THE FUNDAMENTALS OF CONTAINER SEEDLING PRODUCTION

E. Van Eerden[1]

Abstract.--Experimental and operational production of container stock during the last 10 years has repeatedly demonstrated that seedlings of required morphological and physiological characteristics will be produced only if the principles of containerization are closely adhered to. Mass production of seedlings in small containers at close spacing will continue to yield positive results if the hard-won lessons of the past are put into practice.

Résumé.--Au cours des dix dernières années, la culture expérimentale et à grande échelle de semis en motte emballées permis à maintes reprises de démontrer qu'il n'est possible d'obtenir les caractéristiques morphologiques et physiologiques désirées que si on se conforme étroitement aux principes de ce type de culture. La production à grande échelle, à l'aide de petits contenants peu espacés, continuera de donner des résultats positifs si on met en pratique l'expérience durement acquise par le passé.

INTRODUCTION

Much of the information that will be presented at this meeting has been reported previously at the 1974 Denver symposium (Tinus et al. 1974), in several manuals, and in numerous other technical reports and articles. In addition, a large body of operational experience has been amassed during the last decade. Accordingly, the saying "to understand the past is to know the future" might be expected to apply to the subject under discussion at this symposium. In reality, however, we do not always capitalize on the experience of our past accomplishments and mistakes. The thin line between success and failure is frequently overlooked, and the potential benefit and intricacies of controlled environment growing are generally not fully appreciated. Thus, it seems that we have not yet heeded the words of an early philosopher who said, "the best fertilizer on any farm is provided by the farmer's footsteps". In my presentation, I intend to retrace some of the footsteps of our experience by highlighting the key ingredients for successful containerized forest seedling production.

PLANTING STOCK STANDARDS A PREREQUISITE

The ability to manipulate stock size and quality of container-grown seedlings through controlled environment culture holds the promise of "tailoring" stock to specific site characteristics and requirements. Morphological and physiological quality standards are indispensable prerequisites for realizing that promise. However, in spite of voluminous nursery records and a plethora of reports on the performance of various stock types, current stock specifications frequently reflect opinions rather than a sound interpretation of past experience. For the most part, such specifications are limited to a designation of species, stock and/or container type, and age class.

Preoccupation with the "numbers game", compounded by the effects of periodic crop failures and inventory fall-down, often leaves no alternative but to go "potluck" and to take what is available. As a result, stock is frequently shipped and planted with

[1]Container Systems Coordinator, Silviculture Branch, Ministry of Forests, Victoria, British Columbia.

little regard for size and quality, and irrespective of any standards that may have been specified.

The significance of various physiological criteria for seedling performance remains to be determined for many species. Sufficient information is available, however, to define preliminary morphological standards. In setting such standards, it should be considered that the potential for rapid early growth is of greater consequence than initial survival, especially for stock destined for rich sites. From my experience in the boreal and sub-boreal forests of British Columbia, this built-in potential for rapid early growth is particularly important for white spruce *(Picea glauca* [Moench] Voss). The notion that white spruce is inherently subject to planting check is a myth. Lack of rapid early growth reflects deficiencies in site preparation and/or planting stock size and quality, with the latter being the primary cause of poor initial growth. Hence, Armson's (1976) observation that "standards must be based on the best growth attained and not on the average, or mediocrity will result", applies to nursery stock as much as it does to plantations.

Experience in British Columbia has shown that container-grown seedlings of the minimum standards presented in Table 1 are both attainable and suitable for a wide range of forest conditions throughout the boreal and sub-boreal forests. Sites subject to heavy brush invasion may require significantly larger planting stock, although the details of producing such stock need not concern us here. The important point is that the nurseryman is provided with the site-specific stock specifications at the time the sowing request is made.

THE CONTAINER

Despite many years of experimental and operational production with a variety of containers, misconceptions about containerization persist. Let us deal with some commonly held views about containerization at the outset:

1) Container-grown stock has the intrinsic ability to compensate for shortcomings in nursery practice, stock size and quality, handling, storage and transport, site preparation, and planting.

   This statement is false.

2) The larger the container, the better the planting stock will be.

   This statement is also false.

3) Containers cause root deformation which, in turn, may lead to instability, basal sweep and toppling.

   Although this statement may be valid for some species growing under certain environmental and climatic conditions, notably some of the pines, or in containers of faulty design, no significant economic losses of boreal and sub-boreal species grown in containers have yet been reported in Canada. In reality, the risk of root deformation and subsequent plantation failure is no less significant for other nursery production and planting techniques.

4) Container stock can be used to extend the planting season.

Table 1. Minimum standards for container-grown white spruce and lodgepole pine *(Pinus contorta* Dougl. var. *latifolia* Engelm.) in British Columbia.

		Minimum specifications						
		Primary		Secondary				
Species	Size class	Height (cm)	Root coll. diam. (mm)	Shoot dry weight (g)	Root dry weight (g)	Total dry weight (g)	Shoot:root ratio	Container equivalent required[a]
White spruce	small	12.5	2.2-2.5	0.8	0.4	1.2	1.5-2.0	PSB 211
	medium	17.0	2.5-3.0	1.0	0.5	1.5	1.5-2.0	PSB 313
	large	20.0	4.0-4.5	3.0	1.5	4.5	1.5-2.0	PSB 415
Lodgepole pine	-	12.5	2.2	0.7	0.3	1.0	1.0-1.5	PSB 211

[a]PSB 211 - Styroblock-2A cavity.
PSB 313 - Styroblock-4A cavity.
PSB 415 - Styroblock-8 cavity.

While this statement is generally true, extension of the planting season through the use of container-grown stock represents a relative advantage only. Although adverse climatic conditions do take their toll of container stock, the effects are generally not as severe as they are for bare-root stock. Performance of stock under specific climatic and weather conditions is a function of seedling condition rather than stock type *per se.*

The desired characteristics of seedling containers are well documented, notably by Kinghorn (1974). In summary, for a container to be biologically acceptable, it must:

1) have a cavity volume and spacing which permit seedlings to be grown to a size and quality dictated by site requirements. Cavity volumes of 40 to 60 cm^3 and a spacing of 700 to 1100 cavities/m^2 are generally satisfactory for the production of a size and quality of stock suitable for most sites. Only if the biological limits of a certain size of container have been fully exploited can use of larger containers be justified. If this is the case, care should be taken to ensure that any increase in cavity volume is accompanied by a concomitant increase in cavity spacing. In the interest of cost-effectiveness, transplanting from initially small to successively larger containers or transplant beds may be a preferred method of production for large stock.

2) protect stock and root systems in the nursery.

3) prevent pot-binding and extension of roots below the container through proper container design and provision for air-root pruning; minimize cross-over of primary laterals by vertical ribs on cavity walls. A facility for mechanical or chemical pruning of primary laterals at the point of contact with the container wall would be a desirable feature for some species.

4) prevent roots from growing into container walls, and/or into adjacent cavities.

5) minimize the risk of contamination and sanitation problems. Designs which permit the accumulation of growing medium, grit, or other material between blocks or trays are unacceptable in this respect.

To be logistically and economically acceptable, containers must:

1) be relatively inexpensive;

2) be modular in design to permit efficient mechanized loading, seeding, and handling for a variety of cavity sizes and spacings, and require only minor modifications of equipment during the preparation or growing phases to accommodate various container sizes;

3) be of such a composite size and contain such a number of cavities that efficient manual handling, where required, is feasible;

4) permit ready extraction of seedlings without injury prior to planting;

5) facilitate high rates of planting productivity without compromising planting quality.

THE NURSERY PHYSICAL PLANT

Capital Investment

At present, 30 to 40% of container seedling production costs are due to interest charges on investment and working capital. Consequently, there is an urgent need to minimize investment in equipment and growing facilities. The argument that high interest costs simply reflect the present realities of doing business does not lessen their impact. There are already examples in North America of excessive capital investment in container-growing facilities leading to closure of those facilities and a return to bare-root practice. Therefore, if container production is to remain an economically viable seedling production system, we must be vigilant and prudent in our selection of and investment in container nursery physical plant.

Of the factors that influence the design, development, and location of a nursery, those that have the greatest impact on costs are, fortuitously, also the most flexible. Species, planting stock standards, container dimensions, required environmental conditions, and logistics are relatively fixed, but growing facilities, crop schedules, and nursery location can be varied to suit various biological and economic objectives.

Growing Facilities

In designing and building growing facilities, we should always ask ourselves to what extent the natural environment needs to be modified.

Experience in public and some private nurseries in British Columbia has demonstrated that the environmental conditions of low-cost plastic houses are suitable for production of white spruce and logepole pine in most locations. They can be operated with minimal heating and the use of natural ventilation by rolling up the plastic sidewalls, as recommended by Towning and Turkewitsch (1980). Double poly-covered houses not only minimize heating costs but also preclude the need for additional expenditure on shading equipment by providing about 30% shade, which is ideal for the early growth phase of spruce.

The costs of plastic houses are less than half those of glass or fibreglass houses. Sullivan (1975), addressing the Tennesee Valley Greenhouse Vegetable Workshop, when interest rates were much lower than they are today, reached similar conclusions. He noted that annual variable operating costs are largely unaffected by the type of growing facility. Furthermore, he observed that annual fixed production costs for temporary plastic houses, including depreciation and maintenance of various types of greenhouses, were $3.87/m^2, in comparison with $3.77 and $5.27 for glass and fibreglass houses, respectively, and that initial capital costs for plastic houses were one-third those of glass greenhouses. Sullivan concluded that in times of scarce capital, low-cost plastic houses are clearly the preferred alternative, and that savings in initial capital cost for growing facilities might profitably be applied to other components of the production unit. Irrigation equipment is a good example; undue economies in the selection of an irrigation system can prove disastrous, both directly and indirectly. Although the magnitude of the investment involved in 1981 is much greater, Sullivan's observations are as valid today as they were in 1975.

In addition to provision of a suitable growing environment, it must be recognized that the nursery business is essentially a materials handling business. Consequently, it is important that a facility be designed for maximum efficiency in the flow of materials (Sheldrake and Sayles 1974) and use of labor. Most commonly, the equipment and labor are taken to the crop (Short 1975). The other approach, transporting the crop to the machinery and labor, requires construction of special facilities and, hence, increases capital costs. In British Columbia, most government nurseries employ the first option of moving the equipment and labor. This low capital investment approach works effectively for many locations in the province and will, undoubtedly, work elsewhere also.

Greenhouse Benching

The subject of bench systems is one of continuing controversy. The type of benching not only affects plant quality and root form, depending on whether it provides for air-root pruning, but can also have significant effects on the cost of crop processing and greenhouse management.

Unlike many horticultural operations, production of forest tree seedlings is a nonprofit or, at best, a low profit/unit industry. Once germinated and thinned, seedling crops are rarely handled until shipping. As a consequence, the need for walkways is minimal, permitting high efficiency in the use of floor space. Although the use of stationary crop support systems obviously requires some degree of compromise in labor efficiency, experience in government nurseries in British Columbia indicates that some of the more sophisticated rolling bench systems used in horticultural nurseries cannot be justified in forest container nurseries if capital costs are to be minimized. In addition to being expensive, such systems may also create storage problems during annual cleanup operations. The aluminum stringer bench system which is widely used in government nurseries in British Columbia has proven cost-effective, and culturally and logistically suitable.

Equipment versus Labor

Opinions vary widely on the extent to which capital investment should substitute for labor. Short (1975) suggests that the potential gain associated with replacement of labor by capital is limited, because it is often difficult and expensive to replace delicate hands and a trained eye. As Tinus and McDonald (1979) point out, it is important to evaluate both the short-term and long-term implications of mechanization by considering the following two questions:

1) Is equipment needed to meet biological requirements?

2) If it is not, is it prudent to save on labor?

In characterizing the forest nursery business as comprising brief periods of high volume, high employment, and intense activity, the same authors advise that short-term jobs can be accomplished efficiently through intensive application of labor, and that, if activities are long-lasting or continuous, mechanization becomes more feasible. Here lies the key for deciding which tasks to mechanize and which activities to leave to manual labor. Experience in British Columbia serves to illustrate the point. Until mechanized equipment for container filling, seeding and seed covering was developed, these operations posed serious impediments to the further development and expansion of container production. Not only were those operations exceedingly expensive when done manually, but they were slow and precluded completion of sowing within the short time necessary to produce uniform and good quality crops. It was therefore essential that mechanized equipment be developed, to ensure that the job of sowing was done quickly and efficiently. This same reasoning, however, cannot be applied to seedling extraction and preparation for storage, shipment, or planting. Grading and culling are essential in the production of high-quality stock, and are best carried out at the nursery by trained workers to ensure that they are done in a well organized and efficient manner. There is no merit in shipping empty cavities and cull seedlings to the field.

Energy Considerations

The cost of energy in greenhouse operations is a major topic, and will be addressed by another speaker at this Symposium (Cameron 1982). My remarks in this area will therefore be brief.

With the continued increase in energy costs, it is essential that the design and location of container nurseries be such that energy consumption is minimized. In addition, cultural schedules should be adopted that will minimize the amount of heating required. In British Columbia, this requirement has traditionally been satisfied by locating container nurseries in the climatically more favorable regions of the province, and by employing single-crop schedules which capitalize on a somewhat extended normal growing season. However, with the recent introduction of the concept of local seedling production, nurseries are now being established in regions with less than optimum climates as well. Indications are that the use of double-poly-covered and free-standing houses, together with single cropping, will circumvent the need for extensive heating in those areas.

Notwithstanding the logistical advantages of localized production, it may be preferable to produce or start stock in localities with more favorable climates--perhaps even at distant locations--and to transport the finished product if heating costs become prohibitive. As was pointed out by Perkins et al. (1975), the rising cost of fuel for transport will never match the energy costs of heating and cooling of greenhouses, with the latter always significantly greater.

It appears that efforts to minimize energy consumption in the greenhouse industry have focussed largely on energy conservation in traditional and standard facility designs. While these efforts are laudable, I believe that much more could be accomplished through development of new greenhouse designs and through innovations in cultural practices and schedules.

Nursery Physical Plant: A Synopsis

Critical evaluation of fixed and variable costs, prior to construction (Perkins et al. 1975), is essential to ensure that container stock production remains an economically viable seedling production system. Such analyses should include capital investment projections, the costs and benefits of tradeoffs between labor and equipment, and energy budgets for various types of facilities in different climates.

CONTAINER SEEDLING CULTURE: BASIC INGREDIENTS

Intensive Management

In the introduction to their Nursery Soil Management Manual, Armson and Sadreika (1974) state that "production of seedlings in a nursery represents an intensive form of management". The principle embodied in this statement is of even greater consequence in the production of container stock than it is in bare-root culture.

For economic reasons, container systems used in forestry typically utilize small containers at close spacing. Such mini-plant pots confine seedlings to an environment which is characterized by narrow limits of reserves and tolerances, in which reserves of water and nutrients are rapidly depleted while excesses of any kind quickly predispose seedlings to injury or even mortality (Van Eerden 1974). The effects of inadequate facilities, poor equipment, water quality, and imperfect environmental conditions can, to a large extent, be compensated for by the application of sound cultural practices. However, failure to recognize the fundamental principle that container seedling crops require intensive management will inevitably lead to failure and negate the promise of consistent and reliable production of high-quality seedlings that container growing offers.

Administrative responsibilities and the problems associated with the complexities of running a large operational nursery should never be accepted as a legitimate excuse for deficiencies in cultural practices.

Production Schedules

Multi-cropping and winter growing are controversial subjects, not only with respect to forest seedling production, but also in the horticultural industry. On the horticultural side, the desire for year-round growing obviously stems from an interest in lower per unit costs and higher net annual profits. On the forestry side, multi-cropping is probably similarly motivated, as well as an attempt to play the "numbers game" with limited resources. However, as Sullivan (1975) points out, double cropping can result in higher break-even requirements for large operations and can be uneconomical for nurseries with less than 4600 m^2 of capacity. In my view, this conclusion probably applies to forest nurseries as much as it does to horticultural operations.

Although imaginative techniques (e.g., rotation of crops between facilities with varying degrees of environmental control, or the development of a fully mechanized transplanting system for transplanting stock from mini-containers) and the application of other technological advances hold some promise, it is doubtful that multi-cropping and winter growing are feasible at the current stage of development.

Towning and Turkewitsch (1980) have recommended that greenhouses be closed from December through February. As it takes a minimum of 30 to 32 weeks at about 20 °C to grow seedlings to required specifications, I am left to conclude that multi-cropping and winter-growing have limited value in present forest seedling container practices.

Single cropping during a somewhat extended "normal" growing season currently provides the only biologically optimum and cost-effective operational production schedule. This approach will ensure that crops can be grown to required specifications in relatively low-cost facilities with minimal consumption of energy.

Growth Monitoring

The collection of growth data, including periodic measurement of height, root collar diameter, and dry weights is useful not only for training or historical purposes but also for providing the beginnings of a quality control program. Once sufficient growth data have been collected and standard growth curves have been prepared for a particular combination of species, container, growing facility, and cultural regime, nurserymen have the basic ingredient for tracking growth at any point in the crop cycle. In other words, growth records in the form of standard growth curves provide a management tool which can be used to alter growth through cultural manipulation. Accordingly, monitoring of seedling growth on the basis of standard growth curves is highly recommended.

Test Programs

The use of untested materials and equipment, and unquestioning acceptance of the instructions and guarantees of suppliers and manufacturers, in many instances have proven to be an open invitation to disaster. The dictum "Let the buyer beware" is not to be taken lightly. Unqualified modification of proven cultural techniques, biological materials and equipment should be viewed as highly speculative; without prior testing, such changes carry a very significant risk. Frequently, techniques and materials which have proven satisfactory for production of seedlings in relatively unlimited soil volumes are not suitable for the production of seedlings in the mini-plant pots used in forestry (Kinghorn 1971). Therefore, a testing and pilot production program must always precede the introduction of new or modified materials, techniques and equipment into operational production.

Sanitation

Many of the pest problems encountered in forest tree seedling container nurseries reflect deficiencies in crop monitoring and cultural practice. This applies not only to weeds, including mosses, algae, and liverworts, but also to insects and diseases. Generally, development of a pest problem requires (1) a susceptible host, (2) a pest organism, and (3) a suitable environment (Sutherland and Van Eerden 1980). Experience in British Columbia indicates that most pest problems are preventable. More often than not, major problems occur only if a suitable environment is created through lack of proper crop management. For example, injury from fertilizer burn, overwatering or underwatering, lack of a proper seed covering, and scattering of dead plant materials have created conditions under which pests can become established. As has been emphasized by Sutherland and Van Eerden (1980), the key to nursery pest management lies in prevention through sound cultural and sanitation practices.

Seed and Sowing: An Urgent Problem

The effects of poor seed quality and, in some cases, poor quality control during the sowing operation, together with culls, constitute the most serious problem in present container practices in Canada. As a result of these problems, an average of 30 to 35% of unproductive cavities and growing space is not uncommon.

Although multiple sowing can help to reduce the number of unproductive cavities, the cost of thinning and wasted seed is high, and the problem of unproductive space remains. Notwithstanding the potential improvements associated with better quality seed and more efficient sowing, I believe that the concept of mechanized transfer of mini-container transplants offers the only promising solution to this serious problem. If the technique is developed into a cost-effective system, I can foresee the day when all container stock, or bare-root stock for that matter, will be started in mini-containers, eliminating the problem of unproductive space and unduly costly production. Not only will such a system eliminate the blank cavities due to germination failure, but it will also permit early culling and thereby eliminate the carrying of culls through the full rotation. Therefore, I suggest that any developments in this area deserve our collective support.

SUMMARY

It is said that success foreshadows the beginning of failure and that failure signals the beginning of success. If the fundamentals of container growing are clearly understood and if the principles of intensive and least-cost management are rigorously applied to produce seedlings according to predetermined size and quality standards, success is assured. If, on the other hand, these same principles are abandoned, for whatever reason, the result will surely be failure.

The costs of container seedling production must not, of course, be considered in isolation but should be considered from the perspective of the total costs of plantation establishment. Nonetheless, the high capital investment requirements characteristic of container production are of concern, and no effort must be spared in exploring cost-effective alternatives. The ever-present temptation to substitute sound crop husbandry with never-ending investment in physical plant and equipment must be resisted, if container seedling production is to remain economically feasible.

At present, single cropping during an extended normal growing season appears to provide the only proven and rational production schedule for most Canadian container nurseries. However, efforts to extend the use of growing facilities through development of biologically and economically acceptable techniques of multi-cropping must proceed unabated.

I hope that I have been successful in identifying the causes of failure and the ingredients for success. If we are willing to learn from the lessons of the last decade, I believe that past failures do indeed signal the beginning of future success in container seedling reforestation.

LITERATURE CITED

Armson, K.A.
1976. Keynote Address. p. 1-4 in Proceedings of the Plantation Establishment Symposium. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Symp. Proc. 0-P-5.

Armson, K.A. and Sadreika, V.
1974. Forest tree nursery soil management and related practices. Ont. Min. Nat. Resour., Div. For., For. Manage. Br. 177 p.

Cameron, S.I.
1982. Conserving energy in container greenhouses. p 91-108 in J.B. Scarratt, C. Glerum and C.A. Plexman, *Ed.* Proceedings of the Canadian Containerized Tree Seedling Symposium. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. COJFRC Symp. Proc. 0-P-10.

Kinghorn, J.M.
1971. Foreword. In Matthews, R.G. Container seedling production: a provisional manual. Dep. Environ., Can. For. Serv., Victoria, B.C. Inf. Rep. BC-X-58. 48 p.

Kinghorn, J.M.
1974. Principles and concepts in container planting. p. 8-18 in R.W. Tinus, W.I. Stein and W.E. Balmer, *Ed.* Proceedings of the North American Containerized Forest Tree Seedling Symposium. Great Plains Agric. Counc. Publ. 68.

Perkins, D.Y., McCombs, C.L., Norton, J.D. and Dillard, J.G.
1975. Production economics. p. 137-139 in Proceedings of Tennessee Valley Greenhouse Vegetable Workshop. Chattanooga, Tennessee, 18-20 March, 1975.

Sheldrake, R., Jr. and Sayles, R.M.
1974. Plastic greenhouse manual--planning, construction, and operation. Cornell Univ., N.Y. State Coll. Agric. and Life Sci., Dep. Veg. Crops, Ithaca, N.Y. 21 p.

Short, T.H.
1975. Greenhouse mechanization in perspective. p. 78-80 in Proceedings of Tennessee Valley Greenhouse Vegetable Workshop. Chattanooga, Tennessee, 18-20 March, 1975.

Sullivan, G.H.
1975. Economic trends and expected changes in the greenhouse vegetable industry. p. 30-35 in Proceedings of Tennessee Valley Greenhouse Vegetable Workshop. Chattanooga, Tennessee, 18-20 March, 1975.

Sutherland, J.R. and Van Eerden, E.
1980. Diseases and insect pests in British Columbia forest nurseries. B.C. Min. For./Can. For. Serv., Victoria, B.C. Joint Rep. No. 12. 55 p.

Tinus, R.W. and McDonald, S.E.
1979. How to grow tree seedlings in containers. USDA For. Serv., Rocky Mount. For. and Range Exp. Stn. Gen. Tech. Rep. RM-60. 256 p.

Tinus, R.W., Stein, W.I. and Balmer, W.E., *Ed.*
1974. Proceedings of the North American Containerized Forest Tree Seedling Symposium. Great Plains Agric. Counc. Publ. 68, 458 p.

Towning, D.J. and Turkewitsch, A.
1980. Energy efficient greenhouse design and operation. Growers Technical Consultants, Mississauga, Ont. Report prepared under contract to Dep. Agric., Ottawa, Ont. DSS Contract No. 0752-01843-0-1908.

Van Eerden, E.
1974. Growing season production of western conifers. p. 93-103 in R.W. Tinus, W.I. Stein and W.E. Balmer, *Ed.* Proceedings of the North American Containerized Forest Tree Seedling Symposium. Great Plains Agric. Counc. Publ. No. 68.