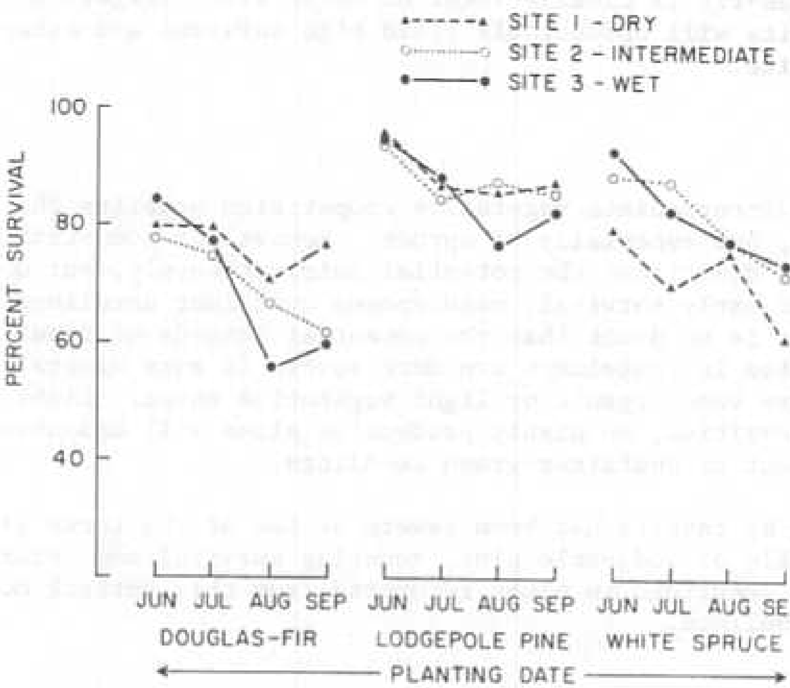

Figure 4. Survival, after 2 years, of March-sown bullet seedlings of Douglas-fir, lodgepole pine and white spruce, planted at monthly intervals from June to September on three sites.

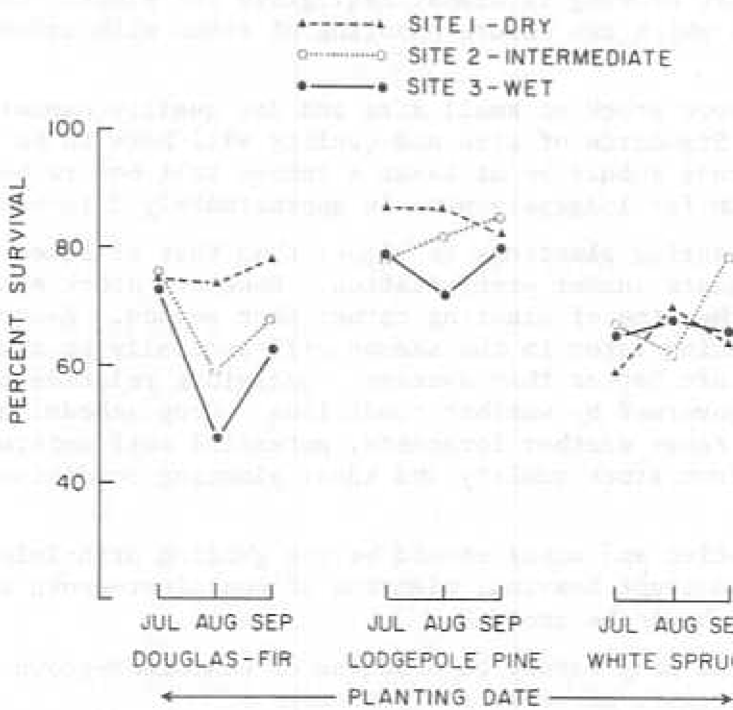

Figure 5. Mean survival, after 2 years, of March- and May-sown bullet seedlings of Douglas-fir, lodgepole pine and white spruce, planted at monthly intervals from July to September on three sites.

pine and Douglas-fir is clearly lower on these sites (Figure 2). Matching species with site will undoubtedly yield high survival and acceptable growth rates on any site.

COMPETITION

Light to intermediate vegetative competition benefits the establishment of all species, but especially of spruce. Removal of competition by scarification not only diminishes the potential nutrient supply, but more seriously with respect to early survival, predisposes container seedlings to frost heaving. There is no doubt that the potential hazards of frost heaving of seedlings planted in containers are more severe in bare mineral soil than in soils which have some organic or light vegetative cover. Light burning, to controlled intensities, on highly productive sites will undoubtedly benefit the establishment of container-grown seedlings.

Browsing by rabbits has been severe at two of the three sites under study, especially of lodgepole pine, reducing survival and retarding growth. Lodgepole pine seedlings in plugs recovered from this setback more readily than those in bullets.

SUMMARY

1. Plugs offer great potential for planting in the north central interior of BC. Survival is superior and growth is somewhat faster than for bullets. Mortality from frost heaving is almost negligible for plugs. Currently it is the only method which can ensure planting of stock with undamaged root systems.

2. Container-grown stock of small size and low quality cannot be expected to survive well. Standards of size and quality will have to be established. In my opinion, spruce should be at least 4 inches tall before being planted, whereas the minimum for lodgepole pine is approximately 3 inches.

3. Survival of spring plantings is higher than that of later plantings in years with adequate summer precipitation. However, stock size and quality should determine the time of planting rather than season. Reductions in survival from planting later in the season will generally be minor if quality and size of stock are better than average. Decisions relative to planting season should be governed by weather conditions. Crop scheduling should take into account long-range weather forecasts, potential soil moisture levels, etc., so that optimum stock quality and ideal planting conditions will coincide.

4. Matching species and sites should be the guiding principle. To minimize mortality from frost heaving, planting of container-grown seedlings in bare mineral soil should be avoided.

5. Site treatment preparatory to planting of container-grown seedlings should leave the organic mat relatively intact.

6. On the basis of a pilot scale test with coastal-grown seedlings, as well as experience elsewhere, fertilization of outplanted container-grown stock may be expected to yield real benefits, particularly in terms of early growth, and therefore should be further investigated.

PERFORMANCE OF CONTAINER STOCK IN ALBERTA

H.J. Johnson[1]

Operational planting of container stock commenced in Alberta in 1965 with the planting of 200,000 tubelings by North Western Pulp and Power Ltd. After a few years of experimental work the Alberta Forest Service launched its operational container planting program in 1967 with the planting of 238,000 tubelings. By 1970 over 2.3 million seedlings were container grown and planted in 3/4-inch x 3 1/4-inch Ontario-type plastic tubes by industry and the Alberta Government. (21st Annual Report, Dept. Lands and Forests, Alberta).

Monitoring of operational and trial container plantings by the Canadian Forestry Service (CFS) started in 1966 with the evaluation of 1965, '66 and '67 container plantings of North Western Pulp and Power Co. Ltd. Plots of 100 container-planted seedlings were replicated on a variety of sites and were examined 1, 3 and 5 years after planting. Survival and growth of white spruce and lodgepole pine as well as plot descriptions were transferred to punch cards, and compilation and statistical analyses done by computer. First-year results have been reported in the CFS Internal and Information Report series (Johnson and Marsh 1967, Johnson and Dixon 1968, Dixon and Johnson 1969) and a report combining third-year results is in preparation. (See also Tables 1-3, Figures 1-12). In all, a total of 8,000 white spruce and 5,000 lodgepole pine were marked for re-measurement and analysis.

In 1968, a cooperative reforestation trial was established with the Alberta Forest Service. Fall 1969 and spring 1970 container planting, mud packs, and conventional planting of white spruce was carried out in blocks of 2,800 seedlings per treatment. Trials were conducted in Footner Lake, Peace River, Whitecourt and Slave Lake and provide good coverage of productive forest sites of the B.18a Forest Section of Alberta. Early results of the container and mud pack plantings are shown in Tables 4 and 5.

In 1971, an evaluation of provincial reforestation projects was started in Alberta, Saskatchewan and Manitoba. Results of operational container plantings are available for Alberta and Saskatchewan (Table 6).

In 1970, the BC/CFS Styroblock was introduced in Alberta and 1,000 seedlings growing in these containers were planted at each of the Edson, Peace River, Whitecourt, Slave Lake and Lac La Biche forests. These white spruce and lodgepole pine seedlings were examined in the fall of 1971 (Table 7). In addition to the above, several small-scale trials have been established by J. Soos (1970) and preliminary results are available.

[1]Canadian Forestry Service, Northern Forest Research Centre, Edmonton, Alberta.

1971 trials demonstrating seedlings (plugs) grown in Styroblocks, R.C.A. "peat sausages" planted without the thin plastic film, and bare-root conventional stock were established in representative cut-overs in the Footner Lake, Grande Prairie, Whitecourt and Lac La Biche forests of Alberta. This trial will be replicated in Saskatchewan and Manitoba in 1972.

Generally, our results show little success with the 3/4-inch rigid, split plastic (Ontario-type) container both from the standpoint of survival and growth. During 1971, both industry and the Alberta Forest Service have emphasized development of the "plug" form of seedling without the "root-restricting" container.

Table 1. Survival of white spruce and lodgepole pine seedlings, North Western Pulp and Power[1] container[2] planting program (1965-1967)

Year of planting	White spruce Survival (%)			Lodgepole pine Survival (%)		
	1st year	3rd year	5th year	1st year	3rd year	5th year
1965	84	69	55	82	70	65
1966	65	42		71	55	
1967	69	46		45	32	

[1]Hinton, Alberta.
[2]Ontario-type 3/4-inch x 3 1/4-inch plastic tube.

Table 2. Distribution of seedling survival classes for white spruce and lodgepole pine, North Western Pulp and Power[1] container[2] planting program (1965-1967)

Species	Percentage distribution of plots by percentage survival classes[3]				
	0-20	21-40	41-60	61-80	81-100
White spruce	11.6	16.1	28.6	33.9	9.8
Lodgepole pine	19.8	20.9	18.6	31.4	9.3

[1]Hinton, Alberta.
[2]Ontario-type 3/4-inch x 3 1/4-inch plastic tube.
[3]3-year old seedlings.

Table 3. Average total height of 3 year-old and 5 year-old white spruce and lodgepole pine seedlings, North Western Pulp and Power[1] container[2] program (1965-1967).

Year of planting	White spruce[3]		Lodgepole pine[3]	
	Average total height (inches)		Average total height (inches)	
	3rd year	5th year	3rd year	5th year
1965	2.23	3.40	2.80	5.10
1966	2.30		2.50	
1967	2.52		3.23	

[1]Hinton, Alberta.
[2]Ontario-type 3/4-inch x 3 1/4-inch plastic tube.
[3]Average seedling height (both species) before planting - 1.10 inches.

Table 4. Survival and average total height of white spruce seedlings grown in containers[1] and mud packs, Alberta Forest Service cooperative reforestation trials (1969).

Forest district	Date planted (fall)	Type of planting	Fall 1970 measurement	
			Average total height (inches)	Survival (%)
Footner Lake	1969	container	0.9	37
	1969	mudpack	2.2	85
Peace River	1969	container	1.2	23
	1969	mudpack	-	0
Slave Lake	1969	container	0.4	48
	1969	mudpack	6.0	63
Whitecourt	1969	container	0.9	67

[1]Ontario-type 3/4-inch x 3 1/4-inch plastic tube.

Table 5. Survival and average total height of white spruce seedlings grown in containers[1], Alberta Forest Service cooperative reforestation trials (1970).

Forest district	Date planted (spring)	Fall 1970 measurement	
		Average total height (inches)	Survival (%)
Footner Lake	1970	1.0	65
Peace River	1970	1.5	98
Slave Lake	1970	1.6	83
Whitecourt	1970	1.3	96

[1]Ontario-type 3/4-inch x 3 1/4-inch plastic tube.

Table 6. Survival of white spruce, lodgepole pine and other coniferous species grown in containers[1] and field planted in Alberta and Saskatchewan (1967-1970).

Forest district	Species[2]	Age of stock (weeks)	Date planted	Years since planted	Number of seedlings	Survival (%)
ALBERTA						
Bow	lP, wP, dF	15	July, 1970	1	70,350	60
Crowsnest	lP	14	July, 1970	1	65,200	4
Rocky	lP	-	Aug. 1967	4	13,600	50
Clearwater	lP	12	Aug. 1967	4	9,600	12
	lP	16	Sept. 1967	4	54,300	13
	lP	-	Aug. 1967	4	5,200	39
	wS	16	Aug. 1967	4	6,800	31
Slave Lake	wS	10	1965	6	-	46
Whitecourt	wS	10	June, 1967	4	8,000	43
Athabasca	wS	10	June, 1967	4	8,000	25
	wS	-	1970	1	-	68
	wS	-	1970	1	38,200	58
SASKATCHEWAN						
Fort a la Corne	jP	15	July, 1970	1	87,200	24

[1]Ontario-type 3/4-inch x 3 1/4-inch plastic tubes in Alberta; 9/16- x 3-inch tubes in Saskatchewan.
[2]lP = lodgepole pine; wP = white pine; dF = Douglas-fir; wS = white spruce; jP = jack pine.

Table 7. Survival and growth[1] of white spruce and lodgepole pine seedlings (plugs) grown in BC/CFS Styroblocks and field planted by the Canadian Forestry Service (1970).

Forest district	Species	Survival (%)	Average total height when planted (inches)	Average total height fall, 1971 (inches)	Remarks
Edson	white spruce	95	4.00	4.50	
	lodgepole pine	89	4.90	5.40	
Lac La Biche	white spruce	98	5.80	6.16	16% of stock damaged by rabbits
	lodgepole pine	80	4.10	5.78	20% of stock damaged by rabbits 11% of stock killed by rabbits
Whitecourt	white spruce	98	5.00	5.20	
	lodgepole pine	97	5.00	5.90	
Slave Lake	white spruce	99	5.12	6.30	1% of stock damaged by rabbits
	lodgepole pine	96	4.40	6.40	9% of stock damaged by rabbits
Peace River	white spruce	69	5.20	2.60	67% of stock damaged by rabbits
	lodgepole pine	18	4.50	3.10	100% of stock damaged by rabbits

[1]Seedlings planted in 1970; measured fall 1971.

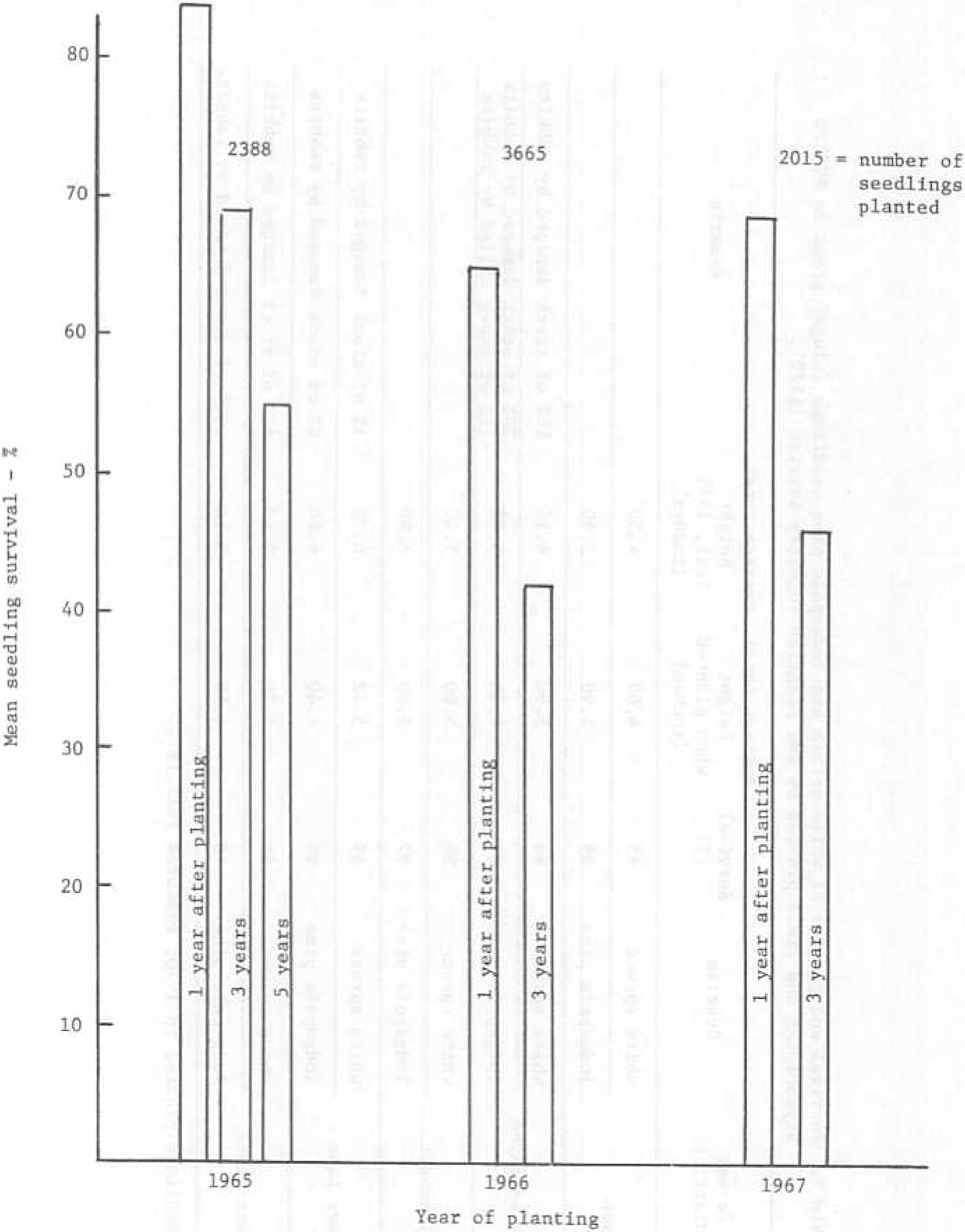

Figure 1. First, 3rd and 5th year survival of white spruce seedlings grown in Ontario-type ¾-inch plastic tubes and field planted by North Western Pulp and Power in 1965, 1966 and 1967.

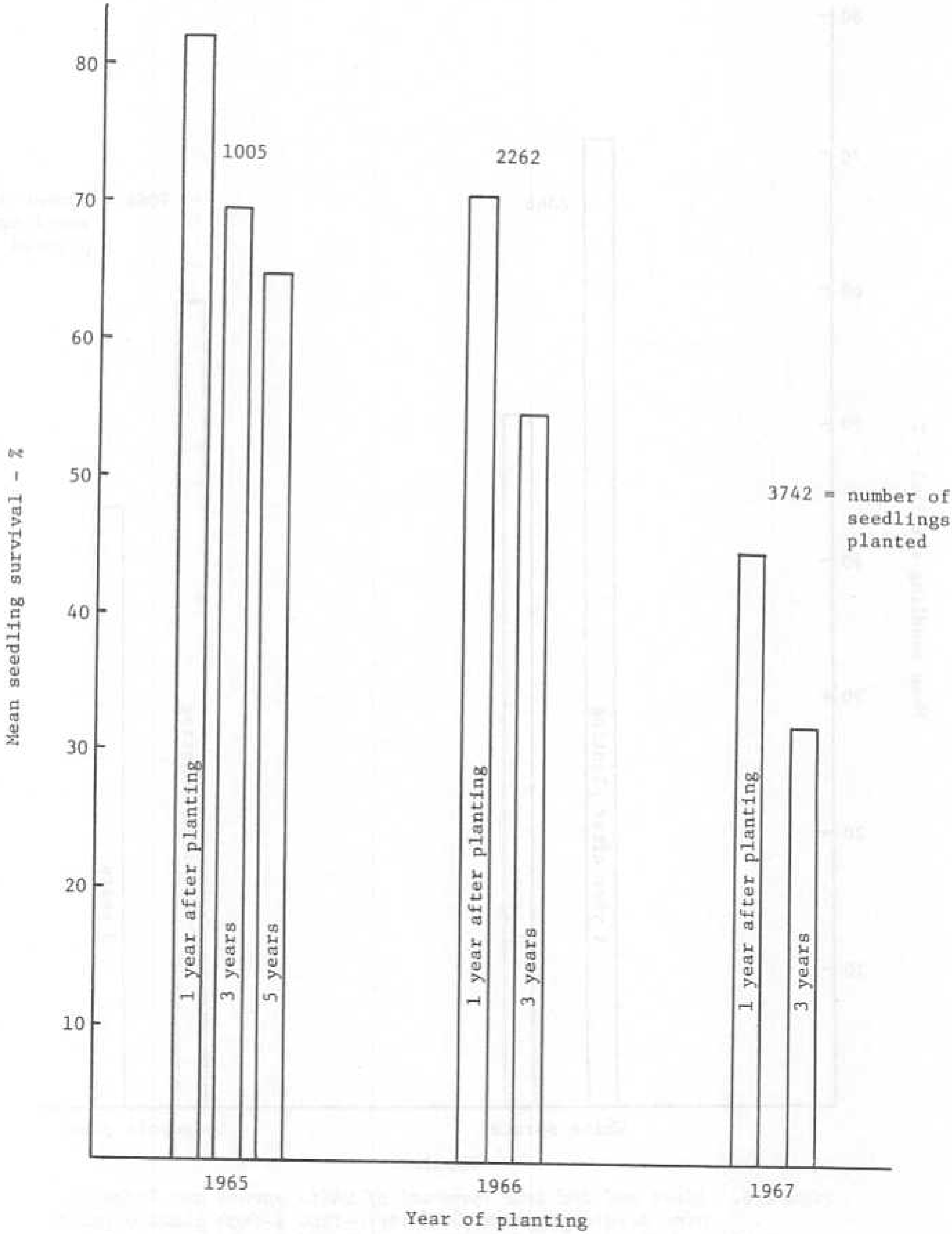

Figure 2. First, 3rd and 5th year survival of lodgepole pine seedlings grown in Ontario-type ¾-inch plastic tubes and field planted by North Western Pulp and Power in 1965, 1966 and 1967.

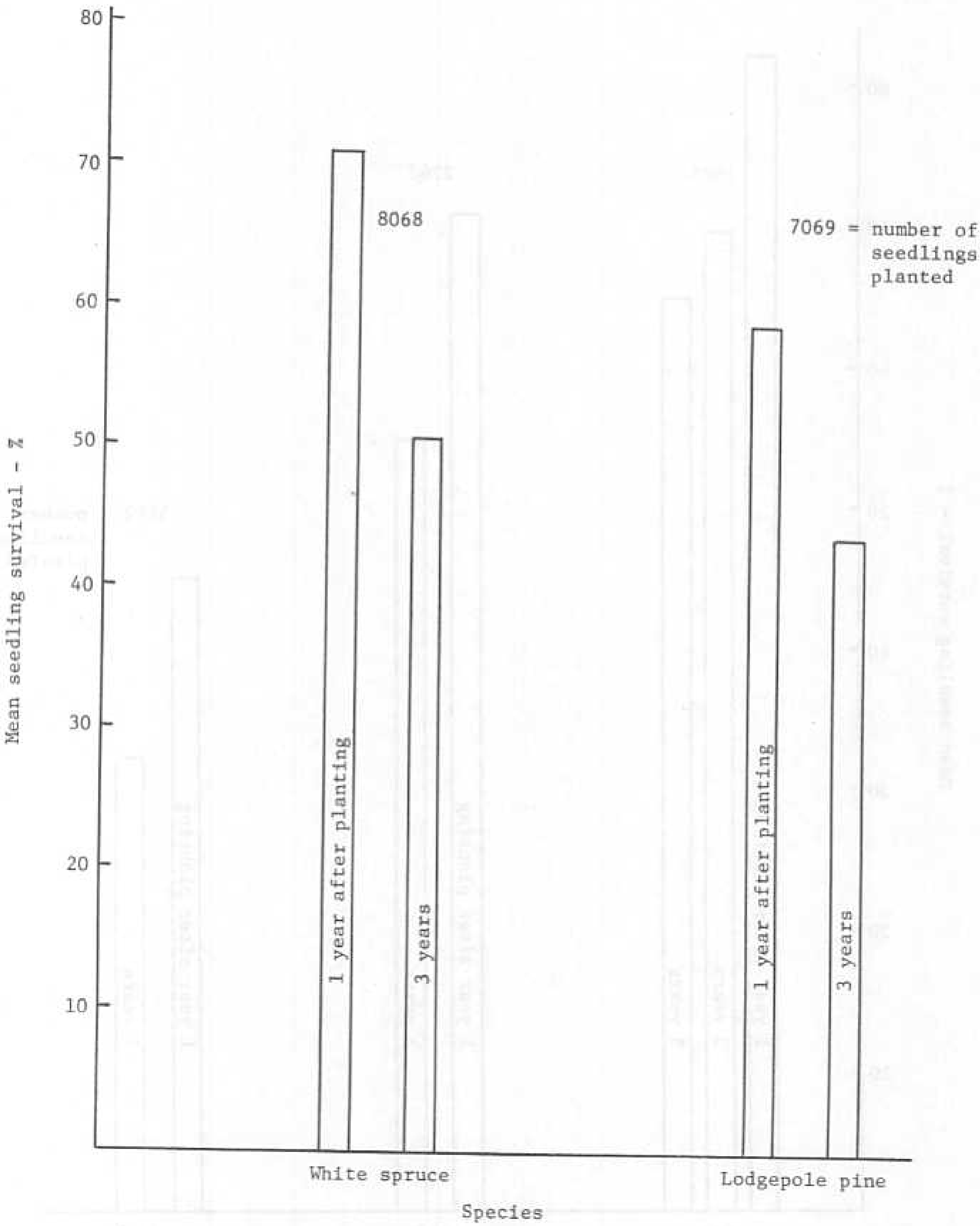

Figure 3. First and 3rd year survival of white spruce and lodgepole pine seedlings grown in Ontario-type ¾-inch plastic tubes and field planted by North Western Pulp and Power (all planting dates - 1965, 1966 and 1967 - combined).

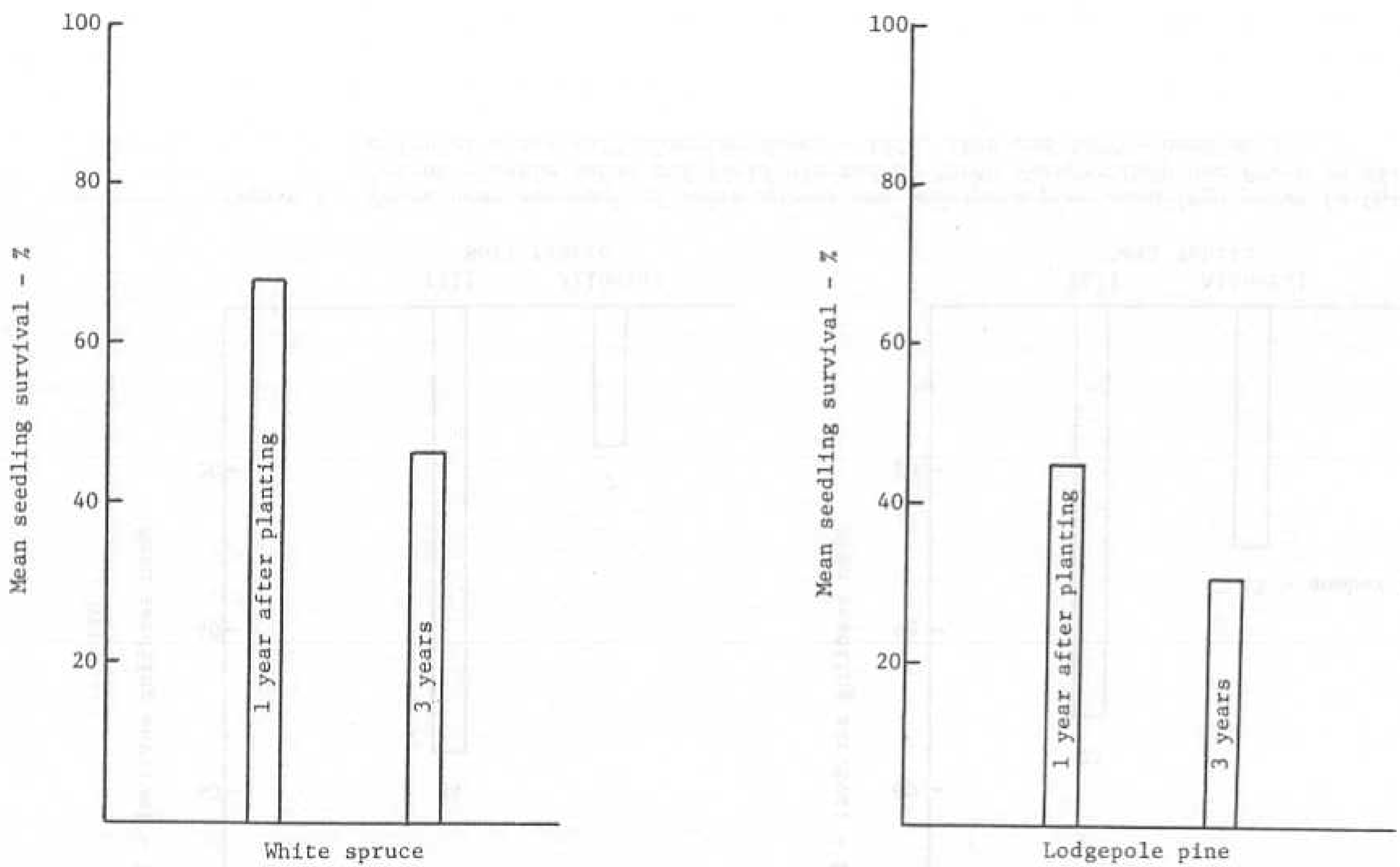

Figure 4. First and 3rd year survival of white spruce and lodgepole pine seedlings grown in Ontario-type ¾-inch plastic tubes and field planted by North Western Pulp and Power in 1967.

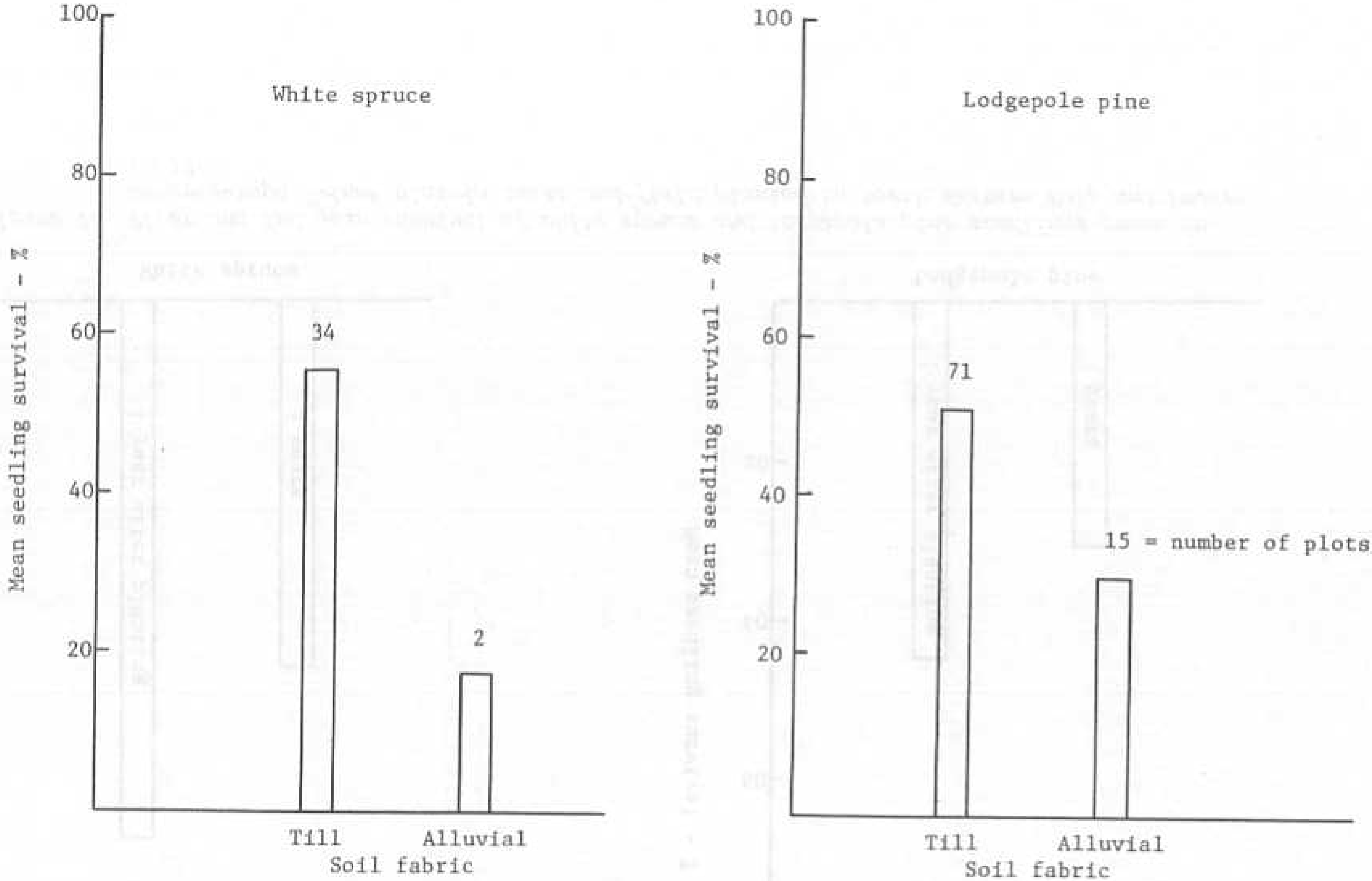

Figure 5. Third year survival of white spruce and lodgepole pine seedlings grown in Ontario-type ¾-inch plastic tubes and field planted by North Western Pulp and Power on till and alluvial sites (all planting dates - 1965, 1966 and 1967 - combined).

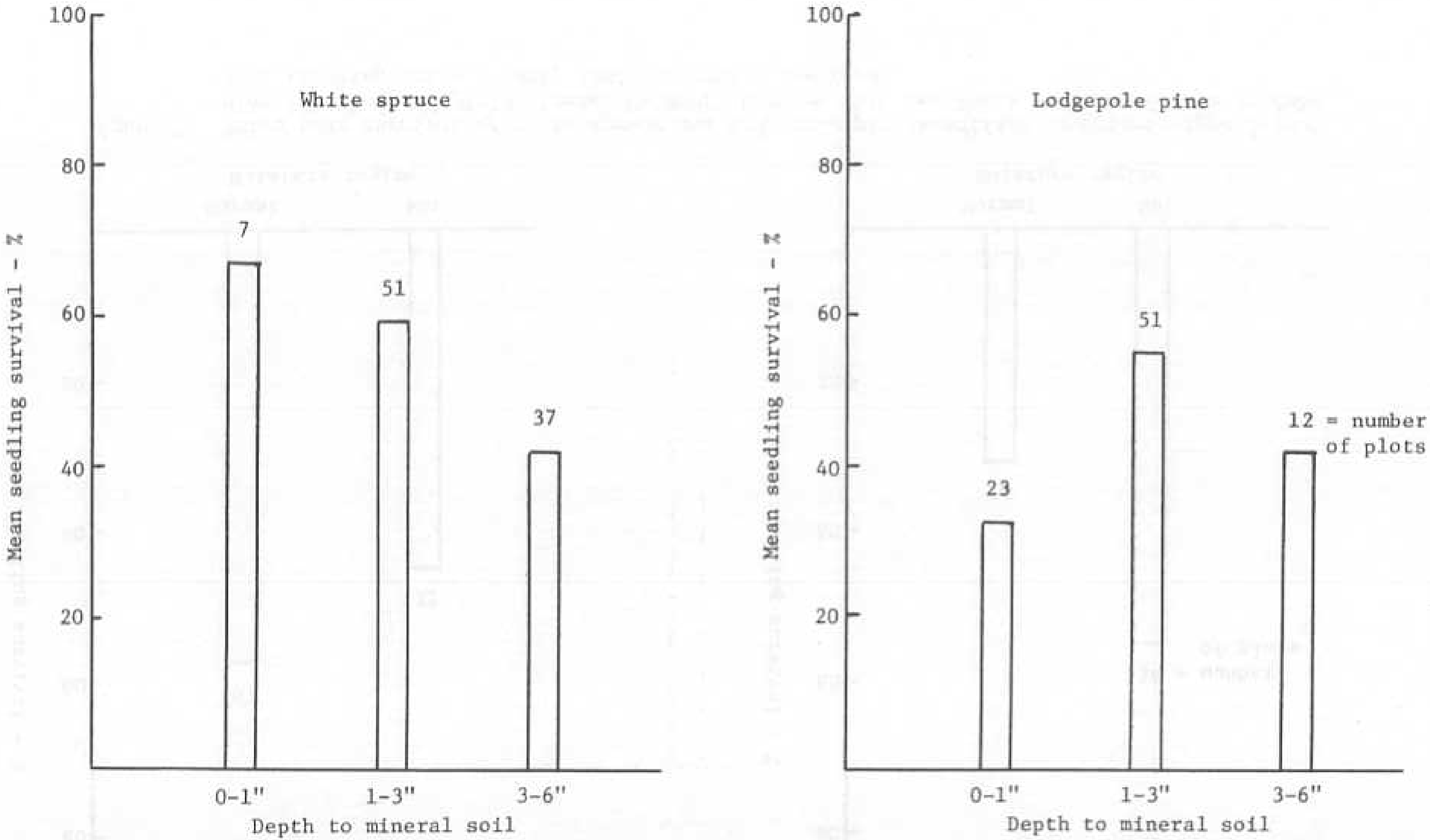

Figure 6. Third year survival of white spruce and lodgepole pine seedlings grown in Ontario-type $\frac{3}{4}$-inch plastic tubes and field planted by North Western Pulp and Power on sites varying in depth to mineral soil (all planting dates - 1965, 1966 and 1967 - combined).

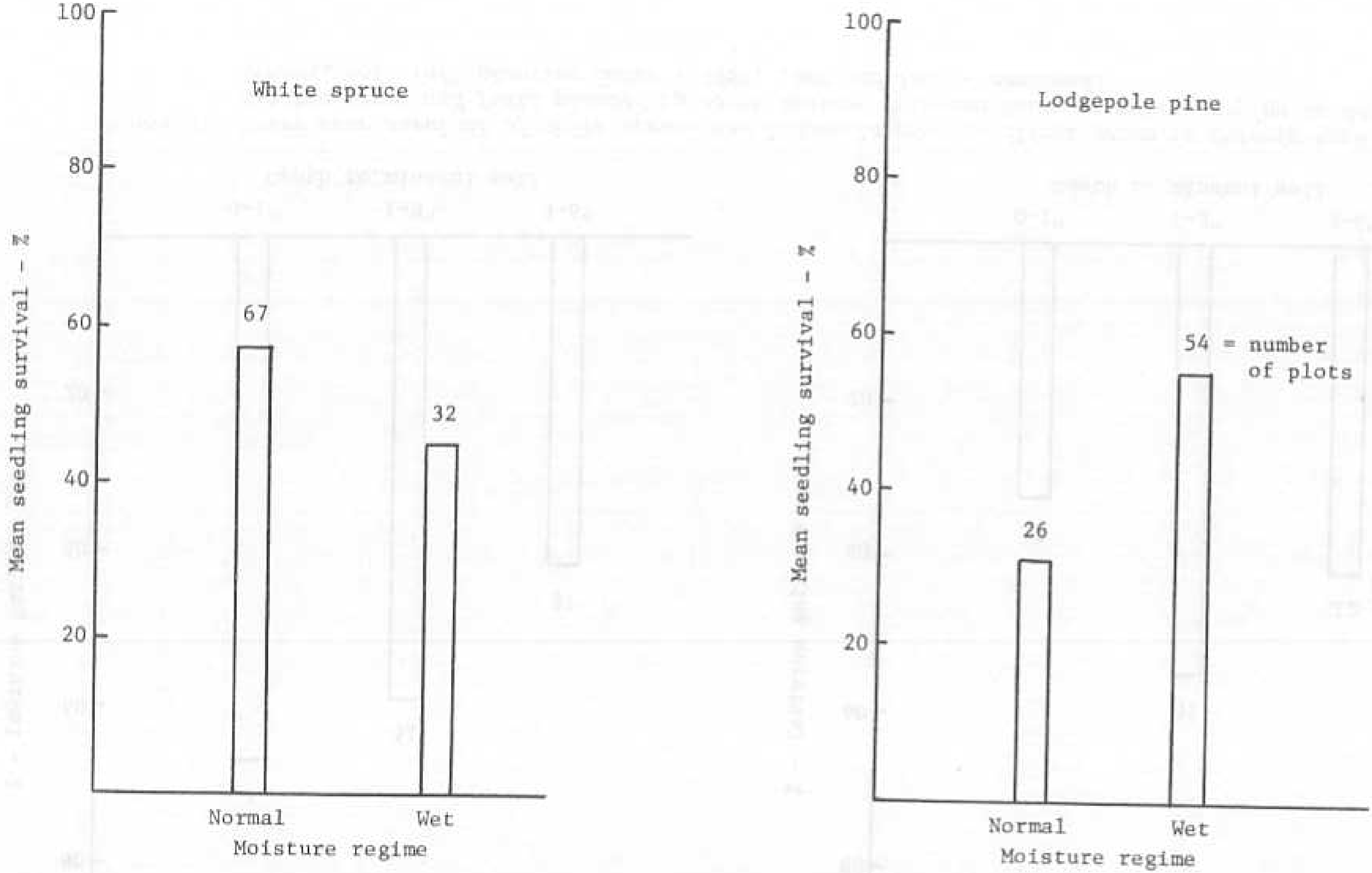

Figure 7. Third year survival of white spruce and lodgepole pine seedlings in Ontario-type $\frac{3}{4}$-inch plastic tubes and field planted by North Western Pulp and Power on two moisture regimes (all planting dates - 1965, 1966 and 1967 - combined).

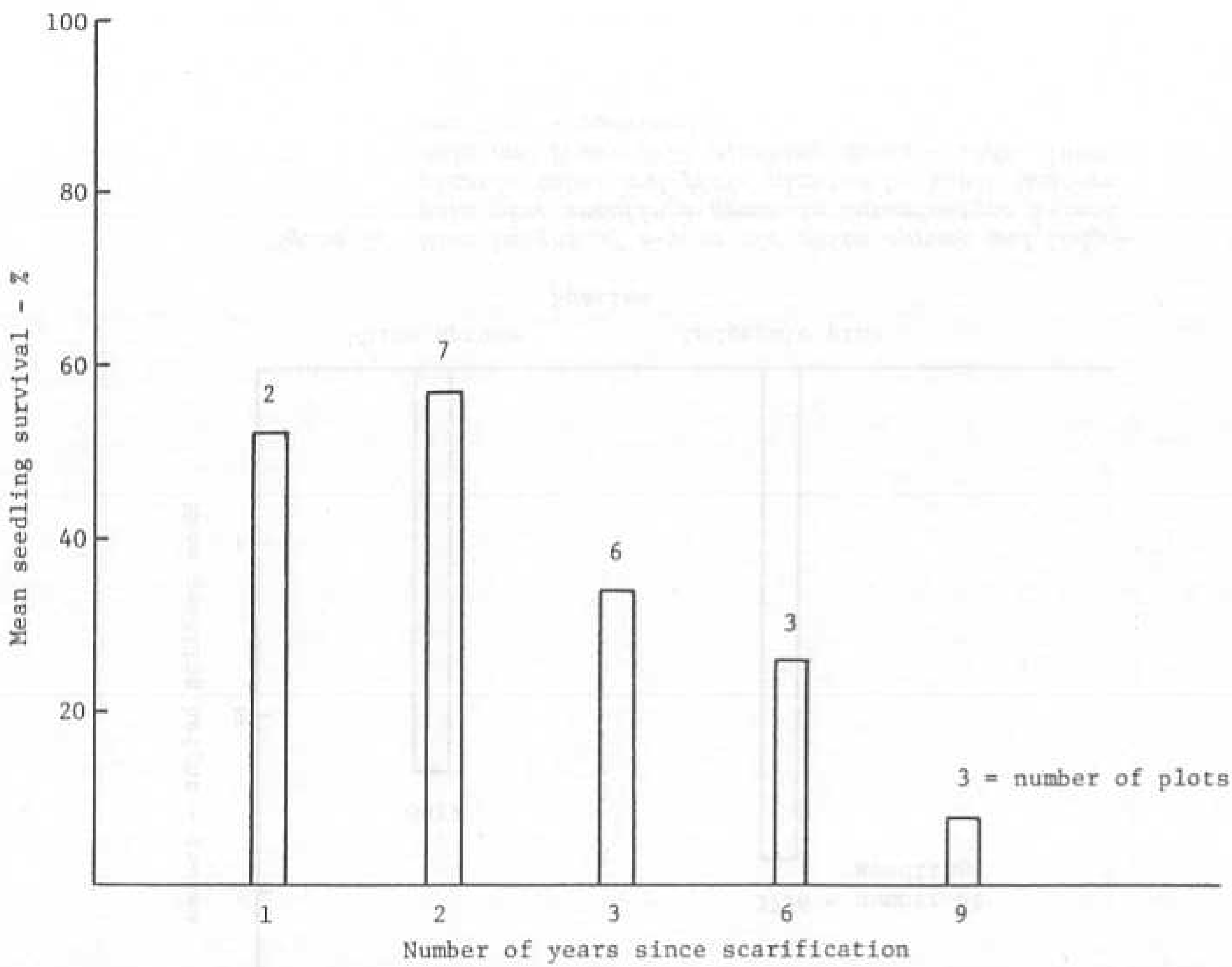

Figure 8. Third year survival of lodgepole pine seedlings grown in Ontario-type ¾-inch plastic tubes and field planted by North Western Pulp and Power on 1- to 9-year old scarification (all planting dates - 1965, 1966 and 1967 - combined).

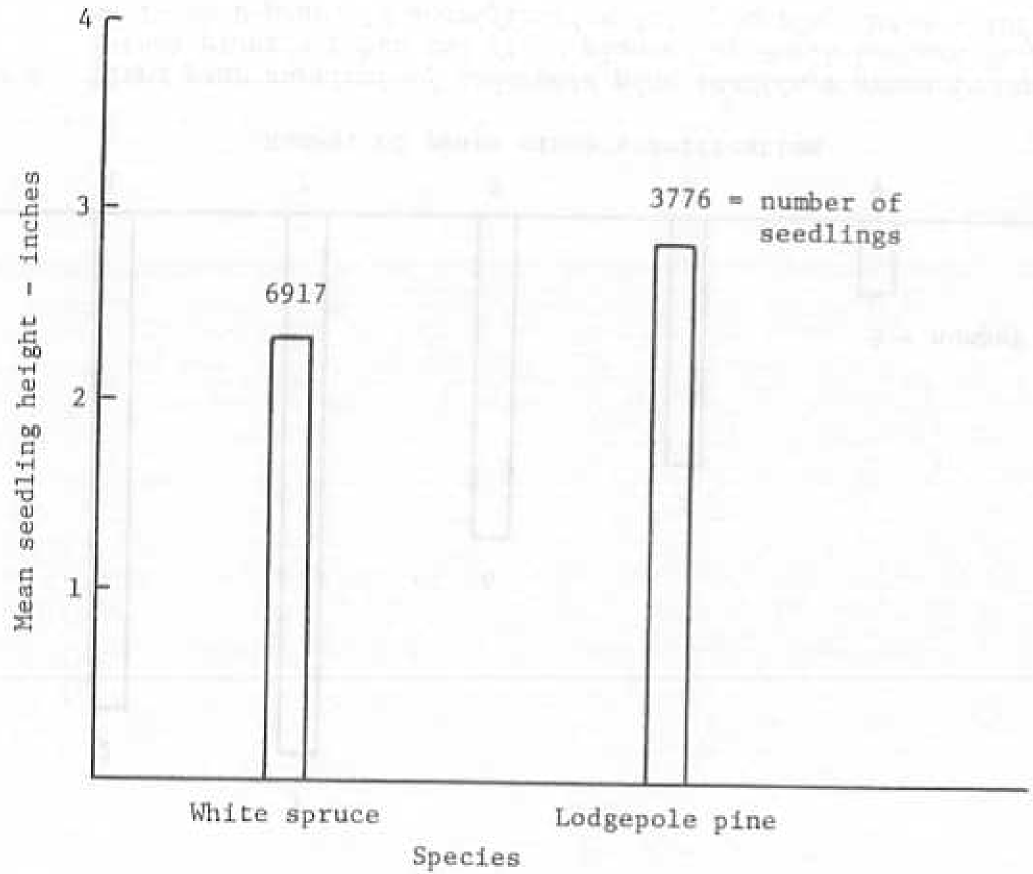

Figure 9. Mean height of 3-year old white spruce and lodgepole pine seedlings grown in Ontario-type ¾-inch plastic tubes and field planted by North Western Pulp and Power (all planting dates - 1965, 1966 and 1967 - combined).

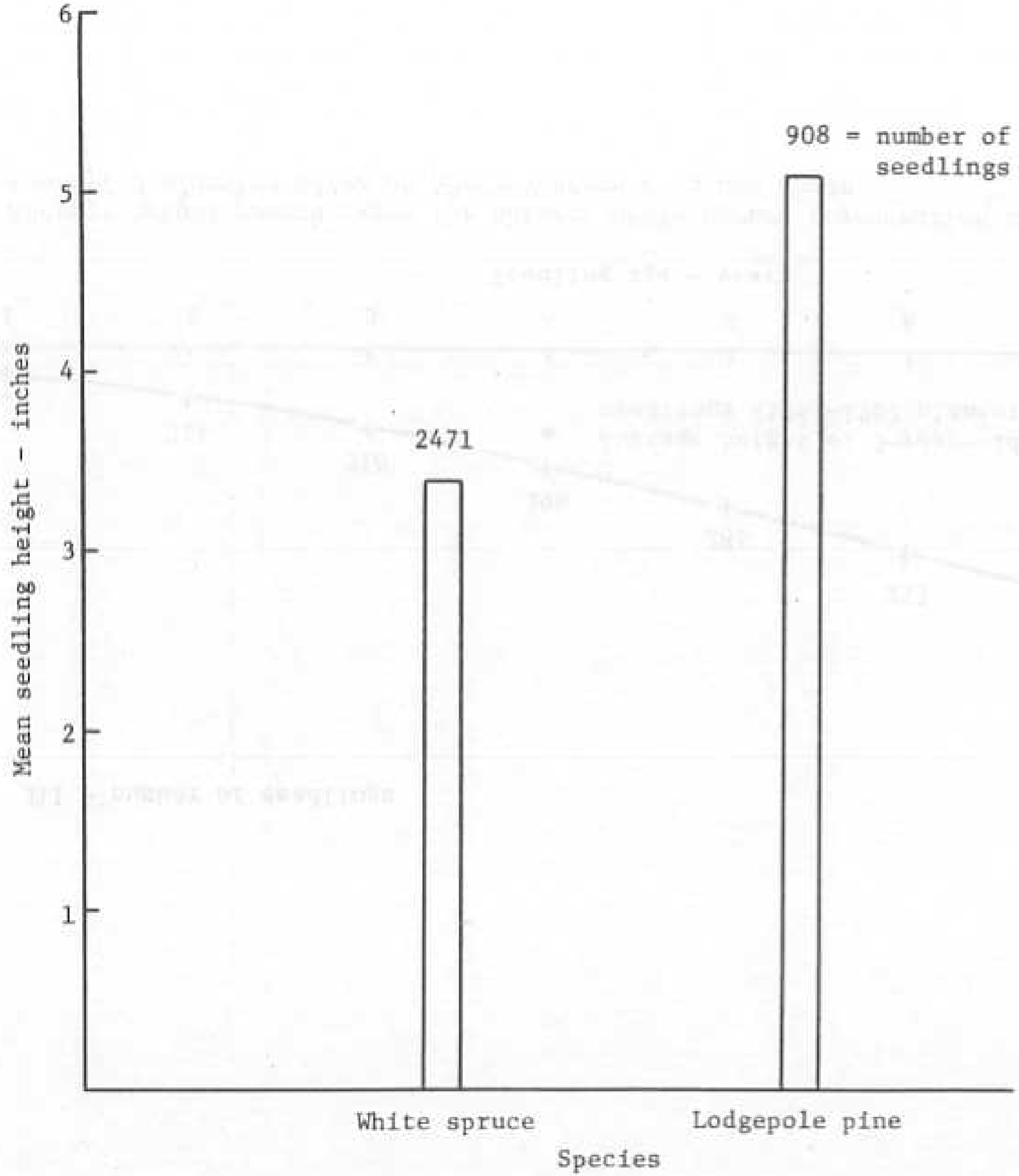

Figure 10. Mean height of 5-year old white spruce and lodgepole pine seedlings grown in Ontario-type ¾-inch plastic tubes and field planted by North Western Pulp and Power in 1965.

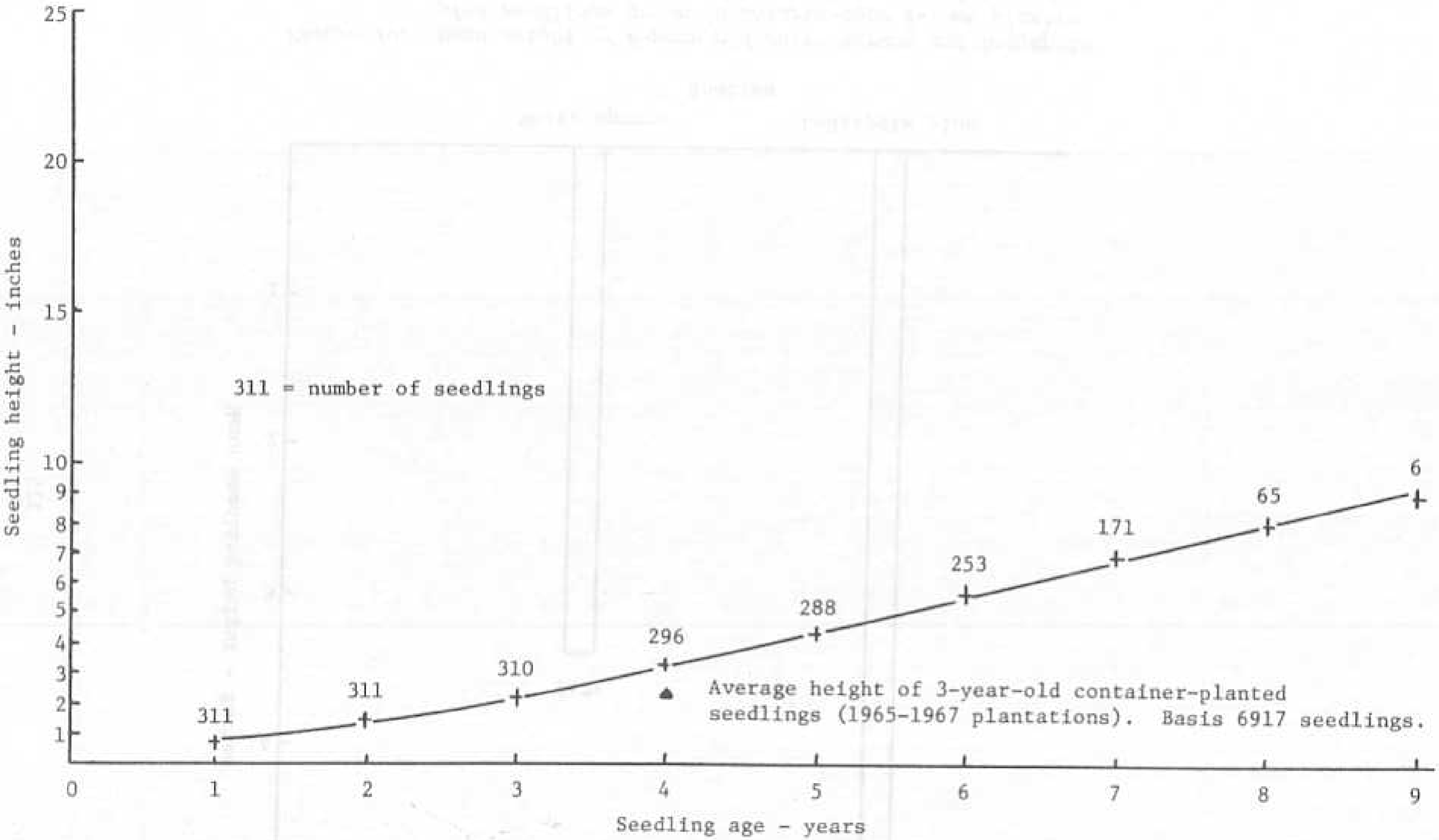

Figure 11. Average height growth curve for natural white spruce regeneration on the 1965, 1966 and 1967 scarified planting sites at North Western Pulp and Power.

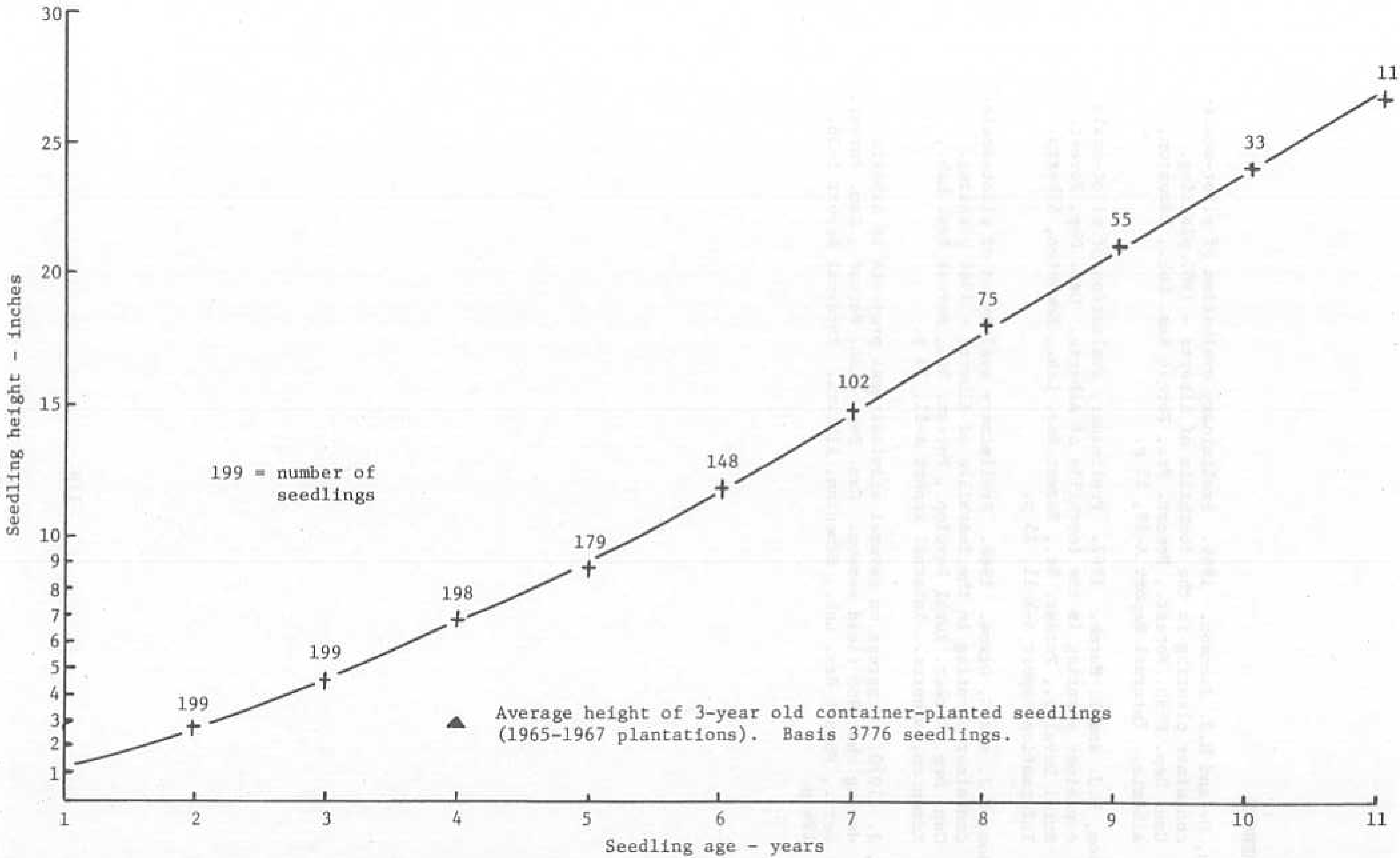

Figure 12. Average height growth curve for natural lodgepole pine regeneration on the 1965, 1966 and 1967 scarified planting sites at North Western Pulp and Power.

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ASSESSMENT OF DIFFERENT TYPES OF CONTAINERS FOR GROWING SEEDLINGS IN ALBERTA

F. Endean[1]

INTRODUCTION

By 1968 field observations of seedlings grown and planted in 3/4-inch x 3¼-inch Ontario-type plastic tubes and 2½-inch Walters' bullets (by both the Alberta Forest Service and North Western Pulp and Power) suggested that although initial seedling survival was adequate, seedling mortality was still increasing at a significant rate three years after outplanting. Furthermore, growth in many cases was not good and there were doubts about the adequacy of root establishment. Excavations of seedlings grown and planted in Ontario-type tubes and 2½-inch bullets showed serious root deformation and a paucity of roots outside the container. However, there was inadequate field data to support these suspicions, and the system in use was so attractive in terms of cost and logistics to the Province and North Western Pulp and Power, that the Canadian Forestry Service felt bound to examine the situation carefully before pressing for any changes.

Beginning in 1968 a number of greenhouse and field trials were designed and executed by the Canadian Forestry Service to determine the effect of a wide variety of containers on seedling survival and on root and shoot growth. These trials were carried out over a two-year period with the last field plantations being established in the spring of 1970.

The rationale behind these experiments may be briefly set out as follows:

1) The climate in Alberta is harsh, with a short growing season (about 6 weeks at 4,000 feet and above). Periods of drought are common in the growing season and in the autumn following it. It is desirable that any plant to be used should be grown, hardened off and planted in the same year. It has to establish quickly so as to withstand drought and later frost heaving both of which require the development of an extensive root system in the year of planting.
2) Both of our main species, lodgepole pine and white spruce, are relatively slow growing in this environment, and any container which inhibits rooting will make it difficult for these species to achieve the desirable development just described. With such slow growth, it would take several years for our seedlings to rupture a hard container which seemed to happen very quickly in coastal conditions.
3) The excellent growth of seedlings planted out in sponge blocks in early experiments pointed to the benefits of unrestricted rooting.

[1]Canadian Forestry Service, Northern Forest Research Centre, Edmonton, Alberta.

4) Rooting volume in the 3/4-inch container (Ontario-type plastic tube) was suspected as being inadequate, probably limiting growth in the rearing period and certainly so in the field where roots were emerging slowly, forcing the plant to exist within the container.
5) Finally it was suspected that 8-week-old seedlings were not adequately prepared for the harsh conditions of outplanting in terms of size, and physiological condition.

Four experiments were set out between 1968 and 1970. Three at Kananaskis in the subalpine region and one at Hinton in the high foothills region. Two Kananaskis experiments, and that at Hinton are described.

The results of these experiments have not yet been fully analysed and detail in this presentation has been reduced to a minimum. In some cases the numbers of observations are small but the use of dry weight as an accurate measure of growth compensates for this.

KANANASKIS (EXPT. 1).

This experiment was initiated in the summer of 1968, using lodgepole pine grown in pure sieved peat in 15 different types of container (Table 1). Container types comprised the 3/4-inch Ontario-type plastic tube, the plug from it, four modifications of this tube by slits and holes to give varying degrees of root egress, larger containers with slits or holes, gauze containers to give maximum root egress next to a plug form, and a range of sponges of different degrees of porosity.

The seedlings reared in these containers were older than the 56 days then in current use because it was felt that 8-week-old seedlings were too small. Ages are given in Table 1; generally they range from 80 - 107 days from germination (seed was pregerminated to give uniform stock).

The experiment was set out in two parts: a field outplanting with three replications on an average and on a dry site, each replication containing six or more seedlings of each container type; a greenhouse planting using soil from the average site and grown with abundant moisture, 70°F day and 50°F night temperatures and 16 hour photo-temperature period.

The field experiment was excavated in 1970 after three growing seasons, the greenhouse in January 1969 after 5 months.

Results

One of the first things learned was that each container type had different rearing requirements and it was almost impossible to rear equivalent stock in each type. Plants grown in sponges and veneer tubes were the poorest.

Unfortunately dry weights were not sampled at time of planting.

Table 1. Dry weight of roots and root egress at time of excavation - lodgepole pine

Container type	Age at planting (days)	Field planting[1]				Greenhouse			
		No. obs	Wt of roots (mgs)	Rank	Wt of roots outside container as % of total	No. obs	Wt of roots (mgs)	Rank	Wt of roots outside container as % of total
¾-inch Ontario-type tube	107	54	116	7	10	17	225	5	9
¾-inch tube plug[2]	107	46	143	4	-	17	150	12	-
¾-inch tube 8 slits[2]	107	34	103	8	21	20	216	7	21
¾-inch tube 16 slits[2]	107	17	79	13	29	23	105	13	17
¾-inch tube spiral slits[2]	107	13	101	9	19	14	307	4	15
¾-inch tube with holes[2]	107	21	99	10	13	19	167	10	13
1¼-inch x 3-inch tube with holes	39	32	146	3	29	16	353	3	18
½-inch x 2-inch tube with holes	39	27	63	15	36	18	175	9	41
Conical - Large	74	12	383	1	37	13	535	1	30
Conical - Small	65	6	162	2	28	7	479	2	35
Med. Sponge - L.[3]	107	6	117	7	43	9	87	15	40
Med. Sponge - S.	85	3	50	18	53	-	-	-	-
Hydro Foam - L.	107	7	139	5	36	8	87	16	29
Hydro Foam - S.	85	3	55	17	40	4	32	18	0
Oasis Foam - L.	107	5	122	6	38	16	208	8	42
Oasis Foam - S.	85	6	62	16	41	6	28	19	9
Fine Sponge	107	10	38	19	54	14	47	17	45
Gauze	107	18	79	12	26	20	89	14	17
1-inch x 3-inch porous	39	17	80	11	37	17	219	6	29
Veneer (poplar)	74	18	73	14	10	17	150	11	8

[1]Average site.

[2]Ontario-type split styrene tube.

[3]L. or S. = Large or Small seedling - see age column.

1. Survival

The dry site proved too severe, and survivals were in the range 10 - 25% except for sponges where it was 0%. The largest plants survived best. On the average site, survivals were in the range of 75% except for the sponges which gave 50%. Greenhouse results were similar.

All further results are taken from the average site and the greenhouse plantings.

2. Root growth

In the field, of all the 3/4-inch container types, the plugs showed the best total root growth; modifications by slits or holes have produced little improvement over the solid container (Table 1). In the greenhouse, the position was reversed and the performance of the plug is poor by comparison with the rest. The reasons for this are not clear. In terms of proportion of roots outside the container, both test conditions produced similar results with the 3/4-inch solid tube being the poorest. The surviving seedlings in sponges did well in the field and all were superior to the 3/4-inch tube, especially in terms of "root escape".

In all cases the conical containers produced most growth and had some of the highest proportions of roots outside the container. These were the largest seedlings put out, but not the oldest.

3. Total plant weight

Again the plug performed best of all the 3/4-inch types; modified forms did not do as well as the solid tube (Table 2). Again plug performance in the greenhouse was poor whilst the modified tubes did better.

Except for plugs and some sponges, the ranking of performance in both test situations is similar.

One interesting point, which is no doubt related to rooting volume, is that the larger containers produced the larger seedlings and this seems to outweigh differences in age.

4. Shoot/root ratios

These varied from 1.6 - 2.9 at the end of the field trials and 1.7 - 3.1 in the greenhouse. In both cases the larger containers, plugs and sponges had the highest ratio, i.e., 2.0+.

KANANASKIS (EXPT. 2).

This experiment was initiated in 1969 in order to obtain a direct comparison between the hard 3/4-inch styrene (Ontario-type) tube and a mesh container ('conwed') which we felt offered maximum opportunity for root egress and a larger rooting volume.

After excellent early growth the experiment was decimated by drought in autumn 1970. I will mention only some results since this was the first experiment where dry weights were measured at the time of planting. Sampled seedlings were excavated in 1970 after two growing seasons.

Table 2. Total dry weight of lodgepole pine seedlings at time of excavation

Container type	Age at planting (days)	Field planting[1] No. obs	Mean dry wt (mgs)	Rank	Greenhouse No. obs	Mean dry wt (mgs)	Rank
¾-inch Ontario-type tube	107	54	300	11	17	613	9
¾-inch tube plug[2]	107	46	428	6	17	508	10
¾-inch tube 8 slits[2]	107	34	316	8	20	816	6
¾-inch tube 16 slits[2]	107	17	244	14	23	378	13
¾-inch tube spiral slits[2]	107	13	284	12	14	1015	4
¾-inch tube with holes[2]	107	21	300	10	19	476	11
1¼-inch x 3-inch tube with holes	39	32	462	5	16	1158	3
½-inch x 2-inch tube with holes	39	27	193	16	18	655	8
Conical - Large	74	12	1437	1	13	2048	1
Conical - Small	65	6	545	2	7	1940	2
Med. Sponge - L.[3]	107	6	349	7	9	249	16
Med. Sponge - S.	85	3	137	19	-	-	
Hydro Foam - L.	107	7	502	3	8	341	14
Hydro Foam - S.	85	3	180	18	4	123	18
Oasis Foam - L.	107	5	465	4	16	795	7
Oasis Foam - S.	85	6	237	15	6	112	19
Fine Sponge	107	10	101	20	14	151	17
Gauze	107	18	252	13	20	335	15
1-inch x 3-inch porous	39	17	311	9	17	834	5
Veneer	74	18	192	17	17	463	12

[1]Average site.

[2]Ontario-type split styrene tube.

[3]L. or S. = Large or Small seedling - see age column.

Root Growth

The benefit of the easy root egress for lodgepole pine grown in the conwed container is obvious; seedlings had more roots, a greater root increment and a greater percentage of roots outside the container (Table 3). Both spruce and pine seedlings in the conwed containers at time of planting were larger than in the solid tube.

The behavior of spruce was quite different (Table 4). It put on more root growth in the solid tube than in the conwed, but had only the same weight and a lower proportion of its total root system outside the container. This is the fault of spruce performance in the solid container, it needs the extra protection provided by the tube and does not establish well outside it.

In terms of total plant weight lodgepole pine performed better in the conwed by several times. For white spruce the results in the two containers were similar but increment was better in the 3/4-inch Ontario-type tube. The final plant was actually smaller than in the conwed container (Tables 5 and 6).

Table 3. Root growth of lodgepole pine seedlings

Container type	Age at planting (days)	No. obs	Final wt (mgs)	Increment (mgs)	Increment %	% roots outside
Conwed	71	29	140	124	775	35
Conwed	90	30	170	114	203	38
¾-inch tube (Ontario-type)	90	15	92	43	88	25

Table 4. Root growth of white spruce seedlings

Container type	Age at planting (days)	No. obs	Final wt (mgs)	Increment (mgs)	Increment %	% roots outside
Conwed	90	30	59	35	250	43[1]
¾-inch tube (Ontario-type)	90	15	71	58	446	35[1]

[1]Same actual weight.

Table 5. Total dry weight of lodgepole pine seedlings

Container type	Age at planting (days)	No. obs	Final wt (mgs)	Increment (mgs)	Increment %
Conwed	71	29	614	518	540
Conwed	90	30	690	469	212
¾-inch tube (Ontario-type)	90	15	295	115	64

Table 6. Total dry weight spruce seedlings

Container type	Age at planting (days)	No. obs	Final wt (mgs)	Increment (mgs)	Increment %
Conwed	90	30	286	202	240
¾-inch tube (Ontario-type)	90	15	240	186	344

HINTON (EXPT. 3).

This experiment was set out in 1969 on areas which had been burned according to prescription in the previous year. Five types of seedlings of both white spruce and lodgepole pine were planted to test this method of ground preparation. These were

1) bare-root 2 + 0;
2) conweds;
3) 3/4-inch styrene tube (Ontario-type);
4) 3/4-inch styrene tube (Ontario-type) overwintered;
5) plugs from 3/4-inch styrene tubes (Ontario-type).

The results given here are after one growing season.

Survival varied between 85 and 91% for lodgepole pine and 67 - 87% for white spruce (conweds and bare-root were 67%, the rest were 76 - 87%). Dry weight measurements were made for all types except overwintered stock at the time of planting. By an oversight, the samples of conweds were not done until three weeks later and thus the field increments shown are smaller than they really were.

Table 7. Average dry weight of roots at time of excavation

	Container type									
	Lodgepole pine					White spruce				
	¾-inch	¾-inch (0)[1]	Con-wed[2]	Bare-root	Plug	¾-inch	¾-inch (0)	Con-wed[2]	Bare-root	Plug
Avg wt mgs	130	157	114	1028	165	70	150	37	640	75
No. obs	20	15	20	20	14	19	15	19	20	14
Avg increment %	272	-	104	222	371	436	-	165	80	475

[1]¾-inch (0) = overwintered stock.

[2]Based on late analysis of planting time samples.

In lodgepole pine, bare-root stock had the largest average weight of roots, but not the best increment; bare-root stock was followed by plugs, overwintered in 3/4-inch tubes, 3/4-inch tubes and conweds (Table 7). It will be noticed that the performance of overwintered stock is not much better than standard stock grown in 3/4-inch tubes. This is attributed to suppressed growth due to inadequate rooting volume. In terms of root increment the plug and 3/4-inch tube showed best results. When compared on the basis of roots outside the container the conwed is better than the 3/4-inch tube in both actual weight and proportion of total root system.

For white spruce, performance was quite different, the overwintered stock (3/4-inch tubes) had the largest amount of root after the bare-root stock, followed by plugs, 3/4-inch tube and conwed in that order (Table 7). In terms of percentage increment the plug is best but closely followed by the 3/4-inch tube. For proportion of root system outside the container the conwed was better than the 3/4-inch tube (38% as opposed to 23%). Actual weights were approximately the same.

Looking at total plant weight of lodgepole pine in the various container types, plugs are best, followed by conweds, overwintered stock in 3/4-inch tubes, and 3/4-inch tubes in that order (Table 8). In terms of increment, the plug is by far the best. For white spruce, the position was again quite different, overwintered stock in 3/4-inch tubes gave best results, then plugs, 3/4-inch tubes and conweds.

In terms of increment, plugs were best, followed by 3/4-inch tubes.

Table 8. Average total dry weight at time of excavation

	Container type									
	Lodgepole pine					White spruce				
	¾-inch	¾-inch (0)[1]	Con-wed[2]	Bare-root	Plug	¾-inch	¾-inch (0)	Con-wed[2]	Bare-root	Plug
Avg wt mgs	343	409	414	3703	521	189	475	121	2577	242
No. obs	20	15	20	20	14	19	15	19	20	14
Avg increment %	368	-	99	104	585	626	-	64	51	830

[1]¾-inch (0) = ¾-inch overwintered.

[2]Based on late analysis of planting time samples.

GENERAL CONCLUSIONS FROM CONTAINER EXPERIMENTS

There is such a marked difference in the behavior of the two species that they are best discussed separately.

Pine

The performance of plugs, sponges and to a lesser extent 'conweds' where there is free root egress is outstanding. The larger plants produced by greater rooting volume are also noticeable; the tendency for younger, or possibly smaller, plants to have a larger field increment is a feature to be kept in mind in moving to larger and older container seedlings.

There is no great advantage in overwintering lodgepole pine stock where rooting volume is small, such as in 3/4-inch Ontario-type plastic tube. Performance in these experiments has not been markedly better than standard stock.

Spruce

White spruce is much more sensitive to outplanting in Alberta conditions even when 2 + 0 bare-root stock. Seedlings of container origin seem to seek the protection of the container and do not establish well outside it. The performances of white spruce seedlings in plugs and solid tubes are similar which again illustrates its reluctance to exploit the rigorous field environment. The better performance of overwintered stock is taken as an indication of the need for more robust and better adjusted seedlings.

Based on these and other Canadian Forestry Service experiments and field observations, we are now convinced that for both lodgepole pine and white spruce, planting in containers hinders establishment and reduces growth and survival by comparison with free rooted seedlings. We are also convinced that larger seedlings - of at least 15 weeks in appropriate rooting volume - should be used.

These conclusions have also been reached by the Alberta Forest Service and North Western Pulp & Power Co., and all future research and operational programs in Alberta will be based on plugs of some type with minimum rooting volume provisionally set at 2.3 cubic inches.

Further research will concentrate mainly on seedling condition, and how this can be manipulated by rearing processes, time of planting, growth rhythms and further work on rooting volume. Consideration of mechanization will start as soon as these aspects have been dealt with.

In adopting this course, we are aware of the difficulties we will encounter and which were avoided by the past system; these are: longer rearing periods which may preclude a steady outturn of seedlings, the possible need to take more than one year to rear spruce, all the difficulties attached to planting larger plants in a flushed condition when root growth is possibly at a minimum.

TUBED SEEDLING RESEARCH IN NORTHERN ONTARIO

J. B. Scarratt[1]

The first involvement of staff of the Great Lakes Forest Research Centre, formerly Ontario Region, in the area of container planting took the form of an evaluation of the field performance of tubed seedlings in one of the Ontario Department of Lands and Forests' early operational planting programs[2]. A primary objective of this study was to identify factors which appeared to have a significant effect upon seedling survival and development in the field. However, even as this study was being established, it was becoming increasingly clear that the initial performance of tubed seedlings in many parts of Ontario was far from encouraging — a situation which was intensified by rather disastrous and widespread frost heaving during the winter of 1966/67 — and this led, early in 1968, to more detailed investigations being undertaken at the request of the province.

Early results of these initial survival assessments clearly indicated that, from a practical point of view, the most immediate requirement in terms of the current provincial program was to evaluate the importance of seedling age (size) at planting and planting date over a range of site conditions. Consequently, most of the work initiated in 1968 has been concerned with evaluating seedling performance in relation to the age/planting date relationship; other aspects under active investigation relate to the effects of container size, response to release from competing vegetation, and overwintering performance. Until now, effort has been concentrated almost exclusively on the Ontario plastic tube and variants thereof. However, with the approaching maturity of existing studies, we will be looking much more critically at other systems in the future.

The results reported here are from a study which compares, for three species (white spruce, black spruce and jack pine) the outplanting performance of four seedling age-classes (6, 8, 10 and 12 weeks from sowing)[3],

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[1]Canadian Forestry Service, Great Lakes Forest Research Centre, Sault Ste. Marie, Ontario.

[2]Utilizing a 9/16- x 3-inch Ontario split plastic tube.

[3]Mean dimensions at planting of the four age-groups (average for all planting dates):

	White spruce		Black spruce		Jack pine	
	Height	Weight	Height	Weight	Height	Weight
	mm	mg	mm	mg	mm	mg
6 weeks	27	7	24	5	56	25
8 weeks	36	21	34	12	62	49
10 weeks	43	36	46	29	69	74
12 weeks	48	58	57	51	74	104

(continued)

for five planting dates (28-day intervals from June 3 to September 25, 1968), on seven site conditions representative of those most commonly encountered in the area where the study is located (White River, Ontario: site region B.9).

All planting stock used in this study was raised in a standard plastic greenhouse, adhering strictly to cultural techniques embodied in the Ontario Department of Lands and Forests' tubeling production manual. Seedlings were grown in a black peaty muck as is the present custom, using the same fertiliser amendments, treatment schedules, etc. The only variation from operational practice was in the age of seedlings at time of planting (the average age at planting in provincial operations at this time was 42 days). Seedlings in all age classes were held in the greenhouse for all but a 10-12 day hardening off period. Planting simulated operational procedures; this being achieved by having the planting crew work for a period directly under Lands and Forests' supervision.

A total of 42,000 seedlings were planted on the seven sites. For each seedling a multi-factor description of the planting microsite was made at the time of planting. From this it is hoped, by correlation with seedling survival and condition, to determine the more important site requirements for successful establishment. Seedling survival and condition has been assessed periodically on an individual basis also, to give a full record of the development of each seedling from time of planting to the present, in terms of condition and appearance, damage or mortality, and cause of mortality wherever possible. In addition, an individual growth record has been maintained on a 20% sample from each treatment combination. These trees are currently being excavated for final measurement.

Although there are marked differences in survival and growth between the seven sites included in this study, the relative response to differences in age at planting and planting date has been very similar for all sites. In general, the earlier the planting date and the older the seedlings at planting the better has been survival/condition and growth. Space does not allow full consideration of the accumulated data so I propose to confine my remarks to one site only and give a very highly summarised account of survival and growth for the three species planted. The site selected has had

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[3](concluded)

The use of seedling age as a treatment factor can be criticised on the grounds that a whole range of seedling sizes can be produced within a given period depending on the cultural techniques adopted. However, in this study a size criterion was unworkable because of the closely scheduled planting date prescriptions. Furthermore, the cultural techniques were pre-defined, in that provincially prescribed production methods were adopted throughout. It may also be argued that, from a purely practical viewpoint, production scheduling on the basis of time is likely to be more feasible with relatively unskilled staff than strictly on the basis of size. In this study, the effect of adopting an age criterion was that, due to more favourable growth conditions, seedling size for a given age was generally greater than average for the (third) late July planting.

better survival than most other sites and has produced some of the best growth rates. Of the sites tested it is the closest approach to a typical mixedwood site — a fresh, well-drained boulder till originally supporting spruce-fir-aspen-birch, felled in 1960 and scarified with barrels in the year previous to planting.

Average survival up to the end of the first growing season was excellent for all species (97%) (Figs. 1-3), being favored by higher-than-average rainfall during the summer months. Mortality was most pronounced for 6- and 8-week-old seedlings, the spruces showing the greatest losses (Table 1). Much of the mortality in spruce of this age range was attributed to rodents or insects (probably grasshoppers), seedlings often being destroyed in the first few days after planting. This form of destruction was most typical of 6-week-old seedlings and ceased abruptly once they had reached an age and size (8-9 weeks) where the seedling stem had become woody (i.e., within 2-3 weeks of planting).

The effect of date of planting upon first season mortality appeared to be relatively minor, again probably due to the generally moist conditions which prevailed. The apparently higher level of survival for all species in the September planting is an artifact caused by the assessment having been made only 1 month after planting.

Seedling losses during the first winter, although not particularly heavy on this site, were the highest recorded for any seasonal period in the first 3 years following outplanting (Table 1). Thus, losses during the first winter alone accounted for roughly 45% of total mortality to the end of the third growing season, while, including previous mortality, total losses to the end of the first winter accounted for 62% of the 3 year mortality figure. In all species there was markedly higher overwinter mortality of 6-week-old seedlings than of other age-classes, with the 8-week-old spruce generally taking an intermediate position.

Although all species and age/planting date treatments have suffered a gradual depletion in numbers since the first winter, numbers are now (1971), after four growing seasons, becoming stabilised. Rates of depletion have been greatest in the youngest age-classes and for the later plantings, and it is these treatments which continue to suffer the heaviest losses. It is noteworthy that much of this depletion has been due, not so much to any specific catastrophic destruction of healthy, vigorous seedlings, but rather to progressive debilitation of poor quality plants. In many instances, such seedlings had been given poor quality ratings as early as the first growing season, with individual seedling histories showing a gradual decline in condition at subsequent assessments. This suggests that seedling quality assessments in the second summer after planting may provide an early indication of subsequent establishment rates.

Seedling survival to the end of the third growing season (1970) is summarized in Figs. 1-3. Average total survival remains high for all species (white spruce 80%; black spruce 83%; jack pine 89%), but with markedly lower survival in the 6- and 8-week-old age classes, particularly in

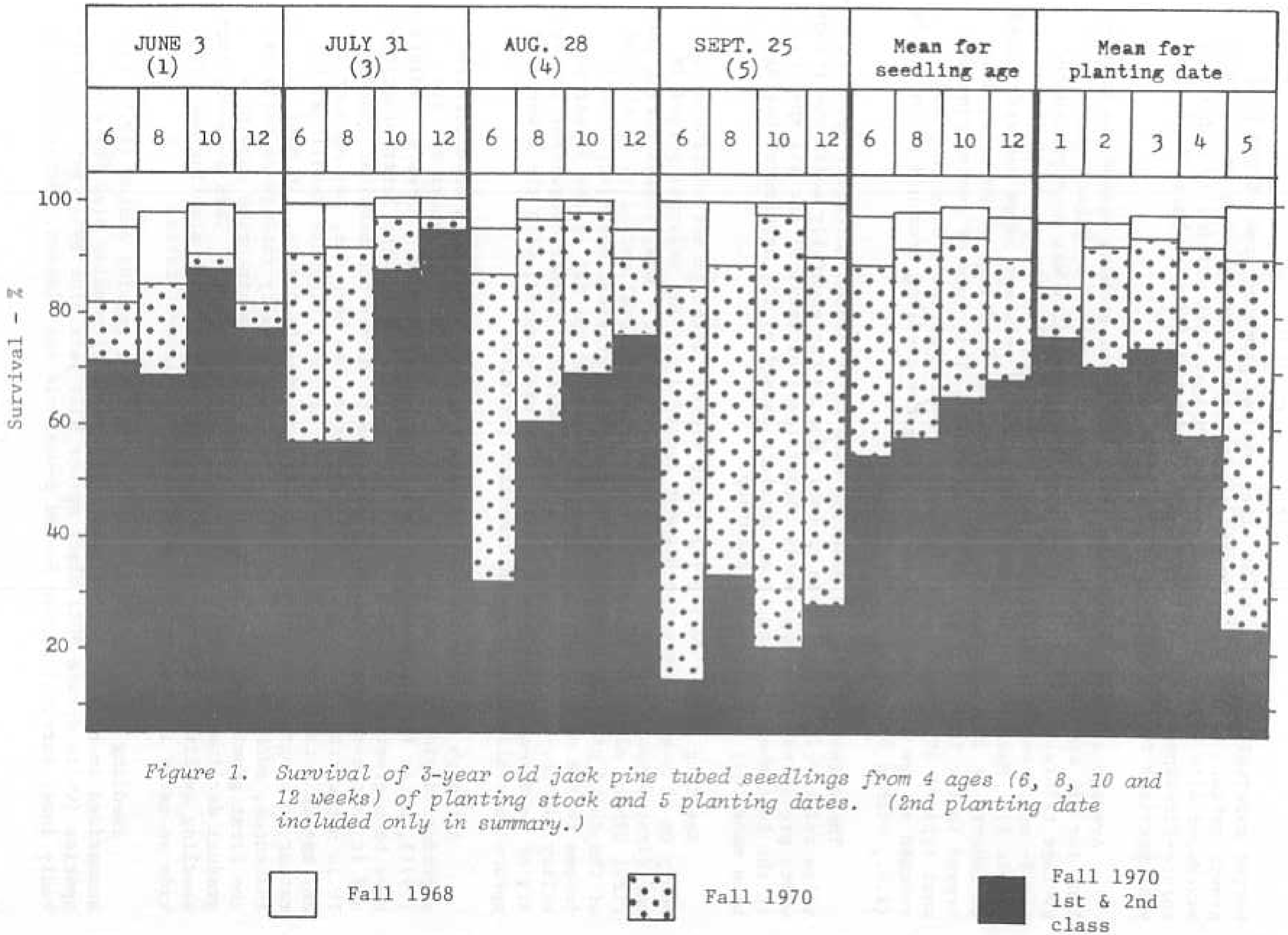

Figure 1. Survival of 3-year old jack pine tubed seedlings from 4 ages (6, 8, 10 and 12 weeks) of planting stock and 5 planting dates. (2nd planting date included only in summary.)

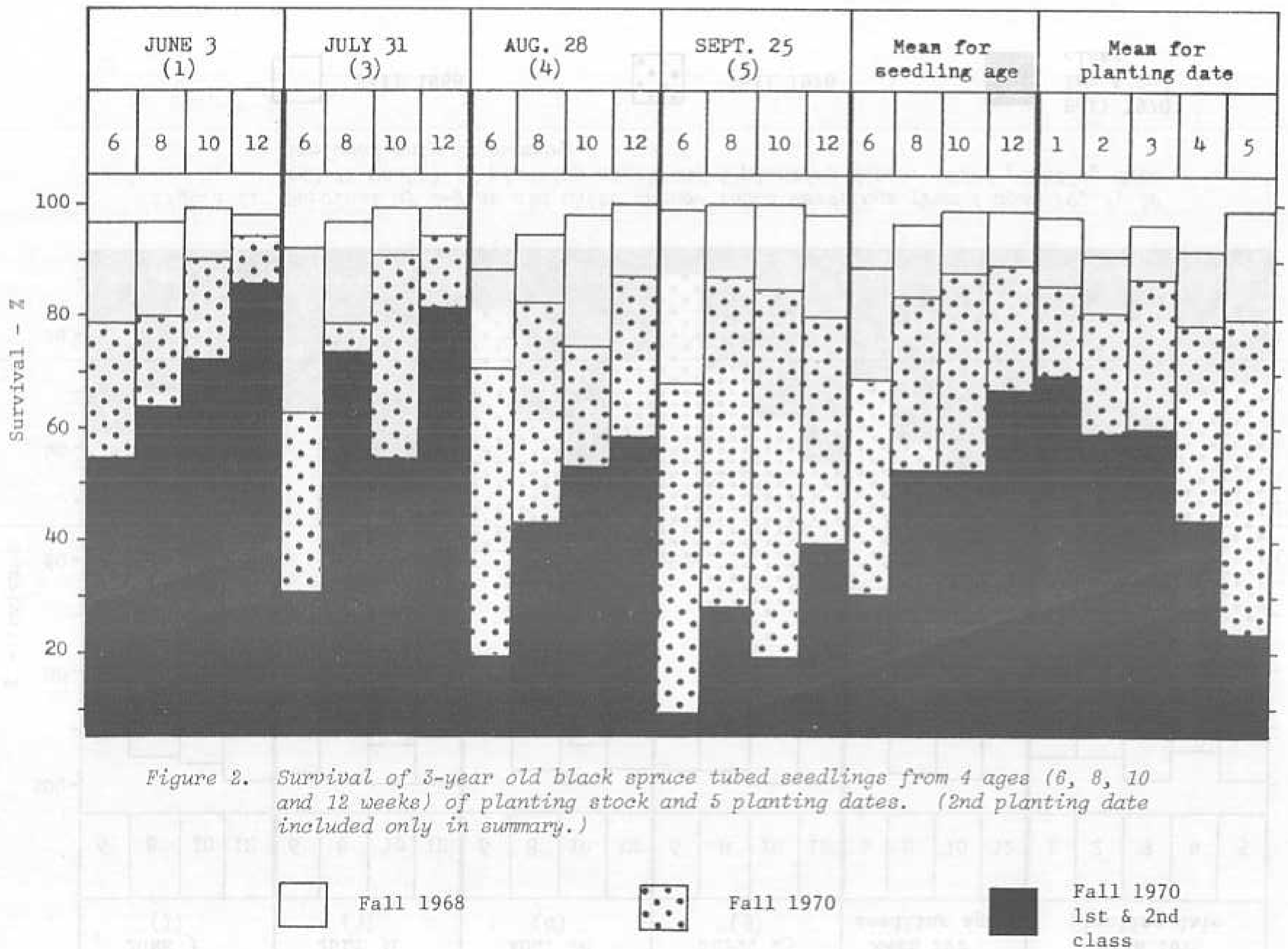

Figure 2. *Survival of 3-year old black spruce tubed seedlings from 4 ages (6, 8, 10 and 12 weeks) of planting stock and 5 planting dates. (2nd planting date included only in summary.)*

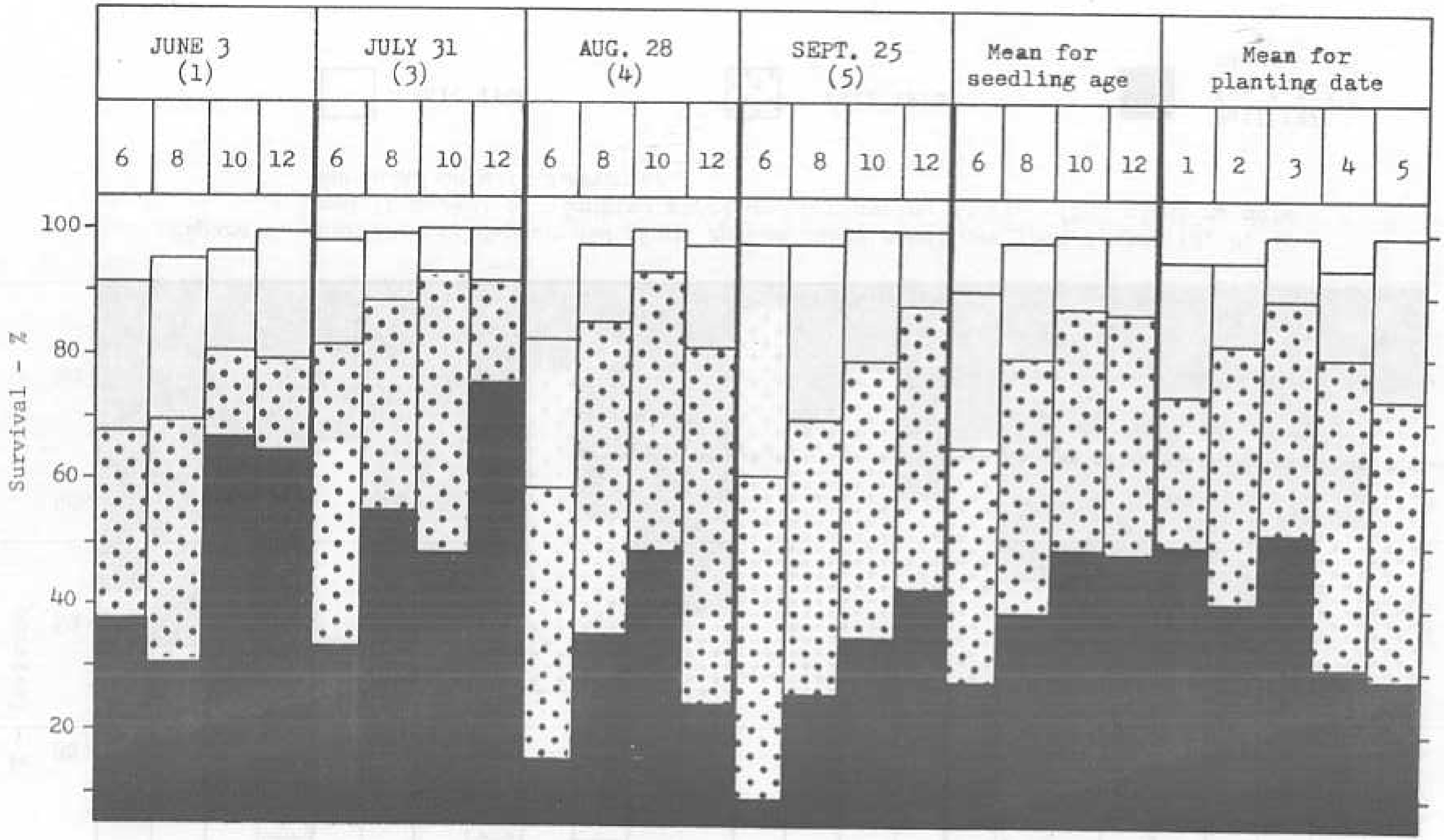

Figure 3. Survival of 3-year old white spruce tubed seedlings from 4 ages (6, 8, 10 and 12 weeks) of planting stock and 5 planting dates. (2nd planting date included only in summary.)

Table 1. Course of seedling mortality over a 3 year period — seedling age averaged over planting date (percentage of total planted)

Age class	Period[1]					Total mortality to fall 1970
	1	2	3	4	5	
White spruce						
6 weeks	5.0	9.4	10.0	6.8	7.4	33.6
8 "	1.0	2.0	8.4	3.0	6.8	20.2
10 "	0.4	0.8	6.0	2.0	3.8	12.6
12 "	0.6	0.8	5.0	2.2	5.4	13.4
Black spruce						
6 weeks	4.8	10.6	11.6	3.2	5.2	30.6
8 "	2.0	2.6	7.8	1.8	3.4	15.6
10 "	0.6	1.0	7.0	1.4	2.8	12.2
12 "	0.6	1.0	4.8	3.0	1.8	10.6
Jack pine						
6 weeks	1.4	2.4	5.0	1.8	1.8	11.0
8 "	0.8	1.4	3.6	1.0	2.4	8.4
10 "	0.2	0.6	3.4	1.0	0.8	5.8
12 "	2.0	2.6	4.2	0.4	2.4	9.6

[1] 1 - Up to 1 month from planting.
2 - Up to end of 1st growing season (1968) (cumulative).
3 - 1st winter (Fall 1968 to Spring 1969).
4 - 2nd growing season (Spring 1969 to Fall 1969).
5 - Fall 1969 to Fall 1970.

the spruces. There appears to be little relationship between planting date and total survival in jack pine or black spruce, although in white spruce total survival is clearly superior for seedlings planted in midsummer.

Although total survival is the most commonly quoted parameter of initial plantation performance, it may seriously overestimate crop potential, for it ignores seedling condition and includes all grades from the very poor and moribund to those of excellent quality and vigor. If, in the present situation, we consider only those seedlings assessed as first or second class quality[4], then the figures for average survival after three growing seasons are depressed rather dramatically (white spruce 41%; black

[4] Defined as healthy seedlings of at least moderate vigor, with no abnormalities of color or form, considered capable of producing an established plant of reasonable quality within 5 years of planting.

spruce 51%; jack pine 61%) compared with total survival. More significantly, the effect is to accentuate the differences in survival due to age at planting and planting date. In all species, the lower survival of 6- and 8-week-old seedlings is emphasised by the greater differential between total and 1st/2nd class survival in these age-classes. In other words, not only is survival poorer in the younger age-classes, but the average quality of surviving seedlings is inferior to that resulting from the use of older plants. Jack pine has obviously survived best of all and has a higher proportion of high quality seedlings than the other species. Of the spruces, black spruce has done best in all age-classes, again with a higher proportion of high quality seedlings than white spruce. A similar situation is found on other sites also.

Although the 1970 data shows no consistent relationship between date of planting and total survival, the histograms for 1st/2nd class survival demonstrate clearly the rapid decline in quality of surviving seedlings resulting from the last two planting dates. The September planting is obviously a failure, in terms of numbers of surviving high quality seedlings, for all species and all ages at planting. However, while in general seedlings from the August planting have also performed badly, this appears to be related to age at planting, the 10- and 12-week age-classes producing reasonable numbers of high quality plants compared with other planting dates.

Plantation success depends not only on a high survival rate, but also, if seedlings are to survive competition and other site hazards, on a reasonable growth rate coupled with unchecked, vigorous growth following outplanting. Fig. 4 compares the heights of the three species at the end of the third growing season. In terms of growth response, jack pine has outgrown both spruces, but in all species the pattern of growth in relation to age at planting and planting date closely parallels that of survival. As we might expect, the larger (i.e., the older) the seedling at planting the better in general has been its subsequent development. The size difference between age-classes again highlights the general inferiority of the 6- and 8-week-old seedlings compared with older planting stock. Similarly, growth in all age-classes has been best for the first three planting dates. All species show a marked decline for the August planting while most seedlings from the September planting have shown poor growth in addition to their being of low quality.

The inferior overall quality of white spruce seedlings compared with black spruce, demonstrated by the survival data, is matched by the poorer response in height growth. Not only is height after three growing seasons consistently lower than in black spruce for all age-classes and planting dates but height differences between age-classes are much less within the species also. In fact, the superiority of the 10- and 12-week age-classes only becomes convincing in white spruce when size is considered jointly with average quality. It is of interest to note that the size differential between white and black spruce is greatest for the older age-classes and planting dates.

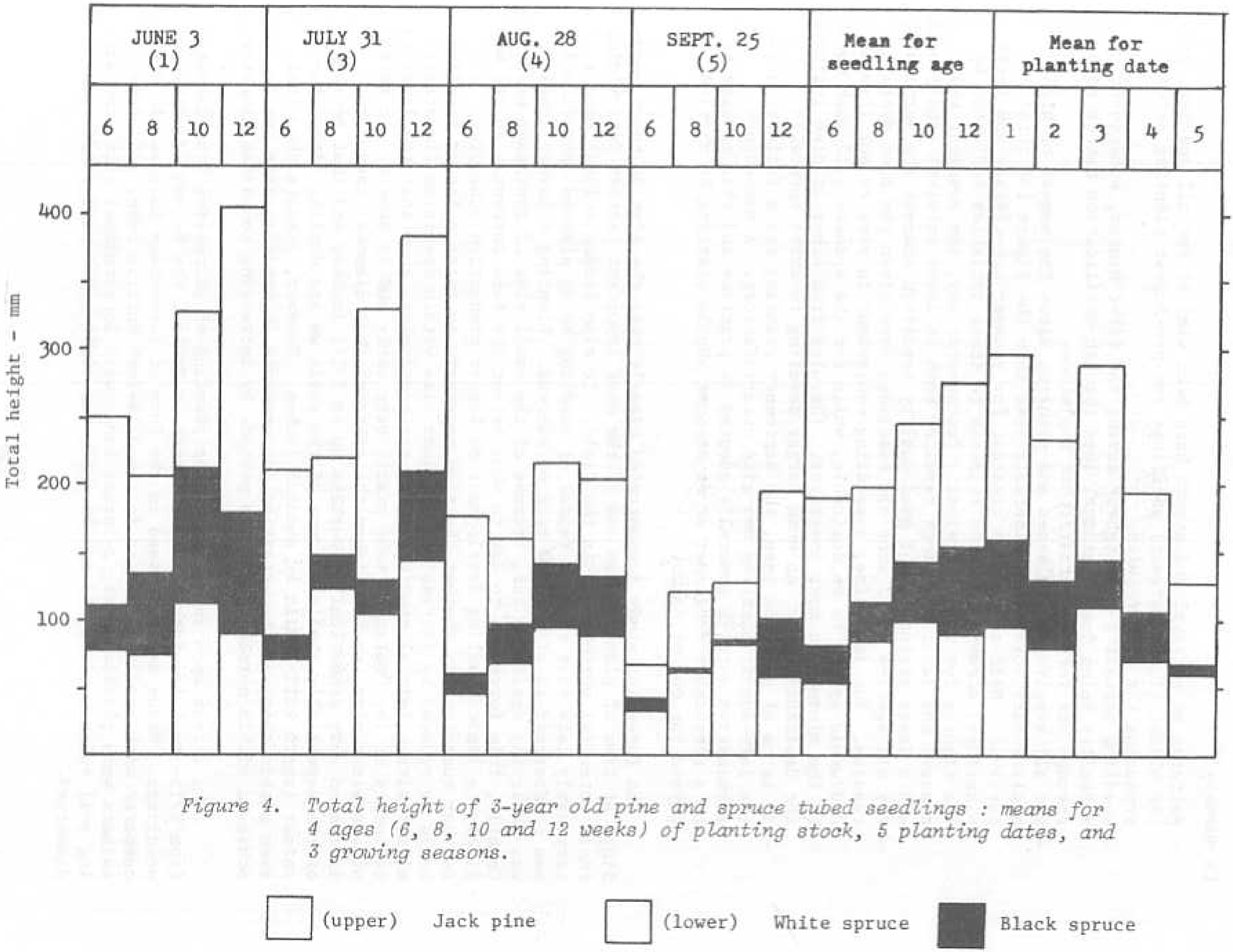

Figure 4. *Total height of 3-year old pine and spruce tubed seedlings : means for 4 ages (6, 8, 10 and 12 weeks) of planting stock, 5 planting dates, and 3 growing seasons.*

In summary

- patterns of survival and growth have been similar for all species, with the oldest (i.e., largest) seedlings and pre-August planting dates producing the best results.
- seedling mortality was highest during the first winter, subsequent mortality being due to gradual loss through debilitation rather than through any form of catastrophic depletion.
- for all seedling age-classes and planting dates the number of high-quality survivors is considerably less than the figure for total survival. Differences are greatest for younger age-classes and later plantings, accentuating the response to these variables indicated by the figures for total survival. Put another way, the youngest age-classes and later plantings resulted both in lower survival (and growth) and a lower proportion of good quality seedlings amongst the survivors.
- for all species 10-12 week old seedlings have given the best overall results. For jack pine, a seedling equivalent in size to our 10-week old would appear to be desirable, while for the spruces a 12-week would be the minimum in most instances. (Results from other studies indicate the desirability for an even larger seedling in white spruce.)
- in terms of planting date, the September planting was a failure, while the late-August planting was also unsatisfactory. A mid-August termination date is generally adopted in practice and this appears to be a reasonable decision; on no account should planting be carried beyond the end of August.

The foregoing study demonstrated clearly that the size of tubed seedlings at time of planting was one of the most important factors determining their potential performance in the field. It also became evident from a very early date that the age (size) of seedling being planted operationally was predestined to give a low rate of success. Planting a larger seedling was obviously desirable but, because of the small size of container used in Ontario, this forced us to ask to what extent the tube currently in use was likely to limit seedling development on longer production schedules. A further question was whether the time necessary to raise a larger seedling could be reduced by increasing container size within operationally acceptable limits. Initial studies, which are continuing, show that the limiting influence of the "Ontario" tube starts very early and is severe. In terms of container size, we have taken the approach that diameter cannot be increased very dramatically, perhaps up to 1 1/2 inches, and that because of the essentially shallow nature of the soils we are dealing with, container length will remain at about 3 inches. However, results show that even within these limits, striking improvements in seedling size can be achieved within normal production periods by increasing container diameter.

The effect upon seedling size at planting of increasing tube diameter from 9/16- to 1 1/4-inches is summarised in Table 2 for 8- and 12-week-old seedlings. Means are expressed in the form of percentage increase in size compared with seedlings raised in the 9/16-inch Ontario tube. All containers were plastic tubes, 3-inches long, with longitudinal slit, containing soil volumes of 11, 22 and 55 cubic cms (9/16-, 3/4- and 1 1/4-inch diameter).

Table 2. Size of 8- and 12-week-old spruce and pine seedlings grown in ¾-inch and 1¼-inch diameter tubes compared with those grown in the 9/16-inch "Ontario" tube

Tubeling description		Percentage increase in size				
		Total height	Root-collar diameter	Top weight	Root weight	Total weight
White spruce						
8 weeks	¾	3.5	3.5	6.5	6.1	6.5
	1¼	2.2	6.1	15.1	7.5	14.2
12 weeks	¾	11.5[1]	4.2	18.4	17.4	18.2
	1¼	58.9[1]	45.1[1]	113.0[1]	90.4[1]	109.4[1]
Jack pine						
8 weeks	¾	8.2	10.7	8.1	18.0	9.7
	1¼	12.3	21.0	45.0	46.1	45.2
12 weeks	¾	0	5.1	19.6	24.7[1]	20.8
	1¼	20.3[1]	28.3[1]	119.2[1]	90.3[1]	113.0[1]

[1]Dimensions significantly different from those of seedlings grown in 9/16-inch tubes at the 5% level.

Generally speaking, differences in seedling size attributable to tube diameter were convincing only in the 12-week-old seedlings. In 8-week-old white spruce increasing tube diameter caused very little improvement in seedling size, although jack pine seedlings grown in the 1 1/4-inch tube had considerably higher dry weights. Although these differences were not significant, they do indicate that the two smallest tubes began to have an adverse influence on jack pine development from a very early age. By 12 weeks, the growth restriction imposed by the 9/16-inch tube had become very evident in both species. Some improvement in growth was obtained with the 3/4-inch diameter tube but this was relatively small and generally non-significant, indicating that it also was severely restricting seedling development. The effect upon dry matter production was the most prominent, with major suppression of both height and diameter growth. Seedling quality suffered also, the small tubes producing spindly seedlings with sparse foliage and little branching compared with those raised in 1 1/4-inch tubes.

The results show that the "Ontario" tube does place a severe restriction on seedling growth at an early age. They also suggest that for a given cultural regime planting stock of the desired size can be raised in a shorter period by using a larger diameter container. In considering a change in container size (not necessarily plastic) there is clearly little advantage to be gained by increasing diameter to 3/4-inch; the only improvement in

Table 3. Survival and growth of 8- and 12-week-old seedlings raised and planted in three diameters (inches) of plastic tube 3 inches in length. Planted July 1969

Tubeling description		1971 survival		1970 growth measurement (means)			
		Total survival	1st & 2nd class	Total height	Increase over 9/16-inch tube	Current height growth	Current height increment
		%	%	mm	%	mm	%
White spruce							
8 weeks	9/16	72	57	63		23	74
	3/4	63	46	71	13	26	68
	1 1/4	71	45	64	2	27	96
12 weeks	9/16	80	62	91		26	44
	3/4	88	74	104	14	33	54
	1 1/4	98	86	109	20	44	70
Jack pine							
8 weeks	9/16	95	74	136		84	182
	3/4	99	85	157	15	108	255
	1 1/4	84	77	203	49	155	374
12 weeks	9/16	95	77	166		95	152
	3/4	99	88	199	20	125	175
	1 1/4	99	90	253	52	178	270

overall size of any practical significance resulted from the use of a 1 1/4-inch diameter container. While the final choice will be influenced by unit production/transportation costs, etc., it is suggested that in terms of seedling production increasing container diameter to 1 1/4- or 1 1/2-inches would be biologically advantageous and practically feasible.

The possibility of tube size influencing initial field performance also exists and in conclusion I will describe briefly results obtained with the same three sizes of tube. This is summarized in Tables 3 and 4.

Total survival within a given age-class after three growing seasons was little different for seedlings raised in any of the three containers. As might be expected from the age-comparative studies, white spruce did show overall differences between age-classes, but these were apparently related to the large differences in size at planting. However, for 12-week-old white spruce and both ages of jack pine, there was still a trend for a higher proportion of high-quality seedlings in the larger tubes after 3 years.

In jack pine seedling height after two growing seasons was clearly related to tube diameter, with substantially larger, more vigorous seedlings

Table 4. Preliminary data for mean size of 8- and 12-week-old seedlings raised and planted in three diameters (inches) of plastic tube after three growing seasons

Tubeling description		1971 growth measurements: Total height mm	1971 growth measurements: Root-collar diameter mm
White spruce			
8 weeks	9/16	139	2.9
	3/4	125	2.6
	1 1/4	120	2.6
12 weeks	9/16	149	3.0
	3/4	175	3.0
	1 1/4	235	4.4
Jack pine			
8 weeks	9/16	510	9.5
	3/4	535	10.6
	1 1/4	584	10.9
12 weeks	9/16	554	10.1
	3/4	556	9.9
	1 1/4	628	11.9

in the 1 1/4-inch tubes. Although a similar response was evident in the 12-week white spruce the magnitude of the differences was far less distinct. It may be argued that the superior growth of seedlings in the larger tubes is a reflection of their greater size at planting rather than any continuing effect of tube size. However, if we compare the figures for percentage difference in height for the three tube sizes at time of planting and after two growing seasons, it will be seen that the differentials have increased since time of planting in jack pine. This suggests the possibility that tube size continued to exert an influence upon seedling development up to this point. This is supported by the fact that percentage height increment in the year after planting also showed a substantial increase in the larger tube sizes. The study is currently being excavated for final measurement, but preliminary data (Table 4) indicates that the influence of tube size is now, after three growing seasons, beginning to decline for both age-classes of jack pine. This may be attributed to greatly expanded rooting in the surrounding soil and the fact that all feeding roots in this species are now outside the container. The restrictive influence is still evident in the 12-week-old white spruce, however, with a noticeable gain in the relative position of seedlings in the 1 1/4-inch tube. It is of interest to note that comparatively few large spruce roots appear to have developed from the 9/16- and 3/4-inch diameter tubes, whereas root egress and subsequent proliferation has been good in the 1 1/4-inch tubes.

OPTIMUM CONTAINER SIZE FOR BLACK SPRUCE

M.E. Boudoux[1]

INTRODUCTION

In recent years container-grown plants have attracted much attention and have been used in increasing numbers for artificial regeneration. This planting method has been most useful where bare-root planting has not been feasible due to either severe environmental conditions (Ackerman *et al.* 1965) or inaccessibility of sites to planting machines (Carman 1967).

Much attention has been given to the nature of the material used in the making of containers: for example, aluminum sheets (Valentin 1967), bamboo stems (Cimatu 1962), cardboard (Chedzoy 1967), compressed peat (Delvaux 1963), kraft paper (Jones 1967), polyethylene films (Dureuil and Claudot 1965, Fuller 1961, Monjauze 1956), tar paper (Fuller 1961) and zinc sheets (Clauzure 1956) have been tested, but most of these are of secondary importance. At the present time polystyrene is quite popular and is being used in two forms: the Ontario tube - a rolled piece of plastic (9/16- X 3-inch) with a slit along the side and the ends open (Carmen 1967); or a rather rigid tube molded in the shape of a bullet (Walters') but having the top open, and the base and one side slit (Walters 1968).

Although some containers seem to lend themselves to automation and have several advantages, there are certain problems such as frost heaving of the tubes (Fraser and Wahl 1969), the formation of root-balls in bullet-shaped containers (Raets 1961, Harris 1967), and occasional high levels of mortality (Hall 1969, Dixon and Johnson 1969). It seems that failure does not result from the method itself but from the fact that a certain number of questions, at times fundamental, have not been solved in a satisfactory way. As Ackerman already pointed out (Ackerman *et al.* 1965), it is most urgent that research be carried out to determine, for each species over a range of environmental conditions, the ideal form and dimensions of the container.

The relationship between container dimensions (height and diameter) and seedling development during the rearing stage should be studied in detail before considering the survival and growth of seedlings after outplanting. For example, an 18-week-old seedling has more chance of survival, all other conditions being equal, if during the first few months, it has been able to develop a shoot sufficiently high and a root system which will allow it to make maximum use of the soil at its disposal. It is important

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to note here, as Alm and Schantz-Hansen (1967) have already indicated, that shortly after planting the container serves as the microsite since it has a definite reserve of water (Clauzure 1956) and nutrients and, to a certain extent, its own microclimate. Therefore, I have chosen as my objectives: to establish the relationship between dimensions of the container and development of black spruce seedlings during the rearing stage; and to attempt to define the dimensions of the ideal container.

MATERIALS AND METHOD

Considering the objectives of the study it was necessary to design a container which could be built with different diameters and lengths. Such a container has been developed. It consists of a thin piece of poplar veneer rolled and stapled at both ends (Boudoux 1969). The veneer sheets are received from the factory while still wet. In the laboratory the veneer is immersed in a very dilute solution of hydrochloric acid to increase its plasticity and then thoroughly rinsed with distilled water. The sheets are cut to dimensions corresponding to the size of the tube desired. After stapling, the tubes are dipped in an acetone-polyvinyl solution to cover them with a continuous plastic film to prevent any lateral evaporation.

The experiment was designed to permit statistical analysis of the results. Tubes of the following dimensions were made: 1:07, 1:10, 1:13, 2:07, 2:10, 2:13, 3:07, 3:10, 3:13, 4:07, 4:10, 4:13, 5:07, 5:10, 5:13, 5:20, 5:25, 6:07, 6:10, 6:13, 6:20, 6:25. The first figure represents the diameter (d), the other two the height (h) in centimeters. Thus, model 1:07 is a tube 1 cm in diameter and 7 cm in height. The experiment was a completely randomized design of five blocks of 10 tubes for each of the 22 sizes of containers. A total of 1,100 tubes comprised this study. The tubes were filled with a steam-sterilized mixture of peat, soil and sand, 5:2:2 (pH = 6.1).

In this study black spruce (*Picea mariana* (Mill.) B.S.P.) was used, as it is considered to be a high priority species in reforestation programs in Quebec (Besley 1959). The seed used gave 83% germination in Petri dishes. To render the germination rate as uniform as possible, we used seeds of similar weight from a single provenance. Empty seeds were eliminated by flotation in ethylalcohol (Morgenstern 1969).

The 220 containers in each block were distributed at random in boxes 12 inches square, the bottoms of which were of heavy screen to permit good drainage and to prevent the roots from growing out of the bottoms of the tubes. Once seeded, the tubes were placed in a growth chamber. During germination the seeds were watered with a dilute solution of captan to prevent damping off (Cayford and Waldron 1967).

After 18 weeks of growth, the seedlings were removed from the growth chamber. Measurements were made of: height of the shoot above ground (H); length of the longest root (L); dry weight of roots (W). The means, variance and standard error for these measurements were calculated for each block and each container size. The coefficient of variation for each mean was never more than 10%. The density of the root systems was calculated using the expressions W/d, W/h and W/V where d, h and V represent the diameter, the height and the internal volume of the container respectively (Boudoux 1970).

RESULTS AND DISCUSSION

I have tried to answer three questions.

1. In the case of *Picea mariana*, do the dimensions of the tube influence the development and growth of the seedlings?

2. What kind of relationship exists between the seedling and the container's dimensions?

3. What should be the optimum dimensions for the tube?

The results of an analysis of variance of seedling parameters and root-system densities as affected by the diameter and height of the containers used are these: In the case of the seedling parameters, the height of the tube has a significant effect on the length of the roots. The roots of 18-week-old seedlings had just reached the bottom of tubes 7 cm in height. However, in tubes 25 cm high, the primary root of some seedlings had reached a length of 20 cm. This superior growth may have been due to a better distribution of water inside the longer tubes and to less fluctuation of the soil's water content. An increase in the length of roots occurred without an increase in dry weight. Farrar (1960) has also noted this effect of substrate depth on the growth of black spruce.

Shoot growth was not significantly modified by length of the container since shoot growth is affected by the dry weight of the roots which in turn is affected only by the container's diameter. I found that the diameter of the container has the greatest effect on growth of the seedlings. Evans and Duyker (1965) also observed similar results with *Callistris intratropica*. This finding is not surprising if one considers that growth, whether of shoots or roots, is linked directly to the supply of nutrient elements. The importance of the diameter of the tubes is apparent in the formula for calculating the volume of substrate ($V = \pi d^2 h$). The weight of roots is highly influenced by the diameter of the container. Thus the diameter of the tube is considered to be a major factor in the development of a better root system.

The density of the root system, that is to say the values for the dry weight of roots (W) divided by one of the tube parameters, can be expressed laterally (W/d), axially (W/h) or on the volume basis (W/V). The last two ratios are affected significantly by the diameter of the container, while only the second ratio is affected by the height of the container.

An earlier experiment, with 8-week-old seedlings (Boudoux 1970) indicated that the action of height of tube was negative. The equation:

$$W/h = .275\ d - .026\ h \quad (R^2 = .350)$$

had been proposed. Data from the 18-week-old seedlings growth in this experiment permits the derivation of more meaningful correlations between container dimensions and seedling growth. Indeed, numerous regression models have been used to determine the kind of relationships which exist between the seedlings and the container's dimensions. Seven of the many regression equations derived are shown in Table 1; these regressions are presented here as they indicate some of the more important relationships derived from this study.

One of the more important relationships which can be deduced from Table 1 is the influence of h (height of tube); its positive contribution to values L, H and W becomes negative when we want to increase the quantity or density of rooting. This data confirms the results of the analysis of variance.

Finally, to define the optional dimensions of the container is to classify the seedlings, according to one or several parameters, and to see which values of h and d favor these parameters.

H and L were both closely correlated to W. In the first approximation, W could be the criterion of classification for the seedlings. On the other hand, it is evident that, if L increases, W also increases, since there is a correlation between length and dry weight of roots (r = .852++). An increase in root length results in a reduction in root dry weight, the absorption of the nutrient elements by roots taking place only at the distal ends (piliferous zone). Consequently, the term W must be modified. We

Table 1. Correlations between the dimensions of the container and the seedlings

Regression equations							a	b	c
L	=	.410	+	1.192 d	+	.441 h	.936++	.783++	.832++
H	=	1.346	+	.201 d	+	.001 h	.672++	.820++	.335 NS
W	=	-.661	+	1.907 d	+	.237 h	.758++	.832++	.564+
W/V	=	-.076	+	.599 d^{-1}				.952++	
W/h	=	.687	+	.191 d	-	.047 h	.751++	.602+	-.335 NS
W/d	=	3.897	-	.261 d	-	.018 h	.290+	-.527+	.106 NS
W	=	-7.434	+	.921 d	+	6.316 H	.807++	.832++	.876++

a: coefficient of determination (R^2).
b: coefficient of correlation with the first independent variable.
c: coefficient of correlation with the second independent variable.

+Significant at the 5% level.
++Significant at the 1% level.
NS Non-significant.

have chosen to consider the W/h ratio as an index of quality of the seedlings. This ratio gives a very good approximation of the use of the tube by the root system. It remains to be seen how this criterion of seedling classification, the W/h ratio, could be linked to the dimension of the container. I used the following regression equations:

$$W/h = 1.1277 - .0236\ h \qquad (r = -.335\ ) \qquad I$$
$$W/h = .3269 + .1322\ d \qquad (r = .602{++}) \qquad II$$
$$W/h = 1.2280 - .0950\ (h/d) \qquad (r = -.705{++}) \qquad III.$$

Equation III is definitely the one which best fits the experimental data ($r = -.705{++}$). The ratio h/d allows us to define the tube which ensures an optimal growth of the seedling. But the linear relation is not the best relationship between the two variables: the correlation is strongly improved using the following model:

$$W/h = 1.705\ (h/d)^{-.605} \qquad IV.$$

However in this case, the distribution of the independent variable h/d is not normal. It is therefore necessary to transform the variable and to substitute for h/d, the new variable:

$$Z = \text{arcsinhyperbolique}\ (h/d)^{\frac{1}{2}}.$$

In fact, this variable Z has in this case a normal distribution which allows more precision in the establishment of the regression. This regression now becomes:

$$W/h = 1.407\ Z^{-2.074} \qquad (R^2 = .809{++}) \qquad V.$$

Figure 1 gives a graphical representation of the equation V. The function Y is represented by a 95% confidence interval. Each dot on the graph represents the mean value of 50 seedlings. The number next to the dot identifies the container size group.[2] Therefore (10) represents the mean density of roots systems produced by seedlings in containers 4 cm wide and 7 cm high.

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[2]

Container size group	Diameter (cm)	Height (cm)	Container size group	Diameter (cm)	Height (cm)	Container size group	Diameter (cm)	Height (cm)
1	1	7	9	3	13	16	5	20
2	1	10	10	4	7	17	5	25
3	1	13	11	4	10	18	6	7
4	2	7	12	4	13	19	6	10
5	2	10	13	5	7	20	6	13
6	2	13	14	5	10	21	6	20
7	3	7	15	5	13	22	6	25
8	3	10						

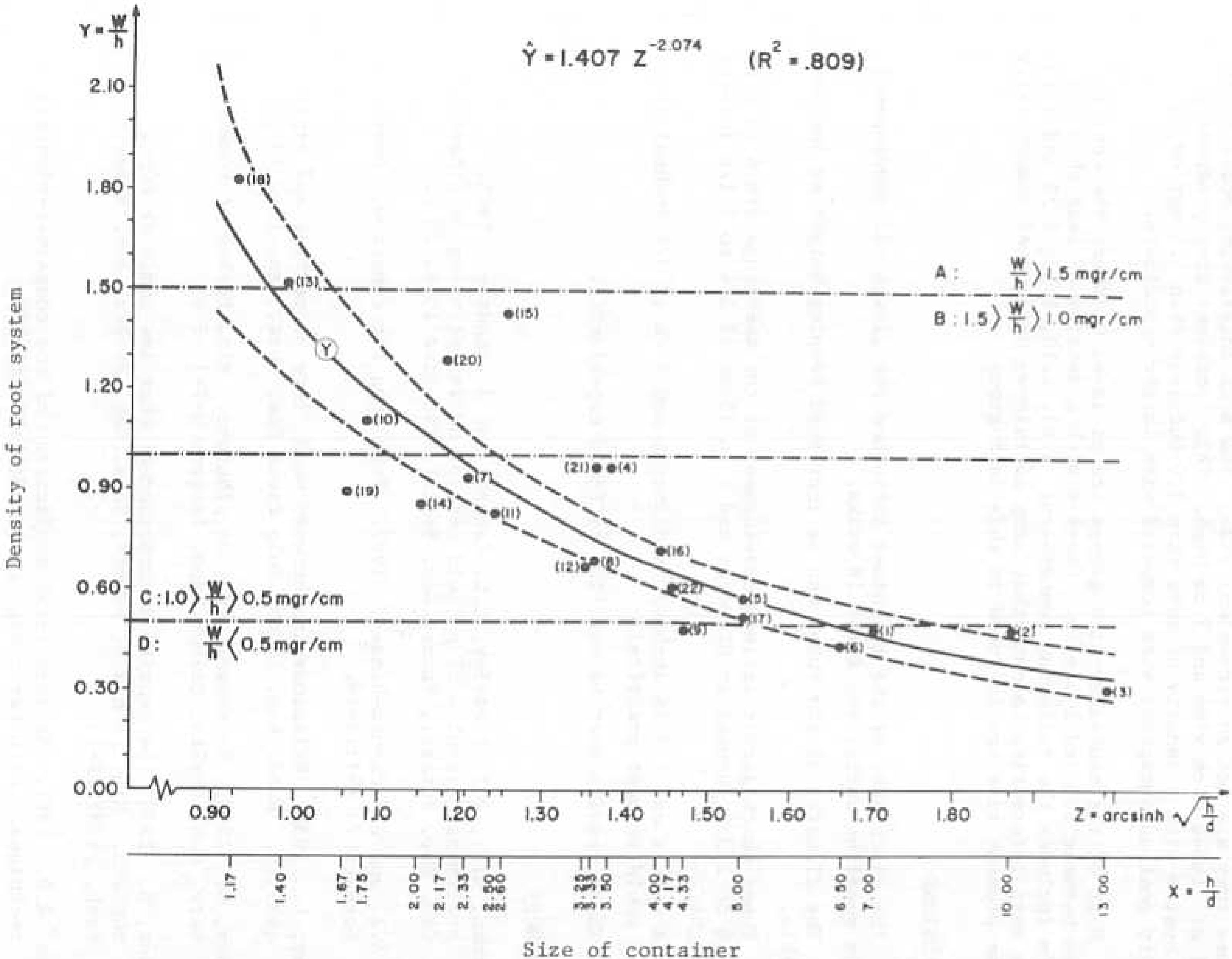

Figure 1. Regression between density of root system (W/h) of seedlings and different sizes of containers expressed as h/d. Each point on the graph identifies 1 of the 22 container size groups.

Four levels of quality for the root system are recognized. Level A (W/h> 1.5 mgr/cm) is reached only by tubes having 5 and 6 cm in diameter and 7 cm in height. These container sizes are of theoretical interest only because they are not an economical size. The most interesting model is in level B: tubes 4 cm wide and 7 cm high. This container size produces a root system with a density of more than 1.0 but less than 1.5 mgr/cm, a density most advantageous when compared with larger containers.

Most of the container size groups are at level C, where the density varies between 0.5 and 1 mgr/cm. Level D with a density of less than 0.5 mgr/cm includes the following containers: 1.07, 1.10, 1.13, 2.13 and 3.13. It is most interesting to note that many containers being used commercially at the present time are included in this last group.

CONCLUSIONS

1. The dimensions of the container influence the growth and development of the seedling during the first 18 weeks.

2. The diameter of the tubes can be increased keeping height as low as possible.

3. Tubes which permit optimum development of the seedlings are 4 to 6 cm (1 9/16 to 2 3/8 inches) in diameter and 7 to 13 cm (2 3/4 to 5 1/8 inches) in height.

4. A tube 4 cm (1 9/16 inches) in diameter and 7 cm (2 3/4 inches) in height would be most practical.

5. These results must be verified by field experiments.

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LOGISTICS, ECONOMICS, PRODUCTION

TECHNOLOGY AND MECHANIZATION

SEEDLINGS ON THE MOVE

J.M. Kinghorn[1]

Much of the current work on containers is concerned with biological considerations. Much debate centers around the size of container required to achieve acceptable field performance of seedlings grown therein. Generally it is agreed that a small (e.g. < 1 cubic inch) rooting volume of soil will limit the size and quality of seedlings that can be grown in a short period. Yet biological considerations should not be the only factors governing cavity volume when developing a container system for large-scale reforestation programs. Logistics must be given equal weight.

Tree planting, like tree harvesting can be reduced to a series of transportation problems. Costs, and hence feasibility of a planting system, are largely governed by the speed of delivering the seedlings from the nursery to their final destination in the ground. Any factor that reduces transportation efficiency, works to the detriment of the system. Size and weight of the individual seedling and its container are the most significant factors affecting handling efficiency.

Instead of asking how large the container should be, one should rephrase the question by asking how small it can be without jeopardizing acceptable field survival and growth. Unfortunately the answer is not likely to be simple or absolute. Minimums may be defined, but safety factors have to be added to provide for extremes in stress factors. Value judgements regarding container size will continue to be made, based on compromises between apparent biological requirements and economic limitations.

Examples of the range in sizes and bulk of various containers presently in use are given in Table 1. Except for the extremes, each container size represents a compromise. The 9/16-inch Ontario tube is the most efficient in terms of weight and volume but probably sacrifices biological performance potential. By contrast, the Weyerhaeuser tube provides adequate rooting volume which should give excellent seedling growth, but because of its large size, seriously sacrifices practicability. Not included in the table are Japanese paperpots which are available in a great variety of diameters and depths.

Compared with bare-root seedlings, container seedlings are bulky to handle because they are usually shipped upright, and trays or holders add significantly to the gross volume. Recently we have investigated repackaging plug seedlings after extracting them from BC/CFS Styroblocks. Plugs

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Table 1. Volume and spacing of selected plant containers

Container	Gross cavity volume[1] (cm^3)	(inch^3)	Spacing[2] (cavities/ft^2)
2½-inch Walters' bullet	11	0.67	125(144)
9/16-inch Ontario tube	12	0.70	375
American Can BR-8	18	1.08	270
4½-inch Walters' bullet	22	1.35	125(144)
¾-inch Ontario-type tube	24	1.45	250
Todd's Speedling plug tray	25	1.52	77(93)
Spencer-Lemaire fold-up plug tray	37	2.26	88
R.C.A. "peat sausage"	39	2.36	120
BC/CFS Styroblock 2	40	2.45	98
Swedish Multipot	45	2.75	82
Crown Zellerbach plug tray	48	2.93	139
Jiffy 7 peat pellet	65	3.96	41
BC/CFS Styroblock 8	125	7.63	41
Weyerhaeuser tube	490	30.00	28
Czechoslovakia-peat pots:			
7 cm dia.	153	9.5	26
8 cm dia.	244	14.9	23
10 cm dia.	526	32.1	19
11 cm dia.	636	38.8	17

[1]Gross cavity volume refers to maximum capacity; net, or effective volume is somewhat less according to the level of soil filling and rooting characteristics of various plants.

[2]The spacings (cavities/ft^2) shown are approximate, and may vary according to the type of tray in which individual containers are supported.

from the Styroblock 2 are wrapped in bundles of 25 in stretchable PVC produce film. Apart from eliminating culls and blanks, this option permits seedlings to be packed in cartons horizontally which reduces by more than two-thirds the shipping volume required. Styroblocks may then be re-used at the nursery, a potential saving that can easily offset the cost of packaging. Equipment required by planters to carry seedlings is simple and comfortable. Although it is still too early to evaluate re-packaging, any deleterious effects will have to prove severe to offset its significant advantages at the time when millions of seedlings will have to be moved hundreds of miles by a variety of transportation systems.

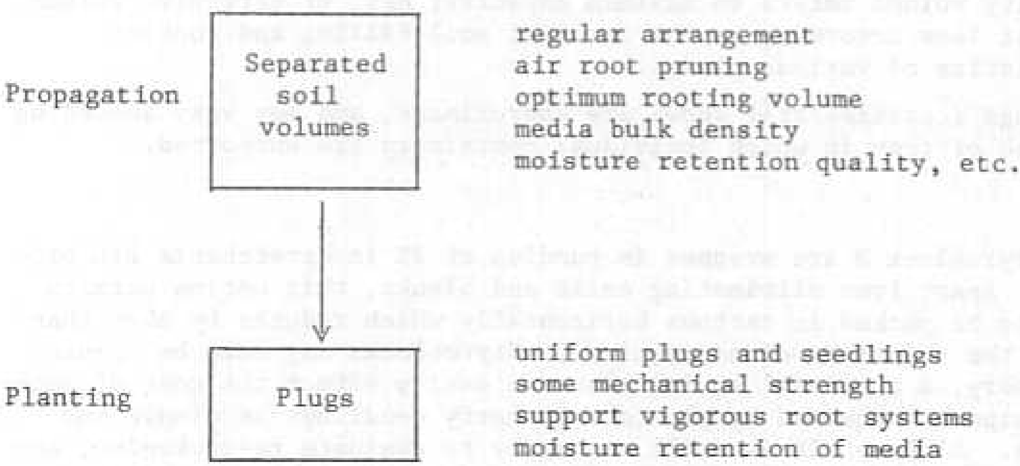
PRODUCTION AND CHARACTERISTICS OF R.C.A. "PEAT SAUSAGE" CONTAINERS

D.L. Mitchell and W.C. Kay[1]

Although no single seedling container or container system has yet been adopted by provincial or state agencies or by industry, considerable convergence of ideas has occurred in the past few years. Many current container specifications and systems do not differ significantly from one another and the sequence of operations through to field planting are principally variations towards a common objective: low-cost propagation and planting of a biologically specified seedling. To a large degree the future of container-grown seedling systems, i.e. plug planting, depends upon the following factors:

1) feedback of field data - confirmation that the container system and seedling specifications are providing acceptable stock according to both survival and growth criteria;
2) optimization of propagation and planting systems with respect to both capital and operating costs.

The following block diagram illustrates the two major stages required in this reforestation system.



Examples of current container systems which utilize these principles are: R.C.A. sausage, BC/CFS Styroblock, Japanese paperpot, Spencer-Lemaire fold-up plug tray, and Swedish Multipot.

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[1]Product Research and Development, Research Council of Alberta, Edmonton, Alberta.

Research and development have now reached the stage where the following question can be posed: "What is the most economic and efficient system?"

The process developed at the Research Council of Alberta produces plugs by a novel media-filling process. The simplicity of the operation should insure low capital and operating costs. The filling process consists of forcing a semifluid peat paste through a die. The die consists of a thin-walled cylindrical tube lined with teflon to reduce friction. A length of 20 to 25 feet of tubular film is threaded onto the outside of the die (Figure 2). The fluid peat paste being forced through the die fills and draws off the plastic film, and a long cylindrical length of media, encased in its thin plastic wall, is produced (Figure 1). The name "peat sausage" has been coined as a suitably descriptive name. The long length can be cut into shorter sections, usually between 2 and 7 inches (Figure 3).

The process offers considerable flexibility and efficiency, as illustrated by the following factors:

1) Shape of the die is variable.
2) Choice of media is open. Composted sawdust, peat, peat-soil, peat-vermiculite, and peat-soil-vermiculite have been tested.
3) Choice of container wall is open. The material may be nondegradable (polyethylene film), rapidly degradable (viscose), controllably degradable (modified cellophanes, polyesters, etc.). Induced enzymatic degradation is also possible when certain carbohydrate and proteinaceous films are employed.
4) Container wall is efficient. The intermediate voids are minimized since one mil or less of film is needed to form the independent soil volumes. The number of containers per unit area is therefore near the maximum.
5) The volume of sectioned sausages is variable. Length and diameter can be independently and easily changed with a minimum of equipment adjustment. Popular diameters are 1 and 1.3 inches, and popular lengths are 3, 4, and 5 inches.
6) Bulk density of the medium is accurately controllable, and yet can be varied as required over the range of 0.13 to 0.28 dry weight (g)/ wet volume (cc). Hand packed containers (Ontario-type 3/4-inch plastic tubes, BC/CFS Styroblocks) have media bulk densities in the range of 0.09 to 0.11.
7) Conservation of moisture in plugs may be controlled by partial removal of the lower portion of the polythene film during planting. This option may be useful for planting seedlings in areas with dry, sandy surface soil.

The following actual material costs were realized on small volume experimental operations.

Material costs/M containers (R.C.A.)

Polythene film	$ 0.60
Peat (commercial)	1.35
Trays (not recycled)	2.00
	$ 3.95

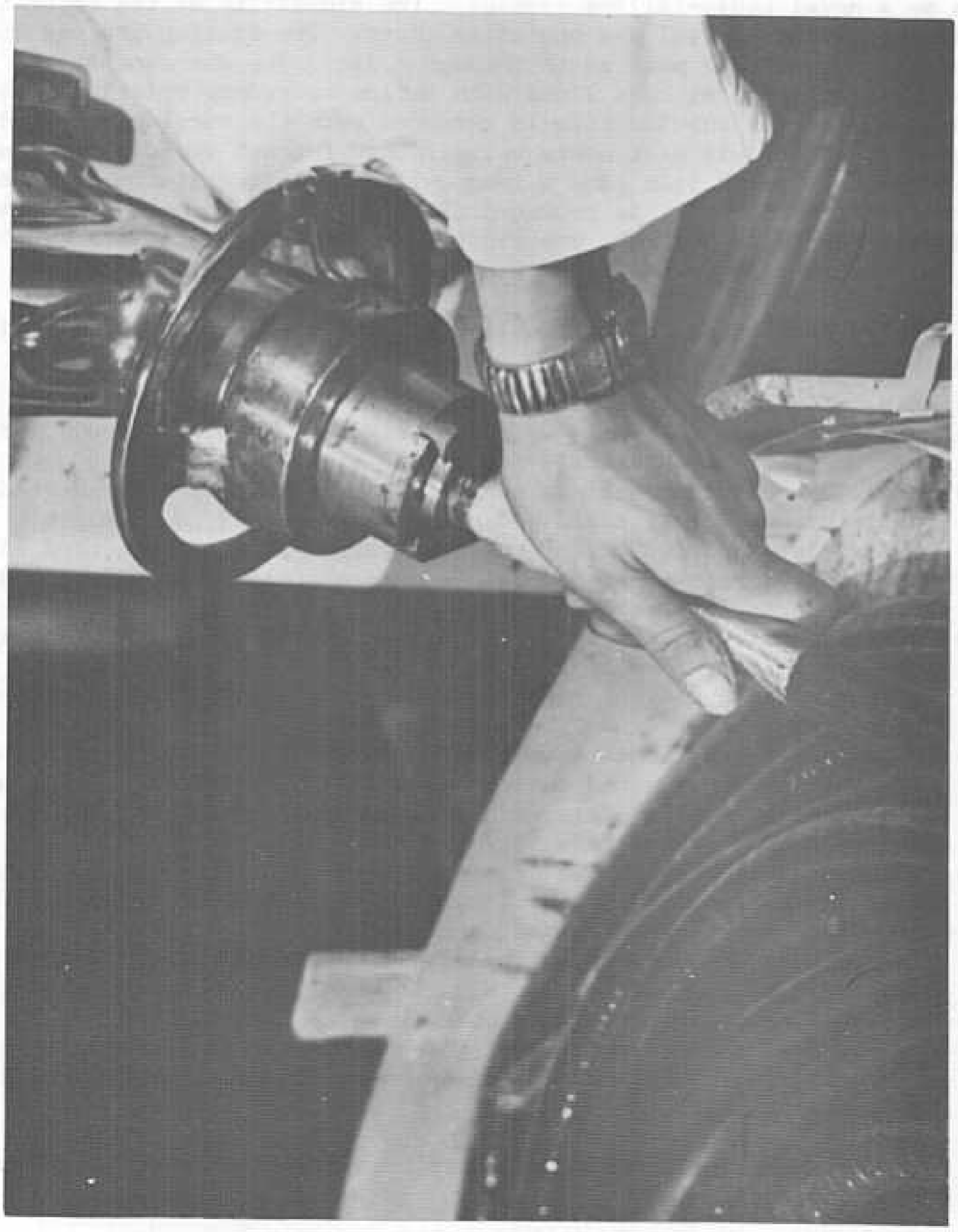

Figure I. Extrusion of peat sausage in 25-foot lengths.

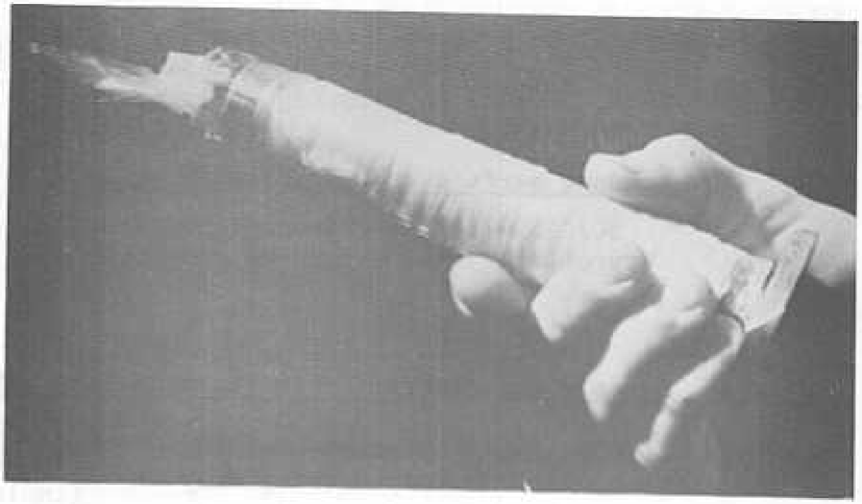

Figure 2. Extrusion die containing 25 feet of polythene film.

Figure 3. Packing tray with 1 x 3 inch peat sausage containers.

Use of bog-harvested wet peat will substantially decrease peat cost. Labor for filling, collating in trays, seeding, handling, etc. is probably between $4.00 and $5.00/M, however no firm figure is available.

Greenhouse surface area required/M plugs

	BC/CFS Styroblock	Spencer-Lemaire fold-up plug tray	R.C.A. sausage
Square feet/M	9.7	9.7	6.5

Material costs/M containers (excluding media and labor)

	BC/CFS Styroblock	Spencer-Lemaire fold-up plug tray	R.C.A. sausage (including tray)
Total cost/M	$6.98	$8.00 (est.)	$2.60

Production of R.C.A. sausage between 1969 and the spring of 1971 has amounted to 500,000 containers, of which 325,000 are currently in test plots. Containers have been supplied to research groups located in three Canadian provinces and five states in the United States.

The attractive features of the R.C.A. system are its flexibility, simplicity, and potential low material costs. Patents for various features of the process have been applied for.

CONTAINER PLANTING IN FINLAND, SWEDEN AND SCOTLAND

CONTAINER PLANTING IN FINLAND, SWEDEN AND SCOTLAND

R.A. Haig[1]

INTRODUCTION

Do not be misled by the title of this paper. Please bear in mind that it is based almost entirely on observations made during a 3-week trip in the summer of 1971. Hence, it cannot be more than my comments on what I saw or was told during this brief period. However, one statement I can make with complete conviction is that an intensive study of container planting systems in Finland and Sweden would be most rewarding.

FINLAND

The costs of planting bare-root stock in northern Finland are high, and survival has not been considered satisfactory. Evidently there is a chronic shortage of seed from northern latitudes and this precludes the extensive use of direct seeding. These two problems appear to have stimulated the development of container planting systems, to the extent that today container stock has virtually replaced bare-root stock in operational planting programs in northern Finland.

Experiments with peat pots and with the Nisula method began in the mid-sixties, and planting success was found to be high even on the most difficult sites. By 1969 Nisula seedlings were produced on an operational scale, and in that year, half of the total seedling production in northern Finland (30 million) was Nisula stock. Nursery costs are about 25% lower than for bare-root transplants, and the stock is showing good survival in the field. However, the Nisula method still requires a form of transplanting (even though this is largely mechanized) and it takes 2 years to produce a plantable seedling (one season in a plastic greenhouse and one season in the open after transplanting into the Nisula roll). Another disadvantage of Nisula stock is that the planting costs are about the same as for bare-root stock.

Experiments with the paperpot method began in 1968, and results were so encouraging that by 1971 total production from the state nurseries in northern Finland was about 49% paperpots, 49% Nisula and only 2% bare-root stock. It is interesting to note that the latter is produced only to provide a check on the performance of container stock plantations.

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[1]Canadian Forestry Service, Great Lakes Forest Research Centre, Sault Ste. Marie, Ontario.

Filling and sowing of paperpots is only half mechanized, largely because there is an abundance of labor. The type of paperpot used is No. Fh 408 which has dimensions of 3.8 x 7.5 cm (1 1/2 x 3 inches) and a capacity of 71 cubic centimeters (4.3 cubic inches). Filling and sowing starts in mid-winter and the filled pots are placed in cold storage. The paperpots are filled with peat to which 1 1/2 kilograms per cubic metre (.1 lb. per cubic foot) of complete fertilizer (plus trace elements) has been added. A deliberate effort is made to sow 2 to 4 seeds per pot, partly because of uncertain germination, and partly as insurance against losses to *Hylobius radicis*.

Germination starts about mid-May in plastic greenhouses (unheated) and the plastic is removed when the seedlings are about 5 cm (2 inches) high (in June or July). Some are planted that year and some are held over for planting in the following spring. Planting takes place from May through September, but June planting has shown the best results.

At the Imari nursery, a small proportion (about 2 million paperpots) are produced in plastic greenhouses heated by means of electric cables in the soil. Heating costs are low because of night rates for power. Production in heated greenhouses starts in early April and seedlings are ready for planting in June.

At Imari nursery, current production costs are about 8 pennies (2¢) a piece for bare-root stock; 6 pennies (1.5¢) each for Nisula, and 4 pennies (1¢) each for paperpot and peat pot seedlings. Evidently, royalty charges on the paperpot material prevent this method from being cheaper than the peat pot method. Planting costs were said to be about the same for bare-root and Nisula stock and considerably less for peat pots and paperpots.

Field trials of bare-root, Nisula, peat pot, and paperpot stock are continuing, but only container stock is being produced operationally. When we questioned the continuing work with peat pots (in view of the success of the paperpot system) the answer was partly technical and partly nationalistic; evidently, there is some indication that roots penetrate the walls of peat pots more readily, but more important is the fact that peat pots are Finnish!

SWEDEN

Paperpot and Multipot (Swedish) appear to be the two main container systems currently employed in Sweden, but my impression was that they have not replaced bare-root stock to the same extent as in Finland. However, at least one of the large companies, Stora Kopparberg, has the complete line of equipment for the mechanized loading and seeding of paperpots, and it is rumoured that they are now developing a planting machine. If so, this will complete the mechanization of the system.

We visited a small developmental nursery of the Bergvik och Ala Company, where Multipot seedlings were being produced at the scale of about

2 1/2 million per year. Multipots are similar to the styrofoam blocks used in the production of BC/CFS Styro-plugs, but the cavities are larger, being about 3 cm (1.2 inches) in diameter at the top and 8.5 cm (3.4 inches) long. Another difference is that the trays are made of hard plastic and are re-usable. Seed is sown in unfertilized peat and balanced fertilizer is added through the watering system. About May, the seeded trays are placed on a substrate of peat or sand in plastic greenhouses, from which the plastic is removed in midsummer. Some of the stock is planted in late summer or fall, and the remainder is held over until the following spring. At present, production at this nursery is not mechanized, and production costs are said to be about the same as for bare-root stock. However, there is a saving of 40 to 60% in planting costs, and survival is higher.

At the Royal College of Forestry in Stockholm, we had a long discussion with Dr. Hulten who began working on "Operation Machine Planting" (Dr. Gustaf Siren's project) in 1966. Most of the following comments originated from that source.

Average reforestation costs in Sweden are 550 crowns/hectare ($45/acre); machine costs represent 20% and labor 80% of this total. The objective of "Operation Machine Planting" is simply to reverse this ratio without increasing the total cost. Presumably they must feel, that since labor costs are rising faster than machine costs, changing the ratio will eventually produce savings.

Of course, planting stock must be compatible with the planting machine, and most of the work done on this project has been concerned with plant production. Two experimental nurseries have been established for this purpose, one in the north and one in the south.

On the basis of their assessment of the various alternatives, Siren's group decided that a large seedling in a large container would be most suitable for mechanized planting. Evidently they felt that elimination of the need for both site preparation and release would offset the additional cost of such large stock. Essentially the stock they are producing is at least 1 + 1, and it appears to be more than 30 cm (1 foot) in height with a container to match. It is my understanding that most of the stock is sown in small paperpots and that the first season is spent in a plastic greenhouse. At the end of the first season the stock is transplanted into larger paperpots or peat pots; seedlings complete their development outside.

Some points that Dr. Siren's group feel they have established in the course of this project are as follows:

1) It is more economical to use oil burners than electric cables for supplementary heat at the beginning of the season. Cables are very expensive to install, in relation to the short time they will be used.
2) The substrate is very important with respect to temperature control, peat being much better than sand as a growing medium because it holds more water for evaporation and cooling.
3) Small containers have much wider temperature fluctuations both up and down, and plastic containers are not ideal because they permit no evaporation.

4) Top covering on containers is very important, with white particles probably best except in early spring when you might want maximum heat absorption rather than reflection. Sand is considered too dangerous.
5) The bigger the container, the bigger the seedling. (This agrees with the findings of others; however, a schedule has been developed to show the length of time seedlings can be grown in containers of different sizes before container size becomes a limiting factor).
6) The best seedling for planting has no container, even paperpots and peat pots are considered to have some disadvantages.
7) The best growing medium would appear to be compressed and chipped peat. It could be easily loaded in containers and after watering it would swell and fill the container.
8) The best container would have a corrugated paper wall coated with a thin layer of brittle plastic. The paper would disintegrate during nursery production, and the plastic would crumble as soon as the stock was moved for shipment to the field.

"Operation Machine Planting" began in 1965, and since then a total of seven million crowns ($1,400,000) has been spent, seven prototype machines have been built, two experimental nurseries developed, and a total of 130 field trials have been established, many of them involving comparisons with hand planting and with bare-root stock. Currently the emphasis is on assessment, simulation and laboratory work, and I got the impression that there may be some difficulty in obtaining further financial backing for the project.

The planting machine itself is carried on a standard rubber-tired self-loading pulpwood forwarder, which means that it is capable of traversing typical cutover conditions. It has two planting heads each consisting of a planting tube attached to a hydraulically powered angle plough which is actuated by a foot pedal. Each planter presses the foot pedal and drops a tree down the tube at the proper interval. If he can see an obstacle that would prevent the planting of a tree, he simply waits until he sees a suitable spot. If the planting head meets resistance too solid to penetrate, it can swivel to either side or retract until it reaches a spot that it can enter. Evidently the machine can plant with no difficulty through several inches of snow cover. The trees simply drop into the slit made by the plough, and on the latest model of the machine there is no provision for packing. Production was said to be about 650 to 800 trees per hour.

As a footnote to this section it should be pointed out that it has not been possible to interest an equipment manufacturer in building and marketing the machines, and I would think that this is due to the high cost of the planting stock rather than the cost of the machine itself.

SCOTLAND

Having been brainwashed into believing that the ideal container seedling is about 50 cm (20 inches) in height, we moved to Scotland and discovered we were back on "square one". There, the 9/16-inch Ontario split plastic tube was being used to plant 8-week-old seedlings on peatlands, and the results were astonishingly good. The production system is patterned very closely on that developed by the Ontario Department of Lands and Forests. I hate to say it, but the major difference appeared to be in the degree of success achieved. However, two important points should be noted, firstly that the work is still on a research scale, and secondly that they are not having great success on mineral soils, where nearly all the Ontario planting has been done. Of course, another obvious difference is climatic; an additional 5 to 10 inches of precipitation is probably a major factor.

Best results are being achieved by planting in notches cut in the side of the overturned furrow slice made by a Cuthbertson plough. Fertilizing with phosphate is standard procedure at the time of planting. Spot fertilizing by hand appears most successful, because broadcast treatment, although cheaper, produces a rank growth of heather.

The rate of hand planting is so high that there is little scope for mechanization. Using a planting dibble and technique developed by the Work Study Unit of the Forestry Commission, planting rates of 1,200 tubelings per hour and 5,000 per man/day are achieved. The big secret is that the dibble is designed so the planter does not have to bend over to insert a tubeling. Half of the end of the dibble is cut away so that the tube itself forms the other half of the circle. A tubeling is simply placed on the open upper side of the dibble, and when dibble and tubeling are thrust into the peat; the tubeling stays there.

Planting has been carried out from April through October, but May to July plantings have shown the best performance in terms of both survival and growth. This suggests that in Ontario we have probably penalized our tubelings by making them wait until all the bare-root stock planting is done. On the basis of what we saw in Scotland, I would suggest that before the 9/16-inch Ontario tube is consigned to the scrap heap, or the museum, it should be tested on peatlands, using large (overwintered) stock, planted in June.

GENERAL COMMENTS

It was interesting to note that the revolution in planting systems taking place in Finland and Sweden, and the less dramatic changes beginning in Scotland, all appear to have been triggered by the pioneering work done in Canada (i.e., McLean in Ontario, and Walters in BC). However, the two Scandinavian countries have certainly overtaken the early Canadian lead by developing biologically satisfactory and economically feasible systems and getting these into operational use. I would anticipate that before long, container stock will replace bare-root stock as the mainstay of Scandinavian reforestation programs. (This has happened already in northern Finland.)

It was encouraging to learn that all the theoretical advantages of container systems are beginning to be realized (i.e., lower production costs, shorter nursery schedule, extended planting season, lower planting costs, and higher survival.) "Ease of mechanization", another theoretical advantage, is also being realized for at least one system. A complete line of equipment is commercially available for the mechanical loading and seeding of paperpots at the rate of 46,000 per hour. A planting machine is all that is required for complete mechanization of the system, and this is expected to be produced in the near future. The total reduction in production and planting costs is at least 50%, and this coupled with the advantages of higher survival and a longer planting season, make it a very attractive system.

In closing I must apologize for this rather superficial treatment of the subject, and repeat my earlier suggestion that an intensive examination of container planting systems in Finland and Sweden is warranted.

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In closing I must apologize for this rather superficial treatment of the subject, and finish by earlier suggesting that an intensive examination of container planting systems in Finland and Sweden is necessary.

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