CONTAINERIZED SEEDLING PRODUCTION IN A SHELTERHOUSE SYSTEM

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INTRODUCTION

There are factors which contribute to containerized seedling production. The major factors include the containers, growing facilities, growing medium, crop scheduling, rearing practices, preparation for field shipment, etc. These factors must be well designed or carefully selected to work in harmony to produce a successful and superior seedling crop.

Containerized seedling production has a relatively short history. It went through numerous growing pains over the last 10-15 years. During this time many different systems were used. It is quite obvious by now that not all the developed and used systems worked as expected, therefore containerization reached a stagnating stage, or a stage of reassessment in the recent past.

Experience compiled during the last decade in certain cases, however, does indicate a great deal of success in producing and using containerized seedlings. The major contributing factors for this can be identified by now and this paper is geared to discuss a combination of such contributing factors that make up a successful system. Such a system has worked in the past under a variety of local climatic conditions and in a wide range of geographic areas. The main thrust of the discussion is geared to describe specific growing areas, containers, climate control units, crop scheduling, rearing practices, and the performance of the end product.

GROWING FACILITIES

The growing facilities in the literature are generally classified in two categories. This includes the semi-controlled and fully controlled facilities.

Recently Georgia-Pacific Corporation has developed a new facility type which is called a shelterhouse growing facility. This facility is not equipped with all the environmental control mechanisms which can be found in completely enclosed and fully controlled greenhouses. But it is still fully controlled, in a sense, to provide all the environmental conditions needed for good seedling production.

Depending on needs and local conditions, the facility may be equipped with removable or permanent roof cover, removable sidewall covers, ridge vents, end vents, heaters, lights, C_02 air enrichment units, irrigation systems, etc. Most of the equipment is motorized and is thermostatically controlled.

This facility type, in the author's opinion, fits in between the semi-controlled and completely enclosed, fully controlled growing facility types. With this addition the growing facilities should have three categories as follows:

1. Semi-controlled growing facilities.
2. Shelterhouse growing facilities.
3. Fully enclosed and controlled growing facilities.

The first facility type or the semi-controlled growing facilities could be used as main growing areas or as support facilities. Such facilities are the least expensive and work well in areas where the climate is mild without extreme hot or cold periods. Naturally, in areas with the potential of extreme temperatures there is a high risk factor involved in growing and holding seedlings in them. Therefore, they may not always be the least expensive facilities in terms of total seedling production costs.

The second facility type or the shelterhouse growing facilities are the subject of this paper. Therefore, they will be discussed in greater detail later.

The third facility type or the fully enclosed and fully controlled facilities are the most intricate growing facilities. Fully enclosed can be defined as having a permanent roof cover and a permanent sidewall cover. Fully controlled means that the environment is mostly regulated artificially through a motorized and fully automated control system. Within this structure the temperature is generally controlled either by heating or cooling. Heating is accomplished by using a combination of natural and artificial heat. Cooling is generally done through the use of vents and cooling pads. This is the only facility type which has the ability to hold the temperature at a desired level year-round. The ability to hold a desired climatic condition near ideal in conifer seedling production, however, is not as important as it is often thought to be. Experience shows that seedlings are able to take some extreme climatic conditions provided that their roots are protected by a proper container. Such extreme exposures to seedlings are often even desirable for producing hardier seedling crops. While trying to hold the temperature in a fully enclosed greenhouse at a given or nearly optimum level, quite often an undesirable high humidity condition is created due to poor ventilation. Such a humidity condition coupled with the "ideal" temperature often creates an excessive artificial seedling growing condition and a hot-bed for diseases.

Completely enclosed and fully controlled greenhouses, besides their inherent disease problems and too artificial seedling growing environment are also costly to build and costly to operate. Such costs must be evaluated very carefully when facilities are designed and built to see if their usage can be justified. In many cases, in order to justify them the excuse of multi-crop production is used. Multi-crop production may be desirable in some cases but it is rarely necessary in the Pacific Northwest. Producing more than one crop a year in this area does require an expensive facility and a lot of energy to operate it. This in turn drives the cost of seedlings up. Besides this, it often causes a logistic problem in scheduling the seedlings to meet optimum field planting conditions.

A TYPICAL SHELTERHOUSE AND ITS FUNCTIONS

Shelterhouse Structures

During the last decade Georgia-Pacific Corporation has developed a shelterhouse system. The infrastructure consists of several components. The most important being the 15.25 meter by 61 meter (50' x 200') main growing unit or units with permanent fiberglass roof covers. In case of a multiple unit facility, the main units are spaced so that there are 6 meter (20') wide alley spaces between them. These spaces, or components, are equipped with doors and serve as access to the given alleys and to the main growing units and also serve as growing areas. The alleys are normally covered with removable plastic. A desired number of main growing units and alleys arranged side by side form a cluster or actually one large growing unit with four outside walls.

If a large working and storage area is also required, a third component in the form of a headhouse could be added. In this case two growing area clusters may be hooked together with the headhouse between the two clusters (Figure 1). This arrangement cuts down even more on the outside wall area and provides an additional low cost and convenient working as well as growing area inside a greatly expanded shelterhouse cluster.

The shelterhouse structures are built out of sturdy galvanized steel and are gutter connected. All of the gable ends and doors are also fiberglass covered. All the walls below the gutter line are covered with removable plastic. The large shelterhouse cluster may be operated as one large growing area but if needed during sowing or shipping, portions of the cluster can be isolated by hanging wall covers on the alley walls.

Environmental Control Mechanisms and Their Purpose

The shelterhouse facility type may be suitable for growing seedlings under a large variety of climatic conditions. The local climatic conditions are the main determining factors for the needed climate control equipment in a given area. For example, our facilities in the tropics have only a roof cover to shelter the growing seedlings against driving rains and direct sun rays. In our mild coastal locations removable sidewalls are also needed but not artificial heat. Where the temperatures may get below freezing, an artificial heat source is required. The main principle in growing seedlings in a shelterhouse system is to

Figure 1. A typical layout of a greenhouse cluster (headhouse, alleys and greenhouses).

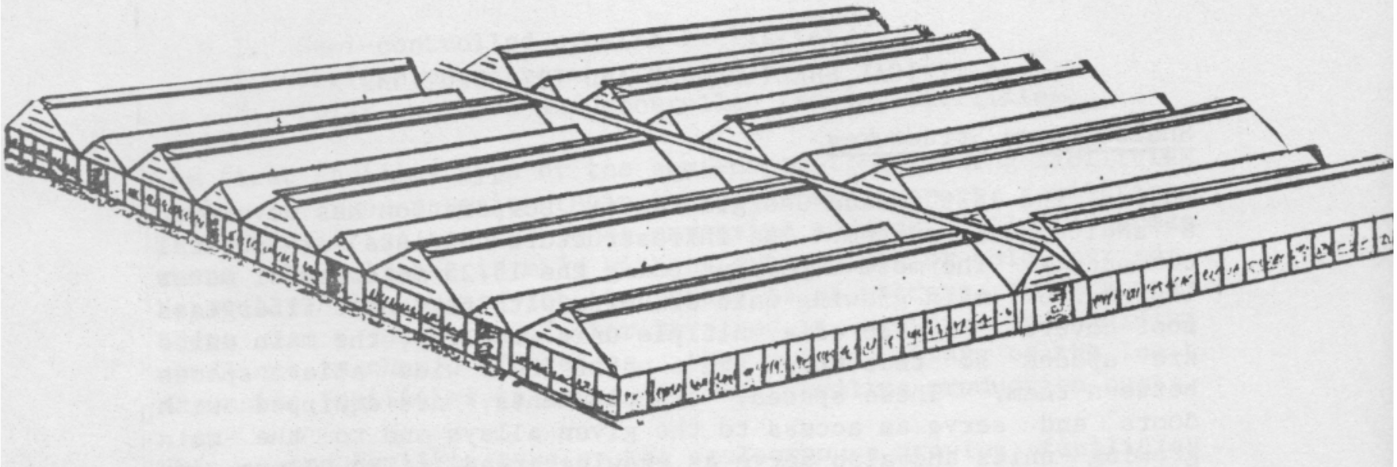
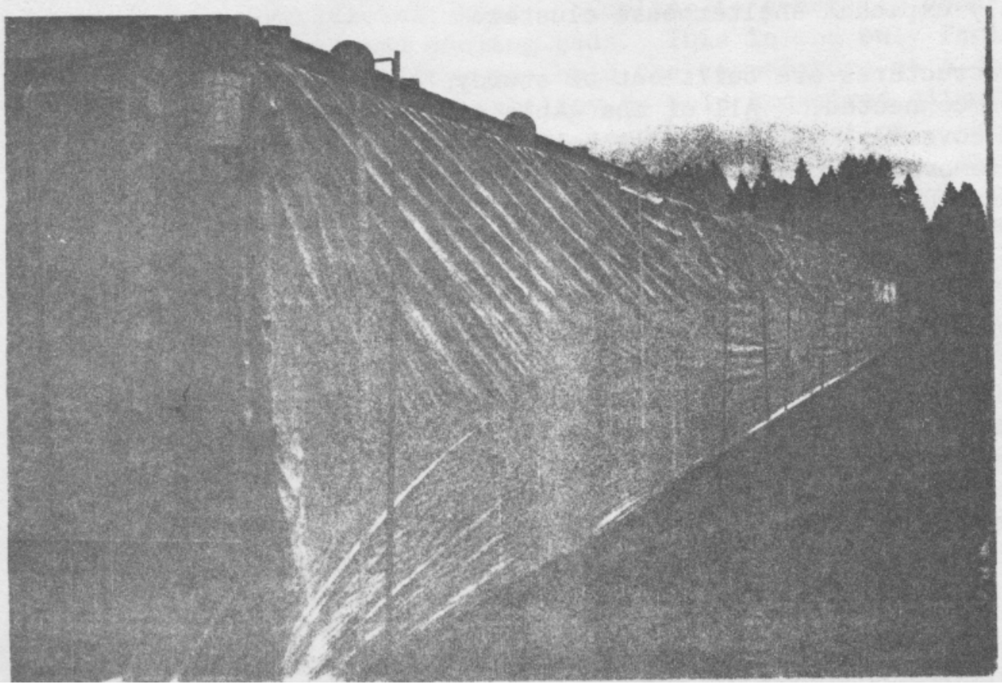


Figure 2. Thermostatically controlled removable sidewall cover.



take advantage, as much as possible, of the natural growing conditions. Therefore, the climate control equipment designed for such facilities should take this into account.

Under fairly extreme weather conditions, shelterhouse facilities have at least two 400,000 BTU rated heaters with suitable fans for an even heat distribution in each main growing unit (15.25 m x 61 m). These heaters also supply heat for the adjacent 6 m wide alleys. Additional heat is often required during germination, for early seedling development, and for frost protection. Since sowing generally takes place in late winter and early spring, additional heat is required only for a relatively short time. As soon as the outside temperature gets warmer there is more concern to ventilate the growing areas than to heat them. Ventilating is very important in avoiding high humidity during moist conditions and it helps in avoiding heat build-up during warm sunny days.

Ventilating and cooling in a shelterhouse is accomplished in a variety of ways. The initial cooling is done through the heater vents. This happens when they take in cool outside air through a louvered wall opening behind the heaters. This air is evenly distributed over the growing area through the perforated heater tubes. Additional cooling or ventilation is done through the continuous and full-length roof vents. Generally two 1.5 m wide roof vent wings are mounted on each side of the roof ridge. When they open up, a chimney effect is created and the rising warm air easily escapes. These roof vents are generally motorized and thermostatically controlled.

The main environmental control features of a shelterhouse growing facility are the removable sidewalls. The removable walls are mostly made out of reinforced plastic. Rigid panels that could be opened and closed are also suitable for such a purpose but are generally expensive. We have developed a system where relatively inexpensive reinforced plastic wall covers are rolled up and down by a thermostatically or manually controlled motorized mechanism (Figure 2).

Additional ventilation, if needed, is provided by the removable alley roof covers. By opening up a 6m wide alley space between each 15.24m wide main growing area the air movement accelerates greatly in a huge shelterhouse cluster.

All the described ventilation features provide good ability to funnel natural air through a shelterhouse growing area. This helps a great deal in cooling without using a lot of cooling pads and vents which are costly to install and operate. If additional cooling is needed it can be achieved by turning the irrigation system on. The natural airflow helps in eliminating high humidity. Such a problem is caused by an artificial cooling system and frequent watering in a closed-in area. Prolonged moisture on the foilage is a hotbed for disease.

Shelterhouses may be equipped, if needed, with grow-lights or other air enrichment devices. However, most shelterhouses don't require such devices because they are generally geared to produce seedlings during the natural growing season. The installation of a minimum lighting system with at least 400 lux light intensity for photoperiod extension, however, is recommended. There is good use for this in avoiding premature budsetting in case of a late winter sowing, especially when seed is used from an area with a short growing season.

SEEDLING PRODUCTION IN SHELTERHOUSES

It must be quite clear by now what shelterhouses are. Since they are relatively inexpensive to build and operate, the grower can afford to grow crops in them when growing is the best. The grower can also afford to hold and move seedlings to the field or to storage areas when such actions are most desirable. As an example, shelterhouses in the Pacific Northwest are used the best in a one-crop system. Here in Oregon the sowing is done in March or April and with additional heat, germination is quick. The early seedling development is also aided with some heat and through photoperiod extension by artificial lighting when needed. The accelerated growing period takes place in June and during the first part of July. This is the time when growing is the best under natural growing conditions. The hardening phase can begin in late July and continue through the month of August. This is also the time when all seedlings start to go into natural dormancy. This way hardening of seedlings, as one of the most important and perhaps the most difficult phase of the rearing practice, can be accomplished with a minimum effort. With this scheduling the seedlings reach the holding, or over-wintering phase by September. Normally by this time of year in some areas in the Northwest there is enough precipitation in the field to facilitate field planting.

Early fall planting is possible with containerized seedlings and it is often desirable to get into high elevation areas where a snow cover prevents winter planting. Most of the lower elevation areas in Pacific Northwest require winter or spring planting; in other words during the dormant season. However, it is possible to plant containerized seedlings with very good success during the non-dormant season if there is enough ground moisture available for the seedlings to survive shortly after planting.

A typical growing schedule for the mentioned five different growing phases is given in a tabulated form in Tables 1-5. This schedule is specifically geared to the Northwest species such as Douglas-fir, hemlock, redwood, cedar, etc. Large portions of the schedule may apply to other species and to different growing areas also. However, the schedule should be used only as a general guideline to aid in developing specific growing requirements for specific local conditions.

SIIELTERHOUSF AND CONTAINER INTERACTIONS

It was briefly mentioned earlier that containers and growing facilities must be compatible with each other. There is normally little problem as far as growing is concerned in using almost any type of containers in a fully enclosed and controlled growing area. In such facilities the environment can be regulated easily to maintain temperatures that are often considered "nearly optimum." Seedlings in shelterhouses or other semi-controlled growing areas may be exposed to more extreme temperatures. Such conditions may not be detrimental if the seedling's most sensitive parts, the roots, receive some protection. The tops of the seedlings can take more severe climatic conditions than their root system. Therefore, a container with good insulating capacity is desirable and can be helpful in producing good crops in all types of growing facilities.

It was found that the commonly used styroblock containers with their good insulating capacity work well in shelterhouses. They help in holding the roots cool during hot weather conditions and prevent the roots from freezing during light freezes. On the other hand, both the slightly hot and slightly freezing temperatures at a given developmental stage could be beneficial for the tops of the seedlings.

During the early seedling development stage, the soil in thin-walled containers with poor insulation capacity allows the soil to warm up. This in turn promotes rapid stem growth. At this stage, however, it is more desirable to hold the height growth to a minimum to allow good side-branch initiation and root development. To achieve a desirable height growth during the growing season isn't as difficult with the present rearing practices as it used to be in the early years of containerization. After achieving good side-branch and root initiation the seedlings enter the early part of the accelerated growing phase (see month of June in phase 3 chart). During this growing period all growing conditions are most ideal to achieve rapid seedling development.

During the later part of the accelerated growth period and especially during the hardening phase, higher air temperature restricts the height growth while good root development is progressing in the insulated container.

Generally the desired height goal has been reached by this time and the emphasis is more on root growth, diameter growth and lignification of the stems.

One of the real advantages of a styroblock container is evidenced when the seedlings are chilled by early light frosts during the hardening and holding phases. This chilling helps bud-setting and developments, deepens the dormancy, hardens the seedlings while the roots still grow and stay active. This is most important for good seedling establishment, for good survival and for good growth in the field. Such an advantage can be easily realized when the shelterhouse and styroblock operation is located in an area where early frosts occur. In a situation like this, the houses are left open until the temperature drops to about 4-5° C below freezing. The styroblocks do a good job in protecting the roots down to such temperatures if the frost isn't prolonged. Naturally, if the temperature stays cold or turns colder the shelterhouses should be closed and even the heat should be turned on to keep the soil-plug from freezing. If the soil-plugs do freeze, the styroblocks don't thaw out easily. Therefore, seedlings in such a condition could get severely damaged or killed by desiccation. Besides their good biological traits, styroblocks are also fairly easy to handle in the nursery. Seedlings can be shipped to the field in them if so desired. The styroblocks are recyclable and they have a low initial cost. Therefore, they also compare well cost-wise to other container types.

Table 1. SCHEMATIC DESCRIPTION OF GROWING PHASES

Typical schedules are given for the five different growing phases as used with Douglas-fir in Oregon. Large portions of the schedules may apply to other species and to differing growing areas also. However, the schedules should be used only as a general guideline to aid in developing specific growing regimes for specific local conditions. The stated schedules may also vary from year to year depending on climatic and seedling conditions.

Phase 1.--STRATIFICATION AND GERMINATION PERIOD

This phase is geared to proper seed preparation, efficient sowing germination and juvenile seedling development.

Timing → / Growth Components	JAN. Weeks 3 & 4	FEBRUARY Weeks 1, 2, 3, 4	MARCH Weeks 1, 2, 3, 4	APRIL Weeks 1	APRIL Weeks 2
Seed Preparation	Soak Seed	Stratify at 2°C for 6´- 8 weeks	Sowing and Germination	Juvenile Development	
Day Temp. (°C) Optimum: Permissible:			25° 18-25°	25° 13-30°	
Night Temp. (°C) Optimum: Permissible:			25° 18-25°	13-20° 10-15°	
Relative Humidity Optimum: Permissible:			80% 50-90%	40-60% 40-70%	
Natural Light			60-80% Sunlight	60-80% Sunlight	
Supplemental Artificial Light			None	To avoid budsetting, extend the photoperiod with 400 lux light intensity.	
Water			Frequent light irrigation	As needed (keep surface dry to avoid disease development).	
Fertilizer			None	None	Formula A (balanced)
pH			4.0-4.5	4.0-4.5	
Fungicide				One preventive application	
Record Keeping	Monitor temp. & humidity in the cooler.		Keep daily records of all activities (see pg. 71)		

Table 2. Phase 2.--EARLY GROWTH PERIOD

This phase aims at the establishment of seedlings, good root and side bran initiation and the prevention of disease and insect problems.

Timing → / Growth Components ↓	A P R I L		M A Y			
	Weeks		Weeks			
	3	4	1	2	3	4
Temperature (^oC) Optimum: Permissible:	20 - 30 10 - 33		20 - 30 10 - 33			
Relative Humidity Optimum: Permissible:	40 - 60% 30 - 70%		30 - 60% 20 - 70%			
Natural Light	60-80% Sunlight		60-80% Sunlight			
Artificial Light	For photoperiod extension (400 lux)		None			
Water	As needed (Keep surface dry)		Mostly applied with fertilizers as needed. Leach each 4 - 6 weeks.			
Fertilizer	Chelate Iron (15g/ 100 l of H_2O), Ca CO_3 (125g/100 l of H_2O)		Fe (15g/100 l of H_2O), $CaNO_3$ (125g/1 l of H_2O), these compounds are appli alternately as needed. Fertilizers applied with each watering twice a w			
pH	4.5 - 5		5 - 5.5			
Fungicide	Apply only if needed		One Benlate-Truban preventive fungic drench (30g/100 l of H_2O).			
Operations	Daily checks on crop		Thin to one seedling per cavity.			
Environmental Control	Automatic heating and ventilation as needed.		Heat only during cold nights. Begi opening roof vents and sidewalls of shelterhouses on warm days for good circulation and cooling.			
Record Keeping	Monitor the crop closely each day. Record all activiti (see Daily Record Sheets). Note potential problems and solutions to them.					
Soil and Foliar Testing	Start routine testing once every two weeks and adjust f ilizer regimes to comply with nutrient needs of the seedl					
Seedling Growth	Keep height growth low (4 - 8 cm). Concentrate on side branch initiation and root development.					

Table 3. Phase 3.--ACCELERATED GROWING PERIOD

This phase aims at pushing seedling height and diameter growth, root development and stem lignification. The natural growing conditions are generally the most optimum in this growing period.

Timing → / Growth Components ↓	JUNE Weeks				JULY Weeks	
	1	2	3	4	1	2
Temperature Control	Natural air temperature during the day (vents, sidewalls normally open). In case of cool nights, vents and walls may be closed.				Natural air temperature. Cool with irrigation water if needed.	
Humidity	Same as relative humidity					
Natural Light	Only the sunlight as it penetrates through the roof covers.					
Supplemental Light	None					
Roof Covers	Roof covers on the main greenhouse units stay on to keep the rain off the seedlings. Alley roof covers may be removed for added ventilation.					
Pre-wetting	5-10 minutes of pre-wetting before fertilization aids in water penetration for better fertilizer utilization.					
Wetting Agent	It is used when water penetration is becoming poor, (about once a month).					
Leaching or Nutrient Flush	Prevents salt build-up (flush about once a month by using about 20 liters of water per m^2 of area).					
Water	Irrigation water is mostly accompanied by fertilizer.					
Fertilizer	High N compounds (3:1:1 and $CaNO_3$) 1000 ppm total fertilizer. Iron chelate 2-4 weeks (300-500 ppm).			High P compounds plus Ca, Mg and K compounds. (1200-1500 ppm total fertilizer solution)		
pH	5 - 5.5					
Ht. & Diameter Measurement	Establish sample trees. Measure and plot on graph these same trees every two weeks.					
Soil and Foliar Tests	Continue testing soil and foliar to adjust nutrient regime as needed.					
Disease Control	Normally there is very little problem with disease in this phase.					
Record Keeping	Same as in previous phase					
Seedling Growth	The natural growing conditions and fertilizer regime favors fast height growth. Push height growth as much as possible to match the growth chart.			During these three weeks, concentrate on rapid height, diameter and root development. The natural growing conditions and fertilizer regimes are favoring this.		

Table 4.

Phase 4. HARDENING PERIOD

The aims in this phase are to initiate and achieve bud setting, to stop height growth, to lignify stems, to boost diameter and root development and to initiate dormancy.

Timing → / Growth components	JULY Weeks 3	JULY Weeks 4	AUGUST Weeks 1	AUGUST Weeks 2	AUGUST Weeks 3	AUGUST Weeks 4
Temperature Control	Close to natural air temperature, cool with irrigation water if needed.					
Humidity	Similar to phase 3.					
Supplemental light	" " "					
Roof Cover	Roof cover keeps rainwater off seedlings. This eliminates interference with hardening.					
Prewetting	Very important after stressing.					
Wetting Agent	Use wetting agent after heavy water stress if needed to re-wet plugs.					
Leaching or Nutrient flush	Start hardening by flushing nutrients from the soil.					
Seedling stress	Dry to wilting point or 22 bars PMS (Repeat stressing 2-3x).					
Fertilizer	After first stress apply 0-52-34 (60g/100 liters H_2O) After second stress apply 0-0-61 (60g/100 liters H_2O) After third stress apply hardening formulas (See Pg.92) alternately with 0-52-34 until bud setting takes place.					
Chilling	none				Cool nights may help in chilling seedling stems.	
pH	5.0-5.5					
Soil & foliar test	Once every two weeks or more frequently if needed.					
Height & diameter	Similar to phase 3. The two graphs help in adjusting fertilizer regimes.					
Disease Control	Watch for Fusarium and Botrytis problems.					
Record Keeping	Similar to the previous phases.					
Operations	Spreading seedling blocks for better aeration. Turning outside blocks to hold down edge effect.					

Table 5. Phase 5. HOLDING OR OVERWINTERING PERIOD

During this phase the crop is held in dormancy while the trees are awaiting field planting. Diameter growth on a reduced scale still continues. Root tips in styroblocks remain active and the transpiration rate is low.

Timing → / Growth components ↓	SEPTEMBER Weeks 1 2 3 4	OCTOBER Weeks 1 2 3 4	NOVEMBER Weeks 1 2 3 4	DECEMBER Weeks 1 2 3 4	JAN. Weeks 1 2
Temp.	Allow cooling in case of frost down to -6°C for short periods. This helps chilling the seedlings for better hardening and dormancy. Avoid freezing of soil-plugs (See Section 15.11).				
Natural light	Natural daylight as permitted through roof covers.				
Suppl. Artificial light	None				
Roof cover	All roofs are covered including alleys.				
Watering	As needed. Less frequent, because of low transpiration rate.				
Fert-ilizer	Resume the use of higher N content fertilizer for a balanced fertilizer regime. This promotes more diameter growth and frost hardiness. (Reduce rates and frequency of fertilization).				
pH	5.0-5.5				
Soil & Fert. tests	Once a month or as needed.				
Height & dia. growth	Continue monitoring until growth levels off.				
Disease Control	Botrytis is generally causing the most problems if not prevented or controlled.				
Record Keeping	Same as in all other phases.				
Operation	Start packaging and shipping seedlings as soon as field planting conditions warrant it. Shipping may be done while seedlings remain in the styroblock containers or while extracted from the containers. Extracted seedlings may be cold stored for later planting also.				

FIELD PERFORMANCE OF SEEDLINGS

Georgia-Pacific has planted in the field over fifty million seedlings that were produced in shelterhouses and in styroblock containers in the Pacific Northwest alone during the last ten years. During this time, many other container types and bareroot seedling types were also tried, used, and field tested.

Routine survival plots are established in all our reforested areas and these are followed for several years until each reforested unit is termed satisfactorily stocked. These surveys generally show only survival rates. In addition to survival plots, our research center conducts many regeneration experiments to evaluate and refine the present methods and to develop future reforestation methods.

Both the routine survival plots and regeneration research plots show similar trends in survival rates for the various seedlings types. This information was closer quantified in the research installations for the effects of animal damage, height growth, specific site conditions and for cost/benefit analysis.

Out of all the regeneration experiments one replicated test is especially worth mentioning. This is perhaps the most complete and typical test where three containerized seedling types (styro 2,5, and 8) were compared to three bareroot seedling types (3-0, 2-1, and P-1) on two test sites (north and south exposures). The entire experiment consisted of 2,200 seedlings at planting time. This replicated installation is located near Eugene, Oregon on typical reforestation site land.

Three-year test results of this experiment fairly well quantifies the performance of the six different seedling types. The same seedling types were used in general reforestation on Georgia-Pacific land also when this experiment was installed in 1979. It was felt that each of the two test sites in this experiment either represents a large acreage of the company's land on the coastal north slope, cooler "wet" sites or on the south slope, warmer "dry" sites. Each site represents a reforestation problem. On the "wet" and "dry" sites the seedlings have to compete against vegetation growth and on the "dry" site they also have to compete against moisture stress.

How Did These Seedlings Perform?

For a meaningful evaluation during survival checks and height measurements, survival and growth restricting factors such as animal damage and vegetation competition were also monitored. This information was compiled and statistically analyzed; a summary of the results is given as follows.

Animal damage on both exposure sites was less than what normally occurs in freshly planted areas. The damage that did occur was the heaviest, in general, on the south facing slope. The ratio was about 2:1 compared to the north slope. The bareroot seedlings on both sites were definitely browsed heavier and more often than the containerized seedlings. Again, the ratio was about 2:1. In spite of this, the overall height growth reduction due to browsing was not significant on either exposure or seedling type. In general, the average didn't amount to more than 1cm/tree in any of the exposures or seedling types.

The original height, present height, survival rate, and percent growth increment/average tree for each seedling type is tabulated in Table 6. It is interesting to note that the containerized seedlings show a remarkable survival rate on both sites. They easily overcame their initial height disadvantage also by outscoring the bareroots in growth increment on the south slope by a margin of 3:1 and on the north slope by a margin of 2:1.

Survival rates and total performances by individual seedling types are graphically depicted in Figures 3 and 4 respectively. Combined bareroot and containerized seedling performances are graphically shown in Figure 5. It is evident from the graphs that the initially taller bareroot seedlings, in general, perform well on the cooler north slope. On this site the "top-heavy" seedlings were not exposed to rapid drying conditions after planting. For this reason they were not subjected to the typical dry site planting shock. Under this condition the initially tall bareroot seedlings were able to stay above the brush and maintained a good height growth. The adverse effect of the dry site on survival and height growth for the tall bareroot seedlings is well documented in seedling performance on the south slope (see Figures 4 and 5). Here their performance trend is exactly the opposite from their north slope trend.

The containerized seedlings maintained a good survival rate on both sites (see Figure 3). The reason for this is thought to be due to their superior root quality and physiological make-up. In height growth they had a hard time competing against the initially taller bareroot seedlings which performed rather well under the more favorable north slope growing conditions. The containerized seedlings, despite their initial shorter height, definitely made up for the height disadvantage on the "dry" south slope (see Figures 4 and 5). Here they performed extremely well.

The above trends are not only true in the just-mentioned experiment. There is a similar trend experienced when reforestation results from large-scale plantations on relatively "wet" and "dry" sites are compared to each other over the years. Large transplant bareroot seedlings do well on cooler and more moist coastal high site lands and on cooler north slopes where moisture is not a restricting factor in plant growth, but vegetation competition is severe. On the other hand, the droughtier sites on the inlands or in southern Oregon are showing a considerably better opportunity for containers. It is strongly felt that the good performance of the containerized seedlings is closely linked to their shelterhouse rearing practice and conditioning before field planting.

Cost/benefit ratios were also computed based on the various types of seedling performance in the above experiment. Commercial, large-scale reforestation cost figures for each seedling type were available for the time this experiment was established. Such cost figures are more useful to calculate reliable or operationally useful cost/benefit ratios than using the installation cost of the experiment. The cost/benefit ratios were calculated while dividing the establishment (seedling and planting) cost for each seedling type by the total performance of the same.

The result of this calculation shows a straight line correlation in cost/benefit for the containerized seedlings on each planting site. As the establishment cost increased for a given container type so did the performance. The styro 2's were on the low end of the cost and performance scale and the styro 8's on the high end. The total variation in this correlation was + 2%.

The cost/total performance or cost/benefit ratio varied greatly among the bareroot seedlings. Since the 3-0's, with the lowest initial cost, showed a very poor total performance they ended up with the worst cost/benefit ratio category on both sites. The 21's were slightly better than the P-1's on the north slope. The opposite was true on the south slope.

Since there was practically no variation in cost/benefit ratio among the three containerized seedling types on either location they were used as a base of comparison for the three different bareroot seedlings types. The relative cost/total performance difference for each bareroot seedling type, when compared to the containerized seedlings, is graphically depicted in Figure 6. Combined figures for the bareroots indicate that the cost of using bareroot seedlings is about twice the cost of containerized seedlings on the south facing slope, while this difference drops to 25% on the north exposure.

In summary, the experiment indicates that well developed containerized seedlings demonstrate good ability to survive and grow fairly well on all sites and do very well on drier sites. They are doing better than expected under animal browse pressure also. In addition to this, the containerized seedlings provide a considerably better cost/benefit ratio on all sites than the tested bareroot seedlings do, but especially on drier sites.

CONCLUSION

The shelterhouse and styroblock combination system in seedling production is used quite effectively by all the Georgia-Pacific nurseries from the harsh New England states to the tropics, and by other operations also. This system is especially gaining acceptance in the Pacific Northwest. It is hoped, though, that with slight modifications to fit certain local needs, this system will be widely accepted in most areas where there is a desire to produce and use containerized seedlings.

Table 6. Seedling Type Survival and Growth Increment Comparison on the North and South Exposure Test Sites.

Exposure and Seedling Types	Average Height/Tree in cm.		Survival Rate	Percent Growth Increment/Average Tree
	Original Ht.	Present Ht.		
	2/79	12/81	12/81	
<u>North Slope:</u>				
2-1 (Bareroot)	46 cm	135 cm	86%	193%
3-0 (Bareroot)	59 cm	109 cm	80%	85%
P-1 (Bareroot)	36 cm	108 cm	89%	200%
Total Bareroots	49 cm	111 cm	84%	127%
Type 2 (Cont.)	17 cm	74 cm	89%	335%
Type 5 (Cont.)	22 cm	82 cm	92%	273%
Type 8 (Cont.)	33 cm	96 cm	93%	191%
Total Containers	24 cm	84 cm	91%	250%
<u>South Slope:</u>				
2-1 (Bareroot)	48 cm	97 cm	92%	102%
3-0 (Bareroot)	61 cm	102 cm	65%	67%
P-1 (Bareroot)	38 cm	106 cm	80%	179%
Total Bareroots	50 cm	103 cm	74%	106%
Type 2 (Cont.)	17 cm	95 cm	94%	459%
Type 5 (Cone.)	25 cm	100 cm	97%	300%
Type 8 (Cont.)	33 cm	112 cm	97%	239%
Total Containers	25 cm	103 cm	96%	312%

Figure 3. Survival Rates of the Various Types of Planting Stock.

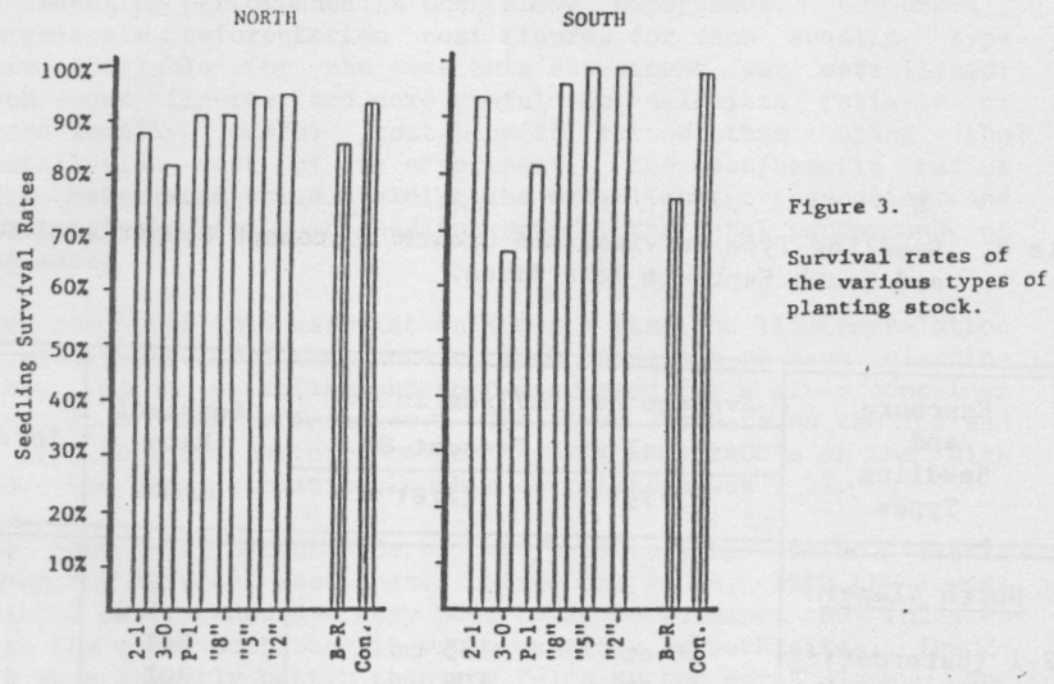


Figure 4. Total (Height x Survival) Performance Comparison of the Various Seedling Types.

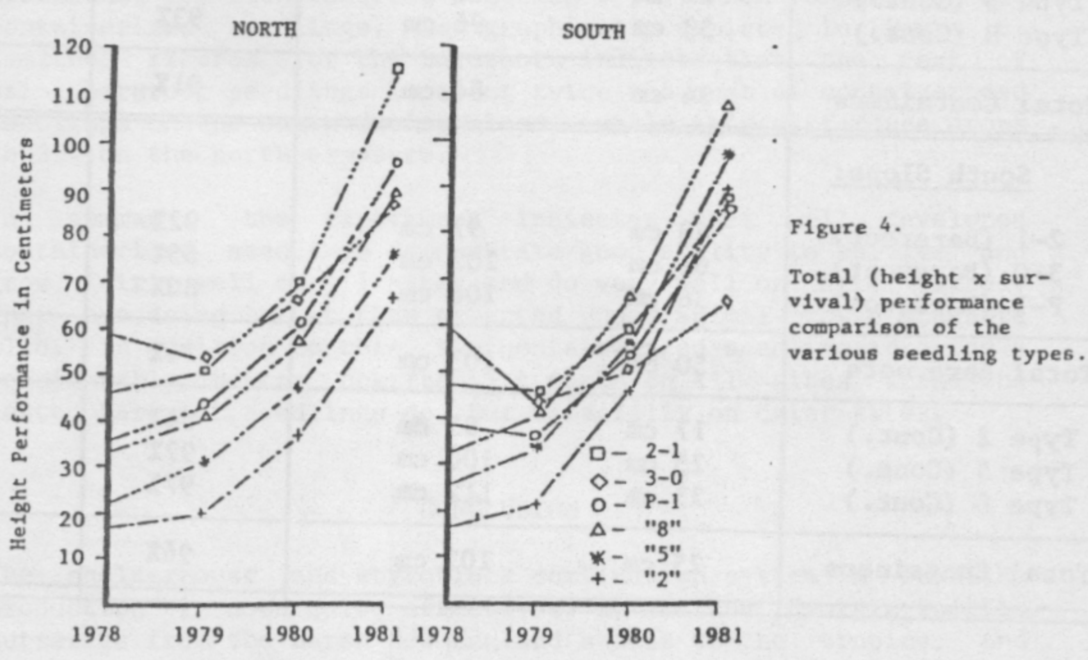


Figure 5. Total (Height x Survival) Performance Comparison for the Combined Container and Combined Barefoot stocks.

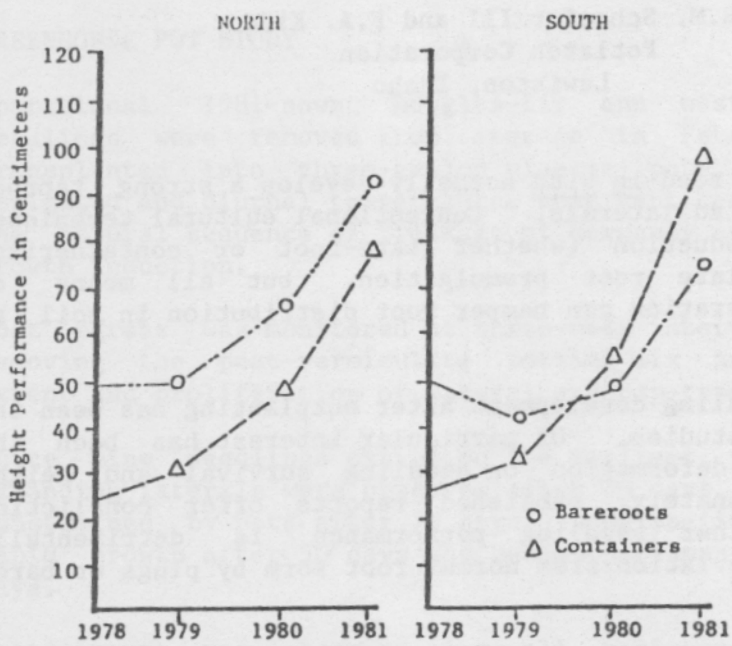


Figure 5.
Total (height x survival) performance comparison for the combined container and combined bareroot stocks.

Figure 6. Relative Costs/Benefit Ratio Difference for the Types of Bareroot Seedlings when Compared to the Cost/Benefit Ratio of the Containerized Seedlings.

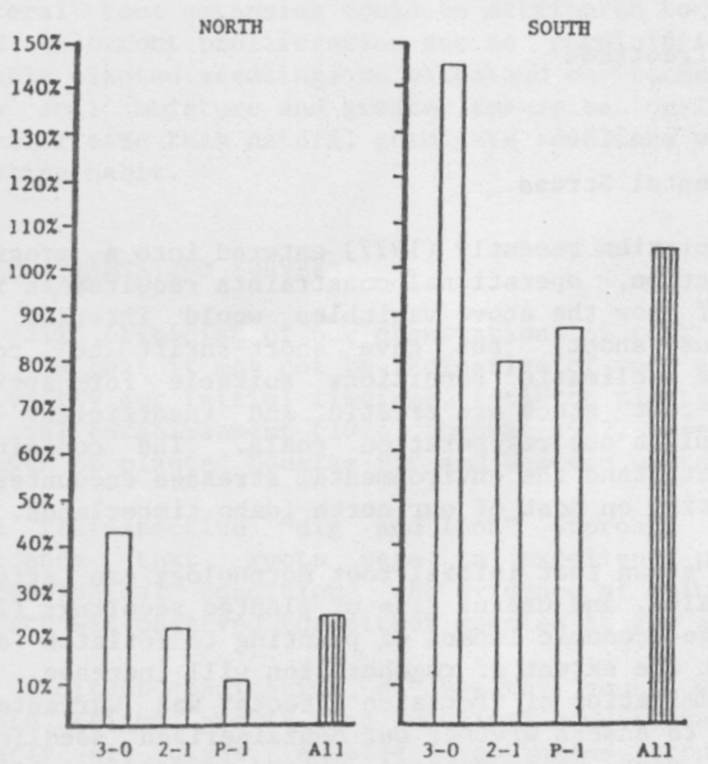


Figure 6.
Relative costs/benefit ratio difference for the various types of bareroot seedlings when compared to the cost/benefit ratio of the containerized seedlings.