CONTRASTING APPROACHES TO CONTAINERIZED SEEDLING PRODUCTION

1. BRITISH COLUMBIA

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Abstract.--Container seedling production in British Columbia has expanded to 38 million seedlings annually in public nurseries and about 25 million annually in private nurseries with the BC/CFS styroblock serving as the principal container. Seedlings are grown in single crops during an extended normal growing season in facilities ranging from natural to climate-controlled environments.

Résumé.--En Colombie-Britannique, on produit maintenant 38 millions de semis en mottes emballées par année dans les pépinières publiques et 25 millions dans les pépinières privées; le principal contenant utilisé est le BC/CFS styroblock. Les semis sont produits individuellement au cours d'une saison de croissance prolongée, dans des installations où les conditions vont de naturelles à contrôlées.

INTRODUCTION

In 1981, production of container-grown seedlings for use on Crown lands in British Columbia totalled 58 million, of which 38 million were grown in Ministry of Forests nurseries and 20 million in commercial and industrial nurseries. Ministry nurseries are ultimately expected to produce at least 50 million container seedlings annually, while anticipated production by private nurseries is about 45 million container-grown seedlings by 1985-1986. The Ministry production totals represent seven nurseries, all located in the southern half of the province, with most of the production coming from southern coastal nurseries.

The present trend in nursery planning favors development of more northern nurseries to support the two largest and most northerly forest regions, Prince Rupert and Prince George. These regions currently account for most of the 23 million interior spruce (*Picea* spp.) trees produced annually. Lodgepole pine (*Pinus contorta* Dougl. var *latifolia* Engelm.) production totals 12.7 million trees, of which only a portion are for use in the boreal forest.

The name interior spruce is used locally to distinguish it from coastal Sitka spruce (*Picea sitchensis* [Bong.] Carr.). It encompasses white spruce (*P. glauca* [Moench] Voss), Engelmann spruce (*P. engelmannii* Parry) and their hybrids, and will be referred to in this paper as spruce. Spruce and lodgepole pine are two of approximately 15 commercially important species grown in British Columbia nurseries. This paper will discuss cultural methods common to all container crops, and specific requirements of spruce and pine.

Production methods for container crops in British Columbia have been reported elsewhere (Van Eerden 1974, Matthews 1979). Many of the basic cultural techniques have remained unchanged, and have become a matter of routine as a result of experience gained during the past 12 years. As more precise knowledge of the relationship between growing

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environments and quality of stock has become available, the degree of assurance of desired quality in routine production has improved. Nonetheless, to ensure improved reliability in attaining desired morphological and physiological characteristics, some techniques are still being modified and facilities are being upgraded as budgets permit. Accordingly, it is anticipated that nearly all shadeframes will ultimately be replaced by low cost plastic-covered greenhouses, because much of the stock produced in shadeframes has been too small (dry mass and root-collar diameter).

GENERAL METHODS IN CONTAINER CULTURE

Growing Medium

The growing medium should have a high water holding capacity, good aeration, high cation exchange capacity, appropriate pH, low natural fertility, low salinity, no weed seeds or pathogens, and good fibre length. Such a medium can be obtained only if the source and quality of peat are carefully evaluated. In Ministry nurseries, the supply of peat is limited to one or two local commercial peats which have proven acceptable and consistently reliable. Peat should be a low pH (4.0-4.5) sphagnum type with low calcium content.

The growing medium is comprised of three parts peat to one part (by volume) of #2 horticultural vermiculite. To this is added 3 kg/m^3 dolomite lime (12-mesh and finer) from a specific supplier. This is a relatively coarse lime which moderates pH slowly and does not increase salinity substantially. It is the basic source of calcium and magnesium for crop nutrition. The pH of the medium initially ranges from 4.0 to 4.2 but, under the influence of the lime and soluble fertilizers, pH rises slowly throughout the season to about 6.0 before declining to 5.2-5.5. Contrary to the pH/nutrient relationships in mineral soils, there is some evidence that the optimum pH for nutrient availability in media containing a high proportion of sphagnum peat is about one pH unit lower than previously thought optimum for conifers (Lucas and Davis 1961). In nurseries where the water contains substantial amounts of calcium and magnesium, the amount of lime incorporated into the growing medium may be reduced to 1 kg/m^3. Mixing of the medium is done with commercially available equipment. Water is added until a level of 400% above oven-dry weight is achieved, the point at which water can just be squeezed from the medium.

Styroblock Loading and Seeding

Experience with various methods of loading the growing medium into styroblocks and information generated by limited growth trials have resulted in guidelines for compaction or bulk density. On the basis of oven-dry weights and a usable volume of 33 ml in a styroblock 211 (2A) cavity, optimum compaction is thought to be 0.11 g/ml. Usable compactions may vary from 0.08 g/ml to 0.13 g/ml. Compaction above 0.14 g/ml will result in difficult extraction. Depending on species, variation on either side of the optimum may affect the dry weight of roots produced.

After loading, block cavities are tamped to an appropriate depth for sowing, after which the waste peat is washed from the block surfaces. The seed is sown with a vacuum-drum seeder, and receives a 5 mm covering of #2 granite grit or, more recently, a locally produced coarse industrial washed sand. The seeder was originally developed by the Agricultural Engineering Department of the University of British Columbia, under contract to the Canadian Forestry Service.

Water Quality

One of the most critical aspects of the culture of container-grown seedlings is the availability of adequate quantities of good-quality water. The trend away from coastal nurseries to those in the central and northern interior has necessitated the use of water of poorer quality. The pH of water should be on the acid side of neutral. However, pH in itself is not as important as other factors, such as salinity or total dissolved solids, and levels of sodium, calcium, magnesium, and bicarbonates. Excellent quality water is exemplified by the analysis for the Koksilah nursery on Vancouver Island given in Table 1. In the Ministry nurseries, poor quality water occurs in locations such as the Red Rock nursery in central British Columbia at Prince George. Even poorer quality water is being used in recently developed industrial and commercial nurseries. This may result in reduced overall growth and difficulty in controlling soil salinity levels because of the absence of a low salinity water source which may be used for leaching. Acidification of water sources has not proven necessary or advantageous in any Ministry nurseries to date.

Table 1. Comparative water analysis for two British Columbia nurseries.

Location	pH	TDS[a]	Bicarb alka-linity	Hard-ness $CaCO_3$	Ca	Mg	Na	K	Cl	SO_4	Fe[b]	Mn	Al
		ppm											
Koksilah[c]	6.7	42	25	26	8.6	1.0	2.0	0.2	1.4	1.0	.06	.01	.10
Red Rock[d]	7.5	264	241	280	66	28	5.2	.25	.88	57	.08	.19	.15

[a]Total dissolved solids
[b]Dissolved iron
[c]Koksilah-Vancouver Island-Municipal
[d]Red Rock-Prince George-Deep Well

Seedling Nutrition

Fertilization of crops is accomplished by using soluble fertilizers and/or by incorporating controlled-release fertilizers in the growing medium. Soluble fertilizers are injected into the irrigation system at almost every watering. A high phosphorus fertilizer (10-52-17) is used as a crop starter and finisher, and a balanced fertilizer (20-20-20) is used during the main growing season. All species are grown on this regimen, with variations in concentrations for individual species requirements. With 20-20-20, concentrations of 500-750 g/1000 L give N levels of 100-150 ppm. In addition, the heptahydrate form of ferrous sulphate is applied every 2 weeks to improve crop color and to prevent symptoms of iron chlorosis. Satisfactory results can be achieved with a predetermined nutrient schedule which specifies fertilizer applications two to four times weekly depending on expected evapotranspiration stresses. Ideally, crops should be watered and fertilized whenever necessary (e.g., for a styroblock 211, when approximately 2 kg of water has been lost from the saturated weight). As with other key elements, the source of soluble fertilizer is restricted to one supplier whose product has performed satisfactorily. Alternative proprietary fertilizers will be introduced slowly after initial test programs have determined their safety and acceptability.

Recently, controlled-release fertilizers have been incorporated into the growing medium with generally good results. This is particularly useful in outdoor facilities where rain often frustrates efforts to control nutrient levels with soluble fertilizers, and where sprinkler systems with poor distribution patterns make uniform application of nutrients difficult. A 3:1 peat: vermiculite growing medium would include:

3 kg/m^3 Green Valley dolomite lime (12-mesh and finer),
5.85 kg/m^3 Osmocote 18-6-12 (9 months),
0.13 kg/m^3 FTE 503 trace elements.

These nutrient rates are used for all species except the faster growing coastal Douglas-fir and Sitka spruce, for which Osmocote levels are reduced to 4 kg/m^3.

To incorporate Osmocote into the growing medium, mixing equipment must be capable of distributing the material uniformly without breaking or scarring the coating on the fertilizer prills. Because the release rate of Osmocote is temperature dependent, difficulties are sometimes experienced under cool growing conditions. Consequently, release rates are subject to annual variation. When Osmocote performs optimally, substantial increases in top and root dry weights over those of the present soluble fertilizer program can be achieved. The color of stock grown on Osmocote is excellent, and no difficulties have been experienced in achieving bud set and maturity. Soluble high phosphorus fertilizer is applied in conjunction with Osmocote as a starter and finisher, in preference to adding superphosphate to the growing medium.

It has been observed that when a low rate of Osmocote is incorporated into the soil medium, growth rates with conventional soluble fertilizer programs are improved. Therefore, all crops scheduled for soluble fertilization in 1981 had 1.3 kg/m^3 of Osmocote 18-6-12 incorporated into the growing medium.

Salinity of the Growing Medium

The experience with Osmocote demonstrated that past salinity levels were probably so conservative as to be limiting to growth. With soluble fertilizer programs, soil salinities often did not exceed 500 pmhos, with leaching recommended at about 600 pmhos. Use of Osmocote has resulted in salinity levels in the 1000-1250 range, with leaching occurring at levels approaching 2000 pmhos. Growth has been excellent in this range, and there is no known salinity damage. The appropriateness of these levels is confirmed by Boodley (1981), who contends that salinity levels in peat-vermiculite soil types can safely be higher than in mineral soils (Table 2). Boodley suggests that the medium range is best for continuous crop fertilization. In the low range, growth will probably be limited by lack of nutrients.

Table 2. Salinity levels in mineral soils and peat-lite mixes.[a]

Mineral soils µmhos (mhos x 10^{-6})	Peat-lite mix	Rating
Above 2000	Above 3500	Excessive
1750-2000	2250-3500	Very high
1250-1750	1750-2250	High
500-1250	1000-1750	Medium
0- 500	0-1000	Low

[a]Source: Boodley 1981.

Growing Facilities

Facilities for growing container crops range from outdoor compounds to climate-controlled greenhouses with fibreglass. Between these extremes are shadecloth-covered shadeframes and lower cost greenhouses covered with single or double polyethylene. The different types of facility accommodate the varying requirements of different species and allow for special requirements, such as producing crops for early fall planting. Almost all closed greenhouses have removable side walls and some also have roof vents. When summer temperatures rise to the point that fan systems must operate almost constantly, the side walls are removed and the fans are turned off. Natural ventilation is then utilized until it becomes desirable to close houses in late fall.

More expensive facilities are furnished with aluminum T-bar bench systems which support styroblocks and utilize a high percentage of floor area. Such houses are equipped with irrigation booms for greater efficiency and economy of operation. Simpler facilities generally use treated wood pallet supports, with conventional sprinkler heads on the perimeter of single houses or throughout shadeframe units.

Crop Scheduling

Most seedlings in British Columbia are spring planted, utilizing cold storage facilities between extraction at maximum hardiness in January, and planting from March to June. Container-grown stock is extracted, wrapped with PVC film in bundles of 25, put in polycoated paper liners in waxed cartons and placed in cold storage at $2^{\circ}C$. Species susceptible to storage molds have been stored at $-2^{\circ}C$. However, with frozen storage considerable difficulty has been experienced in ensuring that plug bundles are thawed prior to planting.

Most seeding is done in March and April, with some May sowing of pine in interior locations. Crop scheduling closely follows the natural growing season, requiring minimum input of fuel to moderate temperatures in spring and fall. Some double cropping has been attempted. This involved a February-sown crop which was moved from greenhouse to shadeframe after several weeks of initial growth. A second crop was then sown in the greenhouse, extending growing conditions into late fall. Because the quality of seedlings, especially in the second crop, was not entirely satisfactory, this procedure was discontinued. However, with improved growing schedules and a more judicious mix of species, multiple cropping may again be investigated.

SPRUCE AND PINE PRODUCTION

Seeding

Spruce seed is soaked for 24 hr and surface dried prior to a minimum stratification period of 3 weeks at $2^{\circ}C$. Surface drying prevents the spread of the cold fungus *Caboscypha fulgens* during stratification. Lodgepole pine seed is generally given the same treatment, although some seedlots germinate better without stratification. Germination levels have improved with better collection and seed sorting methods, but there are still many seedlots that have viabilities of 65-85%. To strike a balance between the efficient use of greenhouse space and thinning costs, the sowing rules given in Table 3 were utilized in 1981.

Table 3. Sowing rules for various germination rates, 1981.

Germination (%)	No. of seeds per cavity	Cavities to sow over request
96-100	1	1.25
86-95	1	1.35
76-85	2	1.25
66-75	2	1.35
56-65	3	1.45
46-55	4	1.45

Spruce is sown during the first half of April in interior nurseries and during the latter half of April in coastal nurseries (Fig. 1). The later sowing date on the coast reflects the use of simpler shadeframe facilities in this area. Pine is sown in the latter half of April on the coast and about a week later in interior locations.

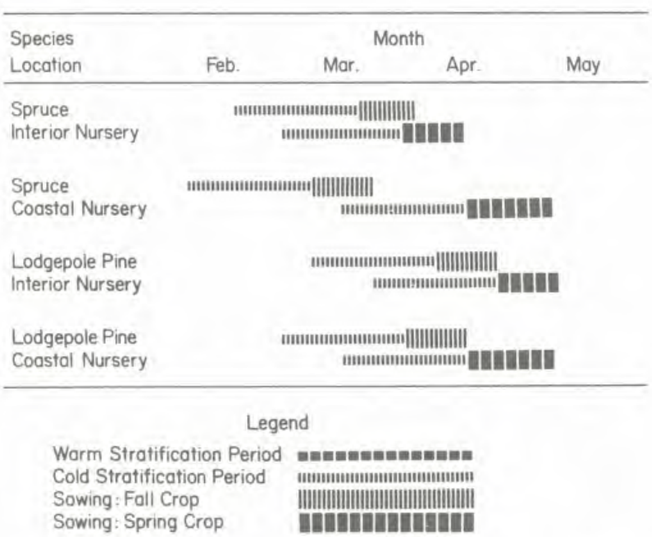

Figure 1. Optimum sowing dates and stratification periods for container stock in interior and coastal British Columbia nurseries.

Germination

Pine crops are usually germinated in open compounds. With spruce, and where facilities are available in pine nurseries, greenhouses may be used as germination facilities. Styroblocks are stacked 12 high on pallets and moved by forklift into germinators where they are left for approximately 7 days before being placed in their growing location. Greenhouses used as germinators are generally more efficiently heated, i.e., they may have double-poly roofs or an inner poly lining fitted for the purpose. Stationary misting nozzles or special misting booms maintain high moisture and humidity levels. Germinators tend to accelerate germination and give more uniform germination with some species; they may also reduce heating costs during the germination phase.

Misting of germinants continues until seed coats drop. When germination is complete, seedlings are thinned to one per cavity. Fertilization begins when the majority of seedlings show primary needle development.

Seedling Culture

At present, most of the spruce is grown in shadeframes in coastal nurseries. Shadecloth providing 46% shade has been used but 30% shade is now preferred. Double-poly houses also give satisfactory shade levels for spruce production. Because of deficiencies of stock grown in shadeframes, especially under unfavorable growing conditions, it is anticipated that all spruce production will ultimately be carried out in relatively inexpensive greenhouse structures. Some spruce is grown in fibreglass greenhouses but this is generally done only to accommodate requests for larger stock and for a small amount of fall planting.

Although a small percentage of lodgepole pine is grown in greenhouses, it is grown mostly in unshaded compounds, in both coastal and interior nurseries. Warmer locations are preferred for good growth. Pine can be greenhouse-grown, but it is important to maintain high light levels to prevent overgrowth of tops.

Because of the quality of stock produced in the past, and as a result of changing field requirements, it appears that spruce will increasingly be grown in styroblock 313s (4A) with a cavity volume of 60 ml and a seedling density of $936/m^2$. Pine, on the other hand, will likely continue to be grown in styroblock 211s (2A) having a volume of 40 ml and a density of $1130/m^2$.

Spruce originating in northern and/or high elevation locations and grown in southern nurseries are likely to initiate bud set at any time after germination. To avoid premature cessation of height growth, artificial light (5 foot-candles at crop level) is used to extend the natural photoperiod to 18 hr (Arnott 1974). In some cases, lights are mounted on irrigation booms to provide illumination at approximately half-hour intervals. Photoperiod extension is discontinued when it is necessary to initiate budset.

In facilities which permit some degree of control, day temperatures for spruce should be maintained at 20°C for optimum growth. The relative humidity should be kept low by adequate ventilation to enhance air root pruning, and to discourage growth of algae and disease. After germination is completed, wet-dry cycles should be established at the block surfaces. This can be accomplished with a watering schedule which relies on some measure of crop need for water (such as block weights or some measure of plant moisture stress) rather than on a fixed schedule. With soil compaction levels of approximately 0.1 g oven-dry weight per ml of cavity volume, a saturated styroblock 211 will weigh between 7 and 8.25 kg. A weight loss of 2 kg indicates the need for water. Approximately 10% of the nutrient solution applied should drain through the cavities at each irrigation to avoid excessive soil salinities.

The size of pine seedlings grown in outdoor units can vary widely according to location and annual weather conditions. Fortunately, pine plugs are generally adequate for planting through a wide range of top sizes. Pine plugs are no longer grown to the very heavy rooting standard of previous years because this predisposes the seedlings to root form problems after planting. A potential solution to this problem developed by Burdett (1978) utilizes a coating of copper carbonate in latex paint on cavity walls. Operational trials of this technique are under way in Ministry nurseries.

The majority of spruce crops currently being grown in shadeframes receive Osmocote as the basic source of nutrients, with supplementary 10-52-17 in spring and fall (Table 4). Spruce crops under cover will likely be grown on a soluble fertilizer schedule if an irrigation boom is available, or with Osmocote if a fixed irrigation system is used. Most pine crops are currently grown with soluble fertilizers, because growth increases with Osmocote have not been as great in the pines as in spruce.

Soluble 20-20-20, which also contains trace elements, may be increased to 750 g/1000 L to increase growth rates. In addition, daily fertilization may be utilized for brief periods to encourage growth. Finishing applications of 10-52-17 may be increased to 925 g/1000 L and Osmocote crops may receive supplemental applications of 20-20-20 for similar reasons. Ferrous sulphate (heptahydrate) at 150 g/1000 L is applied every 2 weeks during the main growing season for crops grown with soluble fertilizers, and may also be applied to crops grown on Osmocote to improve color. Nutrient concentrations for various fertilizer application rates are given in Table 5.

When desired height growth has been attained (generally by mid-August), the conditioning process begins. For spruce, photoperiod lights are turned off, fertilizer is changed to 10-52-17 for both species, and drought stressing is applied for 10-14 days. Drought stressing is quite moderate, when a 3 kg loss in block weights is used as a guide rather than the 2 kg water loss generally used as an indicator of water need. Stressing to the wilt point does not usually occur except in some edge cavities. A wetting agent may be necessary to re-wet plugs which have become too dry. Because removal of shadecloth in early September seems to negate efforts to initiate budset, current practice with spruce is to leave shadecloth in place until November in coastal locations. There are indications that higher seedling dry weights can be achieved by removal of shadecloth in midsummer. In interior loca-

Table 4. Typical fertilizer applications (625 g/1000 L)

	Fertilizer type	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
Pine Spruce	Soluble		←10-52-17→	← 20-20-20 →		←		10-52-17 →	
Spruce	Osmocote		←10-52-17→	← Water only →		←		10-52-17 →	

tions, pine crops are extracted and packaged for cold storage in October or November; spruce crops are cold stored mainly in January or February at their peak of dormancy.

Table 5. Concentrations of N, P, K in soluble fertilizers (ppm)

Fertilizer	Rate (g/1000 L)	N	P	K
10-52-17	625	62	142	88
10-52-17	925	92	210	130
20-20-20	625	125	55	104
20-20-20	750	150	65	125

Stock Specifications

Stock specifications for 1981 are presented in Table 6. The specifications for spruce are for crops grown in shadeframes; specifications for greenhouse—grown spruce would call for considerably larger seedlings. Representative growth curves for spruce and pine are presented in Figures 2 and 3, respectively.

In addition to morphological standards, container—grown stock is freezer tested to determine the level of frost hardiness prior to cold storage. The root growth capacity of container stock is generally very high and is not checked unless root damage is suspected.

CONCLUSION

Much has been learned about container stock production over the past 10 years. There is now a much better appreciation of the facilities and cultural techniques that are required to produce seedlings of specific morphological standards, consistently. Continuing expansion within Ministry nurseries and the recent development of industrial and commercial nurseries have created many problems associated with the handling of this greatly increased production, and in the provision of adequate facilities and equipment.

On many occasions, cultural principles have been compromised to compensate for other problems. These physical and organizational problems generally have one visible result: reduced quality of stock and/or numbers of seedlings produced.

Table 6. Container stock specifications for spruce and pine produced in British Columbia nurseries.

	Height (cm)	Root-collar diameter (mm)	Top dry weight (g)	Root dry weight (g)
Spruce				
211 Minimum acceptable	9.0	1.7	0.4	0.2
211 Optimum target	12.5	2.2	0.7	0.3
313 Minimum acceptable	10	1.8	0.5	0.25
313 Optimum target	17	2.5	0.9	0.4
Pine				
211 Minimum acceptable	7.0	2.2	0.45	0.25
211 Optimum target	12.5	2.6	0.7	0.4
313 Minimum acceptable	10	2.5	0.6	0.4
313 Optimum target	15	3.0	0.9	0.5

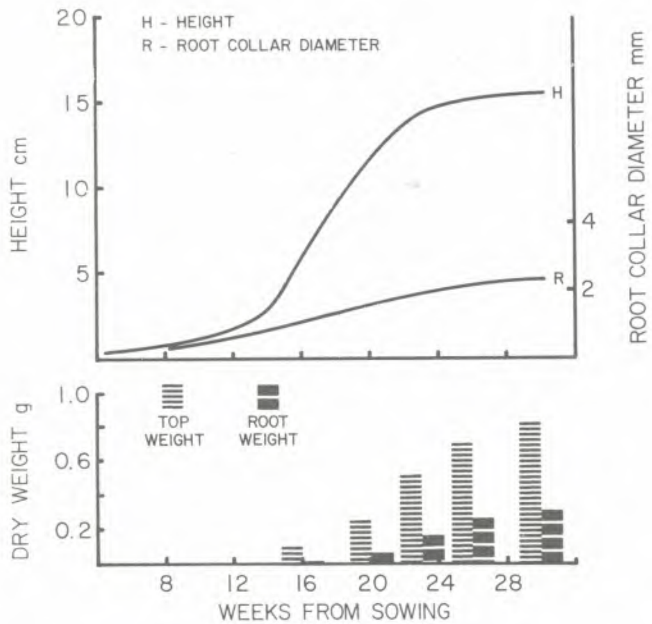

Figure 2. Typical growth curves for spruce grown in styroblock 211 (2A).

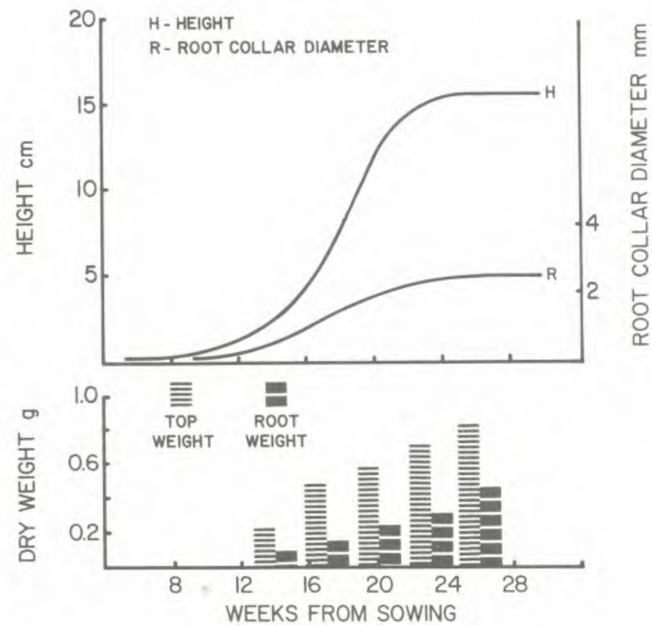

Figure 3. Typical growth curves for pine grown in styroblock 211 (2A).

If we are to produce high-quality stock consistently, there must be a continuing effort to adhere to known biological principles. The challenge in moving from a relatively small production to many millions annually is in organizing a smooth expansion of services and facilities, which will not jeopardize cultural principles and therefore seedling quality.

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