Refrigerated Storage for Hardwood Cuttings of Willow and Poplar

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When machine-planted in late spring, fall-and spring-harvested cuttings rooted as well after refrigerated storage at 24 ° F as those heeled-in over the winter.

Nurseries in the northern plains region have traditionally stored hardwood cuttings outdoors for spring planting by "heeling-in" at the time of fall harvest. However, these cuttings frequently break dormancy and begin to grow when planting is delayed. As a result, such cuttings not only root poorly, but are also difficult to handle with mechanical planters (*2*) developed for large-scale planting of cuttings.

Hocking and Nyland (*3*) reported extensive studies on refrigerated storage for conifer seedlings, but similar information is lacking for hardwood cuttings. In an exploratory test, the rooting of willow and poplar cuttings was, on the average, superior for those heeled-in overwinter. Polyethylene coverings improved the rooting of cuttings for all clones when refrigerated over the winter. Rooting of poly-covered cuttings for one poplar clone after overwinter storage at 0° F equaled that of those heeled-in, while rooting for some clones after 24° and 35° F storage equaled that for 0° F storage. This paper reports results of a study on overwinter storage of hardwood cuttings for late spring plantings.

Materials and Methods

Fall-harvested cuttings of two willow and two poplar clones were stored overwinter at three temperatures, then planted with spring-harvested and heeled-in cuttings.

Shoots from "stooling beds" were collected and cut into 8-inch (20 cm) lengths on November 1,1967; but in order to provide uniform material, only the two median cuttings from each shoot were used. These were tied in bundles of 25 and stored outdoors by heeling-in or indoors at 0°, 24°, and 35° F (-18°, -4°, and 2° C) in sealed poly-lined bins. Additional cuttings were harvested on Apri11, 1968, and stored in sealed polyethylene bags at 24° F. The heeled-in cuttings were also lifted and similarly stored the same day.

All cuttings were field planted with a four-row planter (*2*) on May 24,1968. The planting was a randomized block design with 25 cuttings of each storage treatment per plot, replicated five times for each clone. An overall spray of linuron herbicide was immediately applied for weed control and incorporated by 1 inch (2.5 cm) of irrigation. During the subsequent growing season, 6.3 inches (16 cm) of rainfall were recorded and 6.5 inches (16.5 cm) of irrigation were applied as required to promote rooting.

Moisture content of cuttings was determined at harvest time in the fall and spring and at time of planting after the five storage treatments. Moisture content was calculated as a percentage of the dry weight from eight samples of cuttings from each treatment, with the results listed in table 1.

The number of planted cuttings that manifested top growth was recorded for each storage and clone at 10 weekly intervals from June 10 to August 23. From these records, the rate of top growth was calculated to evaluate the effects of storage treatments on top growth of cuttings and the relationship of top growth to rooting.

All cuttings were lifted on October 2 and the number with roots was recorded for each storage treatment. The rooting capacity was then calculated as a percentage of the cuttings planted for each treatment and clone, as listed in table 2. Percentage data for moisture and rooting were transformed for analysis of variance to determine the significance of mean differences, but are reported as percentages in the tables.

Results and Discussion

Moisture content of poplar cuttings was, at time of harvest and after five storage treatments (table 1), some 30 percent greater than for willow cuttings. Moisture content was consistently lowest for the spring-stored cuttings and significantly higher for heeled-in cuttings of all clones.

Rooting capacity of hardwood cuttings after five storage treatments (table 2) was significantly different

Table 1.—*Moisture content[1] of hardwood cuttings of two willow and two porflar clones (means for eight samples)*

Storage treatments		Clones				Storage treatment means
		Poplar		Willow		
Harvest time	Temperature	Northwest	Tristis	Basford	Laurel	
	°F	%	%	%	%	%
Spring	24	101a[2]	94a	69a	70a	84
Fall	0	103b	96a	73b	77c	87
Fall	24	1060	99ab	75bc	73b	88
Fall	35	103b	104b	76bc	77c	90
Fall	Heel-in[3]	152d	142c	104d	114d	128

[1] Moisture content as a percentage of the dry weight after ovendrylng for 24 hours at 100' C.
[2] Means within a column followed by a common letter are not significantly different at the 5-percent level.
[3] Heeled-In cuttings lifted April 1 and stored at 24° F until planted.

Table 2.—*Rooting capacity[1] for hardwood cuttings of two willow and two poplar clones after five storage treatments for fall and spring harvests (means for five replications of 25 cuttings)*

Storage treatments		Clones				Storage treatment means
		Poplar		Willow		
Harvest time	Temperature	Northwest	Tristis	Basford	Laurel	
	°F	%	%	%	%	%
Spring	0	56a[2]	60b	19a	13a	37a
Fall	35	61a	38a	53b	59b	53a
Fall	24	65a	65b	66bc	42b	60abc
Fall	24	65a	82b	74cd	39b	65bc
Fall	Heel-in[3]	68a	76b	86d	84c	78c

[1] Fall-rooted cuttings as a percentage of the spring plantings.
[2] Means within a column followed by a common letter are not significantly different at the 5-percent level.
[3] Cuttlngs heeled-In outdoors over the winter were lifted April 1 and stored at 24' F until planted May 24.

for clones and species. On the average, the rooting of cuttings after overwinter storage was highest (78%) for those heeled-in and significantly lower (37%) for refrigerated storage at 0° F. Although rooting for both willow clones (Basford and Laurel) was significantly reduced by storage at 0° F, rooting was greatest (86% and 84%) after heeling-in. However, rooting for Basford willow was not better after heeling-in than after 24° F storage. On the other hand, rooting for Tristis poplar was significantly reduced by storage at *35*° F, whereas that for Northwest poplar was not significantly different for any storage treatment. Rooting of spring-harvested cuttings was, on the average, mediocre (60%) for willow and poplar and not significantly different from that for overwinter storage at 24° or 35° F.

These rooting results for machine planting of poplar cuttings after heeling-in compare favorably to those reported by Cram (*1*) for hand-plantings.

Records on rate of flush showed that top growth of cuttings after planting was earliest for clones heeled-in over the winter. Growth after refrigerated storage was significantly later and gradually declined with lower temperatures.

The relationships of moisture content and storage temperature to rooting of willow and poplar cuttings were variable and confusing. For example, moisture content of the fall-harvested cuttings for all clones was increased an average of 40 percent by overwinter heeling-in (when lifted after 0.3 inch (8 mm) of rain on April 1 and stored in polyethylene at 24° F until planted on May 24). This additional moisture improved the rooting capacity, apparently for the same reason as reported by Peterson and Phipps (*4*). However, the slight increase in moisture content of refrigerated willow cuttings sealed in polyethylene failed to increase rooting. On the other hand, refrigerated storage at 0° F also delayed top growth after planting for all clones, but also significantly reduced the rooting of willow cuttings. Storage at 24° F also delayed top growth for all clones, but still produced the highest rooting for one willow and one poplar clone.

Top growth records, which have been used by Peterson and Phipps (4) as a criterion for rooting of cuttings, proved unreliable for evaluating storage treatments. Although records for top growth and rooting were highly correlated (n = .97), some cuttings manifested top growth but failed to root. As a result, in the study, the top growth values exceeded the rooting data by 1 to 16 percent for Willow cuttings and by 8 to 78 percent for poplar cuttings.

Conclusions

The following storage treatments are recommended for delayed spring plantings of hardwood willow and poplar cuttings:

1. Outdoor storage by heeling-in overwinter. This method produced maximum yields (75%) of rooted cuttings, but the heeled-in cuttings must be lifted in early spring, sealed in poly bags, and stored at 24° F until planted.

2. Overwinter refrigerated storage at 24° F with cuttings sealed in polyethylene. This produced good yields (65%) of rooted cuttings with minimum labor in fall and spring.

3. Spring-harvested cuttings stored at 24° F in poly bags. This provided fair yields (60%) of rooted cuttings, but created more labor demands during the spring rush.

In addition, sealed polyethylene coverings are essential for refrigerated storage of hardwood cuttings to prevent dessication and retain viability.

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Fifth Year Results of Direct Seeding Yellow-Poplar on Tennessee's Eastern Highland Rim

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Yellow-poplar seeds sown in the fall in prepared spots or rows produced well-stocked stands. Spring seeding was much riskier, especially for row seeding. Broadcast seeding of yellow-poplar failed to produce adequate seedlings for regenerating cutover areas. Burning seedbeds before sowing had little effect on performance.

Past logging practices have virtually eliminated yellow-poplar *(Liriodendron tulipifera L.)* from many suitable sites in central Tennessee. Studies have shown that yellow-poplar can be established on these areas by planting (*2*). Direct seeding can also be a regeneration alternative when planting is not practical. At present, most planters do not consider direct seeding as a viable option because of past failures. On the other hand, a few land managers each year attempt seeding under conditions where regeneration cannot succeed. The 5-year results of the direct seeding study reported here describe several successful seeding methods, as well as methods that have consistently failed.

The study compares spot seeding, row seeding, and broadcast seeding on burned and unburned seedbeds and on fall and spring sowing dates. Each treatment combination is replicated four times. The study area is a medium-quality site (site index 90) on Baxter-Dickson soil on gently rolling land near Tullahoma. Before initiation of the study, the area supported a well-stocked, but low-quality, stand of hardwoods. Trees larger than 1 inch at ground level were injected with herbicide. The yellow-poplar seeds were collected in October and stored in dry cold until December. All seeds were treated with 5-percent Arasan, using a 10-percent latex sticker. Seeds were lightly dusted with aluminum powder to prevent clumping and sticking. The yellow-poplar seeds were very good as germination tests indicated 20-percent viability.

Treatments

Methods of sowing. Sowing rates were adjusted so that 20,000 viable seeds per acre were applied in each sowing method.

For broadcast seeding, seeds were mixed with sawdust and carefully distributed over the plot by hand. Fifteen mechanically spaced milacre subplots were marked in each plot for seedling counts and measurements.

For new seeding, furrows were made with a one-person, motor-driven flail trencher. This operation was intended to simulate the effects that could be obtained with a tractor-mounted flail trencher equipped with a seed-dropping mechanism and a packing wheel. Rows were about 7 feet apart. Seeds were sown in a furrow at a rate of 20 viable seeds per 6.6 feet of furrow and were pressed firmly into the soil by foot.

For spot seeding, spots were located to provide 1,000 spots per acre. Before sowing, each spot was raked to remove litter and to loosen surface soil. Enough seeds were sown to provide 20 viable seeds per spot. Seeds were planted about 1 inch apart and about ¼ inch deep.

Seedbed preparation. Twenty-four of the 48 plots were burned in November. The burn removed most of the new leaf fall and some of the accumulated litter. There were some patches of exposed mineral soil. The other 24 plots received no seedbed treatment.

Season of sowing. Fall sowing was performed December 8 with seeds taken directly from the dry cold storage to the sowing area. Spring sowing was performed April 18 with seeds stratified from December 9 until April 18. Stratification consisted of soaking the seeds for several hours, draining, and storing in a plastic bag in a cooler.

Monitoring Animal Use

Previous studies have shown that animal depredation of seeds could be a major factor in direct seeding of yellow-poplar (*1*). In December, 50 seeds were clustered, fully exposed, around the center of each of the fall-sown plots. By April, seeds in each of the 24 plots had been gnawed, and 13 plots had heavy damage. A similar procedure was followed for the spring-sown plots. Considerable damage to the exposed seeds was noted on most plots the following day; and by June 8, moderate to heavy damage had occurred on all exposed seed spots.

Results

Germination. Total accumulated germination of seedlings at the end of the first growing season ranged from 5,500 per acre for seeds planted in spots in the fall on burned seedbeds to none for seeds broadcast in the spring on burned seedbeds or broadcast in the fall on unburned seedbeds (table 1). In general, fall-sown plots, with some plots approaching 35-percent germination rates, had substantially better germination than spring-sown plots. Seeds sown in spots had higher total germination than those sown in rows, but both spot and row seeding were far superior to broadcast seeding.

Survival. First-year survival followed essentially the same pattern as total germination. However, substantial mortality occurred between the end of the first and the second growing seasons (table 2). Only a few seedlings died between the second and fifth growing seasons. Enough seedlings to produce a new stand survived except for the broadcast treatments and spring-sown row seeding.

Stocking. Stocking percentages based on one seedling per row segment, spot, or milacre stabilized after the second growing season (table 3). After 5 years, stocking percentages are high in fall-sown row and spot seedings, acceptable in spring-sown spots, and very low in spring-sown rows and all broadcast treatments. Burning of the seedbeds before sowing did not affect stocking.

Height. Seedling height growth on all treatments has been acceptable, but not outstanding. Small height advantages achieved by some treatment combinations at the end of the first growing season have been maintained through the fifth growing season (table 4). Heights are somewhat greater on the unburned seedbeds, and fall-sown seedlings are taller than spring-sown seedlings.

Table 1.—*Seeds germinated per air*[1]

Plot, subplot, and seedbed	Season and method of seeding					
	Fall			Spring		
	Broadcast	Row	Spot	Broadcast	Row	Spot
Burned	216	3,300	5,556	0	566	2,430
Unburned	0	3,016	4,916	34	489	1,278
Both seedbeds	108	3,158	5,236	17	533	1,854

[1] Twenty thousand viable seeds per acre were supplied to each treatment.

Table 2.—*Seedling survival per acre*

	Fall			Spring		
	Broadcast	Row	Spot	Broadcast	Row	Spot
			First growing season			
Burned	216	3,134	5,180	0	550	2,403
Unburned	0	2,667	3,764	34	489	1,125
			Second growing season			
Burned	183	2,667	2,597	0	467	1,792
Unburned	0	2,083	2,958	34	400	1,000
			Fifth growing season			
Burned	150	2,150	2,389	0	334	1,584
Unburned	0	1,850	2,667	34	335	972

Table 3.—*Stocking based on surviving seedlings*[1]

	Fall			Spring		
	Broadcast	Row	Spot	Broadcast	Row	Spot
			Percent			
			First growing season			
Burned	22	93	94	0	45	80
Unburned	0	95	86	2	25	58
			Second growing season			
Burned	18	88	70	0	37	68
Unburned	0	82	78	2	22	53
			Fifth growing season			
Burned	15	84	70	0	26	65
Unburned	0	80	76	2	18	51

[1] A spot, row segment, or milacre is considered stocked If It contains at least one established seedling.

Table 4.—*Average height of tallest seedling in each spot, row, or milacre*

	Fall			Spring		
	Broadcast	Row	Spot	Broadcast	Row	Spot
			Feet			
			First growing season			
Burned	0.5	0.6	0.7	—[1]	0.4	0.6
Unburned	—	1.0	1.1	0.7	0.6	0.6
			Second growing season			
Burned	2.3	2.2	2.2	—	1.8	2.0
Unburned	—	3.3	3.0	3.6	2.0	2.4
			Fifth growing season			
Burned	8.0	8.4	7.9	—	6.8	7.8
Unburned	—	9.8	9.5	14.3	8.0	8.1

[1] – = not available, zero germination. (See table 1.)

Discussion

Considerable success can be expected when yellow-poplar is seeded in prepared spots or rows. These procedures can be very useful when traditional planting methods are not practical. This study shows that broadcast seeding, which is less expensive than other methods, will not produce a new stand of seedlings. The spot and row seeding did well because the raking and trenching allowed the seeds to come into full contact with mineral soil and reduced early competition. Fireweed, ironweed, goldenrod, and other forbs proliferated around the spots and rows, but not in them, enabling the yellow-poplar to become established. Later, blackberry entered the area and eventually covered the site, but many yellow-poplar seedlings in spots and rows maintained freedom to grow.

In this study, fall sowing was more effective than spring sowing, because animal activity was at its peak in the spring. Rainfall was adequate and well distributed following the sowings, and there were no adverse climatic conditions.

In some cases, fire may be useful site preparation for direct seeding. In this study, however, no consistent benefits were observed. The herbicide injection of all woody stems before sowing was very effective, as woody vegetation is not a major factor on any of the plots.

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Growth and Survival of Black Oak Seedlings Under Different Germination, Watering, and Planting Regimes

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Fall-planted black oak seedlings grew and survived better than spring plantations. Summer watering at 2 liters per seedling per week had no effect. Stratified acorns may have a higher survival rate than nonstratified ones and are more synchronized in their germination, making potting more efficient.

The importance of the California black oak *(Quercus kelloggii* Newb.), both as a component of wildlife habitat (*1*) and as a commercial species (*2*), is now widely recognized, but there has been insufficient practical information to develop a formal silvicultural program. Differing views on germination techniques (*3*) and a total absence of direction on planting regimes led us to conduct a study to prepare basic guidelines for oak silviculture on the San Bernardino National Forest. Our interest centered on finding the most effecive germination strategy, determinng the importance of summer watering of spring-planted seedings, and comparing spring and fall planting relative to growth and survival.

Study Area

The two experimental plantations were located on southwestern slopes at a 1,400-meter elevation approximately 8 kilometers northwest of Idyllwild, Calif. In general, natural reproduction on prime black oak sites in our area is adequate. Since extension of hardwoods into more marginal (but once forested) habitats was one of our long-range goals, test sites were chosen in chaparral, with predominantly chamise-ceanothus vegetation and coarse granitic soils. Southern California has a characteristic Mediterranean climate with hot, dry summers and cool, wet winters. Rainfall averages 56 centimeters per year.

Materials and Methods

To minimize the effects of genetic variation, all acorns used in the data (*N* = 192) were collected from a single parent tree on September 14, 1979. We picked only acorns that had matured without falling and were visibly free of insect damage.

Acorns were air-cured for 10 days outside in shade, examined again, and sorted for signs of insect attack. Three different germination techiques were tested. The first and second groups were placed in plastic garbage bags along with an equal volume of commercial potting soil and approximately 10 grams of a broad spectrum fungicide (Physan 20). The tips of the acorns (about 3 mm) in the second group were removed, and both groups were kept at room temperature (18° to 24° C) for 90 to 120 days until potting. The third group was similar to the first, but acorns were stratified at 6° C for 45 days and then stored at 18° to 24° C for 45 to 75 days until potting. Each germination group inluded 21 acorns.

During January 1980, the sprouted acorns were transplanted into 8- by 46-centimeter, open-nded tar-paper pots made from asphalt-saturated roofing felt. The pots had been filled with soil gathered from beneath the parent tree. The filled pots were placed on hardware cloth mesh racks under a 12-hour artificial light regime at room temperature for approximately 100 days until planted or moved outside.

We planted 90 randomly selected seedlings, 30 from each germination treatment, on our two experimental sites between April 28 and May 5, 1980. On the average, seedlings were 7.4 centimeters tall at planting and were not dormant. The spring-lanted trees were divided into three watering regimes. The first treatment used a circular berm around the seedling for surface watering. The second, which was developed to minimize evaporation, used a 5- by 60-centimeter black plastic pipe buried with the seedling with the end 5 centimeters above ground and extending at a 45° angle to just below the end of the tar-paper pot. The third group was an unwatered control. Each watering treatment group included 30 individuals.

Spring-planted trees were watered once each week until September with approximately 2 liters per tree per week poured onto the berm or into the watering tube. The amount and interval of watering was deter mined by our estimate of what we could integrate into a permanent silvicultural program. We assume that intensive watering will produce bigger trees, but only weekly watering with relatively small amounts is practicable in the field, given existing staffing.

The remainder of the seedlings (102 individuals) were kept in partial shade through the summer and watered liberally at least once per week. They were planted on the experimental sites on September 26, 1980. On the average, they were 7.0 centimeters tall at planting. No leaves had dropped, but slight browning on the edges indicated that dormancy had just begun. Fall-planted trees were not watered.

All trees were protected by 8- by 91-centimeter, plastic mesh (Vexar) tubes covering the entire tar-paper pot and extending 48 centimeters above ground to minimize deer and rodent damage. Spacing between trees averaged 10 meters square on both sites.

Height growth was measured, to the nearest 2/10 centimeter, from the ground's firm surface to the tip of the terminal bud. Readings were taken at planting, at 6 months after planting, and (for spring-planted trees) at 1 year.

Results and Discussion

Germination techniques had no apparent effect on the total percentage of acorns germinated at 7 months after collection and no significant effect (ANOVA test) on mean height at 12 months after planting (table 1). Careful selection of acorns and germination in airtight plastic bags gave a germination percentage in excess of 90 percent in all three treatments. Stratification, recommended by earlier sources (*4*), appears to be unnecessary for black oak germination. However, seedlings from stratified acorns had somewhat higher survival rates; and stratification concentrated germination into a shorter period of time, which made the potting operation more efficient.

Watering made no significant difference (ANOVA test) in growth (table 2). This "negative finding" may be of some importance to hardwood silviculturalists. It may be that

Table 1.—*Effect of germination technique on California black oak seed germination percentage, seedling mean height, and seedling survival*[1]

Seed treatment	Seed germination (after collection) 2 mo.	7 mo.	Seedling mean height (12 mo. after planting) [2]	Seedling survival (12 mo. after planting)
	- - - Percent - - -		*Cm*	*Percent*
Nonstratified, tips removed	30	90+	6.83	80
Nonstratified, tips Intact	0	90+	7.5	71
Stratified, tips intact	0	90+	6.9	95

[1]Data Include spring-planted trees only.
[2]Mean heights Included dead trees as 0, and totals are sometimes lower than mean height at planting.
[3]No significant difference in means (P>.1), ANOVA test.

Table 2.—*Effect of watering on California black oak seedling mean height and seedling survival*[1]

Treatment	Seedling mean height (12 mo. after planting)	Seedling survival (12 mo. after planting)
	Cm	*Percent*
No watering	6.462	77
Surface watering	7.00	86
Tube watering	6.30	82

[1]Data Include spring-planted trees only.
[2]No significant difference In means (P>.1), ANOVA test.

watering was not sufficient to achieve an effect. More extensive watering, however, would be too expensive to maintain, whether or not it was successful. In any case, an overall average survival rate of 75 percent suggests that we can grow oaks in chaparral.

Table 3 gives data for height, growth, and survival relative to spring and fall plantings. Fall-planted trees fared significantly better. Fall-planted trees also attained a final average height 12 percent greater. Unpublished data from oak plantations on the Angeles National Forest show a very similar trend.

Since spring and fall trees were the same height at planting, the differences in growth in the field are probably not attributable simply to the added vigor of older trees. It may be that planting just before dormancy allows the trees to adjust more easily to field conditions.

Pending generation of further data, our efforts with black oaks will involve fall collection of acorns, stratification to insure time efficiency in early spring potting, oversummering under shadehouse conditions, and fall planting without watering.

Table 3.—*Mean winter growth, height, and survival of spring- and fall-planted California black oak seedlings*

Planting season	Seedling mean growth Nov. 1980 to Apr. 1981			Seedling survival to Apr. 1981	Seedling mean height to Apr. 1981		
	Site 1	Site 2	Both	Both	Site 1	Site 2	Both
	Cm	*Cm*	*Cm*	*Percent*	*Cm*	*Cm*	*Cm*
Spring	0.681	0.67	0.68[1]	77[2]	8.70	5.20[1]	8.90
Fall	1.50	0.93	1.20	94	7.80	7.60	7.70

[1]Difference between spring and fall means significant (P<.01), t-test.
[2]Difference between spring and fall survival significant (P<01), chi-square test.

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The Effect of Damaged Radicles of Presprouted Red Oak Acorns on Seedling Production

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Breaking the radicles on presprouted Shumard and cherry-bark acorns sown in the spring did not adversely affect seedling production. Fall sowing of unsprouted acorns was as good as or better than sowing stratified acorns in the spring.

Even though acorns of most southern red oak species can be stored for up to 3 years (*3*), their tendency to sprout during storage has discouraged some nursery managers from storing acorns. These nursery personnel have believed that presprouted acorns could not be sown without excessive damage to the tender, emerged radicles. The study reported here was undertaken to assess the significance of such damage to nursery seedlings of two southern red oaks: cherrybark oak *(Quercus falcata* var. *pagodaefolia)* and Shumard oak *(Q. shumardii).*

Methods

Acorns were collected from stands in central Mississippi in November 1979. Each species collection was from a minimum of five trees. The acorns were floated in water on the day of collection, and all acorns that floated and those with visible damage were discarded. The remaining sound acorns were stored at 3° C until sowing. Standard germination tests (*9*) and tetrazolium chloride staining tests were run on samples of each species soon after collection. Tetrazolium staining methodology was the same as reported by Bonner (*4*), except that the incubation period was only 24 hours.

Each species lot was divided into 18 sublots of at least 75 acorns each. These sublots were randomly assigned to one of three treatments: fall sowing (treatment A); spring sowing, radicles undamaged (treatment B); and spring sowing, radicles damaged (treatment C).

Fall sowing (treatment A) consisted of sowing unsprouted acorns with no pretreatment. These acorns were sown on December 12, 1979 (cherrybark), and January 3,1980 (Shumard), in the nursery at the Forestry Sciences Laboratory in Starkville, Miss. A treatment plot consisted of three rows of 25 acorns each across the bed. The acorns were placed 1 to 1.5 centimeters deep and mulched with pine straw. The entire bed was covered with a chicken wire cover to exclude birds. Overhead sprinklers kept the bed moist.

Sublots for treatments B and C were returned to storage, but at 8° C. This elevated storage temperature was used to stimulate sprouting of the acorns during storage. Four weeks before sowing, these sublots were soaked overnight in tapwater at room temperature and then returned to 8° C storage. This step insured full hydration, an aid to sprouting.

The two spring treatments (B and C) were sown on April 11,1980. Acorns for treatment B were carefully placed in a shallow furrow and covered. Only sprouted acorns were used. Acorns for treatment C had the terminal half of each emerged radicle pinched off by hand before sowing. All acorns in these treatments were also covered 1 to 1.5 centimeters deep and mulched with pine straw.

In spite of the warm storage temperature, presprouting was not as widespread as desired, especially for cherrybark oak. Only 50 acorns were sown in these plots (two rows of 25 each), and some acorns with extremely short radicles (2 to 4 mm) had the entire length removed to simulate the damaged condition for treatment C.

The nursery plots were watered all spring, summer, and fall by overhead sprinklers. No other cultural treatments, except for hand-weeding, were employed.

The seedlings were lifted by hand in late January and early February 1981. All taproots were deep, and they were cut to a standard 10-inch length. Seedling survival, seedling height, shoot dry weight, and root dry weight were measured. The latter three measurements were taken on 10 plantable seedlings chosen at random from each plot. (Obvious culls were discarded.) Dry weights were determined after drying the shoots and roots separately for 24 hours at 90° C.

Table 1.—*Survival and growth of cherrybark oak in a nurserybed as influenced by sowing treatment*[1]

Parameter	Sowing treatment Fall sowing	Spring sowing, undamaged radicle	Spring sowing, damaged radicle
Survival (%)	54.9	64.0	57.7
Total height (cm)	45.9	45.9	40.6
Shoot dry weight (g)	4.0	3.8	2.8
Root dry weight (g)	13.0	12.2	10.4

[1] Each value is the mean of six replications. No treatment effects were significant.

Table 2.—*Survival and growth of Shumard oak in a nurserybed as influenced by sowing treatment*[1]

Parameter	Sowing treatment Fall sowing	Spring sowing, undamaged radicle	Spring sowing, damaged radicle
Survival (%)	65.3a[2]	79.7b	82.7b
Total height (cm)	66.5a	54.3b	51.5b
Shoot dry weight (g)	7.5a	4.4b	3.7b
Root dry weight (g)	14.0a	10.3b	9.5b

[1] Each value is the mean of six replications.
[2] For a given parameter, means followed by a common letter are not significantly different (P>0.05).

Results and Discussion

Cherrybark oak. Fall-sown seedlings emerged first and made the best early height growth. At the end of the growing season, however, there were no significant differences in survival, height growth, shoot dry weight, or root dry weight (table 1).

Survival ranged from 54.9 to 64.0 percent, somewhat below laboratory test data. The germination test gave 91.0 percent and the tetrazolium test yielded a score of 87 percent. A small, but undetermined, percentage of seedlings were lost to birds who got underneath the wire cover, and 3 to 4 percent were killed by insects.

Shumard oak. Just as for cherrybark oak, the fall-sown Shumard oak emerged first and made the best early height growth. In contrast to cherrybark, the fall-sown Shumard maintained an advantage throughout the season (table 2). Fall-sown Shumard averaged 66.5 centimeters, which was significantly taller than both spring treatments (54.3 and 51.5 cm). This same relationship held for shoot and root dry weight. Fall-sown acorns produced seedlings averaging 7.5 grams in shoot dry weight, as opposed to 4.4 and 3.7 grams for the spring treatments. In root dry weight, fall-sown acorns yielded seedlings with an average 14.0 grams, while the spring treatments averaged only 10.3 and 9.5 grams. In all three growth parameters, there were no significant differences between damaged and undamaged radicles in spring-sown acorns.

Spring-sown acorns of both treatments had a significant advantage over the fall-sown acorns in seedling survival (table 2). As in the cherrybark plot, there were small losses to birds and to insects. Overall survival was better than survival in cherrybark oak, even though the laboratory test for Shumard was only 64 percent. The tetrazolium test for Shumard gave a score of 91 percent, however.

There was also an apparent treatment effect on the shape of the root system (fig. 1). Most Shumard seedlings from treatment A (fall sowing) had a single, carrotlike taproot. Seedlings grown from spring-sown acorns with broken radicles (treatment C) had multiple roots, as expected. Treatment B seedlings were a mix of both types, although the carrotlike taproots predominated. It is assumed that damage to the emerged radicles promoted the

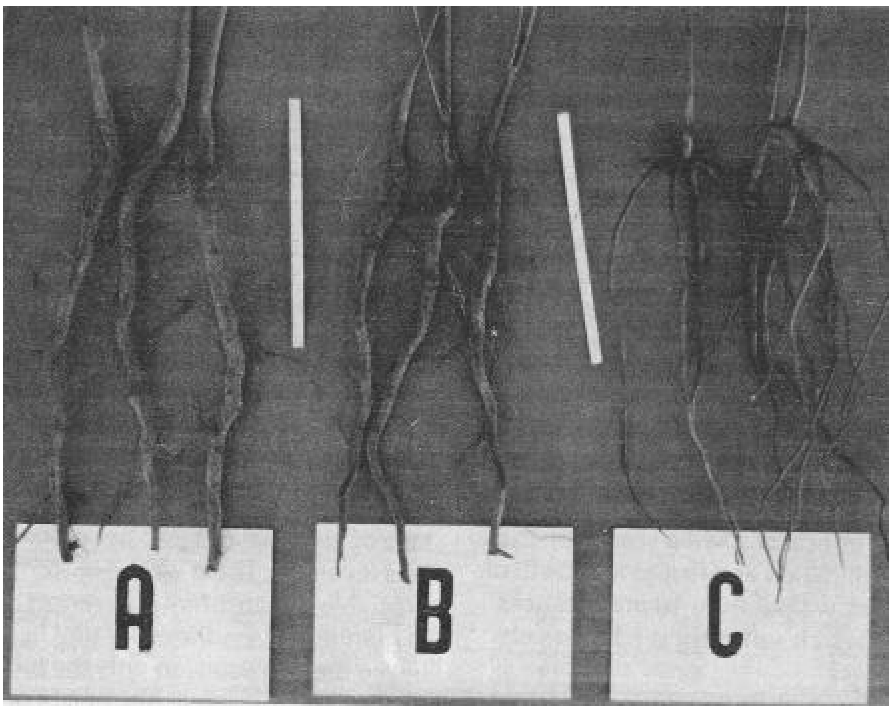

Figure 1.—*Characteristic root systems on seedlings of all treatments: A. fall sowing; B. spring sowing, radicles undamaged, and C. spring sowing, radicles damaged.*

multiple configuration. Proper root pruning in nurserybeds, which could not be done in this study, would create a similar, although not identical, effect.

Seedling density in the beds, although high, was probably not a major factor in seedling response. Random counts in November gave average bed densities of 13.2 seedlings per square foot for cherrybark oak and 12.6 per square foot for Shumard oak. These densities are considerably higher than the four seedlings per square foot recommended by Barham (*2*), which may account for the small seedling sizes in all plots.

Conclusions

Results from this study suggest that nursery personnel should not be concerned if acorns sprout before sowing. Damage to the radicles did not adversely affect seedling production of cherrybark and Shumard oaks. Fall sowing of unsprouted Shumard acorns produced significantly fewer, but larger, seedlings than spring sowing.

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The Influence of Spring Sowing on Black Walnut Germination in Northern Vermont

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Spring sowing after artificial stratification resulted in 134 percent more germination of black walnut than fall sowing. Seeds from northern provenances germinated 182 percent better when sown in the spring, but seeds from southern provenances germinated only 22 percent better when sown in spring rather than in the fall.

Black walnut (*Juglans nigra* L.) is one of the most commonly planted hardwood forest tree species in the Central and Midwestern United States. Because of its high timber value, rapid juvenile growth, and desirable nut crop, growers in northern regions have also become interested in planting this species. With this interest has come a growing demand for quality planting stock suited to northern conditions.

Insufficient seed and poor or delayed germination are among the major problems limiting black walnut seedling production (8). To attain the greatest possible seedling yields from a limited seed supply, it is necessary for nursery personnel to maximize seed germination. Research in Central and Southern States has shown that fall sowing of black walnuts generally results in greater germination (*1, 6*) and larger seedlings (*6*) than does spring sowing following indoor cold stratification. This report compares the effects of fall versus spring (following artificial stratification) sowing on the germination and growth of black walnut from 10 provenances in a northern Vermont nursery.

Materials and Methods

During fall 1978, a black walnut provenance test was initiated in Vermont with the collection of seeds from 101 stands located throughout the Eastern United States and southeastern Canada. Because seeds from some provenances were not received until early winter, it was necessary to sow some seedlots in fall and others in spring. As a result, a study was undertaken to determine the effects of sowing season on the germination and first-year growth of black walnut from 10 provenances for which sufficient seeds were obtained.

The study followed a completely randomized design. Nine plots of each provenance were sown in random order from November 7 to 9, 1978, at the Vermont State Nursery in Essex)unction, Vt. Each plot consisted of three rows 102 centimeters wide, and each row contained nine nuts (27 nuts per plot) sown at a depth of 5 centimeters. Rows were separated at 31-centimeter intervals along the nurserybeds. After sowing, beds were covered with chickenwire to minimize rodent pilferage. Seeds from some sources had been hulled before shipment, while others had their husks intact. Because a study had demonstrated no clear germination differences between hulled and unhulled nuts (*6*), seeds were sown as received with no additional hulling performed. Following fall sowing, the remaining seeds from each provenance were placed in cold storage at 2° C. On January 3,1979, the seeds were sealed in polyethylene bags containing moist peat moss. On April 6,1979, the seeds were removed from cold storage and sown using the same procedures as in fall except that the number of plots per provenance varied from 2 to 18, depending on the number of seeds remaining.

On July 10 and again on September 15,1979, seedling counts were made and the percentage of germinated seeds per plot was recorded. There were not appreciable or consistent differences in numbers of seedlings per plot between the two dates, so only the July 10 data are presented. The height of nine randomly selected seedlings per plot was measured on September 15. If fewer than nine seedlings were present, all were measured. Analyses of variance were used to determine the significance of germination and height differences due to season, provenance, and season X provenance interaction.

Results

Germination. Season of sowing had an overwhelming effect on black walnut germination. When averaged over all provenances, spring sowing following indoor stratification resulted in 134 percent greater germination than fall sowing (table 1). This conflicts with the find-

Table 1.—*Average germination and height of black walnut seedlings from 10 provenances as affected by season of sowing in a northern Vermont nursery*

UVM # and origin	Germination when sown in:		Relative increase with spring sowing	Height when sown in:	
	Fall	Spring		Fall	Spring
Northern sources	- - - - - - - - - - - - - *Percent*	- - - - - - - - - - - - -		*Cm*	*Cm*
0654 VT	8	26	225	29	34
0672 NY	24	65	171	35	39
0675 NY	28	62	121	25	29
0700 OH	21	44	110	28	34
0707 NY	28	57	104	37	34
07310NT	13	62	377	22	25
0734 ONT	28	75	168	26	23
Mean	21	56	182	29	31
Southern sources					
06661N	49	62	27	43	39
06671N	24	31	29	34	29
0725 KY	54	60	11	35	37
Mean	42	51	22	37	35
Overall mean	28	54	134	31	32

ings reported from Central and Southern States (*1,6*), but is consistent with those reported from upper New York State (*3*). It appears that the optimum season for sowing black walnuts may be different in cool northern regions.

Although seeds from all provenances germinated better when sown in spring, the relative increase in germination varied with latitude of the provenances (r = 0.73, P $\leq$ .05, 8 d.f.). Seeds from northern provenances (north of 40° latitude) germinated *182* percent better when sown in spring than fall, while seeds from southern provenances germinated only *22* percent better when sown in spring (table 1). One northern provenance (No. 0731, ONT) yielded nearly 400 percent more seedlings when sown in spring.

Height. Season of sowing and provenance X season interaction did not have significant effects on the height of year-old black walnut seedlings. Seedlings from spring-sown nuts averaged *32* centimeters in height and those from fall-sown nuts averaged *31* centimeters in height (table 1). Williams (6) found that fall-sown nuts germinated earlier than spring-sown nuts in Central States nurseries and grew taller the first year, presumably because of the longer growing season afforded by early germination. No clear-cut differences in time of germination were noted between spring and fall-sown nuts in our study.

Provenance differences in height were significant. In general, southern provenances were fastest growing, but two provenances from New York were also above average in height (table 1).

Discussion

There are two possible explanations for the sowing season differences in black walnut germination found in this study. Fall-sown nuts may have been injured by low temperatures or some unknown factor during the winter and spring in the nursery. If this were the case, then nuts from northern provenances were more severely injured than those from southern provenances, since the latter had only a small relative increase in germination when sown in spring. Although possible, this explanation does not seem logical and there is no empirical evidence to substantiate it.

An alternative and more plausible explanation is that fall-sown nuts were not fully stratified in the outdoor seedbeds. Natural stratification may have been incomplete because the fall-sown nuts were frozen in the seedbeds from approximately early January to early April. Heavy rains in early January followed by prolonged subfreezing temperatures resulted in frozen seedbeds until snowmelt in early April. Some evidence exists to indicate that subfreezing temperatures may retard the stratification process and breaking of seed dormancy in black walnut. Williams (*7*) has shown that black walnut seeds can be stored at subfreezing temperatures for 1 year without losing viability, but that subsequent stratification is necessary for adequate germination (R.D. Williams, personal communication, 1980). In addition, Von Althen (*5*) reported that nuts stratified for 7 months in moist sand at 0° C had only 10to 25-percent germinability, while germinability exceeded 80 percent for those stratified under the same conditions for 16 or 19 months. The delayed germination was attributed to a moisture deficiency resulting from a freeze-drying effect on the moist sand (F. W. Von Althen, personal communication, 1980). In contrast, nuts stratified for 3 to 4 months at above-freezing temperatures generally exhibit 50- to 75-percent germinability (*2,4*). In the nurseries of the Central and Southern States, prolonged freezing of the seedbeds is uncommon and fall-sown black walnuts are adequately stratified during the winter.

Germination of fall-sown nuts was only slightly less than spring-sown nuts for southern provenances, but was considerably less for northern provenances. Such a pattern suggests that black walnut provenances may vary in the amount of stratification required to overcome seed dormancy. The strong latitudinal pattern to the variation in relative germination with spring sowing supports this hypothesis. If southern provenances of black walnut require a shorter stratification period than northern provenances, then seed dormancy in southern provenances may have been largely overcome before the seedbeds became frozen in early January. This would explain why fall-sown nuts of the southern provenances germinated nearly as well as artificially stratified spring-sown nuts. Provenance differences in length of stratification requirement have been demonstrated for some coniferous species, but mild-climate seed sources generally have a longer requirement than cool-climate sources. The extent and pattern of provenance variation in seed stratification requirement of black walnut has not been documented to date.

Conclusions

Under northern Vermont conditions, spring sowing after 3 months of indoor stratification at 2° C resulted in far better germination of black walnut than fall sowing, but did not influence the height of 1-year-old seedlings. Germination was particularly low in fall-sown nuts from northern provenances. Differences in germination probably reflect incomplete stratification of fall-sown nuts, rather than a response to season of sowing as such. Prolonged freezing of seedbeds may result in fall-sown nuts being essentially "stored in the ground" instead of functionally stratified, thereby reducing germination the following spring. Whether our findings are typical of northern conditions or are the result of unusual weather conditions in northern Vermont or for a particular winter is not known. However, growers in regions that typically have extended periods with frozen nursery soils are urged to try spring sowing and artificial stratification in an attempt to circumvent poor or delayed germination of black walnut.

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The Impact of Stunting of White Spruce at Eveleth Nursery

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Stunting and purple discoloration of 1-0 white spruce in the Lake States have been shown to be associated with low foliar phosphorus. A $9,800 loss was sustained by the Eveleth Nursery in Minnesota because stunted stock did not meet seedling specifications at lifting.

Stunting and purple discoloration of 1-0 red pine and white spruce seedlings (stunting syndrome) have been recognized as significant problems in Wisconsin State nurseries and two Forest Service (Region 9) nurseries -the Eveleth Nursery at Eveleth, Minn., and the J. W. Tourney Nursery at Watersmeet, Mich. In 1977, Wisconsin Department of Natural Resources nurseries at Hayward, Wisconsin Rapids, and Boscobel recorded 13,18, and 23 percent, respectively, of their 1-0 red pine seedlings were affected (*2*). That same year, a similar problem was noted on both species at the Eveleth Nursery and on red pine at the Tourney Nursery. Stunting has continued to appear since 1977 at all five nurseries.

The stunting syndrome becomes noticeable at the end of the first growing season. Affected seedlings have purple foliage and are about 1/2 the height of the green nonaffected stock. The portions of the beds that have seedlings showing these symptoms are generally poorly stocked with groups of healthy and stunted trees along the bed rows. Although the cause of the symptoms is unknown, the purple coloration of the foliage suggests a phosphorus deficiency (*1*).

Because of the frequent occurrence of stunting, State and Private Forestry personnel conducted a survey to determine the impact of stunting on survival and growth of white spruce at the Eveleth Nursery. White spruce was selected for evaluation because it was generally more severely stunted than red pine. Another objective of the survey was to determine whether soil nutrient deficiencies were associated with stunting of seedlings.

Methods

Fifty percent of the beds with 1-0 white spruce were sampled in August 1978. Disease distribution was determined by systematically selecting six sample points along each of the 26 beds in block 9. At each sampling point, a standard seedling inventory frame, 6 inches by 4 feet (15 cm by 1.2 m), was used to delineate the seedlings to be examined. The total numbers of stunted seedlings and nonstunted seedlings were noted for each row. The distribution of stunted seedlings was then plotted.

Stunted and nonstunted seedlings were tagged for future evaluation. Ten plots of 24 seedlings (12 stunted and 12 nonstunted) were established in September 1978. Seedling height was measured at this time and recorded as first-year growth. Height and root collar caliper measurements were recorded 1 and 2 years later. Upon lifting, the seedlings were graded by nursery personnel to determine the percentage of culls associated with stunted and nonstunted stock. .

To determine the dollar losses associated with white spruce stunting, the number of stunted seedlings was multiplied by the cull percentage (stunted cull percentage minus nonstunted cull percentage). This product was then multiplied by the 1981 cost per 1,000 trees.

After the distribution of stunting was determined, stunted and nonstunted seedlings were collected and taken to the University of Minnesota's Research Analytical Laboratory for foliar analysis. Simultaneously, because the symptoms were those of a phosphorus deficiency, soil samples taken from beneath the stunted seedlings were taken to the University's Soils Department for analysis of pH, total nitrogen (N), phosphorus (P_2O_5), and potassium (K).

Results

Distribution of stunting by unit, sample point, and row is given in figure 1. Stunting was least severe in the northwest portion of the block. Based on stunting-distribution observations for units 2 through 8, 28 percent of the 2.5 million 1-0 white spruce seedlings were affected.

The difference in first-year growth of stunted and nonstunted seedlings was dramatic. Stunted 1-0 seedlings

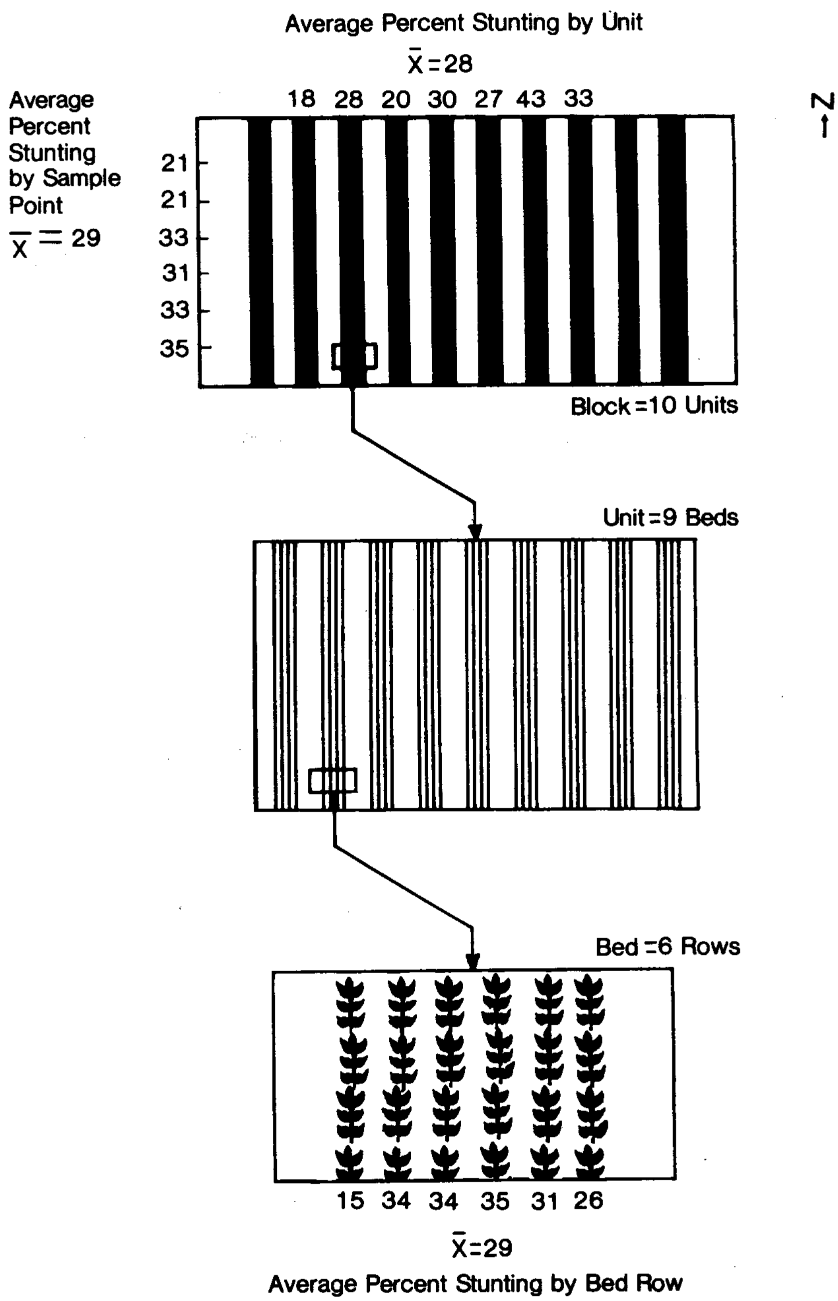

Figure 1.—*Distribution of 1-0 white spruce stunting in block 9 at Eveleth Nursery, September 1978.*

were about 1 /2 the size of non stunted seedlings (table 1). After two seasons, they were 42 percent taller than nonstunted seedlings and 54 percent larger in caliper. At lifting, the average top height of stunted seedlings had increased to 78 percent of that for nonstunted seedlings. A similar recovery was not observed for caliper. The average caliper of stunted seedlings was 61 percent of that observed for nonstunted seedlings after 2 years. No tree mortality was noted during the evaluation period.

Cull percentage for stunted seedlings was five times greater than for nonstunted seedlings (27.6% versus 5.4%). Based on the Eveleth Nursery cost per 1,000 seedlings ($63.00), these added cull seedlings cost the nursery $9,800 in 1981.

Foliar analyses showed a marked difference in total N and P levels in affected and nonaffected seedlings (table 2). Stunted seedlings had 25 percent less N and 72 percent less P than nonstunted seedlings. The foliar analysis for other elements indicated no notable differences between stunted and nonstunted trees.

Soil samples from stunted and nonstunted plots showed no significant differences in levels of pH, N (total), P_2O_5, and K (table 3). All samples were found to contain adequate levels of phosphorus at 200 pounds per acre (224 kg/ha).

Table 1.—*Average height and caliper measurements and percentage of culls for stunted and nonstunted white spruce seedlings at Eveleth Nursery*

	Height[1]			Caliper[1]		Culls at 3-0[2]
	1st yr.	2d yr.	3d yr.	2d yr.	3d yr.	
	Cm	*Cm*	*Cm*	*Mm*	*Mm*	*Percent*
Stunted	1.3	7.9	19.3	1.4	2.6	27.6
Nonstunted	2.8	19.2	24.7	2.5	4.2	5.4

[1]Region 9 reforestation handbook stock specifications recommend a minimum height of 13 centimeters and caliper of 3 millimeters for white spruce seedlings to be planted.

[2]Seedlings were culled because they failed to meet minimum height and caliper specifications.

Table 2.—*Foliar mineral analysis of stunted and nonstunted 1--0 white spruce foliage at Eveleth Nursery*

	Mineral content[1]										
Seedling condition	N	P	K	Ca	Mg	Fe	Mn	Al	Zn	B	Cu
	%	*%*	*%*	*%*	*%*	*P/m*	*P/m*	*P/m*	*P/m*	*P/m*	*P/m*
Nonstunted	2.07	0.28	1.19	0.49	0.17	975	157	958	154	19	10
Stunted	1.51	.08	.87	.52	.19	1,183	260	1,340	120	30	5

[1]All results are expressed on a dry-matter basis.

Table 3.—*Total nitrogen, phosphorus pentoxide, potassium, and pH of soils associated with stunted and nonstunted white spruce seedlings at Eveleth Nursery*

Origin of soil sample	pH	Total N	P_2O_5	K
		Percent	*Lb/acre*	*Lb/acre*
Under nonstunted seedlings	5.20	1.37	200	197
Under stunted seedlings	5.76	1.00	200	219

Discussion

The $9,800 loss presented here represents the situation at a specific nursery for a single year. Within the Lake States, stunting appears frequently on both red pine and white spruce, but in no set pattern. Stunting may occur year after year or may disappear for several seasons and then reappear. The stunting episode outlined in this paper is not a rare occurrence. It is however, the first to be documented with dollar-loss figures. The authors feel that these losses are significant, especially when the general occurrence of this problem is considered.

This study did not follow trees in the field to evaluate the subsequent performance of the stunted seedlings. Although the average height of these seedlings had increased to 78 percent of that for the nonstunted trees by lifting time, it should be noted that the seedlings had been top pruned. Therefore, stunted trees attained *78* percent of the top pruned height, not actual height. It is possible that stunted trees may continue to grow at a slower rate than their nonstunted counterparts. If this is true, dollar losses associated with the stunting of white spruce would be greater than those cited for this nursery evaluation.

The low level of stunting in the northwest portion of block 9 did not correlate with specific nursery practices or seedlots.

The purple discoloration and low foliage P levels of the stunted seedlings suggest that the stunting problem is associated with a P deficiency. The mineral analysis of the soil from portions of the beds that had stunted stock did not show correspondingly low P levels. Therefore, it appears that factors other than soil nutrient content are contributing to this deficiency.

Phosphorus deficiencies may result from low soil pH values, which inhibit the assimilation of P in plants (*3*). At pH levels less than 6, P availability decreases with increaseing acidity. Soil pH values under nonstunted and stunted seedlings were 5.2 and 5.76 respectively (table 3). If pH was the limiting factor for P assimilation, the nonstunted trees would have had lower foliage P levels than the stunted trees. This, however, is the reverse of our findings.

The P deficiency noted here is not in agreement with the findings of Berbee and others (*2*). They analyzed the foilage both of red pine and white spruce and found no significant difference for P levels between stunted and nonstunted seedlings. No explanation can be given by the authors for this discrepancy in results.

No seedling mortality occurred during the period of this evaluation. However, it should be noted that there appears to be poor germination and/or survival during the first growing season in those portions of seedbeds that have stunted seedlings. Our plots were established at the end of the first growing season. If mortality is associated with the earliest phase of stunting, it would not have been recorded in this evaluation.

Conclusions

1. Stunting was associated with phosphorus deficiency of seedling foliage in spite of the phosphorus-rich soils in which they were grown.
2. Stunted 1-0 white spruce seedlings do not show increased rate of mortality when followed through the 3-0 stage.
3. Because of the failure of stunted 3-0 stock to meet grading specifications, significant dollar losses are associated with the occurrence of stunting.

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Storing Stratified Seeds for Extended Periods

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This study evaluates the viability of loblolly pine, slash pine, and Douglas-fir seeds after the moisture content of the stratified seeds has been reduced. The results warrant further tests on a production scale to determine practical potentials for this treatment.

Uncooperative weather during the sowing season may cause nursery personnel to delay sowing seeds. If the seeds are stratified, delays can result in their germination during storage. Prolonged storage of stratified southern pine seeds consistently decreased germination of all species (*3,4*). In the past, anticipated long delays resulted in redrying of stratified seeds. This often led to the loss of the benefits of stratification (1) and required restratifying. Danielson and Tanaka (*2*) found that the stratification effect was retained for up to 9 months in Douglas-fir Pseudotsuga menziesii) when the moisture content of stratified seeds was reduced to about 15 percent.

Increasing the moisture content of nonstratified loblolly pine (*P. taeda*) seeds may decrease dormancy (*3*). The greatest dormancy occurred at moisture contents between 10 and 20 percent and the least above 20 percent.

Materials and Methods

Three lots of loblolly pine, two lots of slash pine (*P. elliottii*), and one lot of Douglas-fir were selected from seed stores. The loblolly lots represented a Georgia seed orchard and two wild collections (coastal plain and Piedmont sources). The slash pine lots represented a Georgia seed orchard and a comparable wild collection source. The source of the Douglas-fir is unknown.

Each lot was thoroughly blended and subdivided into 12 sublots. Two sublots were used for the stratified and nonstratified controls. Four seed samples (each containing 100 seeds) were selected by a vacuum counter for these tests. The seeds were placed on moistened crepe cellulose paper (Kimpak) in plastic boxes. The nonstratified seeds were placed in a germination chamber for 28 days at 22° C with 16 hours light and 8 hours dark. Germination was recorded on Monday, Wednesday, and Friday for the duration of the test. Before germination, the stratified tests were placed in a cold-room at 3° C. The slash pine seeds were stratified for 22 days and the loblolly and Douglas-fir seeds for 30 days. The remaining 10 subsamples were soaked for 24 hours in tapwater, drained, and stratified in plastic bags at 3° C. Following stratification, each treatment was blotted to remove excess moisture and then placed in a column blower for 10 minutes of further drying. A 20-gram sample was dried in an oven to establish the moisture content. The remaining seeds were placed in small jars, capped, and stored at 3 to 5° C. One jar was removed every 30 days, and a germination test was prepared with the seeds.

Analyses of variance were made on the 28-day germination of the filled seeds and on the days required to reach 90 percent of the total germination. Duncan's multiple range test was used to determine differences among treatment means.

Results and Discussion

The average moisture contents, derived by drying after stratification, are given in table 1. They were all between 20 and 27 percent.

Loblolly pine. Germination at 28 days (table 2) indicated differences in seed vigor among the three lots. Lot A was strong and nondormant; lot B was strong and slightly dormant; and lot C was weak and non-dormant. The stratified germination of lot C at 28 days was depressed.

Table 1.—*Moisture content of stratified seed after 10 minutes of drying in a column blower*

Sample	Moisture content
Loblolly (lot A)	23.7
Loblolly (lot B)	21.7
Loblolly (lot C)	22.8
Slash pine (lot D)	25.9
Slash pine (lot E)	28.3
Douglas-fir (lot F)	23.8

Table 2.—*Germination of stored stratified seeds at the end of a 28-day germination test*

	Loblolly pine seedlots			Slash pine seedlots		Douglas-fir seedlot
Length of storage	A	B	C	D	E	F
Months						
			Nonstratified			
0	88a[1]	80a	78a	91a	87a	94ab
			Stratified			
0	89a	84a	64abc	81ab	74ab	86ab
1	99a	95a	74ab	86ab	62bc	100a
2	100a	94a	68ab	79ab	51cd	83ab
3	100a	95a	72ab	72b	54cd	85ab
4	98a	86a	57bc	75b	66bc	79b
5	100a	81a	50c	72b	47de	79b
6	99a	89a	57bc	48c	39de	80b
7	96a	90a	63abc	50c	36e	83ab
8	100a	92a	58bc	54c	32e	79b
9	100a	88a	59bc	52c	35e	85ab
10	99a	85a	54c	37c	43de	85ab

[1]Within each lot, numbers followed by the same letter are not statistically different et the 1-percent level of probability.

Stratification normally depresses germination when vigor begins to decrease because of the aging process or possible seed injury. While lots A and B maintained strong viability, lot C significantly decreased in viability after 4 months of storage. The rate of germination (table 3) remained consistent during storage for lots A and B, but increased with storage of lot C.

Slash pine. The two slash pine lots possessed no dormancy. In fact, they showed signs of low vigor by the depressed germination after stratification (table 2). A significant decrease in viability occurred after 5 months for lot D and 1 month for lot E. A more dramatic decrease occurred after 4 months of storage for lot E. The rate of germination was increased by stratification in lot D and decreased in lot E. In general, the rate decreased with length of storage time to 2 months and then increased. Statistical differences were quite variable. Although the reasons for these variations have not been identified, they may relate to a biological rhythm.

Douglas-fir. The results supported the findings of Danielson and Tanaka. After 10 months of storage, germination was equal to that of the control samplues. The rate of germination was consistent with two exceptions. For unknown reasons, samples stored 3 and 10 months germinated much faster than other samples.

Overall, the most noticeable effect observed in the laboratory was the growth of seed mold. It increased with length of storage and declining vigor. Mold was observed on the seeds both in the storage containers and during the germination tests. In a practical application, seeds should probably be treated with a fungicide before sowing. Although treatment before storage may be possible, unpublished laboratory results indicate that toxic effects of the fungicides on seed viability increase with length of storage.

Conclusion

These results indicate that stratified slash pine, loblolly pine, and Douglas-fir seeds can be dried to between 21- and 26-percent moisture content and held at 3° C. Loblolly and Douglas-fir seeds were

Table 3.—*Days to reach 90 percent of total germination, after different lengths of storage of semidried, stratified seed*

	Loblolly pine seedlots			Slash pine seedlots		Douglas-fir seedlot
Length of storage	A	B	C	D	E	F
Months						
			Nonstratified			
0	22b[1]	23b	22d	7a	14bc	12bc
			Stratified			
0	14a	14a	16c	12bc	11ab	10abc
1	12a	13a	14bc	9ab	10ab	12bc
2	10a	12a	12b	7a	8a	13bc
3	10a	11a	12b	7a	12bc	9ab
4	12a	12a	12b	11abc	11ab	14c
5	12a	13a	15bc	14cd	15c	14c
6	13a	14a	13bc	17d	14bc	13bc
7	13a	14a	14bc	14cd	14bc	13bc
8	10a	12a	7a	12bc	11ab	10abc
9	11a	13a	11ab	7a	7a	12bc
10	12a	14a	13bc	14cd	14bc	7a

[1]Within each lot, numbers followed by the same letter are not statistically different et the 1-percent level of probability.

stored for 10 months and slash pine for 5 months without a significant decrease in germinability. These results also suggest that seeds with low germination percentages will not retain viability as well as those with high germination percentages. Such lots may also produce more seed mold. Caution should be exercised in production implementation of these results. Spontaneous heating may take place if large lots of moist seeds (moisture contents in excess of 20 percent) are sealed in containers, even in a refrigerator. Further tests are needed to investigate use of this technique on a production basis.

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Tree Planter's Notes, Vol. 33, No. 4 (1982)

A Quick Way to Appraise the Performance Potential of Tree Planting Stock

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Tree seedlings for reforestation can be evaluated using the following characteristics: diameter/height ratio, root/top ratio, catalytic capacity of feeder rootlets, specific gravity of stems, and coefficient of variability. The sum of these attributes provides a quality index of nursery stock.

The quality of nursery seedlings can be determined from a few simply measured attributes. These characteristics can be integrated into a single numerical index. Such an index must be derived from properties of trees that bear on their ability to cope with adverse conditions. In addition, the quality of nursery stock is related to uniformity, precluding a large loss of stock in grading. The properties of trees that answer these requirements include: diameter/height ratio (d/h ratio), root/top ratio (r/t ratio), specific gravity of stems, catalytic capacity of feeder rootlets, and the coefficient of variability (*3*).

Measurements

D/h ratio is the average diameter of sampled seedlings in millimeters divided by the average height of the seedlings in centimeters.

R/t ratio, on a volumetric basis, is determined using a water-filled container of about 10-liter volume, with a faucet-shaped discharge tube near the top. The quotient of the volumes of roots and tops is obtained by a successive hand immersion of roots and tops of a bundle of seedlings and collection of displaced water in a graduated cylinder.

Specific gravity of stems is a quotient of an average of ovendry weight of 20-millimeter-long stem sections and their green volume (equal to 1.57 X d^2 where d is the average diameter of stems).

Catalytic capacity of feeder rootlets is determined on seedlings collected from the center of nurserybeds. After washing and air-drying roots for 24 hours, all rootlets smaller than 2 millimeters in diameter are cut from the trees, mixed, and weighed into 2-gram samples. The analysis is performed in a wide-necked 250 milliliter reaction flask provided with a no. 10 rubber stopper. The stopper has an inserted small glass tube for attachment of Tygon tubing and a 20-milliliter reagent container, held by a wire. The 2-gram sample is placed into the reaction flask. The reagent container is filled with 18 milliliters of 6-percent hydrogen peroxide; the stopper is inserted; and the Tygon tubing is connected to an inexpensive 200-millimeter aneroid manometer. The flask is tipped to allow the hydrogen peroxide to pour onto rootlets, shaken for 3 seconds, and placed on a level surface. After exactly 1 minute of oxygen evolution, a manometer reading is taken. The reading divided by 200 gives the catalytic capacity of feeder rootlets in decimeters of mercury per gram.

Coefficient of variability is determined from the following formula:

$$C = \frac{\sqrt{\frac{\Sigma(x-h)^2}{n-1}}}{h} \times 100$$

where x represents heights of individual seedlings, h is the average height, F(x - h)? is the sum of squared differences, and n is the number of measured seedlings.

Calculations

The calculation of the index requires compatibility of the numerical values. Therefore, reciprocal values must be used for the coefficient of variability, whereas the catalytic potential of roots must be expressed in terms of decimeters (dm) of mercury column.

Table 1 includes results of analyses of four samples of 2-year-old red pine seedlings collected from four different soils.

Evaluation

The highest integrated value is exhibited by trees of balanced morphology, dense stems, abundant enzyme-producing root system, and uniform development (B). In comparison, the low indexes for the other samples indicate some adverse effects of nursery culture. These include excessive seedbed density, inferior seed, poor soil fertility, and high concentration of residual eradicants. The latter is especially suggested by the low-quality indexes of samples A and D.

Our work suggests that a quality index of 2-year-old red pine seedlings exceeding 1.5 indicates a high performance potential, 1.0 to 1.5 an acceptable potential, and 1.0 or less a questionable potential. For a more exacting appraisal of nursery stock quality, the properties of trees are determined on at least five composite samples. Each of these samples includes 10 trees collected at 10-centimeter intervals with the use of a sampling ruler laid across the nurserybed (3, p. 165). Five samples is the minimum number permitting calculation of a meaningful standard deviation, if there is a considerable variation in measurements. The standard deviation then permits verification of the reliability of obtained results and rejection of erratic values by using the criterion C = x ÷ d, where *x* is the largest deviation from the average and *d* is the standard deviation (3, p. 197). This more precise appraisal does not require a great deal of extra time and provides more reliable quality indexes of the planting stock.

It should be mentioned that a more complicated ordination analysis (*1, 2*) of the stock samples analyzed in this study yielded similarity indexes (A-18.1, B-100.0, C-56.9, D-19.3) closely related to the index obtained by the mere summation of numerical values of important attributes of trees (table 1).

Summary

A systematic determination of the quality index of nursery stock may increase the effectiveness of reforestation. Low values of the index are caused by excessive density, inferior seed, unbalanced soil fertility, unequal distribution of chemicals and organic matter, and high concentration of residual eradicants.

The appraisal can be applied to the stock produced in different nurseries or the stock produced at different locations in the same nursery.

Table 1.—*Properties of 2-year-old red pine seedlings produced in nursery soils of different fertility levels and residual eradicant contents*

	Nurseries			
Properties of nursery stock	A	B	C	D
Diameter/ height ratio (mm/cm)	0.23	0.30	0.21	0.24
Root/ top ratio (ml)	.30	.45	.38	.31
Specific gravity of stems	.28	.33	.35	.32
Catalytic potential (dm HQ/ plant)	.10	.35	.17	.14
Reciprocal of variability coefficient	.12	.24	.16	.08
Total	1.03	1.67	1.27	1.09

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Potential Use of Crushed Fruit Shells of West Indian Mahogany as a Potting Media Ingredient

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Crushed fruit shells of West Indian mahogany were evaluated as a potting soil media ingredient, both pure and mixed with sand in a 1:1 ratio by volume. Results indicated that the fruit shell/sand mixture was equal to a commercial growing medium for production of healthy, attractive croton plants.

West Indian mahogany *(Swietenia mahagoni* Jacq.) grows throughout the island of St. Croix, Virgin Islands, where it is used as a major part of the road landscape, a good storm-resistant shade tree, and a valuable source of lumber (*5*). This tree grows 1 to 2 feet in height per year and flowers and fruits abundantly. The fruit, a woody, pear-shaped capsule 2 to 4 inches long, is shed during the dry months of the year. Fruits are collected and sometimes harvested by the Forestry Division of the Virgin Islands, Department of Agriculture, for seed extraction. Fruit shells are then heaped and abandoned. Several crop residue materials have been tested as growth media for potted plants with varying degrees of success (*1, 3, 6*). At present, the increasing cost of imported soil media ingredients is a major limiting factor in the production of high-quality potted plants in St. Croix. This experiment explored the possibility of using a local crop residue (mahogany fruit shells) as a substitute for imported media ingredients.

Materials and Methods

Plants of croton *(Codiaeum sp.* var. *Mortii)* were obtained from the Virgin Islands Department of Agriculture. They had recently been air-layered and potted in 1/2-gallon tin containers using soil. Mahogany fruit shells that had been aged for 6 months were shredded using a 3-horsepower Gibson Compost Shredder-Grinder with a sieve plate modified to 1/4 inch. Particle size of the end product ranged from a fine dust to thin fragments 1/4 inch long. A sharp sand obtained from local streams (guts) was mixed with the crushed mahogany shells in a 1:1 ratio by volume. Commercial mix consisting of imported peat and perlite mixed in equal parts with gut sand and soil was bought from a local nursery. Osmocote 14-14-14 was incorporated in all mixes at 4 ounces per cubic foot and Peter's soluble trace element at 1 ounce per cubic foot. The mixtures were made on July 13,1979, and rooted croton plants were potted on July 17,1979, using 1/2-gallon plastic containers.

Experimental design was a completely randomized 2 by 3 factorial consisting of two levels of fertilizer and three soil media mixes. Fertilizer treatment solutions were F_1—Osmocote alone (1 tablespoon per gallon of water) and F_2—Osmocote plus Peter's soluble 20-20-20 mix (1 tablespoon of each per gallon) applied as a soil drench at 1-1/2 pints of solution per pot. Soil media treatments were Ml-pure crushed mahogany fruit shells, M_2—crushed shells plus gut sand in a 1:1 ratio by volume, and M_3—local commercial mix. Each combined treatment was applied to 10 plants so that there were a total of 60 plants. During the first week, plants were kept under a 50-percent shade netting and then moved to full sunlight. Soluble fertilizer treatments were made biweekly starting on July 31. Plants were hand watered, as needed, with cistern rainwater. For 3 months starting August 17, growth measurements were taken of plant height measured .from the rim of the pot to the apical point and plant width at the widest point of the foliage.

Visual grading on a scale of 1 to 5, based on plant size, plant to pot ratio, and general attractiveness of foliage, was done at the termination of the experiment. Data were analyzed by analysis of variance method and treatment means separated by Duncan's new multiple range test.

Results and Discussion

Without additional soluble fertilizer (F_1), growth increases were not significantly different among the three soil mixes except at 12 weeks (table 1, fig. 1). Plants receiving the additional soluble fertilizer (F_2) grew as well in the mahogany shells and sand (M_2) as in the commercial mix (M_3), but better than in the pure mahogany shell media (table 1, fig. 2). There were no differences between plants grown in pure shells with soluble fertilizer (F_2M_1) and

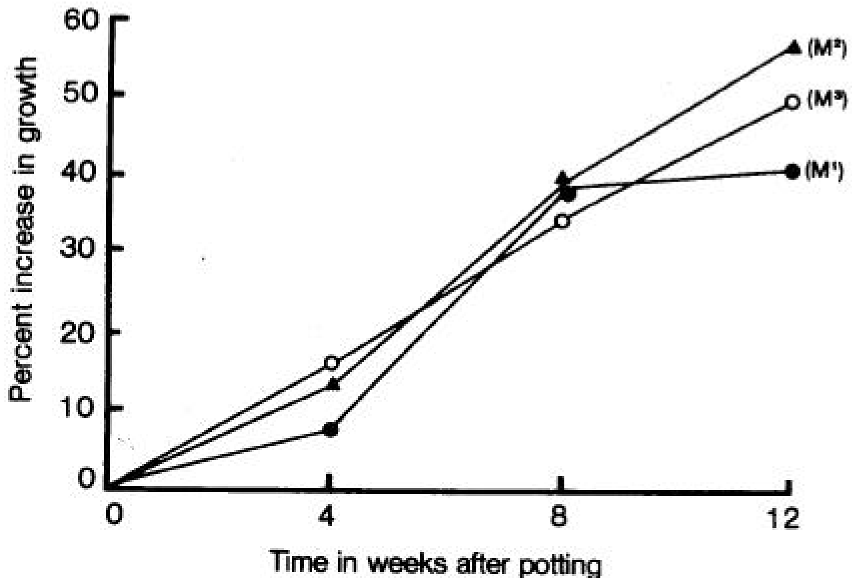

Figure 1.—*Effects* of *three soil media with slow-release fertilizer (F1) on growth* of *croton var.* Mortii *at three monthly intervals.*

Table 1.—*Effects of media and fertilizer on growth and appearance of croton var.* Mortii

Media and fertilizer Treatments[1]	Percent increase In growth[2] 4 weeks	8 weeks	12 weeks	Visual grade (1-5)[3] 12 weeks
F_1M_1	7.2a*	38.1a	40.8a	3.0a
F_1M_2	12.1a	38.3a	56.2bcd	4.3b
F_1M_3	14.8a	34.5a	49.6ad	3.0a
F_2M1	10.8a	40.4a	44.5ac	3.3a
F_2M_2	54.2b	55.7b	73.1 a	4.7b
FM_3	50.5b	56.3b	63.4eb	3.4a

[1]F_1 = Slow-release fertilizer, F_2 = Slow-release and soluble fertilizer, M_1 = Pure mahogany shells, M_2 = Mahogany shells and gut sand, M_3 = Commercial media.

[2]Index (height and width) used as growth measurement.
2

[3]1 = Plants with noncompact unhealthy appearance. 5 = Plants with compact, attractive foliage.

*Means followed by one or more of the same letters do not differ significantly at the 5-percent probability level.

any of the three soil mixes without soluble fertilizer (F_1M_1, F_1M_2, F_1M_3) (table 1). However, at the final growth measurement (12 weeks), the F_1M_2-treated plants had a growth increase similar to the F_2M_1 and F_2M_3 plants (table 1). Two weeks after potting, plants in pure shells without soluble fertilizer (F_1M_1) showed yellowing of basal leaves, an indication of nitrogen deficiency. An application of ammonium sulphate (21-0-0) at 1 tablespoon per pot was sufficient to clear up chlorosis.

In the visual grading, F_1M_2 and F_2M_2 treatments were superior to all others (table 1). This was mainly because of the more luxuriant growth and almost complete absence of weeds in these treatments. Plants grown in the local commercial mix (M_3) grew well, particularly with added soluble fertilizer (F_2M_3); but because of the inclusion of soil in this mix, there were many weeds. Weed species identified were wild or Creole senna *(Phyllanthus niruri* L.), tan tan (Leucaena leucocephala), paletaria (Peperomia pellucida), Pilea sp., and milkweed *(Euphorbia hirta* L.).

A chemical analysis of crushed mahogany fruit shells (table 2) showed the material to be quite high in nutrients except for nitrogen. This would indicate a high C:N ratio and hence the reasons for the chlorosis of plants in the pure mahogany mix (M_1) and the need for added nitrogen in the form of ammonium sulphate. The more aged the crop residue material, the better it is for

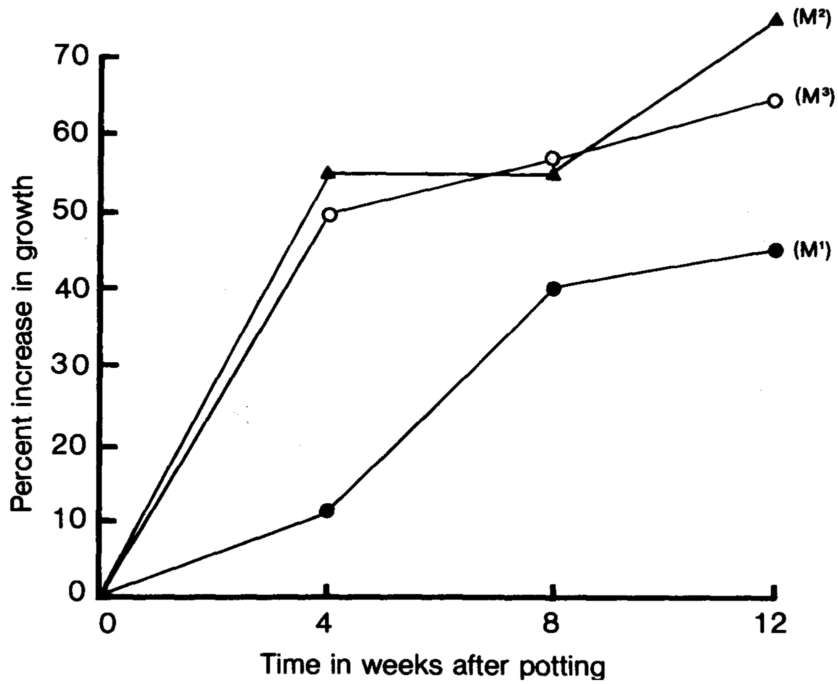

***Figure 2.**—Effects of three soil media with slow-release and soluble fertilizer (FZ) on growth of croton var.* Mortii *at three monthly intervals.*

Table 2.—Chemical composition of a dried, crushed sample of fruit shells of West Indian mahogany (Swietenia mahagoni *Jacq.)* [1]

N	P	K	Ca	Mg	NO_3	Zn	Mn	Cu	Fe	B
%					P/m					
0.24	13.0	496	242	53	20	66.3	34.9	22.8	17.4	0.9

[1]The chemical analysis Is from the United States Testing Company, Inc., Memphis Laboratory, Memphis, Tenn.

potted plants (*2*), so mahogany shells older than 6 months may be even more suitable. Shells also had a good pH, a high cation exchange capacity, and low soluble salts indicative of a good media (*4*). Pure shells held the plants fairly firmly, but the mixture of shells and sand (M_2) held the plants better. Also, the crushed shells were fairly clean, as evidenced by the almost total absence of weeds from pots in which the shells were used. This is an important economical aspect of growing potted plants. The mixture of sand and shells showed no apparent shrinkage, while the pure shells did. The M_1 and M_2 treatments also allowed for good fibrous root development with little evidence of rootbound plants at the end of the experiment. Plants in the M3 mix did not have as good a root structure and many of the roots grew out of the pots at the end of the experimental period.

Availability and costs are other important aspects of a potting medium (4). Mahogany fruits are available for most of the year, and a good supply of cracked fruit shells is available at the Forestry Division, Virgin Islands Department of Agriculture. This medium is therefore cheap and readily available, and its use would convert a by-product into a valuable resource.

The overall results showed that croton plants grew just as well or even better in a mixture of crushed mahogany fruit shells and sand than in a commercially prepared mix containing peat and perlite. For faster, more luxuriant growth, a water-soluble fertilizer should be used in addition to a slow-release fertilizer. However, if plants are to be kept in pots for more than 3 months, there is no need for additional soluble fertilizer. If 6-month-old fruit shells are used alone, plants must be treated with additional nitrogen such as ammonium sulphate. Best weed-free growth and most attractive foliage occurred with a mixture of crushed shells and gut sand.

A wider variety of foliage and floral plants needs to be tested in such a potting medium. However, this initial investigation does indicate that the fruit shells of the West Indies mahogany can be a suitable alternative for expensive imported peat used in the pot plant industry of St. Croix.

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A Vacuum System for Precision Planting of Seeds in a Nurserybed

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A handheld vacuum seeder, which can be used to seed small seedlots rapidly and with the same degree of accuracy obtained by using a planting table or board, has been developed.

It is often necessary to plant small seedlots at precise spacings in nurserybeds. Such seeding is generally done by dropping one seed at a time through appropriately spaced holes in a planting board placed directly on the soil surface. The use of these boards is tiring and time consuming and requires close attention to insure that a seed is placed in each hole. Recently Kok (1) described a planting table—a boxlike structure with one planting board as the top and another as the bottom, with matching holes in the boards connected with plastic tubing. This table eliminates the physical strain of stooping or squatting while placing a seed at each seed spot. However, the table has not eliminated the need to insure that all seed spots are filled, and the release of individual seeds is still time consuming.

A search for a better seeding device led to the development of a vacuum system for rapid pickup and placement of seed in the seedbed.

The system described here was developed for planting small seedlots of Choctawhatchee sand pine (Pinus clausa var. immuginata D. B. Ward). The vacuum head or brush of a small, handheld, alternating current vacuum cleaner was replaced with a piece of 1/2-inch-diameter conduit pipe 25 inches long (fig. 1). Starting at a point 3/4 inch from one end of this pipe, a row of 48 holes, 1/30 inch in diameter, spaced 1/2 inch apart, were drilled in a straight line along the length of the pipe. A 1/4- by 3/4-inch slot was cut out at the center of the conduit pipe on the side opposite and parallel to the line of 1/30-inch-diameter holes. The metal end of the vacuum hose was compressed into an elongated oval and shaped to fit over the slot in the conduit pipe, thus forming a *T*. The two pieces were then taped together to form an airtight seal, but could have been soldered for a more permanent connection. The ends of the conduit pipe were closed with rub-

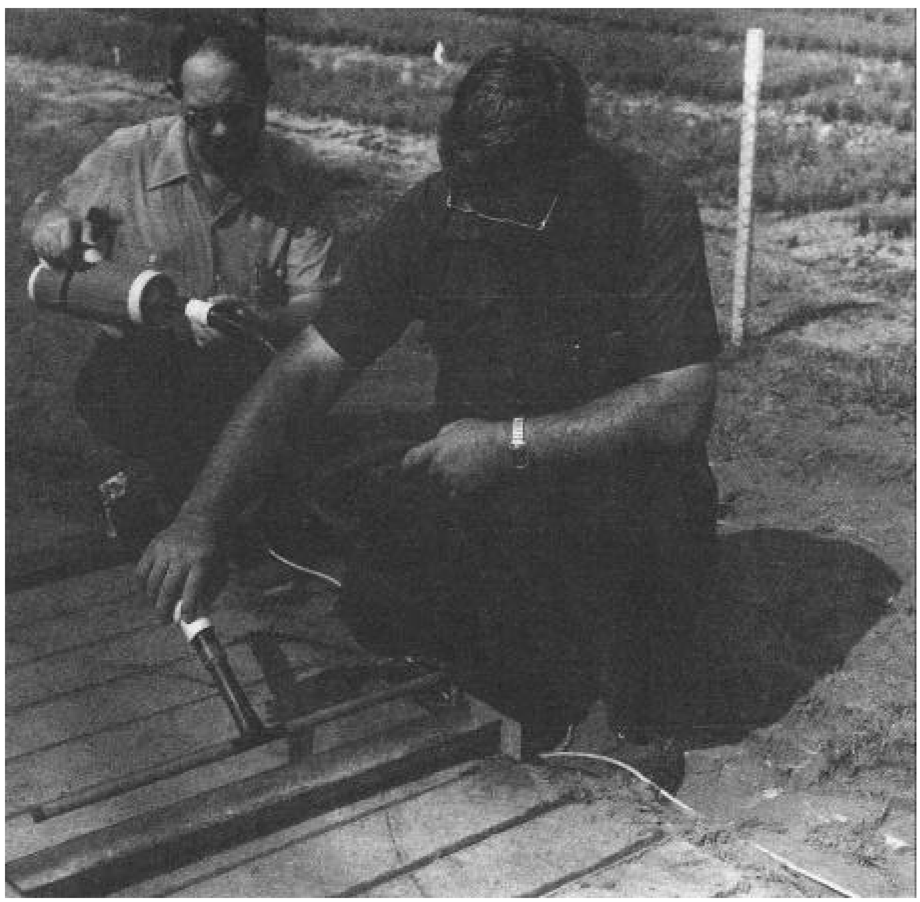

Figure 1.—*Seeding small nurserybeds with a vacuum system is fast and efficient.*

[1] We thank C. D. Dawsey, Broward Davis, and Robert 1. Flanders, J r., for their contributions to the design and construction of the vacuum seeder.

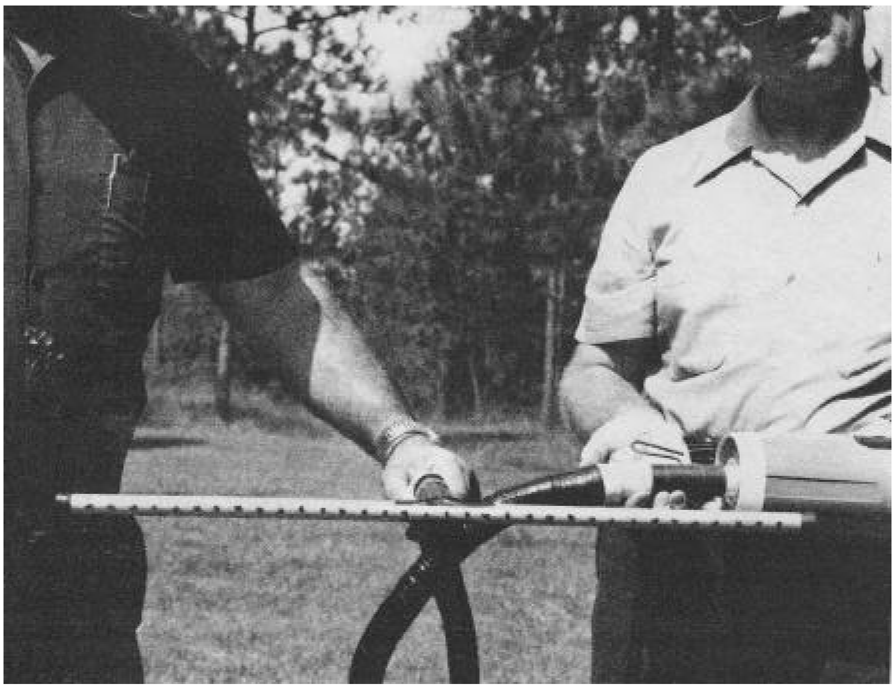

Figure 2.—*Suction through a seed head, made of 1/2-inch conduit pipe, holds small sand pine seeds for accurate placement in the seedbed.*

ber stoppers so that suction could develop at the small pickup holes in the pipe (fig. 2).

A pipe fitted with a flutter valve and control handle was installed between the body of the vacuum cleaner and the hose (fig. 3). This allows suction to be broken at the instant seeds are to be released onto the seedbed.

A tray to hold the seeds was constructed of thin sheet metal (fig. 4). The tray is 26 inches long, 2 inches wide, and 2 inches deep, with a slightly concave bottom to keep the seeds concentrated where they can be easily picked up by the vacuum seed head. The square ends of the tray form a stand to keep it upright.

After the seedbed is marked for the desired row intervals, one person holds the vacuum cleaner and controls the vacuum shut-off valve. At the same time, a second person manipulates the vacuum seed head to place the seeds at the desired location.

This system is faster and less tiring than a planting board and just as accurate in placing seeds. It can be adapted easily to different spacings by sealing the appropriate pickup holes or by making a series of pickup pipes to cover a range of within-range spacings. A pickup pipe can be made to plant different sizes or different kinds of seeds by varying the size of the pickup holes.

A small, gasoline-powered generator could be used to power this seeder if it is necessary to use it in a section of a nursery where there is no electric current. Battery-powered vacuum cleaners are becoming more reliable and could be substituted for the conventionally powered vacuum cleaner.

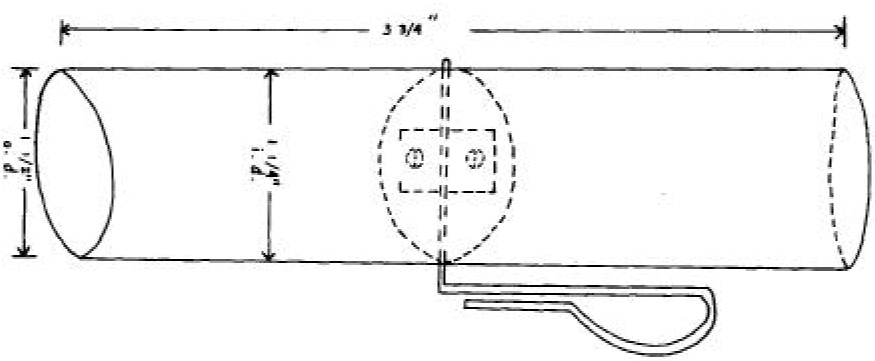

Figure 3.—*Diagram of flutter valve and control handle for breaking suction to drop seeds.*

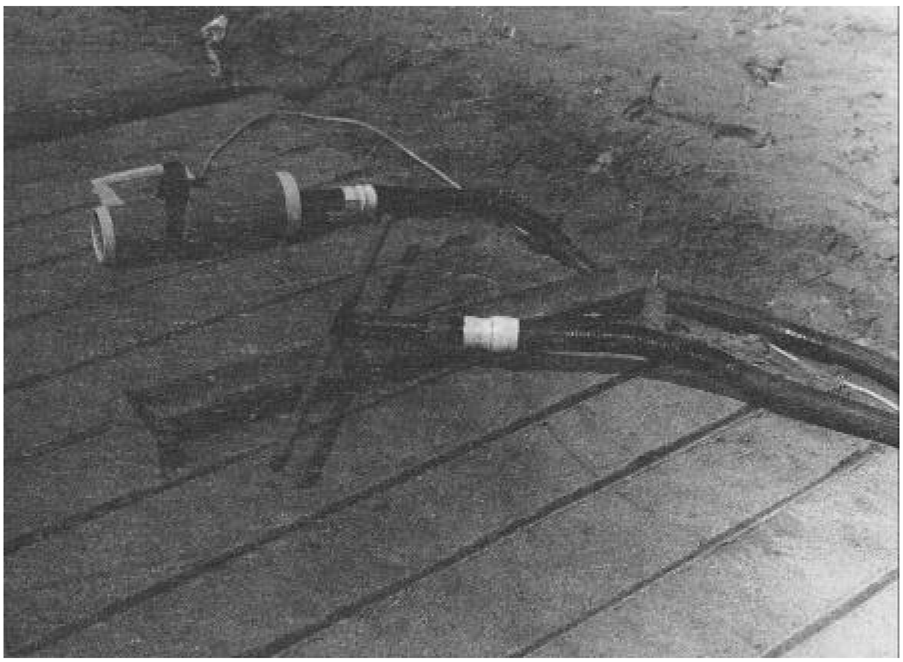

Figure 4.—*A concave metal tray concentrates seeds for easy pickup by the vacuum system.*

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Weed Sanitation Program at the Vallonia Nursery

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A weed control program, which significantly reduced weed control cost and improved the degree of weed control, has been developed. The basic idea is to destroy weed seeds by fumigation and then prevent them from reinfesting the seedbed.

Weed control is an important part of the process of growing high-quality nursery stock. Weeds compete with seedlings for soil moisture, nutrients, and light. This competition is a particularly severe problem in the forest nursery because many tree seedlings grow very slowly for the first few months after germination, whereas weeds grow very rapidly under the ideal soil and moisture conditions of the nursery-bed. Weeds also interfere with tree lifting and may harbor insect and disease pests.

The Vallonia Nursery has developed a weed sanitation program, which has significantly reuced weed control cost, greatly improved the degree of weed control, and avoided the problems posed by herbicides. In 1974, standard weed control practices were followed with handweeding as the primary method. Nursery production was about *4* million seedlings per year. The weeding required approximately 6,464 hours of wage-rate labor. The weed sanitation program was initiated in 1975 and refined over several years. In 1981, after the program had been in full operation for a complete rotation, weed control required only 1,542 hours of wage-rate labor. This is a work-hour reduction of *76* percent and a savings of about $18,000 during the year. At the same time, nearly 100-percent control of weeds was obtained in the seedbeds. To achieve these results, management must first understand the principles behind the program and be committed to carrying out the details. Second, approximately $100 per year in herbicide cost must be allocated to control weeds in areas adjacent to seedbeds. Herbicides are an integral part of the program, but they are applied to areas adjacent to seedbeds rather than directly to the seedbeds.

The following is a description of the essential parts of the Vallonia Nursery weed sanitation program. The basic idea is to destroy weed seeds in the soil by fumigation and then prevent them from reinfesting the seedbed.

1. The first step is a thorough soil fumigation program to kill weed seeds in the soil. Soil fumigation is standard practice in most nurseries for insect, disease, and weed control. The bed ends should also be fumigated so that subsequent nursery operations do not mix unfumigated soil into the seedbed. For example, a bedformer can spread unfumigated soil from the bed ends over the entire seedbed. If soil erosion is a problem on the bed ends, a cover crop such as rye should be sown.
2. The second step is to prevent weed seeds from reinfesting the fumigated soil. Weed seeds can get back into the fumigated seedbed from several sources.
   a. Windblown seeds from plants such as dandelion (*Taraxacum* spp.), fleabane (*Erigeron* spp.), and willow (*Salix* spp.). This source can be greatly reduced by spraying adjacent fields and lawns with a phenoxy-type herbicide such as 2,4-D (2,4 dichlorophenoxyacetic acid). The best time to spray is based on the prevention of weed seed production. Fall spraying is ideal for controlling dandelion, whereas fleabane seeds mature in late summer. When willow or other tree species with windborne seeds are a problem, consideration should be given to removing trees adjacent to the seedbeds. One must determine the source of the weed problem and then attempt to control or eliminate the source.
   b. Waterborne seeds from plants growing adjacent to the seedbed or seeds carried with soil eroding from adjacent areas. This seed source is controlled by fumigating the bed ends and by diverting floodwater away from seedbed areas.
   c. Weed seeds that are carried into the fumigated seedbed

on nursery equipment. A tractor that has been used for mowing or one that has accumulated soil from unfumigated areas can carry thousands of weed seeds, as well as disease organisms. The solution is to keep tractors and other equipment clean. This should be standard practice for disease control.

d. Weed seeds that are not killed by fumigation. Certain weed species such as wild geranium (*Geranium* spp.) and clover (*Trifolium* spp.) have seeds that are resistant to fumigation. The only solution is to remove these weeds before they produce more seeds. Over a period of years, this problem can be greatly reduced.

e. Weed seeds from uncommon sources that may be unique to a specific situation. Examples might be seeds carried in irrigation water or with windblown soil. Irrigation water should be screened and cover crops and windbreaks should be used to reduce windblown soil.

3. The third step is to prevent seed production by weeds that escape prevention efforts. One weed, if allowed to mature seed, can produce hundreds or thousands of new weeds within a few weeks. The solution is to remove these weeds before they can produce seed. At the Vallonia Nursery, the seedbeds are handweeded once a week in early summer and once every 2 to 4 weeks in late summer. The weeds are collected in buckets and removed from the seedbeds. At this nursery, it requires an average of 64 work hours per week to remove essentially all of the weeds in the seedbeds. This could be reduced if safe and effective herbicides can be used in the seedbeds. However, some handweeding will be necessary, because most herbicides are selective in that certain weeds are controlled much better than others.

4. The fourth step is to minimize weed seed production when the area is rotated to cover crops. At the Vallonia Nursery, we use a 3-or 4-year rotation of seedling production (1 or 2 years), cover crop, and a fallow year to decompose the cover crop and prepare the area for fall fumigation and sowing. In the spring, after the seedlings are harvested, the seedbed area is heavily fertilized and sown to a crop of sorghum-Sudan. This crop germinates and grows very rapidly, thereby crowding out most weeds. Weed control in irrigation lines and bed ends is continued by using contact herbicides. The sorghum-sudan is allowed to grow all summer and is plowed under the following spring. The area is then disked as often as necessary to prevent weed seed production (about once a month) and to hasten decomposition of the cover crop. It is not necessary to follow this type of rotation as long as weed seed production is minimized during the rotation. At the Vallonia Nursery the weed population has decreased with each rotation.

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Lesser Cornstalk Borer Damage to Forest Nursery Seedlings in Florida

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The lesser cornstalk borer is an insect pest in Florida's forest nurseries. Generally, seedling losses are minimal; however, one nursery in 1981 lost about 1 million seedlings, and seven tree species were attacked. Field diagnosis and control measures are described.

The lesser cornstalk borer (LCB) (*Elasmopalpus lignosellus*) attacks a variety of agricultural crop species such as corn, peanut, sorghum, and soybean (*4*). LCB larvae will also feed on tree seedlings in southern forest nurseries. Known host species are black locust (*Robinia pseudo-acacia*), loblolly pine (*Pinus taeda*), (*1*), and Arizona cypress (*Cupressus arizonica*) (*2*).

In Florida, seedling losses to LCB have apparently varied year to year and by species. Forest nursery personnel, responding to a 1980 questionnaire, estimated that the LCB impact rariged from 0 to 2 percent of total nursery production in recent years. Unfortunately, no data were available to develop a comprehensive description of LCB activity. An LCB infestation in one nursery in 1981 has since provided the opportunity to remedy, in part, this lack of knowledge.

Situation

The nursery, located in central Florida, estimated final production to exceed 47 million softwood and hardwood seedlings; however, about 1 million seedlings were subsequently killed by LCB. In addition, nearly 1 million seedlings were injured by LCB, yet survived in the nurserybed. The field performance of these seedlings is unknown. Overall, total production at the nursery decreased 1.8 percent.

Several species were susceptible to LCB attack—baldcypress (*Taxodium distichum*), black tupelo (*Nyssa sylvatica*), flowering dogwood (*Corpus florida*), loblolly pine, southern red cedar (*Juniperus silicicola*), sand pine (*Pinus clausa*), slash pine (*Pinus elliottii*), and sycamore (*Platanus occidentalis*).

Species not attacked were black cherry, catalpa, laurel oak, live oak, longleaf pine, magnolia, spruce pine, and Virginia pine.

Based on the location and number of observed moths, the LCB infestations were probably centered in the millet (*Panicum miliaceum*) and field corn (*Zea mays*) covercrops (about 30 acres) in the nursery. Subsequently, it was found that nearby soybean fields were severely damaged by LCB as well.

In the nursery, LCB moths were first observed in mid-May, predominantly in the covercrops. Not until early July did the magnitude of the problem become apparent in the seedling beds. Thousands of seedlings exhibited discolored foliage and/or stems broken at groundline because of LCB larvae girdling below ground.

Control Action and Results

Two insecticide applications of carbaryl were made in July to affected seedling beds; however, foliage density probably decreased insecticide effectiveness. A soil drench insecticide (carbaryl) application to the covercrops was facilitated by chopping the plants to an 8-inch height. Selected seedling beds and the covercrops were treated again in early August. The covercrops were plowed under and disked repeatedly in late August, primarily as a preventive measure. The lack of additional seedling losses suggests treatment success since LCB damage in agricultural crops typically peaks in August.

The locations of covercrops and predominant seedling species within the nursery are shown in figure 1. Flowering dogwoods in compartment 8 experienced the greatest mortality—nearly 70 percent, and 30 percent of the live seedlings exhibited feeding scars from the LCB. The lesser damage incidence for the coniferous species may have been because resinous sap afforded some seedling protection.

Also, in compartment 7 and east of compartment 2, peanut shells were used as an organic amendment. Peanuts plants are a favored host of LCB, and it has been demonstrated that some insect species use odors associated with host plants to aid in the location of suitable oviposition sites. Thus, seedling losses may have been aggravated because of female moth

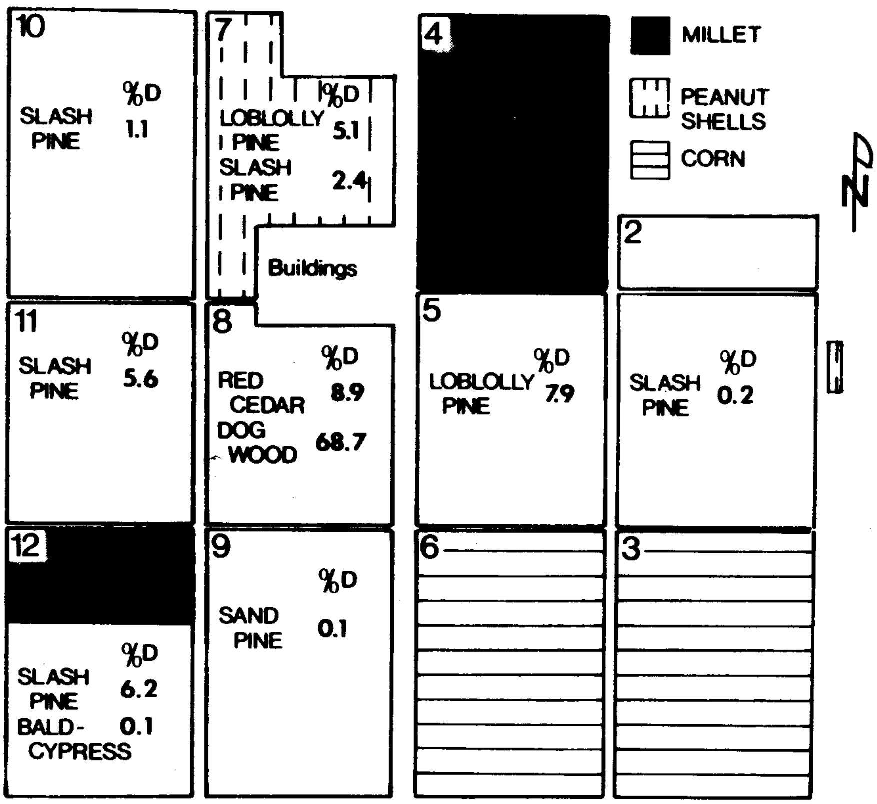

Figure 1.—*Location* of *covercrop and predominant seedling species affected by larvae* of *the lesser cornstalk borer. %D = percent kill; 1-12 = compartment block numbers.*

orientation to residual odors from the shells. Compartment 2 damage was limited to a small area adjacent to peanut shells.

LCB Biology, Diagnosis, and Control Strategy

Insect biology. After emerging from the soil in late spring, adult moths mate and females deposit eggs singly in the soil at the base of host plants or on stems and lower leaves. Eggs hatch within 1 week, and larvae mine lowermost branches or begin semisubterranean feeding on stems and roots. Silk tunnels, radiating from feeding sites, protect larvae. The larval feeding period lasts 2 to 3 weeks. Pupation occurs in the silk tunnels or soil litter, requiring 2 to 3 weeks to complete. The new adults emerge, mate, and may live up to 10 days. Each female lays about 125 eggs. By late summer most life stages can be found because of generation overlap; there are 2 to 4 generations per year. Larvae or pupae survive winter in the soil or soil litter (*3*).

Field diagnosis. Severely damaged seedlings usually die and may either remain upright or fall over; often several seedlings in a drill are attacked. Below ground, larval feeding is indicated by stem girdling (fig. 2), gall-like stem formation (fig. 3), or callous tissue around a feeding wound (fig. 4). The slender larvae (less than 1 in. in length) are pale green with brown banding or stripes. Larvae are difficult to find and wriggle furiously when captured. Moths are brownish gray with a wingspan of about 1 inch. More readily observed than larvae, the moth's flight pattern is short, jerky, and just above seedling tops.

Control. A lesser cornstalk borer infestation is favored by the

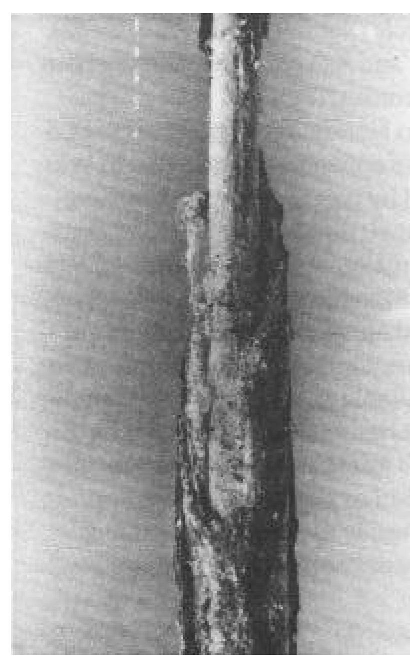

Figure 2.—*Below ground girdling* of *a baldcypress seedling by a lesser cornstalk borer.*

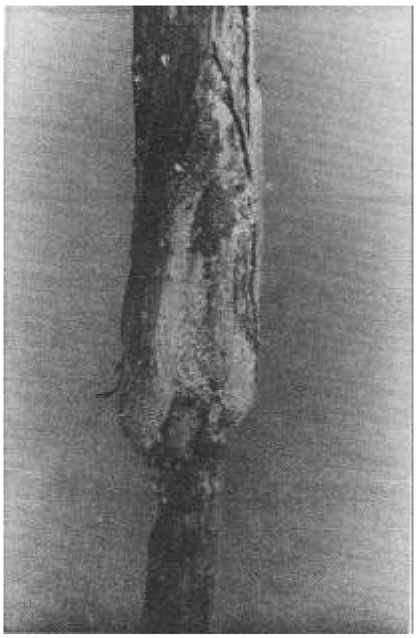

Figure 3.—*Gall-like tissue formation on a baldcypress seedling damaged by a lesser cornstalk borer larva.*

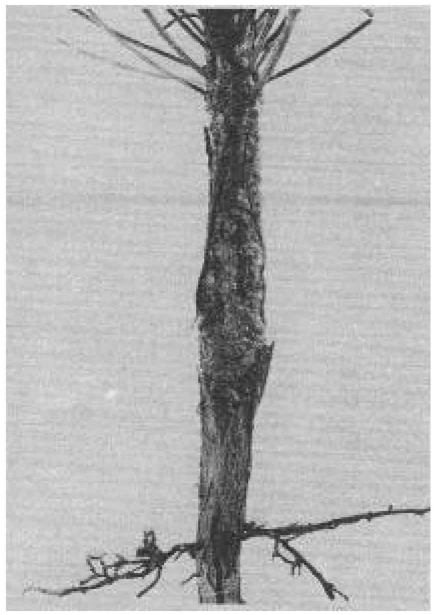

Figure 4.—*Callous tissue and feeding scar on a baldcypress seedling.*

presence of susceptible covercrops, sandy soils, and drought weather-all of which were present in this nursery. Amelioration of these factors, where possible, plus general sanitation measures, late fall plowing, and covercrop rotation should lessen the incidence or impact of the insect. If these measures fail, a preventive insecticide treatment deserves consideration in future nursery efforts (*4*). A granular insecticide (carbofuran, diazinon, chlorpyrifos, parathion) is incorporated into the soil simultaneously with covercrop sowing. The insecticide used will depend on the covercrop being grown. Ultimately, a remedial treatment may become necessary. An insecticide, such as carbaryl, is applied as a soil drench at the first sign of seedling damage. More than one application may be needed because the silk tubes of larvae in the soil make it especially difficult to insure adequate larval exposure to the insecticide.

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