Tree Planters' Notes

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Contents

Cover: Hydraulic bucket lift mounted on van truck used for tree breeding activities in the Michigan State Cooperative Tree Improvement Program at Michigan State University in East Lansing. The maximum working height of the lift is 34 feet. The unit is very stable yet highly mobile. (Photo courtesy of Dr. Jim Hanover, Michigan State University.)

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Italic numbers in parentheses in the text refer to numbered literature citations at the end of each article.

A Test of the Polybin for Frozen Overwinter Storage of Red Pine

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The polybin was as successful as the regular Kraft-polyethylene bag for frozen overwinter storage of red pine. Dipping of tree roots before packaging was not advisable.

Frozen overwinter storage of packaged nursery stock has been an accepted practice at Ontario nurseries since about 1970, and expansion of storage facilities is still proceeding. This report is based on the fifth-year measurements of a 1974–75 storage test with red pine (*Pinus resinosa* Ait.) to examine the effects of (1) two containers (the regular poly-lined Kraft bag and the polybin[2]), (2) water-dipping of roots before packaging for storage, and (3) effects of time of fall lifting on readiness for storage.

Studies of red pine in frozen overwinter storage have shown variable results. However, it has been determined that successful red pine storage requires large, well-balanced stock (with a top-root ratio below 5.0:1).

Previous studies of the polybin in comparison with the regular Kraft-polyethylene bag have found the polybin particularly beneficial in the packing and storing of white spruce (*Picea glauca* (Moench) Voss) and about equal to the bag in the storage of black spruce (P. mariana (Mill) B.S.P.) and jack pine (*Pinus banksiana* Lamb). In white pine (*P. strobus* L.), the polybin was found slightly inferior to the Kraft-polyethylene bag.

The limited number of studies that have compared water-dipping roots with dry packaging for overwinter storage have suggested that this may be an unnecessary or even harmful procedure.

Previous studies of the dates of fall lifting for red pine have indicated that a D–H–D (Degree–Hardening–Days) accumulation, based on daily differences of minimum soil temperatures below 10° C at a depth of 15 centimeters, of about 167° C is appropriate (*5, 6, 7*). This was later revised to D–H–D 185° to 200° C (360° F) (*3*).

Methods and Procedures

Randomized plots were laid out in the fall of 1974 in the regular 3+0 seedbeds of red pine at Midhurst Nursery (about 100 km north of Toronto) to provide stock for four weekly test liftings for overwinter frozen storage. The stock was of the local seed origin. A recording thermometer with a probe set at 15 centimeters was used to record the daily soil temperatures, from which calculations were made for Degree–Hardening–Days. Plots were also reserved for the fresh-lifted controls in the following spring.

The trees were loosened in the bed with the Egedal lifter, pulled by hand, and tied in bundles of 25 seedlings. Trees less than 15 centimeters in top length or 0.40 centimeter in diameter were discarded. All packaging was done in the field according to the following schedule of treatments:

Kraft bags, wet: Bundles of trees were dipped, roots only, in water for about 10 seconds and packed with wet moss, top and bottom, in regular Kraft-polyethylene shipping bags.

Kraft bags, dry: Same as above, without water-dipping.

Polybin, wet: Bundles of trees were dipped, roots only, in water for about 10 seconds, and packed with wet moss, top and bottom, in polybins.

Polybin, dry: Same as above, without water-dipping.

At each of the four liftings, October 7, 24, and 31 and November 7, two containers of each treatment were packed and immediately placed in frozen storage at about −3° C for overwinter holding. The Kraft bags contained about 300 trees and the polybins about 500 trees each, a total of about 12,800 trees in storage. At each date of lifting, 200 trees were taken for laboratory measurements to characterize the stock (table 1).

Two plantings were carried out in the spring of 1975 at the Midhurst Research Unit, in accord with randomized designs. For the first plant-

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[1] This report was prepared while the author was under contract with the Ontario Ministry of Natural Resources and is based on studies undertaken before the author's retirement from the Ministry.

[2] Scepter shipping container #71216, approximately 30 by 45 by 55 centimeters, peg-down cover; Scepter Manufacturing Company Limited, 11 Bermondsey Rd., Toronto, ON.

Table 1.—*Stock characteristics of 3+0 red pine at Midhurst Nursery, fall 1974 and spring 1975*

	Top length	Stem diameter	Ovendry weight	Top-root ratio by ovendry weight
	Cm	*Cm*	*G*	
Fall 1974				
Lift 1, October 17	30.7	0.50	8.78	5.09:1
Lift 2, October 24	28.5	.48	8.57	5.69:1
Lift 3, October 31	33.1	.53	10.28	6.55:1
Lift 4, November 7	32.3	.50	9.12	6.50:1
Spring 1975				
Plant 1 controls				
May 12	34.0	.61	14.70	5.39:1
Plant 2 controls				
June 2	33.9	.58	12.73	5.83:1

ing, from May 12 to 15, half of the frozen containers were removed from storage on May 11. Also, fresh-lifted controls (1,000) were obtained early on May 12 from the same seedbeds as the stored material. At the time of lifting, this stock appeared dormant above ground, although slight root growth to about 1.5 centimeters was visible. The planting was done by hand, using the modified wedge method in furrows turned in sod. Spacing was about 1.2 by 1.2 meters. The weather was generally clear; air temperatures were 15° to 25° C; soil temperature was about 13° C at a 15-centimeter depth; and relative humidity was extremely low for part of the planting, a range of about 12 to 55 percent. The planting consisted of 5,000 trees randomly chosen by bundles from the containers; five replications by five main blocks of 200 trees (four lifts plus control) by four sub-blocks of 50 trees (containers by dipping).

The second planting, from June 2 to 6, comparatively late for planting in this area, was done in a similar manner on a site about 1 kilometer away. The weather was also generally warm and partly clear, air temperature was 18° to 28° C; soil temperature was about 15° C; and relative humidity was again low for part of the planting (20 to 80 percent). The controls for the planting were lifted early on June 2 and showed considerable growth, an average of about 12 centimeters for new top growth and much root growth about 1.0 centimeter long. The planting plan used the same design and number of trees as in the earlier planting. The average measurements of the control trees for both plantings are also given in table 1, excluding the new top growth in the current year, 1975.

Competition control following planting has been limited, largely hand-scything of larger weeds in the first 2 years and machine-mowing two or three times in subsequent seasons.

The results of the experiment were examined in terms of fifth-year survival, total height, and terminal growth (1979 leaders). Analyses of variance were performed using an angular transformation for survival percentages and plot averages for tree heights and terminal lengths. These data have been summarized in table 2. The information from the experiment pertains chiefly to (1) comparison of the two containers (polybin and Kraft bag), (2) water-dipping or dry packaging, and (3) readiness of stock for fall storage.

Results and Discussion

The planting material used in the experiment, 3+0 red pine from Midhurst Nursery (table 1), was exceptionally large ("very large" class, over 6.0 g (*1*)), although not well balanced (top heavy, the average was above the working range of 3.0 to 5.0:1 of top-root ratio by ovendry weight (*1*)). The survival and growth of the material from the better storage methods (Kraft, dry, and polybin, dry) were, however, reasonably good in comparison with the freshly lifted controls (table 2) or with general performance standards for the species in Ontario (*2*). The good performance may also be

Table 2.—*Fifth-year results of two plantings (plant 1, May 12–15; plant 2, June 2–6) of frozen overwinter-stored and freshly lifted red pine by containers (Kraft-polyethylene versus polybin), by dry or water-dipping, and by date of fall lifting*

	Plant 1 May 12–15, 1975			Plant 2 June 2–6, 1975		
	Survival	Height	Terminal length	Survival	Height	Terminal length
	%	*Cm*	*Cm*	*%*	*Cm*	*Cm*
By containers and dipping						
Kraft bag, dry	63.9ab[1]	115.6	33.0	77.1c	114.6b	33.4
Kraft bag, wet	56.7a	116.0	33.5	67.2a	112.6ab	33.0
Polybin, dry	66.5b	116.1	33.0	75.9bc	112.5ab	32.7
Polybin, wet	61.2ab	116.4	33.4	69.2ab	109.7a	32.3
Significance	***	NS[2]	NS	*	*	NS
By dates of lifting						
Lift 1, October 17	38.6a	107.9a	30.8a	63.0a	110.1	31.9a
Lift 2, October 24	71.0bc	113.1b	32.7b	77.5b	112.8	32.8ab
Lift 3, October 31	64.8b	118.7c	33.7bc	70.6b	113.4	33.5b
Lift 4, November 7	73.9c	120.7c	34.5c	78.6b	113.0	33.1ab
Plant 1 controls May 12	82.2d	119.6c	33.0b	NA[3]	NA	NA
Plant 2 controls June 2	NA	NA	NA	80.6b	113.0	32.2a
Significance	***	*	*	*	NS	*

[1] Entries in vertical columns not followed by same letter differ significantly at 5.0-percent probability level.

[2] NS = not significant.

[3] NA = not applicable.

* = significant at 5.0-percent probability level.

*** = significant at 0.1-percent probability level.

partly caused by the special handling and care received in a research program (*8*) and to the exceptionally wet weather of July, August, and September 1977. It is believed that the good performance of the late planting from June 2 to 6 is also in part caused by these two favorable factors.

Polybin versus Kraft bag. This comparison can best be made from the results of the dry treatment of both containers as summarized in table 2. There were no statistically significant differences among the six comparisons (two plantings: survival, height, terminal lengths). In terms of aggregate height (planting rate 3,000 trees/ha × survival percent/100 × average height), the Kraft bag produced 2,434 meters per hectare and the polybin 2,442 meters per hectare at 5 years. The polybin can therefore be considered as an optional container for storage and handling of red pine. It has previously been shown successful for storage of white spruce, black spruce, and jack pine (*4*).

Water-dipping. The comparison of dry and wet (water-dipping) treatments for frozen overwinter storage in both containers is also given in table 2. In only one direct comparison (of 12 possibles) was the difference statistically significant (plant 2, Kraft bag, survival), and this was in favor of dry packaging. However, combining the results of the two containers, the aggregate height for dry storage was 2,438 meters per hectare and that for wet storage was 2,168 meters per hectare. Therefore, it is obvious that water-dipping is unnecessary for red pine storage and possibly dangerous.

Time of fall lifting. A summary of aggregate height in relation to Degree–Hardening–Days (D–H–D) is presented in table 3, in which all treatments and both plantings have been averaged. These results indicate an improvement in performance with later lifting, with some variation, but with no indication that an optimum has been reached. There is, therefore, no cause or evidence to change a previous recommendation of 185° to 200° C (D–H–D) for the fall lifting of red pine at Midhurst (*3*).

Table 3.—*Fifth-year aggregate height (planting density 3,000/ha × survival percentage/100 × average height) and Degree–Hardening–Days (D–H–D) (cumulative daily differences below 10° C for soil temperature at 15-cm depth) for red pine at Midhurst, by dates of lifting*

Lift	Date	Aggregate height	Stock readiness
		M/ha	*D–H–D*
Lift 1	October 17	1,661	10
Lift 2	October 24	2,516	73
Lift 3	October 31	2,357	133
Lift 4	November 7	2,673	163
Control	(May 12, June 2)	2,835	—[1]

[1]— = not applicable.

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A Mechanical Planter for Hardwood Cuttings

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A tractor-drawn mechanical planter designed for planting hardwood cuttings is described. Detailed plans are available.

From 1980 to 1961, an average of 450,000 unrooted hardwood cuttings of poplar were produced and distributed annually by the Indian Head nursery for farm shelterbelt plantings in the three prairie provinces. During this period, rooted cuttings were produced only for nursery stooling beds or clonal tests. These rooted cuttings were produced using hand tools. However, in 1961 most shelterbelt plantings of unrooted cuttings failed because of severe drought conditions. Hence, the development of nursery planters was initiated in 1962 to produce rooted cuttings for large-scale distribution.

The first prototype planter (fig. 1), which utilized a mechanical planter or dibble, was developed in 1963. The prototype had a chisel to make a planting trench for 10-inch (25-cm) cuttings planted with 2 inches (5 cm) of the cutting above ground level, as subsequently proposed by McKnight (*4*). In addition, seats for two operators, with conveniently located, portable cutting boxes and two rubber-tired rear packing wheels, were copied from the Dunlop tree planter described by Cram (*2*). This tractor-drawn machine materially increased the speed of planting cuttings in nurseries, but cuttings were often damaged by the plunger and rooting was reduced.

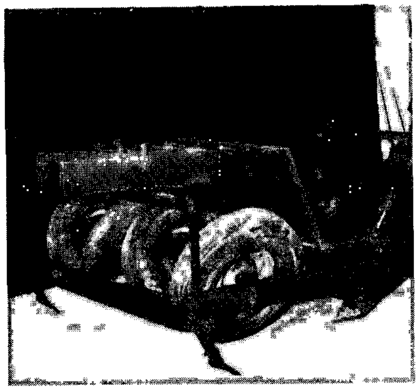

Figure 1.—*Two-row mechanical dibble cutting planter—1963.*

An original planting mechanism was designed, developed, and modified from 1964 to 1968 (fig. 2) by Harold Clarke, a nursery machinist. The basic components were two pairs of rubber-faced rollers, which were hydraulically driven to push cuttings into the chisel trench. These rollers grasp cuttings as they are released singly into a hopper chute by an operator seated above (fig. 3). Sets of springs were incorporated to maintain a uniform tension between each pair of rollers. Such springs permitted automatic expansion and contraction of paired rollers to accept cuttings with diameters varying from 0.1 to 0.8 inch (4 to 20 mm), which is necessary for planting willow and poplar cuttings. Subsequent modifications facilitated replacement of the paired rollers when the rubber facings became worn or developed grooves after planting

Figure 2.—*Hydraulic four-roller cutting planting mechanism—1964–68.*

Figure 3.—*Feeding cuttings into planting mechanisms—1967.*

200,000 or more cuttings with variable diameters.

A four-row cutting planter was developed in 1966–67 (fig. 4), based on the performance of a two-row prototype previously reported by Cram (*1*).

Improved techniques for machine planting hardwood cuttings were developed by applying results of propagation research at Indian Head from 1967 to 1970. The premature sprouting of hardwood cuttings, when heeled-in outdoors over-winter, was found to reduce rooting of late machine plantings. Refrigerated storage was reported by Cram and Lindquist (*3*) to maintain the dormancy of hardwood cuttings and provide 75-percent rooting with machine planting. However, rooting of late machine plantings was decreased by desiccation of exposed cutting tops during the prevailing hot weather of June and July. This problem was overcome by planting 6-inch cuttings, which were pushed down to ground level. In addition, weed control with postplanting herbicides was improved when the planted row area was leveled.

From 1966 to 1971, the cutting planter's packing wheels were modified to incorporate the techniques just discussed (fig. 5). The original two rubber-tired wheels were replaced by metal wheels in 1966 to increase compaction of soil around the cuttings. However, these packing wheels left a depression into which the herbicide-treated soil moved with irrigation, and weed

Figure 4.—*Four-row hardwood cutting planter—1966–67.*

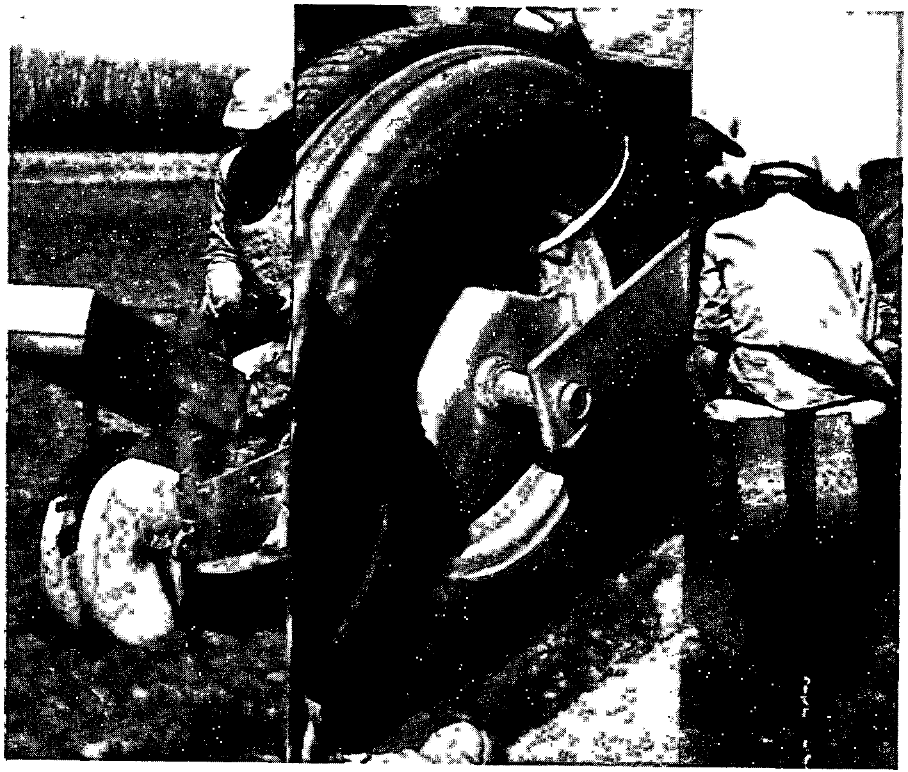

Figure 5.—*Changes in cutting planter packing wheels—1966–71.*

control was reduced. A rubber-tired packing wheel with a slotted face was developed in 1969 to push 6-inch cuttings down to ground level, but this also made a depression. Finally, in 1971, a broad metal packing wheel with a central, slotted band of rubber was fabricated. This wheel proved capable of pushing cuttings down to soil level and into firm soil at the base of the chisel trench. In addition, the wheel left a flat planted strip, which increased the efficiency of postplanting herbicides and irrigation applications.

Two four-row planters with these modifications (fig. 6) have been used since 1972 for annual plantings of 2 million poplar and willow cuttings. When drawn and powered by hydrostatic tractors with creeper gears, the cuttings may be planted at 1- to 2-inch spacings in the row. Willow cuttings, which have a smaller diameter than poplar cuttings, are planted first to reduce wear and the need for replacement of the rubber rollers on the planter.

Plans for the fabrication of this four-row planter, which were donated by Harold Clarke, are available for loan only, on a first-come, first-served basis.

Figure 6.—*Two four-row cutting planters in operation—1972.*

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Evaluation of Six Weed Control Treatments in an Interior Spruce Seed Orchard

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Black plastic provided good weed control in an interior spruce seed orchard, but this treatment was expensive. Simazine, therefore, is recommended as an effective and economical weed control method.

There are currently 54 acres of clonal interior spruce orchards (*Picea glauca*, *P. engelmanni*, or hybrids of these species) in British Columbia. This represents 8,800 ramets. Another 160 acres of interior spruce seed orchards representing 26,000 ramets are to be developed. Significant costs are incurred in parent tree selection, scion collection, rootstock production, grafting, orchard site development, and planting to establish an orchard. The genetic value and initial expense of each ramet necessitate cultural practices that insure tree survival and free growth. Weed infestations in recently established interior spruce orchards must be effectively and economically controlled.

Time of application, species, site, and possible detrimental effects are important factors to consider when developing a weed control program.

The majority of the forestry weed control literature concerns nurseries. The triazine herbicides have resulted in effective weed control in nurserybeds; however, if the herbicide accumulates in the soil, repeated applications can result in a reduction of crop growth (*10*). Weed resistance to the treatment can also develop (*9*). Glyphosate, a postemergence herbicide, is frequently used for weed control, but will injure white spruce (*Picea glauca*) when applied at the time of bud flush (*5*).

Cost factors should also be considered when evaluating weed control methods. Polyethylene mulches have been used successfully (*2, 3*), but have doubled planting-time costs (*7*). The application of simazine, a preemergence herbicide, followed, when necessary, by mechanical harrowing or the herbicide paraquat, was found to reduce costs to less than 10 percent of handweeding costs (*6*).

Handweeding has been the traditional method of weed control in the interior spruce seed orchards and breeding arboretum located at Vernon, British Columbia (lat. 50°14', long. 119°17'). Assuming 10 minutes of labor per tree at an hourly rate of $10.22, the unit cost of weeding a tree is $1.70. Handweeding thousands of trees at least twice during the growing season is costly. Adoption of more economical methods of weed control, rather than complete reliance on handweeding, is required.

The objective of this study was to determine an economical and efficient method of weed control. This study compares the effectiveness of mulch and herbicide weed control treatments in an interior spruce seed orchard located at Vernon.

Methods

On July 8, 1981, six weed control treatments and a control were replicated six times in a completely randomized design. The treatments, consisting of fresh coniferous sawdust, fresh coniferous chips, white polyethylene plastic (.08 in thick), black polyethylene plastic (.16 in thick), glyphosate (Roundup), simazine (Princep 80 w), and a control, were applied in a 16-square-foot area around recently planted 4-year-old interior spruce ramets.

Handweeding was done before treatment application with the exception of the glyphosate plots. Glyphosate was applied at a rate of 1.1 pounds of active ingredient (ai) per acre. During glyphosate application, each tree was covered with a plastic bag to eliminate foliar contact with the herbicide. Simazine was sprayed onto the soil surface at a rate of 2.0 pounds of active ingredient per acre. The plastic mulches were anchored to the soil with wire. The sawdust and wood chips were applied to a depth of 2.0 inches.

On September 3, 1981, the plots were assessed for material and labor costs, seedling tolerance to the treatment, broadleaf weed control, grass control, and the percentage of weed encroachment on the plots.

Seedling tolerance, broadleaf weed control, and grass control were assessed using the rating

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[1] The author is indebted to Mr. J. Konishi and Ms. W. Bergerud of the British Columbia Ministry of Forests for their assistance.

system adopted by the Western Canadian Expert Committee on Weeds (*1*). The rating system consists of 0–9 scale, where 9 indicates complete crop tolerance to the weed control treatment or complete weed control and 0 indicates complete kill or no effect. The data were analyzed by the Kruskal-Wallis test to determine if significant differences among treatments exist and were compared by the simultaneous test procedure to determine what treatments differed (*8*).

Air temperature during the experiment averaged 75.2° F, reaching an extreme of 97.7° F, and precipitation averaged 1.4 inches per month. To insure ramet survival, the trees were watered eight times at a rate of 1.3 to 2.4 gallons per application.

The soil was classified as a black solonetz clay in the Spallumcheen series (*4*). Soil characteristics were relatively uniform among the plots.

Results and Discussion

Black plastic provided the most effective weed control, while the white plastic treatment had the poorest weed control (table 1). Light penetrated the white plastic resulting in a greenhouse effect and stimulated weed growth. Glyphosate killed the weeds present on contact, but new weeds appeared within a month. Simazine provided excellent broadleaf and grass weed control for the duration of the experiment. The weeds present at evaluation in this treatment were perennials apparently from roots not removed by handweeding. The sawdust and wood chip mulches provided fair weed control with some perennial weeds growing through the mulch. None of the treatments caused any toxicity to the trees.

Table 1.—*The effect and comparative costs of mulching and chemical treatments for weed control*

Treatment	Broadleaf weed control[1]	Grass control[1]	Percentage of weed encroachment[2]	Cost of treatments per plot
				Dollars
Black plastic	8.3a[3]	9.0a	0.2a	2.51
Simazine (2.0 lb ai/acs)	7.3ab	8.8ab	8.5b	.86
Sawdust	6.7abc	8.7ab	10.8b	.85
Glyphosate (1.1 lb ai/acs)	6.5abc	7.3ab	22.5b	.87
Wood chips	5.5bc	9.0a	26.7bc	.85
White plastic	4.5c	5.8b	46.7c	1.91
Control	0d	0c	3.3bc	0

[1] 0 = no effect, 9 = complete control (based on Western Canadian Expert Committee on Weeds rating system).

[2] Expressed as (area with weeds in treatment/total area of treatment X 100.

[3] Values in columns by the same letter indicate no significant difference at the 0.05 probability level based on a non-parametric multiple comparison by the simultaneous test procedures (STP) method.

The most common weeds in the plot area were broadleaf weeds. In order of importance (frequency and size) they were Canadian thistle (*Cirsium arvense*), ground ivy (*Glechoma hederacea*), red root pigweed (*Amaranthus retroflexus*), and field bindweed (*Convolvulus arvensis*).

Labor time was the main component of the cost figures (table 1). On an operational basis, the cost per plot would be considerably lower for the herbicide treatments. Assuming that one application of herbicide will result in satisfactory weed control during one growing season, the black plastic would have to withstand weather conditions for at least 3 years to be economically desirable.

With the exception of black plastic, the percentage of weed encroachment was the lowest using simazine (table 1). Therefore, based on a single-year trial, simazine is recommended as an effective and economical herbicide at the orchard site. Continued evaluation of its efficiency and safety will be carried out. Minimum rates should be applied with careful monitoring of weed control and effect on orchard tree vigor. The weathering of the black plastic is being evaluated, and if the plastic lasts for at least 3 years, it may be considered for use.

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Weed Control for Better Black Walnut on Strip Mines[1]

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Weed control substantially improved establishment and early growth of seeded black walnut on fescue-covered spoil banks. The use of herbicides was more effective than cultivation. Roundup applied for 2 years was the most effective overall.

The Eastern Interior Coal Province has great potential for black walnut plantations on surface-mined land, particularly where little or not grading was done (*1*). These soils are typically deep and well drained and aerated and often calcareous—factors associated with excellent walnut sites (*7*). Inconsistent early results from walnut plantings on mined lands held back interest in the use of walnut in forestation; however, the nature and extent of site preparation often adversely affected these results (*3, 6*).

Current reclamation standards require immediate establishment of a permanent vegetative cover for erosion control following reclamation. Tree seedlings must then be planted into and compete successfully with an often dense cover of grasses and/or legumes. Therefore, the potential for maximum survival and early growth of trees planted on mined sites is not achieved.

The importance of controlling competing vegetation in forestation has been well documented by Forest Service researchers and others (*2, 4, 5*). Competition for moisture, nutrients, and light and allelopathic interference by grasses and other established vegetation (*9, 11*) can severely reduce the potential survival and growth of planted tree seedlings. Competition from herbaceous vegetation may be especially detrimental to seedling establishment under present reclamation practices on surface-mined land. We initiated a study in May 1980 to evaluate the effects of chemical and mechanical weed control on the establishment and growth of seeded black walnut on surface-mined land.

Study Area and Methods

Our study area on Sahara Coal Company, Inc., property in Saline County, Ill. was mined in the 1960's. The predominant soil texture was clay loam with appreciable amounts of partially weathered rock. The pH ranged from neutral to medium acid with a few spots being very strongly acid. The tops of the spoil banks had been "struck-off" to a minimum width of 5 meters. Subsequent seeding and development of a mixture of grasses and legumes resulted in a dense vegetative cover primarily of tall fescue, orchard grass, and bromegrass. Previous failures of hardwood plantings established by our research group had suggested that the dense herbaceous vegetation was a limiting factor on this site.

Our experiment consisted of six treatments: (1) control—existing vegetation left intact, (2) hand cultivation—vegetation removed with a mattock at time of planting, (3) Roundup (1 yr)—one application following planting, (4) Roundup and Princep (1 yr)—one application following planting, (5) Roundup (2 yr)—one application after planting and a second the following spring, and (6) Roundup and Princep (2 yr)—one application after planting and a second the following spring.

Eight replicates of each of the six treatments were randomly located in rows within a 0.2-hectare study plot. Each replicate consisted of six planting spots at a 2.5- by 2.5-meter spacing. Two locally collected black walnut seeds were planted per spot using a mattock. Cultivation or herbicide treatments were applied to a 1.5-meters diameter area at each planting spot. The contact herbicide Roundup (41-percent glyphosate) and the residual preemergent herbicide Princep (80-percent simazine) were sprayed at the rates of 9.4 liters per hectare (1 gal/acre) and 5.6 kilograms per hectare (5 lb/acre), respectively, with 940 liters per hectare (100 gal/acre) water. Planting and first-year weed control treatments took place in May 1980. The Roundup (2 yr) and Roundup and Princep (2 yr) follow-up herbicide applications were made in April 1981. Care was taken to avoid spraying established seed-

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[1] Research supported by Sahara Coal Co., Inc., Harrisburg, Ill.

lings. Seedlings were thinned to one per spot in July 1981.

Initial establishment and growth data were collected in October 1980, 4 months after planting (*8*). In September 1981, after 15 months, seedling establishment, height, and diameter data were collected. The 1981 evaluation also included a visual estimate of the percentage of ground cover for the 1.5-meter-diameter area at each planting spot. One-way analysis of variance was performed on all data. Treatment means were compared with Duncan's multiple range test.

Results and Discussion

The establishment of seeded black walnut on the mined sites was significantly improved when cultivation or herbicides were used, with no apparent difference between the weed control treatments after 4 months (*8*). Hand cultivation of weeds and one application of Roundup or Roundup and Princep resulted in a three-fold increase in the number of live seedlings compared to the control treatment. Germination and survival of the untreated control walnuts were apparently inhibited by competition and/or allelopathic interference from the established vegetation present. Seedling establishment, generally poor in all treatments, may reflect the low seeding rate, late planting date, and an unusually droughty summer experienced in 1980.

Data summaries of degree of ground cover and black walnut seedling establishment and growth after 15 months of this site showed significant differences between treatment means for all the tested variables (table 1).

The number of established walnut seedlings changed markedly by the end of the the second growing season. This change reflected the resprouting of seedlings that had died back before the first-season survival counts and seed germination in the second season after planting, both common for black walnut (*10*). Abundant rainfall in the spring and summer of 1981 contributed to these increases in establishment.

Greatest seedling establishment rates were obtained when Roundup alone was applied for either 1 or 2 years. Establishment was not as good when Princep was included in the herbicide mix. The residual nature of this herbicide apparently had an inhibitory effect on black walnut germination and resprouting. A lower application rate for Princep may give adequate weed control and better establishment.

The number of seedlings in the hand cultivation treatment decreased by the second measurement. Removal of surrounding vegetation exposed seedlings and soils to winter and summer extremes. Dead plant residues, which were left as a mulch were herbicides were applied, may substantially benefit seedling survival. The control treatment still had the poorest walnut establishment, but had made a considerable increase over the first-year results. Adequate soil moisture in the second growing

Table 1.—*Establishment and growth of seeded black walnut and ground cover on strike-off spoils after two growing seasons*

Treatment	Seedling establishment	Stem height	Stem diameter	Ground cover
	%	*Cm*	*Mm*	*%*
Control	19a[1]	25.7a	5.3a	47a
Hand cultivation	23a	24.8a	7.4ab	18c
Roundup (1 yr)	46bc	30.6a	7.1a	23bc
Roundup and Princep (1 yr)	29ab	44.3b	10.3bc	24b
Round (2 yr)	50c	48.3b	12.5c	9d
Roundup and Princep (2 yr)	38abc	41.9b	12.7c	2e

[1] Means with the same letter in the column are not significantly different at the 0.05 level according to Duncan's multiple range test.

season apparently lessened competition with fescue and other grasses on the site.

Height growth of black walnut seedlings on the reclaimed land was significantly greater with two successive Roundup applications or when Princep was included in the mix than it was in the control, hand cultivation, and Roundup (1 yr) treatments. The latter two treatments provided only short-term weed elimination and subsequent walnut growth was no greater than for the control seedlings. Similar results were obtained for stem diameter.

Ground cover of the herbaceous vegetation after two growing seasons corresponded closely to the number of seasons that weed control was administered. The best weed control was obtained when the Roundup and Princep mixture or Roundup was applied for 2 years.

Conclusions

Good early growth of seeded black walnut can be achieved on partially graded surface-mined lands.

Weed control is important in successful establishment and early growth on densely vegetated spoil banks. Chemical control of ground cover proved more effective than hand cultivation in promoting walnut seedling establishment.

Roundup applied once was ineffective in controlling ground cover or enhancing walnut growth. Application for 2 years resulted in good weed control and walnut growth. Inclusion of the residual herbicide Princep with Roundup resulted in good weed control and walnut growth, but appeared to inhibit germination and establishment.

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Time Between Application of Bayleton and Irrigation Not Critical for Fusiform Rust Control

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Rainfall or irrigation that occurs 5 or more minutes after a Bayleton foliar spray will not reduce the efficacy of the fungicide for control of fusiform rust in pine seedlings.

Fusiform rust (caused by *Cronartium quercuum* (Berk.) Miyabe ex Shirai f. sp. *fusiforme*) is the most important forest nursery disease in the Southeastern United States. Losses in unsprayed pine beds in southern nurseries averaged 9.8 percent from 1972 to 1976 (*7*). Rust incidence as high as 81 percent was observed in unsprayed slash pine at the Davisboro, Ga., nursery in 1973 (*7*). Ferbam, applied as a foliar spray, has been the standard treatment for control of fusiform rust since 1951 (*1*), but annual losses in ferbam-sprayed beds in Georgia and north Florida averaged 2.5 percent during 18 consecutive years of observations (*3, 7*). Ferbam, a fungicide with only protective qualities, will control fusiform rust when all susceptible pine tissues are covered during infection periods (*1, 4, 5, 7*). The protective and systemic fungicide Bayleton (triadimefon; 1-(4-chlorophenoxy)-3, 3-dimethyl-1-(1H-1,2,4-triazol-1-yl)-2-butanone) controlled fusiform rust with as few as three or four foliar sprays per year or as a soil drench applied 7 days before inoculation (*2, 6, 8*). Disease incidence was also reduced when it was used as a seed treatment (*6, 8*). Because of the dual activity of Bayleton, coverage of susceptible pine tissue may not be as critical for control of fusiform rust as is the case with ferbam. However, rain or irrigation before spray residues dry may reduce the efficacy of the fungicide (*5*).

This paper reports the results of a greenhouse study in which the efficacy of Bayleton sprays was determined in relation to the time interval between spray application and irrigation.

Methods

Twenty 2- to 4-day-old slash pine seedlings were transplanted into each of 40 flats (33 by 13 by 11 cm) containing a sandy loam-sand-vermiculite soil mix (2:1:1 by volume). All seedlings were fertilized 2 weeks, 2 months, and 5 months after transplanting with Miracle-Gro, a commercially available liquid fertilizer.[1] During the fifth week after emergence, 35 flats were sprayed with a solution containing 600 milligrams (active ingredient) of Bayleton and 2.5 milliliters of Agri-dex[2] surfactant per liter at the rate of 8 milliliters per flat (282 liters/ha, 184 gallons/acre). Following application of the foliar spray, five replicate flats were allowed to dry 0.25, 1, 5, 15, 30, 60, and 120 minutes before 6.4 millimeters (0.25 inch) of simulated rain were applied in a rain chamber equipped with a cone Raindrop nozzle[3] that delivered 26 millimeters (1 inch) of simulated rain each 45 minutes. Two hours later, all seedlings, including five flats of nonsprayed (check) seedlings, were inoculated with the fusiform rust fungus (47,500 basidiospores/ml). Aeciospores collected in 1974 from loblolly pine galls from Clarke County, Ga., were used to produce the basidiospore inoculum on northern red oak seedlings. The percentage of seedlings infected (galled) was determined 10 months after inoculation.

Results and Discussion

The incidence of fusiform rust averaged 86.8 percent in control seedlings 10 months after inoculation (table 1).

Table 1.—*Effect of Bayleton spray on fusiform rust infection of slash pine given different time periods between spraying and irrigation*

Time to irrigation after spray	Seedlings infected
Minutes	*%*
Nonsprayed check	86.8a[1]
0.25	1.2b
1	1.2b
5	.0c
15	.0c
30	.0c
60	.0c
120	.0c

[1] Means followed by a common letter do not differ ($P = 0.05$) according to Duncan's multiple range test.

Disease incidence was markedly reduced by the Bayleton foliar spray regardless of the interval between treatment and application of

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[1] Stern's Nurseries, Inc., Geneva, NY.
[2] Helena Chemical Co., Memphis, TN.
[3] Manufactured by Delavan-Delta, Inc., Lexington, TN.

simulated rain. The degree of control (only 1.2 percent infected) in seedlings irrigated 15 seconds after the Bayleton spray was applied is remarkable since the spray was not dry at that time, and some of the spray residue surely was washed off seedling foliage.

Irrigation or simulated rain applied at the same rate used in this study drastically reduced the efficacy of ferbam foliar sprays even when the application was made 60 minutes after seedlings were sprayed (*5*). Thus, equal quantities of Bayleton and ferbam were theoretically washed from surfaces of the pine seedlings. But, because of the systemic nature of Bayleton, the quantity of fungicide left on susceptible seedling tissues together with the quantity absorbed by the seedlings was sufficient for control of the disease. These results suggest that the time between application of Bayleton foliar sprays and irrigation or rain is not nearly as critical for fusiform rust control as it is when ferbam sprays are applied (*5*).

Greater quantities of irrigation or rain than the 6.4 millimeters used in this study would, theoretically, remove greater quantities of fungicide residues from foliar surfaces (*4*) and eventually nullify the effectiveness of Bayleton if such quantities were applied (or fell) before sufficient fungicide was absorbed by the seedling. Irrigation, therefore, should not be applied too soon (<60 seconds) after a foliar spray and, theoretically, the efficacy of such a spray would be further improved if spray residues were allowed to dry before irrigation or rain.

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Loss of Feeder Roots Lowers Seedling Survival More Than Severe Black Root Rot

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Loblolly pine seedlings with 50 or 75 percent of their feeder roots excised suffered greater mortality than did those with severe black root rot.

The etiology of black root rot of slash pine (*Pinus elliottii* Engelm.) and loblolly pine (*P. taeda* L.) is complex and may involve any of several soilborne pathogens. *Macrophomina phaseolina* (Tassi) Goid. (*Sclerotium bataticola* Taub.) and *Fusarium oxysporum* Schlecht. emend. Snyd. & Hans. are most commonly associated with the disease (*4*). However, *F. solani* (Mart.) Appl. & Wr. emend. Snyd. & Hans., *Rhizoctonia solani* Kühn, *Pythium* spp., *Phytophthora* spp., and certain parasitic nematodes may also be involved in this disease complex (*2, 3, 5, 6, 7, 8, 9*).

Black root rot is one of the most important diseases in southern forest tree nurseries (*1, 8*), and it can also cause subsequent problems in outplantings. This was made evident by complaints of landowners that the majority of seedlings purchased from the Andrews State Nursery near Chiefland, Fla., died during each of several successive years. This prompted a State agency to condemn seedlings, quarantine the nursery, and order the destruction of 16.5 million diseased seedlings.

In the winter of 1976, several Florida landowners and State agencies, Southeastern Area State and Private Forestry of the Forest Service, and I joined in a cooperative effort to determine the rate of survival of the most and least severely affected seedlings from this one Florida nursery; results of this study will be published later. However, in a previous and as yet unpublished study, seedlings affected with black root rot were graded into several root rot severity classes and outplanted in an attempt to correlate disease severity in the nursery to field survival (Foster, A. A., personal communication). Significant mortality occurred only where root rot was so severe that only a blackened taproot with few, if any, lateral roots remained. My involvement in the 1976 cooperative study in Florida and knowledge of A. A. Foster's unpublished data led me to establish a study in 1978 to determine if the severity of black root rot or the loss of feeder roots by any cause was more important to seedling survival. In this study, I compared the rate of survival of seedlings with differing degrees of black root rot with that of seedlings with little root rot but with 50 or 75 percent of their feeder roots removed.

Methods

Slash pine seedlings were lifted from one Georgia nursery and loblolly pine seedlings were lifted from five nurseries in Georgia and one in Alabama during January 1978. All seedlings were lifted by hand except those with little or no root rot (average seedlings) from the Continental Forest Industries and Great Southern Nurseries, which were machine lifted. Seedlings were lifted from areas where few, if any, root rot symptoms were visible and from areas with appreciable amounts of root rot in four of the same nurseries. The amount of root rot present was assessed by determining an index of root rot severity. The root systems of 25 randomly selected seedlings from each seedbed area from each nursery were examined under a dissecting microscope. The following data were recorded for each seedling: the number of primary and secondary roots, number of primary and secondary roots with one or more root rot lesions, length of primary and secondary roots, and the length of root rot lesions. The root rot index was calculated as the percentage of primary and secondary root length with lesions.

Seedlings with little or no root rot from four of the five Georgia nurseries (table 1) were subdivided into three groups; and, with the aid of a pocketknife, 50 or 75 percent of the feeder roots were excised from seedlings in each of two of the three groups. All seedlings were outplanted in January 1978 on a deep sand (Lakeland series) in Georgia. The seedlings were planted in a randomized complete block design with five replications. The study included 19 treatments, and each treatment replicate was a 25-tree row planted at a 5- by 8-foot spacing. Initial height measurements were made in February 1978 and the first-year survival and growth increment data were recorded in

February 1979. Correlation analyses were computed between root rot severity and growth increment, between disease severity and field survival, and between percentage of feeder roots removed and field survival. Individual analyses of variance were computed for (1) the average seedlings with little or no root rot; (2) the root rot and average loblolly seedlings from the Herty, Great Southern, Continental Forest Industries, and Hauss Nurseries; and (3) all loblolly seedlings (average, root rot, 50 percent, and 75 percent) from the Herty, Morgan, Great Southern, and Continental Forest Industries Nurseries (table 1). The error mean square of each of these analyses was used to perform Duncan's multiple range test (table 1).

Table 1.—*Percentage of mortality of mechanically injured and black root rot affected (1–0) pine seedlings 12 months after planting on a deep sand in Georgia in January 1978*

Species and nursery source	Average seedlings	Root rot seedlings	Seedlings with feeder roots reduced	
			50%	75%
Loblolly pine				
Herty, Ga.	13.6aAB[1]	3.2aA	29.6aBC	48.0aC
Morgan, Ga.	52.0bcA	—[2]	66.4bA	70.4bA
Great Southern, Ga.	41.6bcA	31.2bA	70.4bB	76.8bB
Cont. For. Ind., Ga.	80.0dB	53.6cA	96.0cB	94.4cB
Hauss, Ala.	42.4bcA	69.6cB	—	—
Walker, Ga.	54.4c	—	—	—
Slash pine				
Morgan, Ga.	38.4b	—	—	—

[1] Means within the same column followed by a common lower-case letter and means within the same row followed by a common capital letter do not differ at $P = 0.05$ according to Duncan's multiple range test.

[2] — = not applicable or not available.

Results and Discussion

Although black root rot was severe on seedlings from the Hauss, Continental Forest Industries, and Great Southern Nurseries, root rot increased mortality only in seedlings from the Hauss Nursery (table 1). On the other hand, removal of feeder roots significantly increased mortality of seedlings from the Herty and Great Southern Nurseries (table 1). Seedling quality, as measured by the number of feeder roots, is a most important attribute of pine seedlings and was significantly correlated with field survival ($r = 0.57$). Root rot severity, on the other hand, was not correlated with field survival ($r = 0.36$). Because feeder roots are often destroyed or lost during routine lifting operations, this nursery practice, whether done by hand or machine, deserves very careful attention so that the number of feeder roots retained on planting stock is at the practical maximum. The high mortality of seedlings from the Continental Forest Industries Nursery with little root rot (average seedlings) compared to the lower mortality of seedlings with severe root rot (tables 1 and 2) was possibly caused by the loss of feeder roots during mechanical lifting operations. Numbers of feeder roots were not counted in this study, but the seedlings affected with root rot had noticeably more feeder roots than the average seedlings.

Except for seedlings from the Herty Nursery, seedling mortality was high regardless of root rot severity or nursery source (table 1). Seedlings from the Herty Nursery were grown at low seedbed densities and had more lateral and feeder roots than seedlings from the other nurseries. The high mortality was augmented by the deep sand on which the seedlings were planted and the severe drought during the summer of 1978. Slash pine seedlings, which may be better ecologically adapted to droughty sites, survived significantly better than loblolly seedlings from the same nursery source (tables 1 and 2).

Growth increment, 1 year after outplanting, was not correlated with root rot severity or rate of seedling survival (table 2). However, because growth increment and rate of survival increased numerically together (table 2), these two parameters may become significantly correlated in some later year.

Table 2.—*Relationship between black root rot severity, growth, and mortality 12 months after planting of pine seedlings on a deep sand in Georgia in January 1978*

Species and nursery source	Root rot severity index	Mortality	Growth increment[1]
Slash pine		%	*Cm*
Morgan, Ga.	0.2	38.4cde[2]	40.8
Loblolly pine			
Morgan, Ga.	.2	52.0eg	26.9
Walker, Ga.	2.3	54.4efg	24.8
Great Southern, Ga.	6.0	41.6cde	35.7
Cont. For. Ind., Ga.	6.0	80.0hi	31.6
Herty, Ga.	8.0	13.6ab	37.3
Herty, Ga.	28.5	3.2a	45.9
Hauss, Ala.	38.4	42.4cde	35.3
Cont. For. Ind., Ga.	39.0	53.6efg	32.0
Hauss, Ala.	66.4	69.6fgh	32.6
Great Southern, Ga.	86.2	31.2bcd	44.6

[1] There was no difference ($P = 0.05$) in growth increment due to nursery source or root rot severity according to Fisher's *F* test.

[2] Means followed by a common letter do not differ at $P = 0.05$ according to Duncan's multiple range test.

The results of this study indicate that root rot, mechanical injury, or any other agent that reduces the number of feeder roots on seedlings at any time before outplanting may substantially decrease field survival. Similarly, a meaningful index of root rot severity must reflect the relative number of feeder roots if the index is to be correlated with the field performance of seedlings.

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Impact of *Gremmeniella Abietina* in a Jack Pine Plantation

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Infection by the fungus Gremmeniella abietina *in a new jack pine plantation increased rapidly during the first 9 years, but tree mortality and main stem damage were negligible.*

Red pine (*Pinus resinosa* Ait.) and jack pine (*P. banksiana* Lamb.) are the two species most often suitable for plantation establishment on sandy sites between approximately 44° N. latitude and the northern climatic limit of each species. Severity of the disease, known as scleroderris canker and caused by the fungus *Gremmeniella abietina*, (Lagerb.) Morelet, is strongly influenced by climate and site (*2*). Restriction of the North American race of *C. abietina* to areas north of approximately 44° N. latitude is often attributed to the pathogen's inability to grow at higher temperatures, but there is no specific proof for this claim. On the other hand, the pathogen definitely needs liquid water to produce infective spores, to disseminate the spores to new host trees, and to infect those trees (*7, 8*). The North American race of *C. abietina*, the only race known in Canada west of Quebec, infects pine tissues within 2 meters of the ground. This "safe height" is generally accepted (though probably conservative) as the point at which disease control operations, such as sanitation (*3*), are no longer required, except where it is desirable to reduce the amount of the pathogen in an area to protect newly planted stock nearby. Conversely, the European race of the fungus, which is currently found east of Ontario in Canada and in the Northeastern United States, kills tissues of various conifers at any height above the ground (*9*).

Earlier reports (*1, 4*) indicated that jack pine is less seriously damaged than red pine under the same conditions. This report outlines 9 years of observations in a 250,000-tree jack pine plantation, which replaced a red pine plantation that had suffered over 95-percent mortality as a consequence of a *Gremmeniella abietina* epidemic.

Procedures

In a 31-hectare red pine plantation near Searchmont, Ont. (46°20′ N., 84°00′ W.), adjacent to Perry Creek, more than 95 percent of the trees were killed by *G. abietina*; and the few that survived were stunted, deformed, and often cankered (fig. 1). In 1972, the area was replanted with 2+0 jack pine at 2- by 2-meter spacing. The average height of 50 randomly selected dominant trees exceeded 4 meters by the fall of 1981. Trees on this plain are subjected to severe climatic stresses

Figure 1.—*Stunted, deformed, and often cankered red pine survivors of a* Gremmeniella abietina *epidemic.*

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[1] The authors are grateful to Mr. Fred Janser, Ontario Ministry of Natural Resources, Sault Ste. Marie, Ontario, for assistance during the course of this work.

such as frequent droughts and an annual temperature range of approximately 80° C (−43° C to +38° C recorded (*2*), and freezing temperatures are encountered annually both in late spring and in early autumn.

An experimental block of 6.5 hectares occupying the southern end of the plantation was selected. Infected residual red pines were removed from the experimental area to reduce the intensive infection sources within the plantation. Most of the infections discussed here occurred when spores of *G. abietina* were blown into the experimental block.

Fifteen strip plots of one row each, three rows apart and 600 meters long, were marked with stakes at 50-meter intervals in the spring of 1973, 1 year after planting. Seedlings thereon were recorded as living or dead and with or without symptoms of infection by *G. abietina* (*3*). Beginning in 1979, the number of trees with clearly discernible basal stem cankers was recorded as well. A canker was defined as depressed area on the lower stem with or without dead bark and possibly with resin exudate and apothecia or pycnidia (spore-producing organs) of *G. abietina*. These are interpreted, through experience, as incipient chronic cankers, but with the understanding that cankers resulting from infection by *G. abietina* and by the rust fungus *Cronartium comptoniae* Arth. occasionally resemble one another at this stage of development. Recognizable rust infections, most of which produced distinctive spores, were recorded on 5 percent of the seedlings the year after planting; these infections were probably carried in from the nursery. Trees recorded as dead were deleted from future records, a factor that explains what appears to be an increase over time in the percentage of healthy trees (table 1).

In total, 33.3 percent of the experimental area or 15 percent of the plantation proper, was examined annually, tree by tree. Examinations were continued for 9 years, by which time most of the surviving trees were more than 2 meters high and impending canopy closure made it difficult to differentiate branches undergoing natural pruning from those dying from infection by *G. abietina*.

Results and Conclusions

Basal stem cankers as long as 1.5 meters are found on red pine in *G. abietina* infection areas (*5*). Such prominent cankers have not yet been reported from older jack pine although cankers up to 0.5 meter long are routinely observed in younger plantations (fig. 2). *Gremmeniella abietina* was disseminated widely on the primary host, red pine, during the 1950's when postwar replant operations

Table 1.—*Impact of* Gremmeniella abietina *on 37,500 trees of a 250,000-tree jack pine plantation during the first 9 years after planting*[1]

	Tallied trees				
Year	Living, without *G. abietina* symptoms	Living, with *G. abietina* symptoms	Dead, with *G. abietina* symptoms	Dead from unknown causes	Living, with stem cankers[1,2]
	%				
1973	80.7	<0.1	0	19.3	0
1974	94.2	1.9	.0	3.9	0
1975	85.8	13.1	.5	.7	0
1976	84.8	13.7	.7	.9	0
1977	75.8	23.4	.8	.1	0
1978	30.7	69.1	.1	.1	0
1979	29.8	67.6	2.6	.1	12.5
1980	3.4	95.2	1.0	.4	17.9
1981	—[3]	—[3]	1.1	.3	15.6

[1] Dead trees were recorded once only, and this accounts for the apparent increase in percentage of trees living and exhibiting no symptoms of *G. abietina* infection, and the apparent decrease in live trees with stem cankers.

[2] 1979 was the first year in which stem cankers were reliably discernible on living trees without dissecting the stems.

[3] Data are lacking for 1981 as it was no longer possible to record the cause of tree branch mortality dependably because of partial crown closure.

***Figure 2.**—Basal cankers caused by* Gremmeniella abietina *on stems of, left to right: a 14-year-old red pine, a 14-year-old jack pine, and a 24-year-old red pine.*

reached their peak. The more resistant jack pine would then have been infected through natural spread of the pathogen. Future examinations will reveal whether the relatively small cankers now seen on young jack pine become covered or "heal" or continue to elongate as is the case with red pine (fig. 2).

Jack pine mortality as a consequence of infection by *G. abietina* is still within tolerable limits (table 1). Examination of other heavily infected jack pine plantations bearing trees twice the age of those described here leads us to believe that future mortality in the Perry Creek plantation will be slight. Although the percentage of trees infected is quite high, mortality has leveled off (table 1) and is confined mainly to trees badly damaged during the first few years after planting.

Individual case studies in forest pathology are not ordinarily regarded too seriously because of the pronounced differences in the effects of site and climate on disease development in various areas. In the present case, however, the climatic extremes characteristic of the plantation area are such that we can regard this as an area of extreme environmental stress in which trees would be maximally predisposed to infection and damage by the pathogen. The fungus, by contrast, grows prolifically in the lowermost portions of the tree where snow cover is usually sufficient to prevent temperatures from dropping below the minimum for *G. abietina* growth (*2*). Therefore, as damage to jack pine was slight (table 1), we might consider this species to have a relatively high field resistance to damage by *G. abietina*.

Earlier work by Mullin (*6*) showed the growth potential of jack pine to be superior to that of red pine on these poorer northern sites. There is little doubt that jack pine is to be preferred to red pine in northern Great Lakes reforestation work where the threat from *G. abietina* is pronounced and where it is difficult to correct problems with preexisting infections through sanitation work.

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Stratification of Sugar Maple Seeds

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Sugar maple seeds collected from 10 trees in northwestern Vermont were stratified at 1° to 3° C for up to 13 weeks. Results indicate that this method is unsatisfactory for obtaining rapid, maximum germination after stratification.

Experience in the nursery has shown that fall sowing usually results in nearly complete germination of sugar maple seeds (*4*). If fall sowing is not feasible or fails, spring sowing must be used; but there must be some means of breaking dormancy before sowing.

Olson and Gabriel (*9*) recommended pretreatment of 1° to 5° C for 40 to 90 days. Heit (*6*) stratified sugar maple seeds in moist peat moss at 2° to 4° C and at 10° to 15° C and buried seeds in the ground for 5 months. Of those that had been stratified at 2° to 4° C, 95 percent germinated during the 3 months of stratification. Germination occurred after 4 months of stratification at 10° to 15° C, but the percentage was less than that at the lower temperature. The buried seeds also germinated during stratification and could not be sown successfully.

From the results of his experiment, Heit (*6*) recommended that spring-sown seeds be stratified for 50 to 75 days at 2° to 4° C. But we found that when we stratified sugar maple seeds at 1° to 3° C, some seeds germinated after approximately 30 days, while others in the same sample required up to 90 days for germination (*3*).

Because the optimum stratification period for spring sowing was still in doubt, this study was done to determine the length of stratification necessary to obtain 80-percent germination, preferably within 2 weeks after stratification.

Methods

The experiment was conducted over a period of 2 years. During the first year, samaras were collected from 10 sugar maple trees in northwestern Vermont. We knew that seedlots from different sugar maple trees germinate at different rates. However, we wanted to determine an average stratification time so we could make a general recommendation. Therefore, we combined the samaras into one lot.

We air-dried the samaras to 10 to 15-percent moisture content. At 13 weekly intervals, beginning in February, we placed 30 replicates of samaras (100 samaras per replicate) in plastic germination boxes on shelves in a walk-in cooler at 1° to 3° C. We made germination counts and removed the germinated seeds weekly after the first 30 days of stratification. After 13 weeks, all of the boxes that still contained samaras were removed from the cooler and placed on nurserybeds beneath shade-cloth in the Forest Service nursery in Essex Junction, Vt. It was felt that the fluctuating nursery temperature would complement the stratification already received, thus increasing germination. Also placed in the nursery were an additional 30 boxes, each containing 100 samaras. We continued the counting until germination ceased and then opened the remaining samaras and counted the ungerminated seeds. Germination percentages were based on the total number of seeds.

On the basis of the first-year results, we decided to repeat the experiment with some modifications. Because the second-year samara crop was generally poorer than in the previous year, we collected samaras from only 5 of the original 10 trees.

We reduced the number of stratification periods to correspond to those periods that gave the best results in the first test. Beginning in March, and weekly thereafter for the next 5 weeks, 10 replicates of 100 samaras each were removed from storage and stratified at 1° to 3° C. The final set of 10 replicates was stratified in April, making a total of six stratification periods. We removed the stratified samaras from the cooler in May, giving us a range of 3 to 8 weeks for the six stratification periods. However, the samaras were kept at 16° C instead of being placed in the nursery. The germinated seeds were counted and the germination percentages were calculated as in the previous year.

Results

The results of the second-year germination tests for the 3 to 8 weeks of stratification were compared with the same periods in the first-year tests; we used a paired *t*-test. There were no significant differences in the germination patterns between the 2 years, so we combined the data for those six stratification periods for analysis. Table 1 shows the percentage of germination during stratification and during the first 2 weeks after stratification, the total germination after stratification, and the total. It should be noted that while most of the germination after stratification occurred during the first 2 weeks, it was strung out over several weeks.

Seeds stratified for 3 to 8 weeks failed to germinate satisfactorily after being removed from stratification and placed in a warm temperature. Total germination increased as the length of stratification increased (table 1). However, most of this increase in total germination was because of the increase in the germination that occurred during the stratification period. Germination after stratification increased until the fifth week. It declined slightly during the sixth and seventh weeks and then dropped sharply. The percentage of germination after stratification was greatest for the 5-week stratification period (37 percent), but the total germination for the same period was only 44 percent. Total germination was greatest for 8 weeks of stratification (77 percent), but germination after stratification was only 24 percent. None of these results were satisfactory; that is, germination did not reach 80 percent during the first 2 weeks after stratification.

Table 1.—*Germination results for the 2 years of testing*

	Germination			
Length of stratification	During stratification	During first 2 weeks after stratification	Total after stratification	Total
Weeks	%			
3	0.0	2.9	5.0	5.0
4	.2	14.4	18.6	18.8
5	6.9	28.3	37.2	44.1
6	18.7	26.8	35.0	53.7
7	34.8	26.8	32.0	66.8
8	52.8	20.8	24.4	77.2

Discussion

The subject of dormancy has been discussed by many (*1, 2, 5, 8, 10*). However, only Amen (*1*) defined dormancy. Dormancy, according to Amen, is an endogenously controlled and/or environmentally imposed temporary suspension of growth and reduced metabolic activity independent of the immediate environment. But even Amen admitted that his definition is inadequate to distinguish various forms of growth cessation.

The factors controlling dormancy are varied, but fall into a few major groups: (1) rudimentary embryos, (2) physiologically immature embryos, (3) mechanical resistance of the structures enclosing the embryos, (4) impermeable seed coats, (5) presence of germination inhibitors, (6) absence of germination promoters, or (7) a combination of the foregoing. According to Jones (*7*), sugar maple has a dormant, morphologically mature embryo. This would rule out the first two factors, and the structures enclosing the embryo offer little resistance to germination. Part of the reason for dormancy of sugar maple seeds, as indicated in an experiment by Webb and Dumbroff (*11*) is a restriction of water uptake by the testa. They theorized that this restriction complements a metabolic block in the embryo. But the cause of this metabolic block is unknown. It is broken by a period of low temperature and a moist medium.

Although stratification of sugar maple seeds at 1° to 3° C broke dormancy, none of the stratification periods yielded the desired result; that is, at least 80 percent germination within the first 2 weeks after stratification. The maximum percentage of germination after stratification was 37, and the total was only 44 percent, far from what is obtainable from fall sowing. It is therefore obvious that some approach other than simple stratification at a low temperature is necessary to overcome the dormancy of sugar maple seeds for satisfactory spring sowing.

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Ethylene: A Problem in Seedling Storage?

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Root regeneration of loblolly pine seedlings increased during 42 days in cold storage when an ethylene-specific chemisorbent was added to the bags in which the seedlings were stored. Field survival also increased. There was no effect on seedling height through three growing seasons.

Ethylene has long been recognized as a significant factor in the storage behavior of many plants and fruits in the horticultural and fruit industry (*1*). In amounts as low as a few hundred parts per billion, ethylene can reduce plant vigor, contribute to senescence of various plant parts, and reduce stock quality. Dormant nursery fruit stock is damaged if stored in an atmosphere containing ethylene (*3*). Plant tissues, as well as ripening fruit, produce ethylene (*5, 6*). Mechanical injury increases this production (*4*), so it can be assumed that lifting nursery seedlings results in some ethylene being produced by the roots. The sensitivity of plants to ethylene varies, and we have little information available on how sensitive pine seedlings may be to ethylene during storage.

In this study, an ethylene absorbent was placed in storage bags of loblolly pine seedlings, and the influence of this chemical on root regeneration and field survival and growth was examined.

Methods

Loblolly pine seedlings grown at the Columbia Nursery of the Louisiana Office of Forestry were lifted on January 4, 1979, and separated to provide for three replications of treatment variables. Treatments consisted of 21 and 42 days of storage with and without ethylene absorbent. The absorbent was composed of potassium permanganate absorbed on an alumina (Purafil ES), which oxidizes ethylene to water and carbon dioxide (*2*). Although Purafil ES is described as "ethylene specific," it also controls other contaminants such as hydrogen sulfide and nitric or sulfuric acid, which can adversely affect live plants. Purafil ES is packaged for several applications. In this study, two small sachets (24 grams each) were placed in polyethylene bags that contained about 50 seedlings. The sachets were stapled inside the bag so that they would not be in contact with water. Such contact could reduce the effectiveness of ethylene absorption.

After 21 and 42 days of seedling storage at 34° and 36° F, five seedlings per treatment replication were potted in sand and placed in a growth chamber for evaluation of root regeneration potential. The growth chamber was programed for constant 75° F temperatures and 18-hour photoperiods of 1,500 footcandles. After 4 weeks in the growth chamber, sand was washed from the seedling roots, and the number of new roots per seedling was counted. This number was then used as an estimate of root regeneration potential.

Another 25 seedlings from each treatment replication were outplanted on a silt loam soil. Survival and heights were measured in the dormant season 1 and 3 years later.

The data were statistically analyzed following a completely randomized design. The 0.05 probability level was used to determine significance in root regeneration potential. The 0.10 probability level was used for statistical tests of field measurements because greater variation was anticipated in the field data.

Results and Discussion

The addition of Purafil ES sachets to bags containing loblolly pine seedlings had no effect on root regeneration potential after 21 days of storage. But after 42 days, seedlings with the ethylene absorbent produced significantly more new roots (table 1). Bags with two sachets enclosed had an average of 149 new roots after 1 month; bags without sachets averaged only 85 new roots.

Seedling survival through three growing seasons was unaffected by length of storage, but seedlings from storage bags that contained Purafil ES averaged 6 percent greater survival than the control (table 1). Seedling heights were not affected by either length or type of seedling storage.

Table 1.—*Root regeneration potential, survival, and heights of loblolly pine seedlings lifted from nurserybeds and stored in polyethylene bags with and without Purafil ES[1] media*

Treatment	Application	Stored 3 weeks			Stored 6 weeks		
		RRP[2]	Survival	Height	RRP	Survival	Height
		No. of new roots	*%*	*Ft.*	*No. of new roots*	*%*	*Ft.*
Control	1	163	92	5.4	80	84	4.8
	2	133	76	4.8	90	80	4.3
	3	120	88	4.5	84	84	4.9
Average		139a[3]	85b	4.8a	85b	83b	4.7a
Purafil ES media	1	125	92	4.8	158	88	5.2
	2	106	92	4.3	143	88	4.8
	3	159	88	5.2	147	92	4.5
Average		130a	91a	4.8a	149a	89a	4.9a

[1] Purafil ES is the trade name of the ethylene absorbent.

[2] RRP = root regeneration potential, which is the number of new roots per seedling after 1 month under controlled conditions.

[3] Means within columns followed by the same letter are not significantly different at the 0.05 probability level for RRP and at the 0.10 probability level for field measurements. Survival and heights reported are those measured after 3 years in the field.

Though no direct measurements of ethylene were made in this study, the improvement in seedling root regeneration and survival with the addition of an ethylene absorbent suggests that ethylene is produced in lifting pine seedlings. If so, this ethylene production may also be at least partly responsible for rapid deterioration of seedlings in storage.

Recommendations

The results from this preliminary study are positive enough to justify further study. Additional studies should better identify the responses of pine seedlings to different concentrations of ethylene and the cost effectiveness of adding ethylene absorbents to sealed storage bags or to coldstorage facilities if seedlings are stored in bales. Filter systems are available that could absorb ethylene produced in storage rooms. These evaluations should be made in terms of improved survival and growth in the field.

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Influence of Interstock on Flowering and Growth of Loblolly Pine Grafts

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Scions from five dwarf and four normal, vigorous trees were used as clonal interstocks for loblolly pine grafts. Interstock affected growth and flowering substantially, but the effects were not related to the vigor of the tree providing the interstocks.

Growth and flowering of grafted Southern pines can be strongly influenced by the origin of the rootstock on which they are grafted (*3, 4*). This is true for rootstocks of different species, as well as for full- or half-sib families of the same species. Using clonal rootstocks would allow the best control of rootstock variation, but most pine species are difficult to propagate from cuttings. Clonal interstocks, where a short segment of stem is grafted between the rootstock and the scion, have been effectively used in fruit trees for controlling size and enhancing fruit production for many years (*2*). Recent work has indicated that using an interstock from a genetically dwarfed tree may control the size of loblolly pine (*Pinus taeda* L.) grafts (*1*).

In the research reported here, the effect of interstocks from dwarf and normal trees on growth and flowering of loblolly pine grafts was studied.

Materials and Methods

Scions from six loblolly clones, one Sonderegger (natural hybrid between loblolly and longleaf (*P. palustris* Mill.) pines) clone, and two shortleaf (*P. echinata* Mill.) clones were first grafted onto bulk loblolly rootstocks in 1969. In 1970, scions from two loblolly clones were grafted on top of these grafts in all possible combinations of scion clone and interstock. More than 200 grafts were made originally, but after mortality, only 75 remained for outplanting in the fall of 1970.

The interstock clones were chosen from 15-year-old experimental plantings. Two of the loblolly clones were extremely slow-growing, abnormal-looking dwarfs. The other four clones were extremely vigorous, ranking in the top 2 or 3 percent for height growth in the planting. The Sonderegger and the two shortleaf clones were also dwarfs.

Male and female strobili were counted yearly; heights and diameters were measured at 3, 7, 9, and 11 years. Ramets showing signs of incompatibility, such as scion overgrowth or yellowing, were considered nonsurvivors. In the fall of 1978 and 1979, a five-cone sample was collected from each study tree. Seeds were extracted and full seeds were separated from empties by ethanol flotation and then weighed. Differences in means were tested by

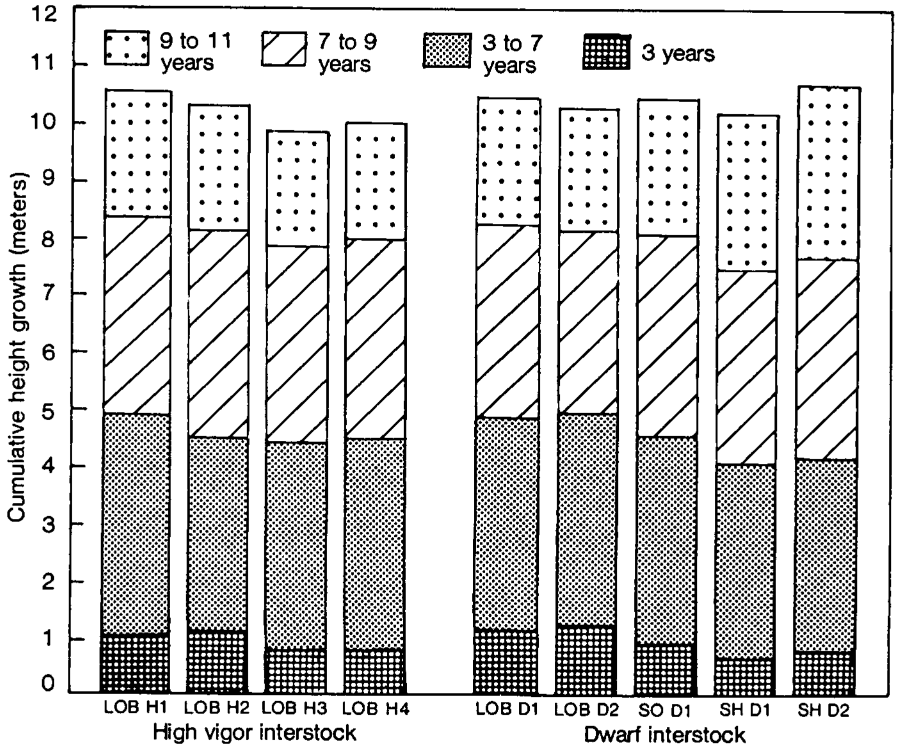

Figure 1.—*Cumulative height growth of interstocks up to 11 years of age.*

analysis of variance at the 0.05 level of probability.

The experimental planting was maintained in seed orchard fashion; that is, mowed yearly and fertilized every other year. Furadan was applied in February of 1978 and 1979 to control seed and cone insects.

Results and Discussion

Initially, grafts on two of the dwarfing interstocks, shortleaf D_1 and D_2, grew much more slowly than the other grafts, averaging only one-half meter in height after 3 years (fig. 1). This apparent dwarfing effect disappeared with time. Grafts on these two interstocks averaged the same as the other grafts, about 10.2 meters after 11 years (fig. 1). Growth of the grafts on the other three dwarf interstocks was comparable with growth of the grafts on high-vigor interstocks; all averaged about 1 meter tall at 3 years. Differences in height among interstocks were statistically significant at 11 years, but they did not vary according to the vigor of the ortets used for interstock.

Diameter at breast height (d.b.h.) of the grafts also differed significantly by interstock, ranging from 19.8 to 22.5 centimeters (table 1), but was not less for dwarf interstock grafts.

Flowering was significantly affected by interstock (table 1). Interstocks were as effective, or even more effective, in causing variation in flowering than the rootstocks used in previous studies (*4*).

Table 1.—*Flowering and growth of loblolly scions grafted on interstocks from high vigor and dwarf trees*

Interstock	D.b.h. at 11 years	Female flowering, 6-year average	Male flowering, 6-year average
	Cm	*Cm*	
High vigor			
Loblolly H1	21.4bc[1]	61.8c	127.3b
Loblolly H2	20.5abc	77.5c	122.1b
Loblolly H3	20.4ab	.1a	66.4a
Loblolly H4	22.5c	67.3c	98.8ab
Average	21.1	62.7	103.6
Dwarf			
Loblolly D1	21.2abc	59.7bc	116.5b
Loblolly D2	20.8abc	.5c	105.8ab
Sonderegger	21.9bc	.0c	163.9b
Shortleaf D1	19.8a	48.1ab	63.8a
Shortleaf D2	20.2ab	38.8a	59.9a
Average	20.8	55.2	102.0

[1] Means followed by the same letter are not significantly different according to Duncan's multiple range test.

Average male flowering ranged from 63.8 flowers for the poorest (shortleaf D_2) to 163.9 for the best (Sonderegger) interstock. Average female flowering did not vary as much as male flowering, ranging from 38.8 strobili per ramet on shortleaf D_2 to 77.5 strobili per ramet on loblolly H_2.

In male and female flowering, variation within loblolly interstocks was as important as variation among species of interstock. No greater variation was induced by using shortleaf or Sonderegger interstocks than was obtained by simply using different loblolly clones for interstock. Thus, interspersing even a small (20- to 40-cm) piece of stem of a foreign genotype affects flowering in loblolly pines, as it does in many fruit trees.

Interstock did not affect cone and seed yields.

Conclusions

Interstocks can have substantial effects on flowering and growth, but their use in orchards would be limited by the time and expense of grafting twice. In any case, there does not seem to be any certain way of predicting the performance of an interstock short of actual testing. Previous vigor of the ortet used for interstock was no indicator of growth or flowering of the grafted ramet in this experiment.

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Douglas-Fir Planting Stock Performance Comparison After the Third Growing Season

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Three different types of containerized and bare-root Douglas-fir seedlings planted on north- and south-slope sites in Oregon are compared. Containerized seedlings exhibited superior survival rates on all sites, good height performance on the harsh south exposure, and considerably lower reforestation costs.

Millions of various types of bare-root and containerized nursery-grown Douglas-fir seedlings (*Pseudotsuga menziessi* (Mirb.) Franco) are planted annually in routine reforestation in the Pacific Northwest. Various types of bare-root seedlings have been used for this purpose for decades, while the use of containerized seedlings is relatively new.

This experiment provided some answers relating to the performance of the "new" containerized seedlings as produced by Georgia-Pacific Corporation in Oregon. Performance of the containerized seedlings was also compared to that of some bare-root seedlings. Comparisons were made of survival rates, height growth, and reforestation costs on two extremely exposured sites.

Materials and Methods

Location. The two sites chosen for the experiment are located at latitude 40° N. and longitude 122°45′ W. near Eugene, Oreg. The sites represent two extreme reforestation conditions. One is a dry and warm south slope considered fairly harsh for Douglas-fir. The other is a more favorable (moist and cooler) site. Each site presents a special reforestation problem. The south slope provides a summer moisture stress, while the north slope generates severe vegetation competition for the newly planted seedlings.

Both the north and south exposure test units were located in clearcut areas, which were logged in 1978. The test plots were in regular reforestation units that did not receive land preparation or protection treatments. The test areas are in a 1,900-millimeter annual precipitation zone. There are no marked differences in precipitation between the sites. The soil series are Peavine on the north slope and Honeygrove on the south.

Seeds and seedlings. The seeds used to produce all the seedlings were from a commercial seedlot. This seedlot matched the seed and elevation zone of the experimental area. The different seedling types were initiated in various years and nurseries; therefore, they greatly varied in age and size at planting time. The containerized seedlings were produced by Georgia-Pacific Corporation in a shelterhouse growing facility in the three most commonly used polystyrene (styroblock) containers. The shelterhouses provide unique growing conditions for seedling production in this area. The houses are equipped with automatically controlled heaters and vents. Therefore, they promote rapid germination and seedling development during the spring. Later, the same facility converts into a nearly natural growing area to aid seedling growth.

The shelterhouse facility interacts well with the styroblock containers. The insulating capacity of the containers protects the roots against heat in the summer and against frost during fall and winter. The containers also provide a good means for hardening and chilling the seedlings, while maintaining an active root system during the dormant season.

The containerized seedlings used in this experiment were produced in the three most commonly used block cavity sizes. These are the 40-cubic-centimeter cavity size (type 2 containers), the 75-cubic-centimeter size (type 5 containers), and the 125-cubic-centimeter size (type 8 containers). The sizes of the produced seedlings are usually very closely linked to the container cavity sizes; the larger the cavity, the larger the seedling. The seedlings were initiated during the early spring of 1978 and were reared for one growing season with the growing regime routinely used.

The plug-1 stock was also initiated in the Georgia-Pacific container nursery facility 1 year earlier in 1977. Type 2 containers were used for the plug production. The seedlings were grown in the containers for one growing season and were transplanted to the bare-root nursery in late summer of the same year. Here, they were reared for another year to develop a stronger top and large fibrous root mass, which is typical for plug-1 seedlings.

The 3–0 stock was initiated in the Industrial Forestry Association's (I.F.A.) bare-root nursery in 1976. These seedlings stayed in the same seedling bed for 3 years before they were outplanted.

The 2–1 stock was also initiated in the I.F.A. nursery in 1976 as 2–0 stock. After the second growing season, they were lifted and transplanted for another year for added stem and root growth.

Design and layout. Both north and south exposure planting sites contain replicated parallel rows of 50 trees for each seedling type. Each seedling type is replicated four times on each site except the 2–1 seedlings. These are replicated only twice. The tree rows are located 2 meters apart, and the distance between seedlings is 1.5 meters. Each planting site contained 1,100 seedlings at planting time for a total of 2,200 seedlings for the entire experiment. The entire experiment was installed in February 1979, considered a favorable time in the region for field planting all the seedling types involved.

Measurements

The initial height measurements for each seedling type were taken immediately after planting and are shown in table 1 and figure 2. This initial measurement showed a great deal of variation in average height among seedling types because of their age difference and the way they were produced. At first glance, it would appear that this comparison is unfair. But it was assumed that each seedling type, regardless of original height differences, would have a built-in ability to compete based on how they were produced. The ability of a seedling type to survive and to grow well while overcoming brush competition and other adverse conditions is of paramount importance and is manifested by superior overall performance. (See the survival and height increment performance in table 1.)

During each measurement period, survival and height growth data were routinely collected. Each, in itself, is a good measure for evaluating seedling performance. However, if the two results are multiplied, a single, total performance factor is produced. This factor provides a more comprehensive measure for comparing seedling performance, especially when other factors like cost are also related to performance.

Results

Seedling survival after the third growing season was generally good on both sites (table 1). Only the initially tall 3–0 seedlings showed relatively poor performance on both sites, especially on the south exposure (65%). The plug-1 seedlings survived well on the north exposure (89%), but more poorly on the south exposure (80%). The 2–1 seedlings did relatively well on both exposures (north 86%, and south 92%). Overall, however, the containerized seedlings had the highest survival rate on each exposure, especially on the "harsh" south exposure (type 2—north 89%, south 94%; type 5—north 92%, south 97%; type 8—north 93%, south 97%). Survival results in graphic form are shown in figure 1.

It appears that the survival rates of the initially smaller containerized seedlings are superior because of their root characteristics and physiological makeup. They were also able to combat planting shock considerably better during the establishment phase than the larger and older bare-root seedling types were.

Height growth. During height measurements, restrictions on height growth such as animal damage to seedlings and vegetation competition were also monitored. Animal damage on both areas was considerably less than normal in freshly planted areas. In general, the damage that did occur was the heaviest on the south-facing slope—about twice the rate of the north-facing slope. Bare-root seedlings were definitely more heavily and frequently browsed than containerized seedlings. Again, the ratio was about two to one. The overall height growth reduction due to browsing was not serious on either exposure or for any seedling type. On the average, it was not more

Table 1.—*Seedling type survival and growth increment comparison on the north and south exposure test sites*

Exposure and seedling types	Average height/tree: Original ht. (2/79)	Average height/tree: Present ht. (12/81)	Survival rate (12/81)	Growth increment/average tree
	Cm	*Cm*	*%*	*%*
North slope				
2–1 (bare-root)	46	135	86	193
3–0 (bare-root)	59	109	80	85
P–1 (bare-root)	36	108	89	200
Average[1]	49	111	84	127
Type 2 (container)	17	74	89	335
Type 5 (container)	22	82	92	273
Type 8 (container)	33	96	93	191
Average	24	84	91	250
South slope				
2–1 (bare-root)	48	97	92	102
3–0 (bare-root)	61	102	65	67
P–1 (bare-root)	38	106	80	179
Average	50	103	74	106
Type 2 (container)	17	95	94	459
Type 5 (container)	25	100	97	300
Type 8 (container)	33	112	97	239
Average	25	103	96	312

[1] Each average represents 200 trees except for 2–1 averages, which represent 100 trees.

than 1 centimeter per tree for any seedling type.

It appears that vegetative competition on the "moist" north slope may have had a significant influence on height growth. This is expressed by the relatively poor height performance of the initially smaller containerized seedlings.

Third-year height growth measurements indicate that the tall 3–0 seedlings did not maintain their original height superiority on either site. Tall 2–1 seedlings, however, performed well on the north-facing slope, while their performance on the south slope was considerably poorer. The plug-1 seedlings had reasonably good height performance on both slopes. Height growth performance of containerized seedlings was proportional to their cavity size; the smallest cavity size produced the smallest tree and the largest cavity size, the largest tree. Their height growth performance was considerably behind that of the bare-root seedlings on the north slope. Performance of containerized seedlings matched that of bare-root seedlings on the south slope, despite their initial height disadvantage.

Total performance. The combined seedling performance (average height of surviving seedlings multiplied by the survival rate) was calculated for each seedling type (fig. 2). A combined bare-root and containerized seedling total performance was also calculated (fig. 3).

Figure 2 (north) shows the initial average height of each seedling type. The curves indicate that the initial height difference pattern was maintained fairly well until the end of the third growing season by each seedling type except the 3–0 seedlings. The drop in the 3–0 seedling performance is mainly because of their poorer survival rate. In figure 2 (south), the total performance of the

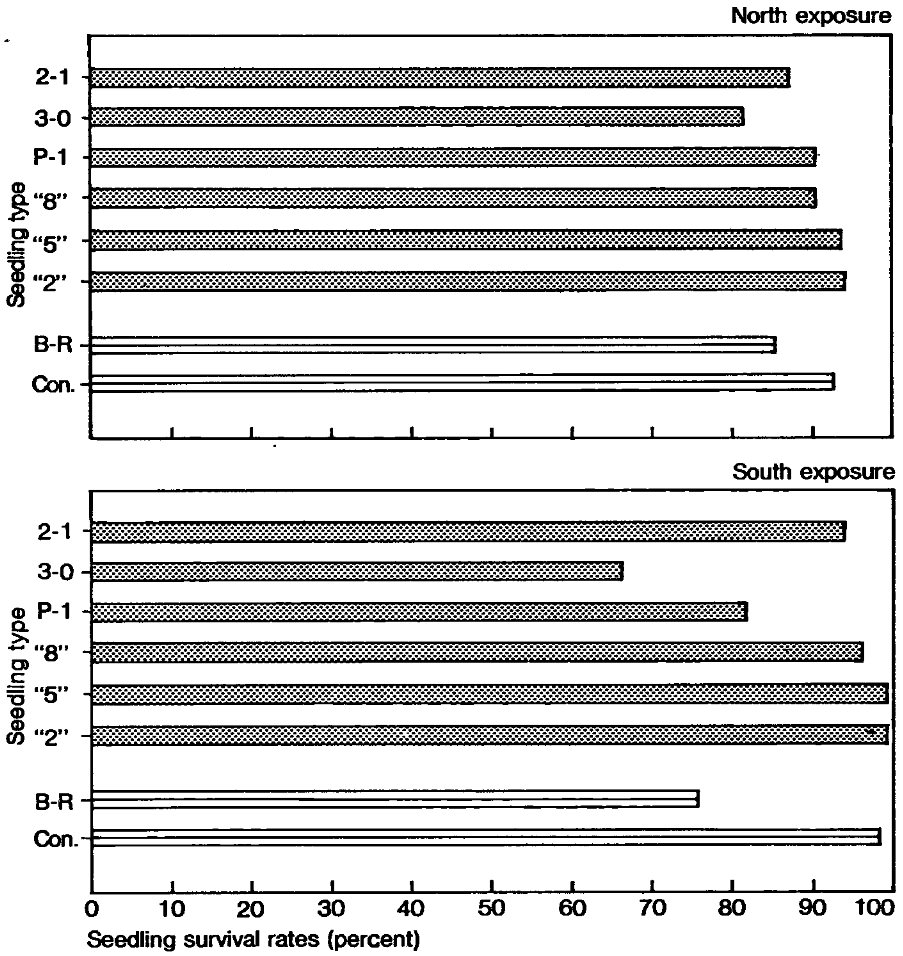

Figure 1.—*Survival rates of the various types of planting stock.*

initially tallest 3–0 seedlings dropped even further, while the other two bare-root types fell behind all three containerized seedling types.

Combined containerized and bare-root seedling performance comparisons (fig. 3 (north)) show superior performance for the initially taller bare-root seedlings, but the difference is being slowly closed by the containerized seedlings.

Figure 3 (south) shows a complete domination in total performance by the initially smaller containerized seedlings. These differences, on both exposures, were statistically significant at the 0.05 level.

Cost comparison. Commercial, large-scale reforestation cost figures for each seedling type were used to predict stand establishment costs based on the results of this experiment. A cost/benefit ratio for each seedling type was calculated by dividing the cost per thousand for planting each seedling type by the total performance of each type.

The result of this calculation showed a straight-line correlation in cost/benefit for containerized seedlings on each planting site. The cost of reforestation for the type 2 seedlings was the lowest, but so was the performance; while the type 8 seedlings represented the other end of the scale. The total variation among the containerized seedlings in cost/benefit ratio was about plus or minus 2 percent.

The cost/total performance or cost/benefit ratio varied greatly for the bare-root seedlings. Since the 3–0 seedlings showed the lowest performance rate among the bare-root group, they became the most expensive reforestation stock in spite of their initial lower cost. The seedling cost/total performance benefit ratio for each bare-root seedling type is compared to the containerized seedling cost/total performance benefit ratio in figure 4. The combined figure for bare-root seedlings indicates that the cost of using them is about twice the cost of using containerized seedlings on the south-facing slope. This difference drops to 25 percent on the north exposure.

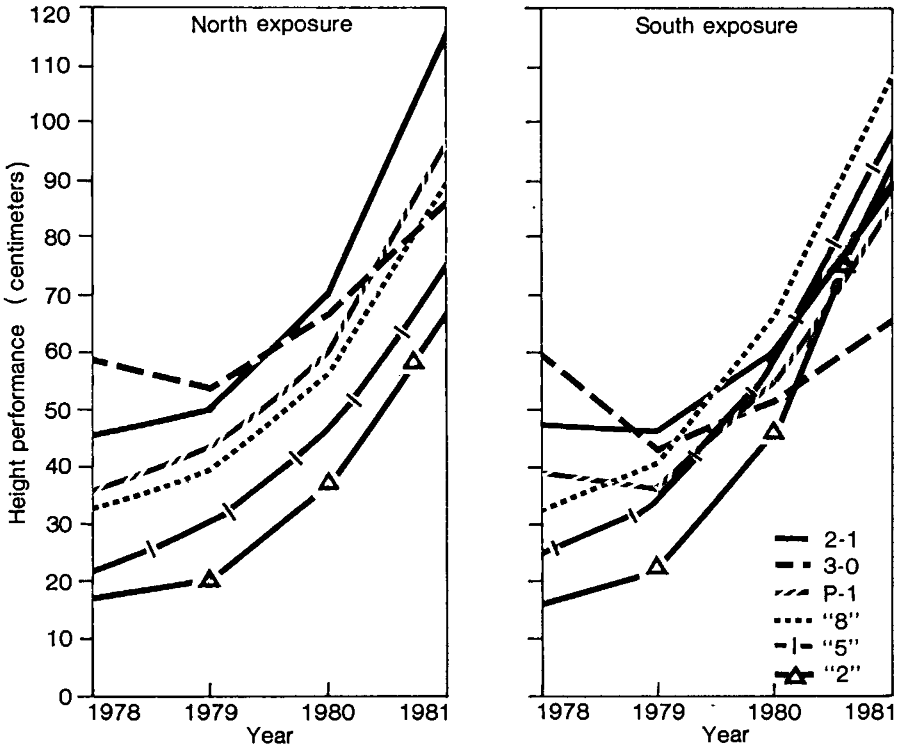

Figure 2.—*Total (average height × survival rate) performance comparison of the various seedling types.*

Conclusion

The 3-year test results of this experiment are indicative of the performance of the six chosen seedling types. The same seedling types were used in general reforestation on Georgia-Pacific land when this experiment was installed. Each of the two test sites represents a large acreage of the company's reforestation land either on the coastal and north-slope, cooler, "wet" sites or on the south-slope, warmer, "dry" sites.

In the final analysis, it was found that the three bare-root seedling types followed a similar trend within each site, but performed quite differently when compared between sites. Similar trends were also observed for the containerized seedling types.

The originally taller bare-root seedling types showed a clear performance superiority on the north slopes (or cooler "wet" sites). On such sites, the "top-heavy" seedlings were not exposed to rapid drying after planting. Consequently, they were not subjected to typical dry-site planting shock, which results is lower survival rates and height growth. Under these conditions, the tall bare-root seedlings were able to stay above the brush and maintain good height growth. The adverse south-slope effect on survival and height growth for the tall bare-root seedlings was well documented (fig. 3). Here the performance trend was exactly opposite the north-slope trend.

Containerized seedlings performance turned out to be quite different. Containerized seedlings maintained higher survival rates on both sides than bare-root seedlings did. This is thought to be because of superior root quality and physiological makeup. Short containerized seedlings had a hard time growing up through north-slope brush. They apparently overcame this handicap on the south slope (figs. 2 and 3).

The observed growth trends are experienced in the company's large-scale reforestation program when seedling performance on relatively "wet" and "dry" sites is compared. The company's coastal areas in the Toledo division definitely show better reforestation results with large bare-root seedlings. On the other hand, containerized seedlings perform better on drier sites near Coos Bay and Eugene, Oreg.

Cost/benefit ratios favor containerized seedlings on all sites. The difference in cost/benefit ratio is not large between plug-1 transplants and containers on the "wet" sites,

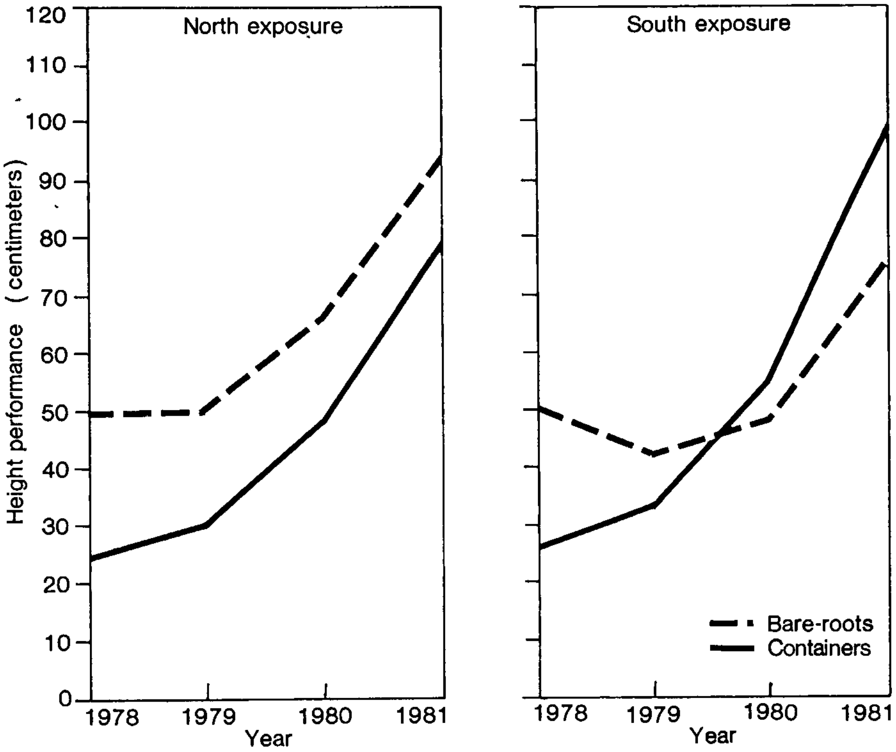

Figure 3.—*Total (average height × survival rate) performance comparison for combined container and combined bare-root stocks.*

and plug-1 transplant use can be justified on such sites.

As a rule of thumb for company lands, we recommend that well-developed, hardy, type 5 containerized seedlings be planted on all sites except on north-facing slopes and "wet" coastal areas (where brush competition becomes severe shortly after planting). Well-developed containerized seedlings survive, grow fairly well, and provide a better cost/benefit ratio on all sites. They do very well on drier sites.

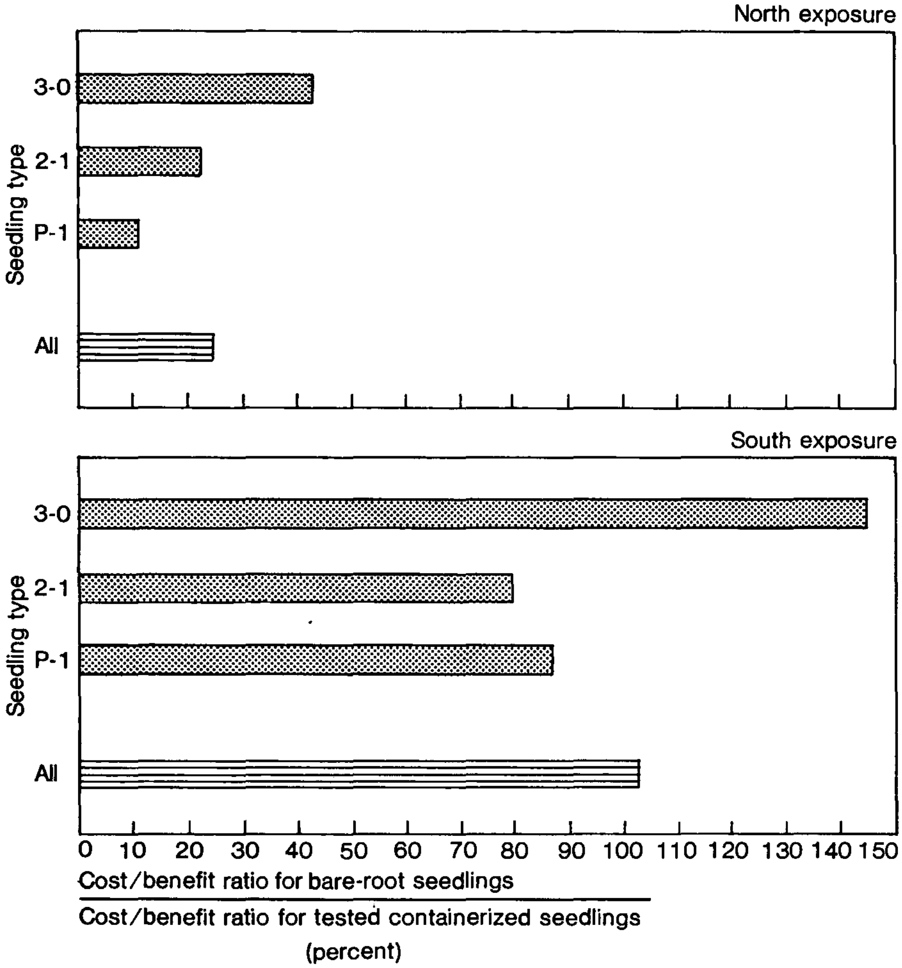

Figure 4.—*Relative seedling cost/total performance benefit for the various types of bare-root seedlings compared to the seedling cost/total performance benefit of all of the containerized seedlings. (Containerized seedling cost/benefit = 0%.)*

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