Direct-Seeded Sawtooth Oaks (*Quercus acutissima* Carruth.) Show Rapid Growth on Diverse Sites

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*Direct-seeded sawtooth oak (*Quercus acutissima *Carruth.) grew very well on the Mississippi River floodplain despite high soil pH, short-term flooding, and poor soil aeration. Early growth was more rapid than that of local oak species. Acorn production was general by the 14th growing season.*

In recent years, sawtooth oak (*Quercus acutissima* Carruth.) has been widely planted in the United States as an ornamental and wildlife food tree. The species occurs naturally through the Himalayas, China, Formosa, Korea, and Japan, and was introduced into the United States in 1862. Most forestry and conservation plantings are descended from trees growing on the University of Georgia campus and at the National Plant Introduction Station, Savannah, GA (3).

Sawtooth oak has shown broad adaptability and many good qualities. Sullivan and Young (5) report no restriction in planting sawtooth oak on well-drained upland soils of the Coastal Plain, Piedmont, or Appalachian areas. Spicer (4) recommends the species for planting in unfavorable urban environments. Schoenike (2) reports good survival and height growth in South Carolina after 5 years. Stem form was relatively poor, however. Sawtooth oaks in small-scale plantings in Georgia and Mississippi produced acorns more prolifically than native oaks. Acorn production began the sixth year (1).

The purpose of this study was to test direct seeding as a way of establishing sawtooth oak and to test the species' performance on sites generally considered too wet for it.

Methods

Two sites were direct seeded. The Huntington Point site (Bolivar County, MS) had a Bruin soil (coarse-silty, mixed, thermic Fluvaquentic Eutrochrepts) with silty clay loam surface layer underlain by fine sandy loam. The soil has a pH of 7.4 and floods to a depth of 2 or 3 feet for 1 to 3 weeks in those springs when the Mississippi River overflows its banks. Otherwise, the site is well drained. The Delta Experimental Forest site (Washington County, MS) (fig. 1) had an Alligator soil (very fine, montmorillonitic, acid, thermic Vertic Haplaquepts) with clayey texture throughout and a pH of 5.2. Although it rarely floods, this soil is generally saturated during the winter and spring.

Both sites were cleared mechanically and disked before seeding. Acorns acquired from a Mississippi source were stored dry at 35 to 40 °F until planting in April 1970. Two to four acorns were sown 1 to 2 inches deep in spots spaced 10 by 10 feet apart. The Huntington Point site had 80 seed spots and the Delta Experimental Forest site had 96 spots. The seed spots were hoed twice during the first year, and the plots were mowed between rows in the second and third years.

Nuttall oaks (*Q. nuttallii* Palmer) were seeded at the Delta Experimental Forest site in rows alternating with the sawtooth oak. The acorns were stored in water at 40 °F through the winter and planted in a manner similar to that of the sawtooth oaks.

During the winter after the 14th growing season, the diameters (breast height) of all trees were measured with a diameter tape. Total heights were measured with an altimeter. If more than one tree was present in a seed spot, the tallest was measured. A tree was considered to be an acorn producer if at least two acorns or two acorn caps could be found under its crown. Diameters and heights of sawtooth and Nuttall oaks on the Delta Experimental Forest site were compared by the unpaired t test (? = .05).

Results

Sawtooth oaks at the Huntington Point site at age 14 averaged 5.1 inches d.b.h. and 34 feet tall (table 1). The d.b.h. ranged from 1.8 to 10.2 inches,

Figure 1—*Plantation of 14-year-old direct-seeded oaks. Nuttall oaks are in the row at* **left**, *sawtooth oaks in the row at the* **right**.

Table 1—*Total height, diameter at breast height, survival, and percentage acorn producers in 14-year-old sawtooth oaks on two sites and Nuttall oaks planted for comparison.*

Trees	Height (ft)	d.b.h. (in)	Percent survival	Percent trees producing acoms
Sawtooth oak				
Huntington Point	34	5.1	59	85
Delta Experimental Forest	28	4.0	60	86
Nuttall oak				
Delta Experimental Forest	23	3.0	69	0

and the height ranged from 14 to 56 feet. Of the seed spots planted, 59 percent contained at least one living oak. (Two of the seed spots produced multiple stems.) Eighty-five percent of the stocked spots had produced acorns.

The Delta Experimental Forest sawtooth oaks averaged 4.0 inches d.b.h. and 28 feet tall. Their range was 0.8 to 6.6 inches d.b.h. and 8 to 34 feet tall. Seedspot survival was 60 percent. Nineteen percent of the live seed spots had two or more stems. Eighty-six percent of the stocked spots produced acorns.

The sawtooth oaks in these two plantings have very strong apical dominance and are straight except for occasional crooks about 3 feet from the ground. Many of their lower limbs are thick and persistent, however. Some of the larger trees appear to be heavy acorn producers.

Nuttall oaks averaged 3.0 inches d.b.h. and 23 feet tall. Diameters ranged from 1.8 to 6.3 inches, and heights ranged from 16 to 31 feet. Both diameters and heights of Nuttall oaks were significantly smaller than those of sawtooth oaks on the same site. Seed-spot survival was 69 percent. No acorns were observed.

Discussion and Conclusions

These plantings demonstrate the sawtooth oak's adaptability to a wide range of sites. The species (or rather the genotypes represented) tolerated high pH, moderate flooding during the growing season, and poor soil aeration. It had previously been reported (3) that sawtooth oak could not tolerate floods or wet conditions during the growing season. Further, this study shows that the species may be successfully reproduced by direct seeding.

Sawtooth oaks exhibit rapid early height and diameter growth after establishment by direct seeding. The species has the potential to produce at least pulpwood and firewood. Its growth exceeded that of Nuttall, one of the faster growing indigenous oak species. However, sawtooth oak had a lower survival rate and was more variable in height and diameter than Nuttall. Indigenous oak species normally grow slowly during the first 5 years. The Nuttall oaks will undoubtedly overtake the sawtooth oaks eventually.

One of the main attractions of sawtooth oak is its ability to produce acorns at an early age. Under plantation conditions, nearly all the average- and above-average-sized trees were producing acorns by the 14th growing season.

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Eighteen-Year Development of Sweetgum *(Liquidambar styraciflua* L.) Plantings on Two Sites

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Average diameter and height of planted sweetgum at age 18 were 5.7 inches and 37 feet on a fine-textured soil compared to 10.1 inches and 65 feet on a medium-textured soil.

Sweetgum (*Liquidambar styraciflua* L.) has a wider distribution than any southern hardwood species. Regeneration may occur from either stump and root sprouts or from seed. Planting of bare rooted seedlings is also feasible, with sweetgum being one of four hardwood species used in intensive plantation management in the Southeast (6). This paper compares the growth of two 18-year-old planted stands of similar genetic makeup on two different soils in Mississippi.

Methods

The two sweetgum plantations were established in the winter of 1964-65 growing season at 10- by 10-foot spacing. One planting was at Huntington Point (HP), Bolivar County, MS, on medium-textured Commerce silt loam soil in the Mississippi River floodplain. The other was on the Delta Experimental Forest (DEF), Washington County, MS, on a fine-textured Sharkey clay soil. Sweetgum occurs frequently on both soils and is rated as a species that should be favored in management and is suitable for planting (1). Sharkey is a member of the very fine, montmorillonitic, nonacid thermic family of Vertic Haplaquepts, and Commerce is a member of the fine-silty, mixed, nonacid thermic family of Aeric Fluvaquents. Each planting consisted of 100 seedlings from each of 81 open-pollinated families. Seeds were obtained from six areas: one each in Arkansas and Tennessee and two each in Alabama and Mississippi.

The sites were kept mostly weed free by cultivation the first 2 years. Mowing was used for weed control the following years. At HP, alternate diagonal row thinning was done on part of the planting at age 6 and on the remainder of the planting at age 8. Similar thinning was done on the DEF at age 12.

After the 18th year, all trees in two east-west randomly selected rows at each site, other than border trees at each end of the rows, were measured for diameter at breast height (d.b.h.) and height. After trees leafed out the following growing season, clear bole length and height to live crown were measured on HP trees.

Cubic volume estimations were obtained from Barr and Stroud dendrometer measurements of 22 trees at HP and 10 at DEF. Equations were developed for stem volume (outside bark) from a 1-foot stump to the tip of the stem (VOB) or to a 4-inch outside bark diameter (VOB4) (table 1). Stem weights were calculated from cubic volumes, with an assumed dry density of 28.7 pounds per cubic foot.

Results and Discussion

The better site (HP) sweetgum was about 75 percent larger in both d.b.h. and height and had three times greater basal area and nearly five times more volume and weight in the main stem from a 1-foot stump to the top than the poorer site (DEF) sweetgum with the same stocking at age 18 (table 2). Outside bark volume to a flinch top was 94 percent (HP) and 69 percent (DEF) of total stem volume outside bark. Assuming 90 cubic feet per cord, volume mean annual increment to a flinch top was 1.6 and 0.2 cords per acre per year on the two sites, exclusive of thinned trees.

Clear bole length of HP trees averaged 10 feet (range 4 to 17 feet) and was unrelated to d.b.h. or total height ($r^2 < 0.01$). Live crown ratio of HP trees averaged 54 percent, and was more closely related to d.b.h. (r^2=0.43) than to total height (r^2 = 0.33).

Early height development of these two plantings, after 1, 3, and 6 years, was 1.5, 5.8, and 12.7 feet at DEF and 2.3, 10.8, and 27.1

Table 1—*Cubic volume estimations for sweetgum grown at two sites in Mississippi*

Huntington Point (Commerce silt loam soil)

$VOB = 1.383 + 0.001876\ D^2H$
$r^2 = 0.95$
$S_{y \cdot x} = 1.28$
$\bar{V} = 15.9$

$VOB4 = 0.002 + 0.001945\ D^2H$
$r^2 = 0.95$
$S_{y \cdot x} = 1.41$
$\bar{V} = 15.1$

Delta Experimental Forest (Sharkey clay soil)

$VOB = 0.285 + 0.002099\ D^2H$
$r^2 = 0.95$
$S_{y \cdot x} = 0.27$
$\bar{V} = 4.1$

$VOB4 = -0.729 + 0.002189\ D^2H$
$r^2 = 0.92$
$S_{y \cdot x} = 0.35$
$\bar{V} = 3.2$

VOB = stem volume (outside bark) from a 1-foot stump to the tip of the stem, VOB4 = 4-inch outside bark diameter, D = diameter at breast height, H = total height.

feet at HP.[1] Other sweetgum planting studies on the same soils on these two areas gave similar results, with sweetgum height at age 4 of 12.0 feet at HP (3) and heights of 1.4, 5.4, and 12.5 feet at ages 1, 3, and 6 on the DEF (4).

From soil series, for natural stands, the estimated site index range is from 80 to 100 feet at age 50 for Sharkey and from 100 to 120 feet for Commerce (1). Dominant tree heights at age 18, based on the 5 tallest trees per sample row or 26 tallest trees per acre, of 72 feet at HP and 43 feet at DEF may be used to calculate site indices from two different sets of natural stand curves. From curves based on plots in Alabama (5), the DEF heights equated to site index 75 at age 50; the HP heights were beyond the curves but calculated as site index 110, a reasonable figure. Extending site index curves based on plots from the lower Mississippi River Valley (2) produced site values of 80 and an unrealistic 135 for the two areas. Therefore, sweetgum site index, whether from planted or natural stands, is probably around 80 on Sharkey and 110 on Commerce. Each additional foot of height, as estimated by site index, amounted to an increase of 74 cubic feet of volume or 13 percent more growth.

That Sharkey clay is a poorer site for planting than Commerce has also been found for cottonwood (*Populus deltoides* Bartr. ex Marsh.), and sycamore (*Platanus occidentalis* L.), where 10-year height growth has only been 55 to 60 percent as good (4). Similarly, sweetgum height growth at age 18 was only 57 percent as good on Sharkey as it was on Commerce.

These sweetgum plantings have shown good survival, and thus plantations are a good means for establishing the species (figs. 1 and 2). However, planting is an intensive and expensive management alternative. As clearing costs are generally similar regardless of sites, planting on better sites represents a much better investment. Natural regeneration may be preferred to planting, especially on poorer sites.

[1] Unpublished data on file at Southern Hardwoods Laboratory, Stoneville, MS.

Table 2—*Eighteen-year values for sweetgum grown at two sites in Mississippi*

Variable	Huntington Point (Commerce soil)	Delta Experimental Forest (Sharkey soil)
Trees per acre	192	194
Diameter (in)		
Average	10.1	5.7
Range	5.5–14.7	4.6–7.3
Height (ft)		
Average	65	37
Range	48–75	30–46
Basal area (ft^2/acre)	111	35
Cubic volume (ft^3/acre)	2780	565
Dry weight (tons/acre)	39.91	8.08

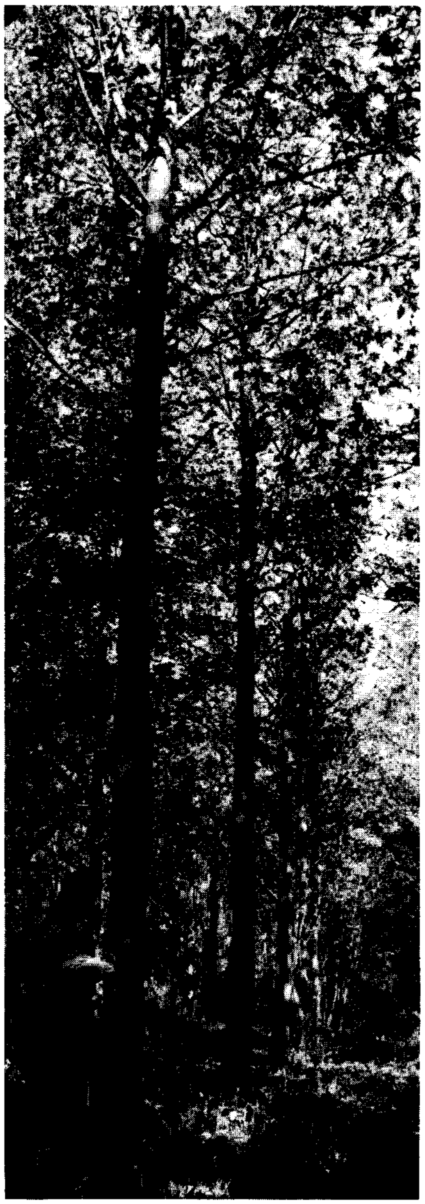

Figure 1—*General view of 20-year-old planted sweetgum on Sharkey clay soil.*

Figure 2—*General view of 20-year-old planted sweetgum on Commerce silt loam soil.*

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'Interstate' Sericea Lespedeza: A Long-Term Nitrogen Source for Loblolly Pine Growing on Coal Mine Spoil

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*The effects of several combinations of nitrogen (N) and phosphorus (P) fertilizers with different cover crops on the growth of loblolly pine (*Pinus taeda *L.) seedlings in Appalachian coal mine spoils were compared from 1970 through 1979. For the first 5 years, two or three N applications during this period resulted in greater tree growth than a single N application in combination with an understory of sericea lespedeza (*Lespedeza cuneata *Dum.) G. Don var. 'Interstate.' However, from the sixth through the ninth years N supplied by the lespedeza resulted in significantly better growth than occurred on plots that had received multiple N applications. Beneficial effects of sericea lespedeza could still be seen after 14 years.*

Experiments have shown that most coal spoils in Appalachia supply inadequate amounts of N and P for good growth of tree seedlings and herbaceous vegetation (1,3,4). Nutrient deficiencies could be corrected, at least for the short term, by conventional fertilizer applications providing at least 50 kg/ha each of N and P. However, maintaining long-term productivity of nonleguminous plants without supplemental N applications has been difficult.

Bengtson and Mays (2) reported on a study conducted from 1970 through 1976 that evaluated the effects of combinations of fertilizer treatments and cover crops on the growth of young loblolly pines (*Pinus taeda* L.). Their work showed the benefits of an initial application of NP fertilizer and repeated applications of N in increasing growth of pines and improving stands of tall fescue (*Festuca arundinacea* Schreb.) and common bermudagrass (*Cynodon dactylon* (L.) Pers.) understory plantings. The beneficial N-supplying effects of an understory of sericea lespedeza (*Lespedeza cuneata* (Dum.) G. Don) var. 'Interstate' was suggested but not fully realized during the period covered by that publication. Data collected from the same series of plots following the 1979 growing season clearly showed the favorable effects of this variety of lespedeza on the long-term growth of loblolly pine.

Methods

The experiment was established in September 1970 at the Arch Coal Company's Fabius mine on Sand Mountain, near Stevenson, AL. Spoil at this mine is derived from sandstone, conglomerate, and shale; its pyrite content is minimal. The site was a graded roadside spoil bank planted about 9 months previously with 1+0 loblolly pine seedlings at 2-meter spacing in rows 2.5 meters apart. At the time of treatment, about 70 percent of the planted trees had survived. Few pines died subsequently.

Analysis of the < 2 millimeter fraction of spoil showed the following mean values: pH (in water), 4.8; organic matter, 12 percent; double-acid-extractable P, 0.5 parts per million; cation exchange capacity, 3.32 milliequivalents per 100 grams; exchangeable bases, 0.06, 0.86, and 0.42 milliequivalents per 100 grams from potassium (K), calcium (Ca), and magnesium (Mg), respectively.

Herbaceous species selected for interseeding were 'Kentucky 31' tall fescue, common bermudagrass, and 'Interstate' sericea lespedeza, a dwarf mutant variety. The lespedeza seeds were treated immediately before sowing with commercially prepared lespedeza inoculum. Fescue was seeded in the fall of 1970; the bermudagrass and lespedeza were seeded in 1971. The NP fertilizer treatment was applied just before planting (table 1).

To minimize extension of pine roots across plot boundaries, in the winter of 1974 we severed

Table 1—*Fertilizer broadcast over experimental plot of graded roadside coal mine spoil planted with loblolly pine (values are in kilograms per hectare).*

Fertilizer treatment	First application[1]			Additional application[2]				Cover crop[3]	
	N	P	Date	N	Date	P	Date	Species	Date
0	0	0	—	0	—	0	—	None	—
NP+N	84	150	9/70	112	9/71	0	—	None	—
NP+N+N	84	150	4/71	112	9/71	112	4/75	None	—
NP+N	84	150	9/70	112	9/71	0	—	K31	9/70
NP+N	84	150	4/71	112	4/72	0	—	CBG	4/71
NP	84	150	4/71	0	—	0	—	ISL	4/71

[1]N and P were applied as ammonium polyphosphate.
[2]N was applied as ammonium nitrate.
[3]K31 = 'Kentucky 31' tall fescue, CBG = common bermudagrass, ISL = 'Interstate' sericea lespedeza.

lateral roots along plot boundaries with mattocks. The temporary trenches were about 10 centimeters wide and 20 centimeters deep. Herbicides were used as necessary to stop the spread of lespedeza seedlings into adjoining plots.

At the time that plots were established, 12 trees in the central portion of each plot were marked for observation. Their heights were measured before treatment (September 1970) and during the winters of 1971,1972,1974, and 1976. These trees were also measured for d.b.h. After the 1979 growing season, $7^1/_2$ years after the final fertilizer application, height and d.b.h. were again measured for 10 trees from each main plot.

Results and Discussion

As Bengtson and Mays (2) reported earlier, 'Interstate' sericea lespedeza appeared to supply little or no N for loblolly pine growth for several years after seeding (fig. 1). Initial stand establishment was poor and resulted in only about 10 percent ground cover during the first year. All varieties of sericea typically exhibit low seedling vigor and grow sparsely during the first 12 months after seeding. This creates a favorable situation for early development of fertilized pine seedlings because competition for water and light by the seeded cover is minimal during the time that young pines are becoming established. In contrast, grass species such as tall fescue, bermudagrass, and annual ryegrass (*Lolium multiflorum* Lam.) offer severe competition to young pine seedlings, particularly when the area is well fertilized with N.

Dwarf varieties of sericea, such as Interstate, are superior to standard size varieties for seeding with trees because they are 25 to 50 centimeters shorter at maturity and do not cause as much damage by overtopping the pine seedlings as the tall varieties do. The primary disadvantage of the lespedeza for ground cover is its ineffectiveness in controlling erosion during the year required for it to develop a thick, vigorous stand.

Data in figure 1 show that during the first four growing seasons, pines fertilized once with NP and growing with sericea lespedeza did not grow as tall as pines receiving a second or third application of N. During the fifth and sixth growing seasons, N from the lespedeza resulted in slightly more pine growth than the NP+N treatment, but the trees did not completely overcome their earlier growth disadvantage. From the seventh through the ninth years, trees growing with sericea lespedeza not only grew more than trees that had received the NP+N and NP+N+N treatments, but they made up for the earlier poor performance and became slightly taller than trees that had received this additional N fertilizer.

Comparisons of tree height and d.b.h. (table 2) among treatments show that after 6 years, pines growing with sericea lespedeza were significantly smaller than those that had received NP+N+N and slightly smaller than those fertilized with NP+N. However, after 9 years, trees growing in association with the lespedeza were slightly but not significantly larger than those that had been subjected to any of the supplemental fertilizer applications and much larger than unfertilized trees. This indicates that sericea has the potential for meeting the long-term N needs of pines grown on coal spoil.

The analysis of soil and pine needles for N concentration (table 2) shows that sericea was ultimately at least as effective in supplying N to the ecosystem as the other fertilizer-cover crop combinations were. Tall fescue and common bermudagrass were gradually shaded out as pine trees increased in size and had mostly disappeared after 4 or 5 years. In contrast, the lespedeza was still in a vigorous condition after 9 years. Sericea lespedeza produces several tons per acre of high N biomass in roots and tops each year and could be expected to contribute a significant amount of N to the system even after the plants died.

During the ninth year only pines growing with sericea lespedeza exhibited the bright

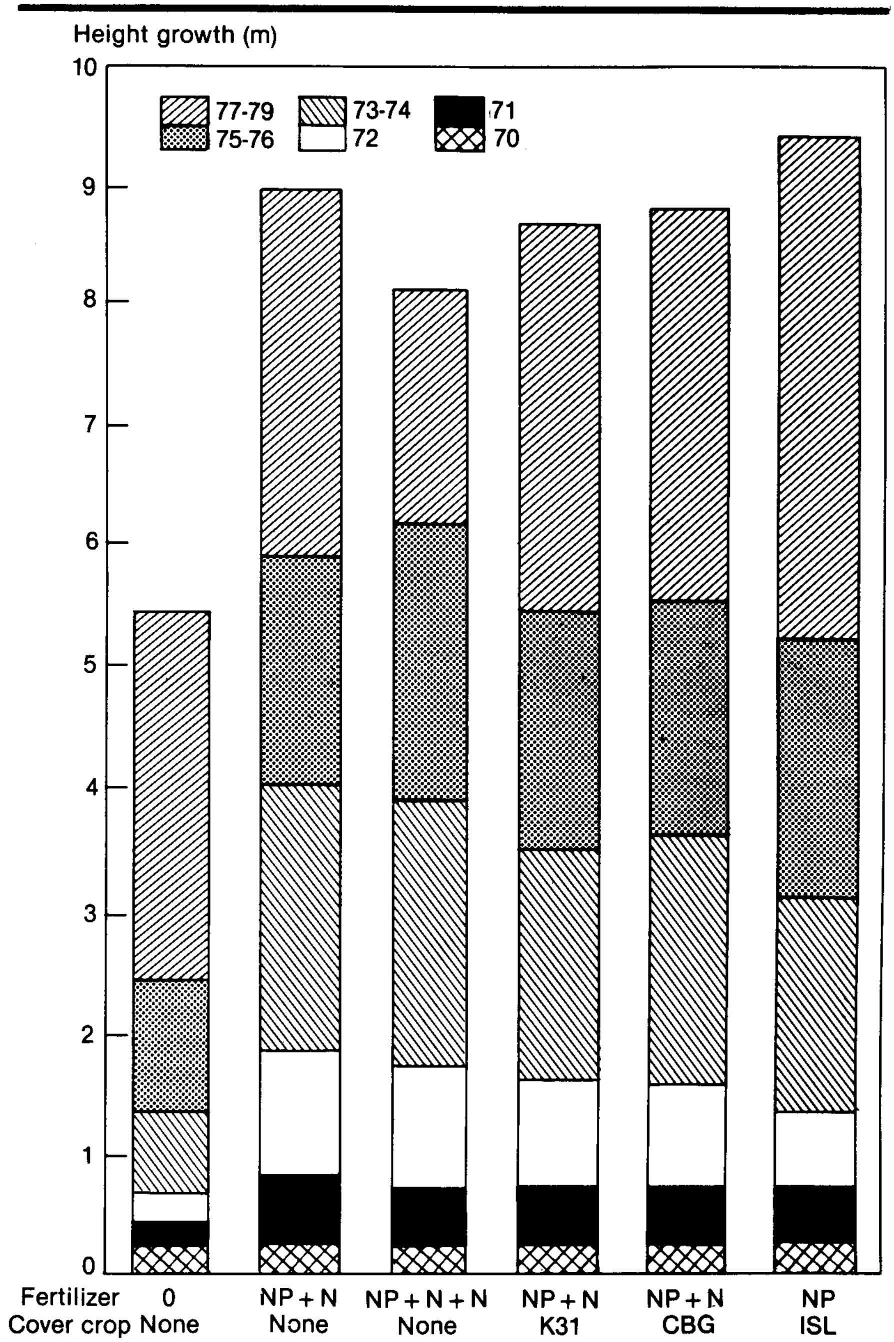

Figure 1—*Periodic and cumulative height growth of loblolly pine planted in graded roadside coal mine spoil as affected by nitrogen fertilization and cover crops (see table 1). K31 = 'Kentucky 31' tall fescue, CBG = common bermudagrass, ISL = 'Interstate' sericea lespedeza.*

Table 2—*Effects of fertilizer treatments and cover crops on growth of loblolly pines and on the nitrogen content of soil and pine needles*[1]

Fertilizer treatment	Cover crop[2]	Pines after 6 yr Height (m)	Pines after 6 yr d.b.h. (cm)	After 9 yr Pines Height (m)	After 9 yr Pines d.b.h. (cm)	After 9 yr Percent N Soil	After 9 yr Percent N Pine needles
0	None	2.4c	1.8d	5.5b	7.8b	0.029c	0.93ab
NP+N	None	5.9ab	8.1b	9.0a	13.1a	.033bc	.83b
NP+N+N	None	6.1a	9.3a	8.2a	12.1a	.030c	.85b
NP+N	K31	5.5b	7.8b	8.7a	12.5a	.039a	.94ab
NP+N	CBG	5.5b	7.7b	8.8a	11.7a	.033bc	.95ab
NP	ISL	5.2b	7.1c	9.4a	13.3a	.037ab	1.04a

[1]Fertilizer treatments and cover crops are described in table 1. Values in columns followed by the same letter do not differ significantly at the 5% level of probability.
[2]K31 = 'Kentucky 31' tall fescue, CBG = common bermudagrass, ISL = 'Interstate' sericea lespedeza.

green color that indicated an adequate N supply; trees in other treatments exhibited the characteristic yellowing of N deficiency.

The experimental plot was examined again in 1984. Trees growing on sericea lespedeza plots were noticeably larger, greener, and more vigorous than other trees in the planting. Some sericea still persisted even though the pine canopy had completely closed.

Conclusions

1. Growth of young loblolly pines was increased by application of NP fertilizers.
2. One or two N applications in subsequent years resulted in greater tree growth than a single NP treatment.
3. Interstate sericea seeded at the same time as the NP fertilizer application was ineffective in supplying N to pines for about 2 years after seeding.
4. Interstate sericea persisted and grew vigorously under pines for 9 years. From the sixth year onward trees growing in association with sericea grew more vigorously than pines receiving 112 kg/ha of N during the second and third years of growth.
5. Beneficial effects of sericea could still be seen after 14 years.

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Long-Term Effects of Scalping on Organic Matter Content of Sandy Forest Soils

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The organic matter content of sandy soils continues to exhibit the effects of scalping 10 years after planting. This may have adverse effects on seedling survival and development.

Of the many forest soil characteristics, organic matter content is one of the most important, especially during the establishment of plantations. Organic matter improves soil structure, increases soil porosity and aeration, and, most important for sandy soils, increases the moisture-holding capacity and ability to hold and exchange nutrients (5). Thus, any activity that serves to maintain or increase organic matter in sandy soils is considered favorable to seedling growth and development.

Chopping and shearing--conventional site preparation methods–produce differing amounts of soil scarification, with shearing usually resulting in greater site disturbance, especially if wind-rowing is combined with the shearing. This difference has been noted for years, along with the advantages and disadvantages associated with each practice.

However, the practice of scalping during the planting process is usually given less consideration, even though it may actually have a greater effect on seedling microenvironment than site preparation activities. In this paper, *scalping* is defined as the displacement of topsoil along the planting row during machine planting operations. This displacement is accomplished by a V-blade mounted to the front of the tractor (usually a crawler-type such as a D-4). Although the principal intent of scalping is to clear the planting row of logging debris and reduce undesirable vegetation, it also creates a "planting trough" with the enriched topsoil piled well away from the planted seedling.

Forest managers agree that scalping may result in short-term unfavorable topsoil conditions, but most think that its effects on organic matter levels and moisture-holding capacity will be of an abbreviated duration. The purpose of this study was to evaluate the organic matter status in sandy soils that were scalped during planting operations. Because differences in organic matter would be obvious immediately after planting, 10-year-old plantations were used in an effort to examine the long-term effects of the scalping on this soil property.

Materials and Methods

The study was conducted in the Upper Coastal Plain region of East Texas. Only plantations located on sandy soils were considered, and textural analysis confirmed that sand content of all study sites ranged from 69 to 80 percent. Criteria for selection were: 1) the plantation was 10 years old, 2) the plantation had undergone site preparation during summer or fall and was planted by machine in the subsequent planting season, and 3) the survival rate was at least 60 percent.

Four plantations (hereafter referred to as locations) were selected. In an effort to test the effects of scalping following different site preparation, two of the plantations chosen had been chopped and burned and two had been sheared, windrowed, and burned. All locations had been scalped during planting.

Twenty 2-acre (295- x 295-foot) study sites were established, 10 in each mechanical site preparation treatment. Three circular half-acre sample plots were established within each study site, giving a total of 60 sample plots.

On each sample plot, nine composite soil samples were removed from the upper 6 inches of soil for analysis of organic matter content. Three sampling positions extended radially from each of three randomly selected trees: OM_T (1

[1] This work was completed while A.W. Ezell was on the faculty of Texas A&M University; it is approved as Texas Agricultural Experiment Station Publication TA-18806.

foot from the base of the tree), OM_M (midway between the planting row and the debris mound created by scalping), and OM_D (the center of the debris mound). A soil punch was used to collect five composite soil samples at each position. Each composite was air-dried for 48 hours, mixed thoroughly, and analyzed for organic matter content according to the wet combustion method (3).

Results and Discussion

Duncan's multiple range test defines the differences among sampling positions (fig. 1). For each location, with the exception of location 4, organic matter values for the tree and debris sampling positions differed significantly at P < or = 0.05, with the midway sampling position acting as a transition zone (table 1).

It is beyond the scope of this study to determine causes for nonsignificant differences among sampling positions at location 4, yet evidence suggests that the trend of organic matter content may be partially attributed to the quality of the planting operation. Planting at this location is exceptionally close, averaging 51 square feet per tree. With this narrow spacing, the operator of the tractor, while clearing the planting furrow with a V-blade, apparently piled some of the scalped soil onto the adjacent planting row, thereby concentrating topsoil and debris against the planted trees.

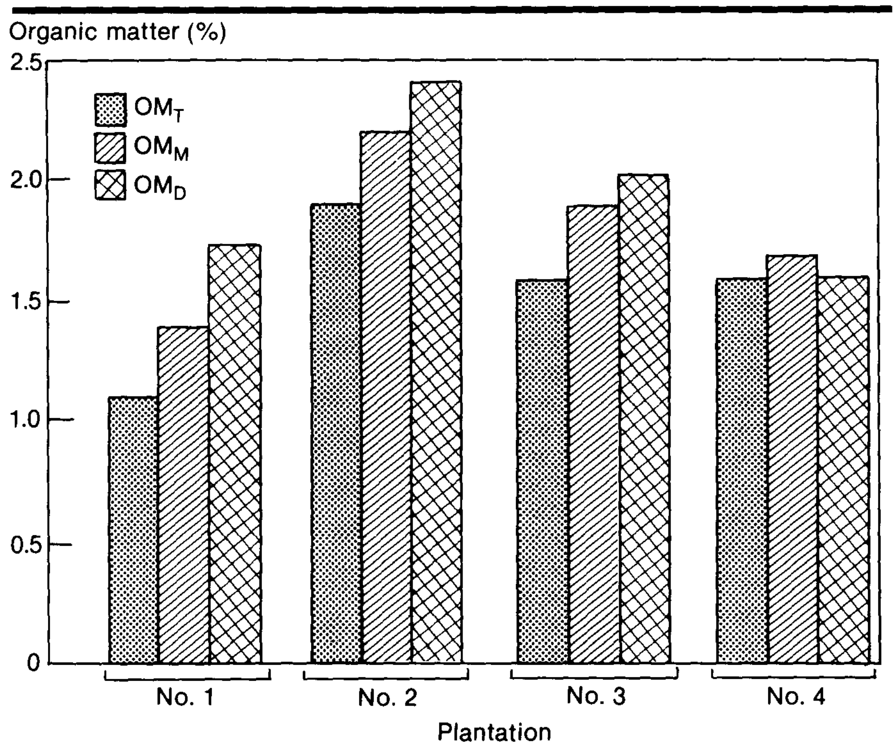

Figure 1—*Average organic matter content by sampling positions for all locations. OM_A = 1 foot from base of tree, OM_M = midway between planting row and scalping mound, and OM_D = center of scalping mound.*

Conclusions

The results of this study indicate that the organic matter content of sandy soils does not recover from the effects of scalping, even after 10 years. Although many other site factors must be considered in an evaluation of survival and growth, the organic matter content in sandy soils is of major importance. Although there are beneficial effects of scalping, there are also detrimental effects due to the reduced organic matter content of the soil. Both moisture retention and nutrient availability may be reduced for prolonged peri-

Table 1—*Organic matter content for each location*[1]

Location	Percent organic matter[1] Tree	Mid	Debris
1	1.1a	1.4ab	1.7b
2	1.9a	2.2ab	2.4b
3	1.6a	1.9b	2.0b
4	1.6a	1.7a	1.6a

[1]Means within locations not followed by the same letter differ significantly at P ≤ 0.05 (Duncan's multiple range test).

ods. This impact should be given serious consideration by plantation managers for sites subject to drought and/or low fertility in their unaltered states.

Lower intensity methods of site preparation have already been noted as preferable on sandy sites because they reduce soil disturbance (1, 2, 4). It appears that reduction or elimination of scalping on sandy sites should be added to the recommendations concerning reduced soil disturbance.

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Estimating Seed Vigor by Sugar Exudates and Radicle Elongation

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*Sugar exudates and radicle growth were evaluated as techniques to estimate the vigor of longleaf (*Pinus palustris *Mill), spruce (*P. glabra *Walt.), and loblolly (*P. taeda *L.) pine seeds. The effectiveness of these methods varied considerably by species. The reliability of sugar exudates as an index of germinability was better for species with softer seedcoats. Seeds with harder coats were apparently less permeable to the passage of exudates that may have resulted from cell wall degradation. The use of radicle elongation as an index of vigor seemed equally as variable.*

As seeds deteriorate and lose viability, their cell membranes break down and allow internal substances to leak out. Heat-killed embryos of sugar pine (*Pinus lambertiana* Dougl.) have greater rates of solute leakage than do viable seeds (9). Pitel (10) demonstrated that increased periods of accelerated aging of jack pine (*P. banksiana* Lamb.) seeds resulted in increased conductivity of the soak water. Hocking and Etter (5) reported a close correlation between germination of white spruce (*Picea glauca* [Moench] Voss) and the sugar concentration in the seed leachate. This relationship of leached solutes and field emergence was first demonstrated for peas (*Pisum sativum* L.) (8). Later research has supported this principle, and electrical conductivity of seed leachates is now included in the International Seed Testing Association's Handbook of Vigour Test Methods (6). Bonner and Vozzo (3) have reported that measurement of leachate conductivity provides valid estimates of seed quality of loblolly (*Pinus taeda* L.) and slash (*P. elliottii* Engelm.) pine.

If exudates can be used to reliably estimate seed viability, they may also be of value in evaluating vigor. Such an indicator of seed vigor is needed, and none of consistent reliability has been developed for pine seeds. One that has been used with seeds of other genera is early seedling development. Although epicotyl growth is normally measured, root growth has also been related to seed vigor (7, 11). Root development would seem to be the better parameter to measure in pines because epicotyl growth is usually slow.

This paper discusses an evaluation of sugar exudates and radicle growth as techniques for estimating the vigor of seeds of longleaf pine (*P. palustris* Mill.), spruce pine (*P. glabra* Walt.), and loblolly pines.

Methods

Twenty-seed lots of longleaf pine and 10 each of loblolly and spruce pine, selected for a range of germinability, were divided into 6 sublots for evaluation of sugar exudates. Empty seeds were removed from the lots before use. One-gram samples from each species-replication were placed in test tubes and surface-sterilized by adding 2 milliliters of 0.1 percent calcium hypochlorite. After soaking for 10 minutes, the seeds were rinsed and 15 milliliters of distilled water was added. The tubes were then capped and allowed to stand for 24 hours at room temperature (24 + 2 °C). After this imbibition period, duplicate analyses for sugars were run by the phenol-sulfuric acid method described by Dubois et al. (4). The percentage of transmittance of the resultant mixture was read on a spectrophotometer at 490 nanometers.

Duplicate 100-seed samples from each species treatment replication were tested to determine percentage of germination. All tests were conducted in a seed testing laboratory according to test procedures of the Association of Official Seed Analysts (1). Seeds of longleaf and spruce pine that had germinated (radicles extended) in these tests were used to estimate vigor by measuring radicle growth. When sufficient numbers were available, about 10 seedlings from seeds that had germinated on the same date were used to measure radicle growth to the nearest millimeter. These measurements were made about 4 days after germination began.

After the correlations between germination and percentage of transmittance of the exudates were made, 10 additional lots of longleaf pine were used to evaluate the accuracy of the estimates obtainable with the technique.

Results and Discussion

Statistically significant (P = 0.05) correlations between germination and reacted sugar exudates in longleaf and spruce pine indicate that this technique has potential for quick estimation of seed quality. Correlation coefficients of 0.820 and 0.851 were obtained for longleaf and spruce pine, respectively (fig. 1). However, the number of seed lots represented was not sufficient to cover a wide range of viabilities of spruce pine. Even in longleaf pine, where a wide range of viability was represented, verification with other seed lots showed that the predictability of germination by measuring transmittance of the reacted sugar exudates was poor. Actual percentage germination was as much as 44 percentage points different from the predicted values (table 1). The error was greater when viability was high and was too great to reliably estimate seed quality. Variability among replications was quite large, with at least six replications

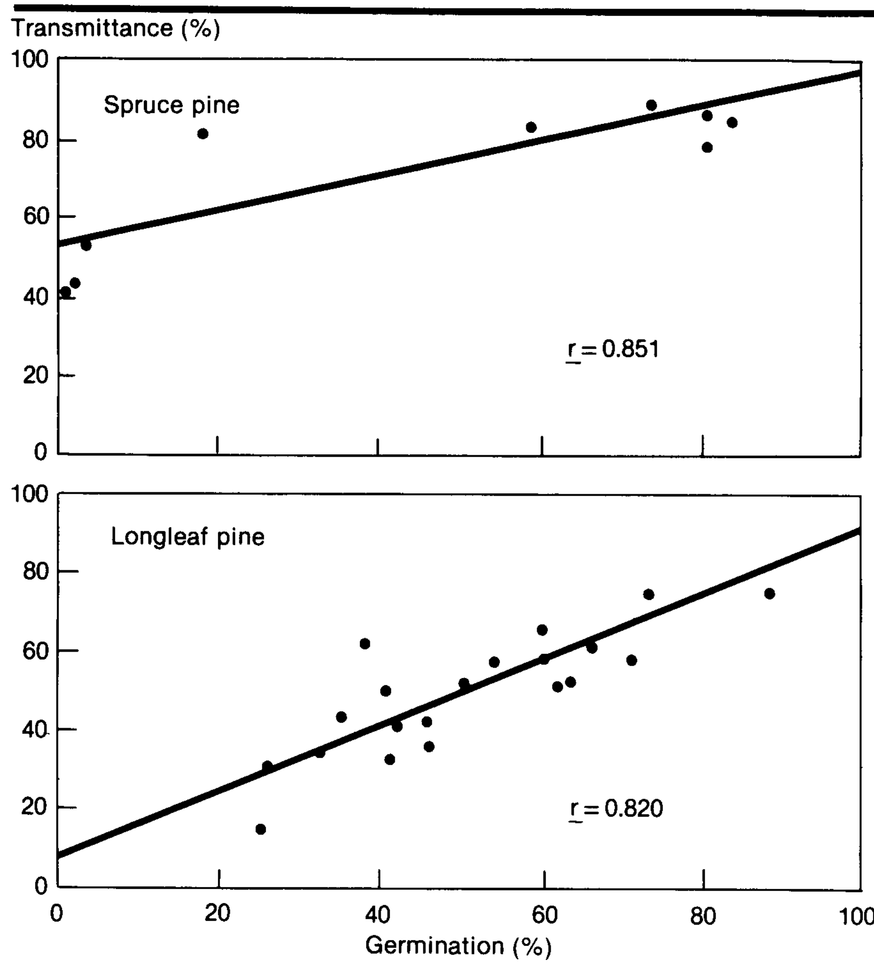

Figure 1—*Relationship of germinability of longleaf and spruce pine to transmittance of seed exudates.*

being required to provide consistent data.

The tests with loblolly pine were completely negative; no colorimetric changes of leachates occurred following the 24-hour imbibition period. The trends established in this study indicate that the effectiveness of leachate evaluations as indices of seed quality may vary by species, depending upon the thickness of the seedcoat or perhaps the size of the seed. Earlier work has shown that seed coats consist of nearly 60 percent of total dry weight in loblolly pine, but less than 30 percent in longleaf seeds (2). The other southern pines fall between these two extremes.

Table 1—*Average transmittance of reacted exudates, radicle length, and both actual and predicted germination of longleaf pine seeds (N = 20)*

Lot number	Percent transmittance	Percent germination		Radicle length[1] (cm)
		Predicted	Actual	
1	9	0	0	ND
2	33	29	73	1.3
3	35	32	10	ND
4	14	6	6	ND
5	66	70	71	1.6
6	50	50	90	1.5
7	75	80	94	1.5
8	72	77	96	1.3
9	72	77	96	1.0
10	66	70	98	1.8

[1] ND = not done; germination was so sporadic that radicles were not measured.

Bonner and Vozzo's evaluation of leachate conductivity indicates that viability of slash pine can be more accurately predicted than that of loblolly pine (3).

Correlations of germination to radicle growth were statistically significant with spruce pine (r = 0.981) (fig. 2), but no relationship was found with longleaf pine (r= 0.064). The data for spruce pine are so limited that this procedure cannot be recommended at this time. Further evaluations will be needed to develop the potential of this technique fully.

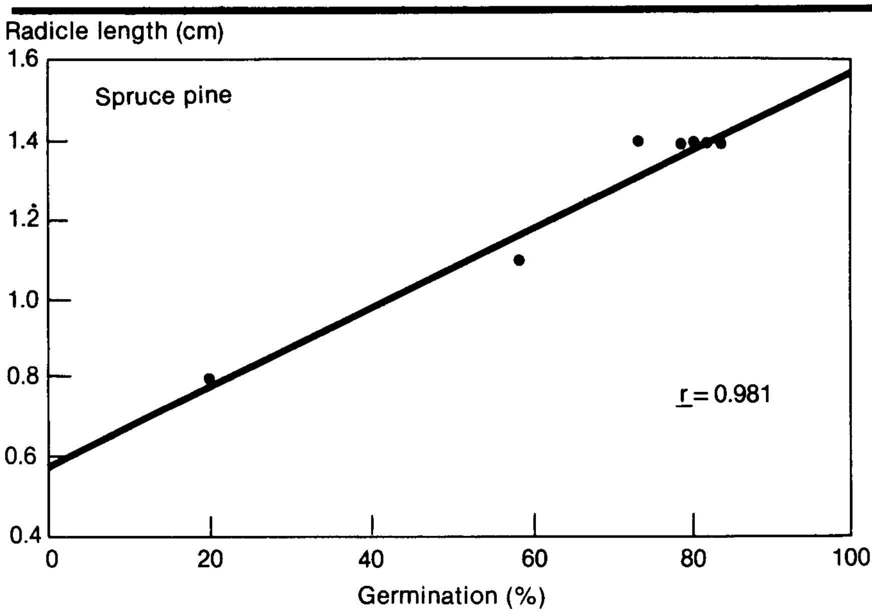

Figure 2—*Relationship of radicle growth to germination of spruce pine seeds.*

Conclusions

These tests indicate that both seed leachates and early radicle growth may have potential as indicators of seed quality. However, neither parameter seems sufficiently reliable to be of practical significance at this stage of development. Electrical conductivity measurements of conifer seed leachates have been developed with greater reliability because commercial equipment is now available for use (3). A major problem in the evaluation of all leachate techniques is the difference in response among species. Focusing on individual species should increase the progress in developing effective seed quality tests.

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A Comparison of Nursery Sowers

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Three nursery sowers were evaluated and compared for precision of seed placement and production of plantable seedlings. A vacuum-drum sower produced in New Zealand gave the most precise seed placement and the lowest percentage of cull seedlings.

Seedbed density in the nursery is a measure of the average number of seeds or seedlings per given area. Seedbed density is important in growing quality seedlings, so that as many seedlings as possible actually have the optimal space they need. In other words, the distribution of spacing is as important as the average. A good distribution would be a narrow bell-shaped curve that peaks at the desired seed spacing. An undesirable distribution would be one that is more spread out or skewed to one side of the mean.

Most forest tree nurseries in the southern pine region employ either a Whitfield or a Love-Oyjord sower (1). Weyerhaeuser Company currently sows all seed in its southern nurseries with a company-developed vacuum sower. The Love Company plans to market this sower, which is designed to precisely place individual seeds. A vacuum-drum precision sower developed in New Zealand by Summit Equipment Ltd. is also being marketed in the United States. The objective of this study was to compare the Whitfield, Love-Oyjord, and Summit sowers for seed spacing distributions and seedling production and morphology.

Materials and Methods

Seed spacing study. Each sower was calibrated to sow approximately 320 seeds per square meter in 8 rows and was operated for approximately 8 meters. For each sower, the interseed distances in each of the eight rows were measured for a distance of 0.6 meter for each of five random samples. Data for the five samples were combined, and a histogram was drawn for each sower to show the distribution of seed spacing (figs. 1-3). The average interseed distance is marked on each histogram. Any interseed distance less than half this value was referred to as a *double;* any distance from $^1/_2$ to $1^1/_2$ times the average was a single; any space greater than a single was called a *blank.*

Nursery study. The sowers were calibrated as above and used to sow four replications of the same seed source on 1.2-meter-wide rows in the nursery. At the end of the growing season, seedlings from each sower-area in twenty 0.37-square-meter samples were dug up and graded.

Results and Discussion

The Summit sower produced the most precise seed placement of the three sowers. Its distribution of seed spacings most closely resembled a bell-shaped curve with a peak near the desired spacing. It also had the highest proportion of singles, the

Table 1—*Summary of seed spacing study*[1]

	Summit	Love-Oyjord	Whitfield
Doubles (%)	28.4b	47.2a	48.7a
Singles (%)	49.5a	28.5b	27.5a
Blanks (%)	22.1a	24.2a	23.5a
Sowing density (no./m²)	340.9a	317.0b	294.9c
Avg. interseed distance (mm)	12.5c	14.5b	17.0a
Coefficent of variation of interseed distance	75.4	130.3	133.0
Range of seeds per meter among rows	49.3-55.7	41.7-57.7	40.7-53.0
(difference)	(6.4)	(16.0)	(12.3)
Coefficient of variation of seeds per row	4.7	9.3	10.3
Tractor speed (km/hr)	1.1	3.2	4.8

[1] Means within a row follwed by the same letter do not differ significantly (P = 0.05) as compared by Duncan's multiple range test.

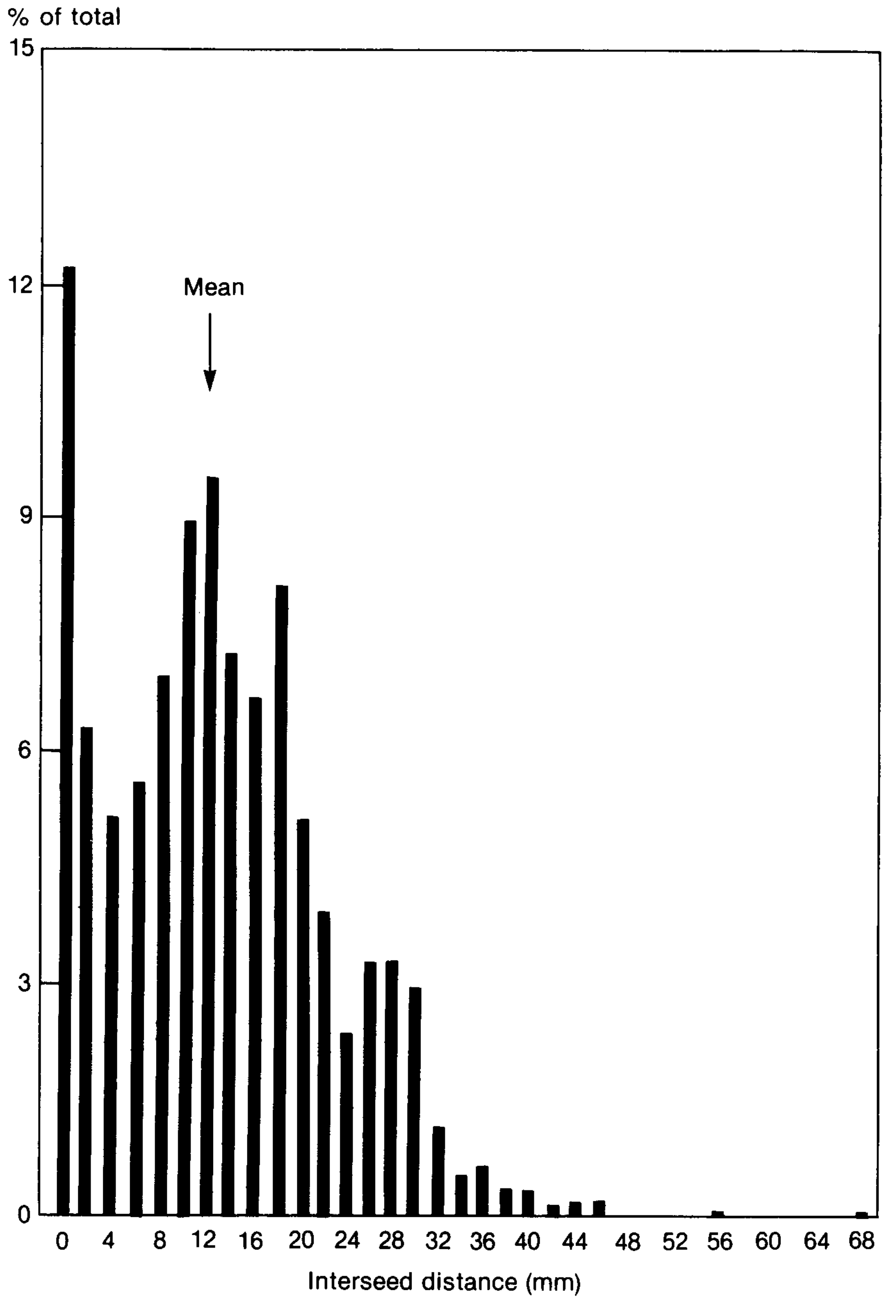

Figure 1—*Distribution of interseed distances for Summit sower.*

lowest proportion of doubles, and the lowest variability among the separate rows in number of seeds per row (table 1). Both the Whitfield and Love-Oyjord Bowers gave high proportions of doubles, had variable spacing, and varied in the number of seeds per row. All three sowers gave about the same proportion of blanks, but the Whitfield and Love-Oyjord sowers tended to leave longer empty spaces (figs. 1-3).

In the nursery study, the Summit sower produced a higher percentage of plantable seedlings than both the Love-Oyjord and Whitfield sowers (table 2). This may have been due to a reduction in doubles by the Summit sower, although the Whitfield sower produced a higher density, which may have contributed to the higher cull percentage. Increasing "seed efficiency" by reducing culls 4 percentage points can be economically important when the present value of genetically improved seed is considered (3).

In addition to having the most precise seed placement, the Summit sower 1) provides excellent control of seed depth and cover, 2) does not waste seed at bed ends, 3) gives narrow drills, which allow lateral root pruning, and 4) is the simplest to calibrate. Calibration is accomplished by simply changing sprockets. The Summit sower can also prepare the bed and sow in one pass.

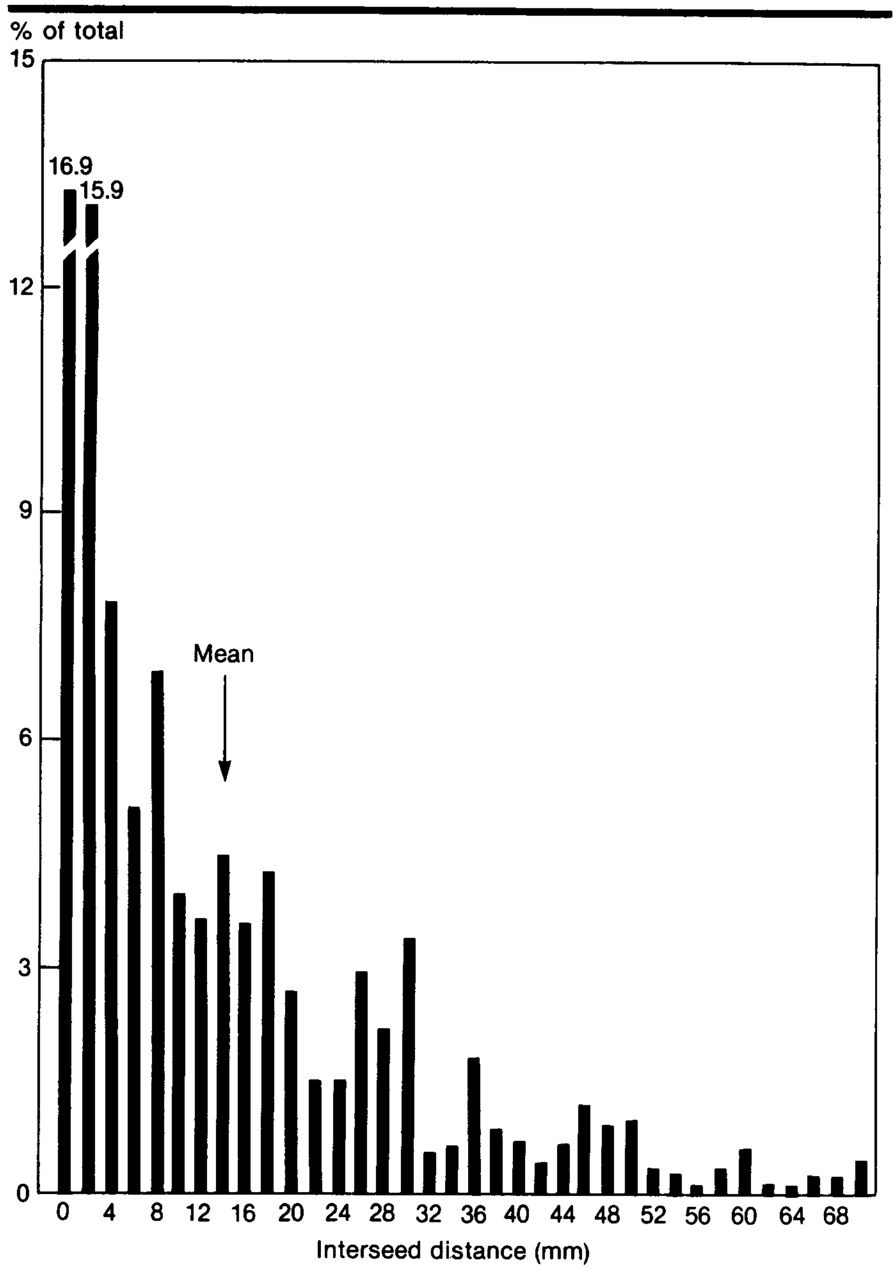

Figure 2—*Distribution of interseed distances for Love-Oyjord sower.*

Disadvantages of this sower include its slow speed, the necessity of having high-purity seed lots with high germination rates, and its higher purchase price than the other machines.

Some advantages of the Love-Oyjord sower include 1) its disk-type coulters, which give narrow drills to facilitate lateral root pruning, 2) easier calibration than the Whitfield, 3) its capability of sowing seed lots with low germination values and yet producing a good stand, and 4) a higher speed of operation than the New Zealand sower. Lott and Lowman (2) found the Love-Oyjord sower to be easier to calibrate (especially for small seedlots) than several other Bowers tested (not including the Summit and Whitfield sowers). Its main disadvantage is its lack of precision of seed placement.

The Whitfield sower cannot precisely space individual seeds and it is the most difficult to calibrate. However, it has a low initial cost, low maintenance, is light in weight, and can be run at a higher speed with a low-horsepower tractor. It can sow seeds in bands or narrow drills, and, like the Love-Oyjord, is capable of sowing seed lots with low germination values.

Conclusions

Precision sowing of seed increases seedling uniformity. Most sowers currently used in forest nurseries are actually drills

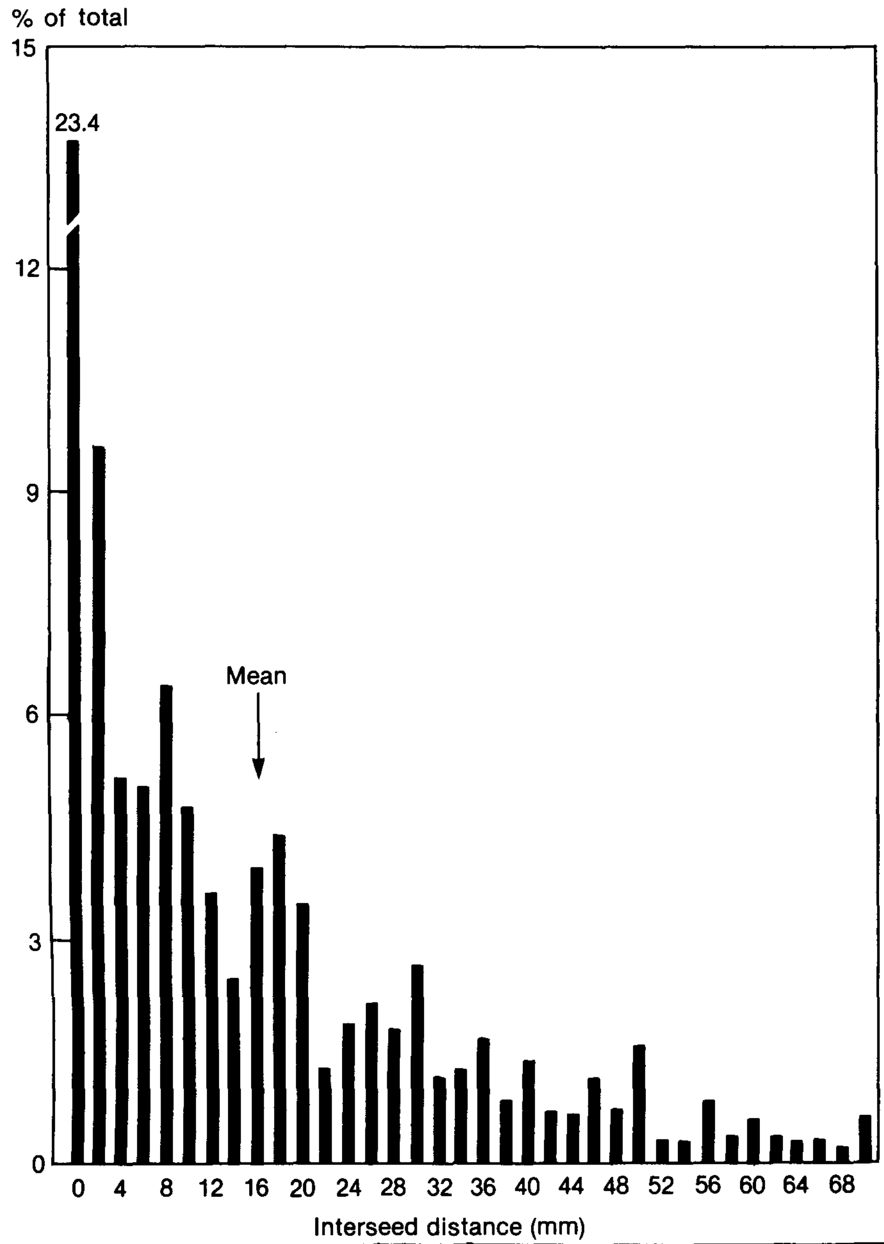

Figure 3—*Distribution of interseed distances for Whitfield sower.*

that often distribute seed in clumps. Cull seedlings can often arise from seeds sown too close together. Precision sowers have been developed that will sow one seed at a time, reducing seed clumping and the production of culls.

With the increasing use of genetically improved orchard seed in forest nurseries, wasting seed is becoming more and more expensive. By improving the seed efficiency or reducing cull percent, increased economic gains easily justify investment in precision sowers. Saving genetically improved seed not only avoids wasting expensive seed, but also increases income from the production of genetically improved seedlings and increases timber volume at harvest.

Table 2—*Summary of nursery study*[1]

Sower	Density/m²	Grade 1 (%)	Grade 2 (%)	Cull (%)
Summit	285b	8a	84a	8b
Love-Oyjord	277b	8a	80ab	12a
Whitfield	315a	6a	79b	15a

[1] Means with a column followed by the same letter do not differ significantly (P = 0.05) as compared by Duncan's multiple range test.

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Tote-Racks-Disposable Shipping Trays for the Ray Leach Super Cells

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Cardboard tote-racks were designed for shipping seedlings grown in Ray Leach Super Cells. The disposable trays hold thirty Super Cells, can be assembled in seconds, and feature two hand holds for ease of carrying.

Small conservation nurseries such as the Lone Peak State Forest Nursery have many customers who need relatively small amounts of trees. Container systems designed for large containerized seedling tree nurseries are often only available in unsuitable sizes. At the Lone Peak nursery we have adopted a container system that features the Ray Leach Super Cells because of its ease of use in the greenhouse, the size of plugs for outplanting, and more importantly, the preference of our customers. The trays made by Ray Leach Container Nursery pose a potential problem in shipping because our minimum order for containerized stock is 30 plants and the trays hold 98 seedlings.

We considered a number of alternatives, including removing the trees from the rack and bundling them in groups of 10 with a rubber band. This practice is inexpensive, but the seedlings become badly damaged during transport.

We also considered charging a deposit for the temporary use of the trays to some of our larger customers. This resulted in the racks being distributed over a wide area with no guarantee of the time or condition of their return. In addition, we would have had to maintain many extra trays on hand to ensure that we had sufficient trays for the next greenhouse crop.

Finally, we developed a disposable cardboard rack that holds the minimum container order of 30 trees, keeps the trees upright, and is easily shipped either alone or inside a cardboard box. The idea came from the Colorado State Nursery, which uses a shipping tray made of plastic for its tarpaper pots. We simply turned the tray upside-down, punched some big holes in it, and came up with a rough model. We then sat down with a representative of a local paper products manufacturer and together developed specifications so that a prototype could be made. After a few modifications, a die was fabricated to facilitate mass production and the final cardboard tote-rack was manufactured (figs. 1 and 2).

The holes in the top are 1-$^{7}/_{16}$ inches in diameter, spaced on 2-inch-diameter centers. The holes were made a little smaller than in the Ray Leach Super Cell trays to allow for a little settling in case the tote-rack got wet. When the cells are in place in the tote-rack, they are still suspended so that the roots are kept air pruned if the trees are

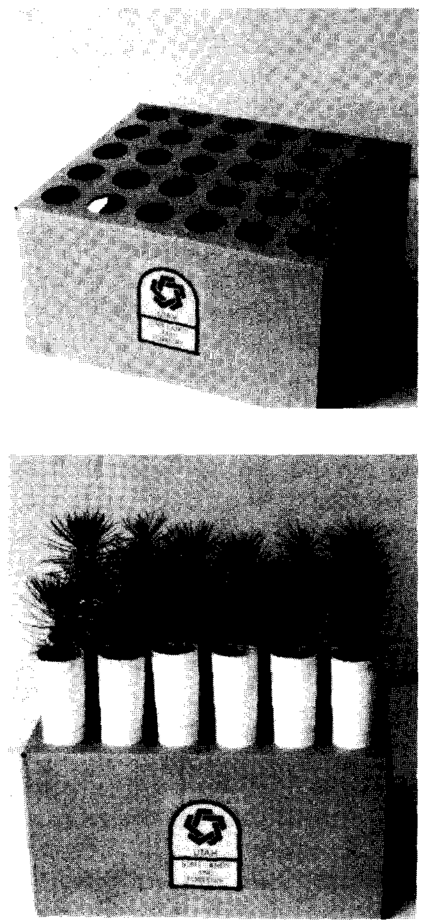

Figure 1A—*An empty tote-rack.* **B**—*A tote-rack holding pine seedlings in the Super Cells.*

not planted immediately. There are hand holds cut in the sides of the tote-racks.

The tote-racks are 10 $^{1}/_{2}$ inches wide, 12 $^{1}/_{2}$ inches long, and 6 $^{1}/_{2}$ inches high. The cardboard is rated at a 150-pound test and made of heavy-duty Kraft paper. Cost for the tote-racks varies according to the quantity ordered, but our cost was less than 35 cents per tray.

The tote racks have proven to be a low-cost solution to the container shipping problem we had at the nursery. We have control over the plastic trays we use in the greenhouse because they never leave the nursery. This cuts down on breakage and lengthens the average life of the tray.

The cardboard tote-racks look more attractive and professional than the alternatives we explored. They easily accommodate a nursery logo or other printing on the side. They are surprisingly sturdy and more than adequate to withstand the everyday use and abuse that they may be subjected to. The tote-racks can be assembled in seconds, are easy to load and carry, and have the added advantage of costing very little. Finally, our customers are quite satisfied with the tote-racks, which keeps our public image at a high level.

Procedures for International Shipment of Seeds and Cuttings of Forest Trees

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The National Tree Seed Laboratory receives many requests for the procedures to make international shipments of tree seeds and cuttings. The basic procedures for preparing seeds and cuttings and obtaining the necessary certificates and permits are outlined in this article to serve as a guide for anyone who wishes to make an international shipment of a small amount of seeds or cuttings.

The Seed Bank at the National Tree Seed Laboratory (NTSL) receives many requests every year for information about the best way to ship seeds or cuttings of forest trees to another country. The following procedures should meet the needs of most parties interested in making international shipment of seeds or cuttings.

Exporting Procedures

Permits and Certificates

Obtaining the necessary permits and certificates is often the most perplexing step in the process. However, once the appropriate contacts are made the process is relatively straightforward. The process should never be taken lightly though, because failure to obtain the proper certificates and permits can easily lead to destruction of the seeds or cuttings at the port of entry in the receiving country.

The sender must obtain a phytosanitary certificate, which declares that the plant material is free from insects and disease organisms and conforms to the current phytosanitary regulations of the importing country. Shipments that cannot pass inspection are not given certificates and cannot be shipped to another country. Information on obtaining a certificate and other requirements of the importing country should be obtained from an office of Plant Protection and Quarantine (PPQ), Animal and Plant Health Inspection Service (APHIS), U.S. Department of Agriculture, well in advance of the intended shipment time. State departments of agriculture often can supply a phytosanitary certificate. Names and addresses of APHIS inspectors can be obtained by contacting:

Regulatory Services Staff
PPQ, APHIS, USDA Export
Certification Room 644
Federal Building 6505 Belcrest
Road Hyattsville, MD 20782
(301) 436-8537

The recipients must obtain any necessary permits from their country's government. The most common of these is the import permit. Permits should be forwarded to the prospective exporter for review by PPQ officers. This must be done before a phytosanitary certificate can be issued. The official documents issued by the plant protection service in the receiving country must be supplied because only the official documents will be accepted by PPQ. Information supplied by the importer alone cannot be accepted.

Preparing Seeds. Seeds should be cleaned thoroughly to remove all trash. This step will make inspection easier. Trash might also be a place for pests to hide and result in the sample's failing to pass inspection.

The seeds should be packaged only in inert material. Do not use any plant residues such as moss or sawdust. At the NTSL we have found that heat-sealing the seed in 4-mil plastic bags is very convenient. Lot identification is also sealed inside the bag. The individual seed packets are placed in a cardboard box with Styrofoam pellets. Once the package is sealed, the necessary permits and certificates are placed in an envelope marked "Packing List Enclosed" that is then affixed to the outside of the package. Attaching the permits to the outside of the container is necessary for easy inspection. Inspections must be easy to conduct or else the shipment may be rejected by a busy inspector.

Preparing Cuttings. Only fresh, healthy, clean cuttings should be shipped. Sometimes they will be dipped in a fungicide/ insecticide mixture according to instructions obtained from the recipient and coordinated with APHIS. Once dipped, the cuttings are air-dried to remove excess surface moisture and then heat-sealed in plastic bags along with their identification tags. Putting peat moss or other organic media in the plastic bags is not acceptable for phytosanitary reasons. It was also found that using any moisture-holding media in the bag encouraged mold growth on the cuttings. Shipment is in insulated cardboard cartons.

These cartons are available commercially or can be constructed by gluing sheets of rigid insulation on the inside of a cardboard carton. A gallon plastic bottle filled with water and frozen solid can be placed in the carton to keep the cuttings cool. The bottle cap should be sealed tightly to prevent leakage and damage to the carton. After sealing the carton, attach all necessary certificates and permits.

Shipping Methods. First Class Air Mail is the fastest and simplest method for shipping seed. A fast method is necessary to ensure that the seed will arrive at its destination in good healthy condition. Registering the package and requesting a return receipt can be useful in tracking it in the mails and should be requested if there is any concern about potential loss of the package in transit. Four pounds is the maximum weight that can be sent by First Class Air Mail. Shipments over *4* pounds can be divided into more than one package or sent Air Freight. Air Freight Collect may encourage a speedy delivery because shipping fees are only collected after delivery.

Importing Procedures

Packaging seeds and cuttings for shipment into the United States is done in the same way as for material being exported. An import permit is required and can be obtained by contacting:

Regulatory Services Staff
PPQ, APHIS, USDA
Permit Unit
Room *637* Federal Building
6505 Belcrest Road
Hyattsville, MD *20782*
(301) 436-5232

Contact can also be made with a local PPQ office to obtain the import permit.

Importing requirements are complex and cannot be adequately described in this paper. The importer of plant material is, therefore, advised to make contact with PPQ well before the anticipated shipping date of any material to work out the necessary details. This step will give the greatest possibility of a successful entry of the material.

Occasionally, fumigation of the seed is necessary when it arrives in the United States. As a safeguard against injury from the fumigant, advise the sender of your seed to dry the seed to a moisture content of *6* to *8* percent. Fumigants are less likely to injure seed at low moisture contents (1). The low moisture contents cannot be tolerated by species such as *Quercus* or *Juglans.* As an alternative to methyl bromide, a hot water bath has been used (2) for *Quercus*. The acorns are immersed in water at a temperature of *49 °C* for *40* minutes. Arrangements for this alternative treatment should also be made in advance of importation.

Literature Cited

1. Jones, L.; Havel, K. Effect of methyl bromide on several species of conifer seed. Journal of Forestry 66(11):854 860; 1968.
2. Schopmeyer, C.S., ed. Seeds of woody plants in the United States. Ag. Handb. 450. Washington, DC: U.S. Department of Agriculture, Forest Service; 1974. 883 p.