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Growth and Yield of a 24-Year-Old Black Cottonwood Plantation in Western Washington

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A 24-year-old black cottonwood plantation in western Washington has total stem volume of 7,242 cubic feet per acre. Heights of dominant trees are 115 to 122 feet. This plantation illustrates the productivity of the species on a deep alluvial soil.

In the forests of the Pacific Northwest, no other tree species can match the early growth of black cottonwood (Populus *trichocarpa* Torr. & Gray) on a favorable site. juvenile height growth of 6.3 feet per year *(4)* and diameter growth of more than 1 inch per year (*1*) have been reported. The species is less commonly distributed than most of its tree associates, however, because it has a distinct preference for abundant soil moisture combined with adequate aeration, a good nutrient supply, and soil pH values close to neutral (*1*).

Some of the earliest known reforestation work in the Western United States involved planting black cottonwood during the 1890's along the Willamette River in Oregon (*7*). Plantings of black cottonwood were also made in British Columbia in the 1950's and 1960's (9, 10). More recently, black cottonwood has been considered a candidate for biomass farming and has been planted and coppiced under various experimental regimes (*2, 3, 5).* Currently, however, the species is not commonly planted or managed. Aside from the British Columbia work, there is little information on its growth in plantations. This report presents 24-year growth and yield information from one of the very few older cottonwood plantations in the Pacific Northwest.

Plantation History

In the mid-1950's, Mayr Brothers Logging Co., Inc., purchased a small farm for reforestation. The farm, located on old river terraces along the North River in Grays Harbor County, Wash., had areas that were considered suitable for planting black cottonwood. At that time, there was considerable interest in black cottonwood as a possible raw material for the local plywood industry.

The soil series, Grande Ronde, is a very fine, mixed, mesic Aquic Dystrochrept. Developed from sandstone and shale, it is a deep alluvial soil, typically found on river benches or terraces. Texture ranges from a silty clay loam in the surface horizons to clay loam in the subsoil. Water movement is generally slow, but tree roots penetrate easily. The water table is usually about 3 feet from the surface during the growing season; however, the area is subject to flooding during peak flows.

In early 1958, 6 acres were prepared for planting by plowing, disking, and applying a layer of crushed oyster shells to serve as a source of limestone. In the spring, the area was planted at an 11.5- by 11.5-foot spacing with 6- to 8-foot unrooted, terminal cuttings collected from young native trees growing along the North River and the lower Wynoochee River. In the first few years after planting, circles 2 feet in radius were occasionally hoed around each tree. Later, horses were grazed in the plantation to help keep the grass down. During the dry summer of 1960, the trees were irrigated with water from the river. Beaver were sporadically troublesome and cut some of the trees close to the water. The beavers were later eliminated by trapping. Once the plantation was considered well established, no additional cultural treatments were applied.

Growth and Yield

In fall 1981, two plots totaling 1/2 acre were established in areas with minimal signs of past disturbance. All trees in the plots were measured for diameter. Thirty trees in the plantation were measured for height; these spanned the range of heights and were selected so that two-thirds of them had diameters equal to or greater than the average stand diameter. Volumes (total stem inside bark) by diameter class were taken from a volume-diameter curve calculated using a diameter-squared-times-height equation *(12).*

This plantation has grown extremely well (table 1) and looks impressive (fig. 1). Mortality over 24 years has been minor, with 291 stems per acre remaining from the original stocking level of 329. Dominant trees are now 115 to 122 feet tall and 13 to 16 inches in diameter. Basal area is 169 square feet per

Table 1.—*Stand characteristics of the North River black cottonwood plantation 24 years after planting*

Diameter class	Number of trees	Height	Total stem volume
Inches		*Ft*	*FP*
4	*6*	*55*	*11*
5	*4*	*69*	*14*
6	*25*	*84*	*160*
7	*23*	*93*	*221*
8	*23*	*98*	*304*
9	*35*	*103*	*612*
10	*41*	*106*	*910*
11	*56*	*109*	*1,646*
12	*27*	*112*	*977*
13	*25*	*115*	*1, 048*
14	*16*	*118*	*773*
15	*8*	*120*	*440*
16	*2*	*122*	*125*
Total	*291*		*7,242*

Figure 1.—*North River cottonwood plantation 24 years after planting.*

acre; the tree of mean basal area is 10.3 inches in diameter. Total stem cubic volume in live trees was calculated to be 7,242 cubic feet per acre or an average of 302 cubic feet of growth per acre per year. This would be roughly equivalent to 3.4 ovendry tons of growth per acre per year (assuming 22.5 pounds per cubic foot of ovendry material).

Discussion

We have not been able to find any reports in the literature where black cottonwood equaled or exceeded the 24-year height and volume growth of this stand (*6, 8, 11*). Higher annual yields have been reported for older stands (*9*) and those under intensive culture *(2, 3, 5*), but not for plantations or natural stands of similar age.

The plantation is now too dense, and some of the trees with small narrow crowns have recently suffered top damage and stem breakage following heavy wet snows. Some areas of the plantation have lower stocking than the measurement plots both as a result of early mortality and some recent cutting. In these areas of lower stocking, damage has generally been less and average diameter is greater, with 10 to 15 stems per acre exceeding 17.0 inches. The largest trees in the plantation (excluding border rows) are 18.5 to 18.7 inches in diameter and 128 to 129 feet tall. As a result, we believe if the stand had been thinned early, diameter growth could have been accelerated, damage reduced, and future mortality forestalled.

Black cottonwood can be used to produce pulp, paper, lumber, veneer, and energy. Past cutting has reduced available inventories; consequently, current markets are fairly localized. Markets may expand in the future, however, if more wood becomes available or technological changes allow greater substitution of black cottonwood for other species to produce some end products.

Forest management practices are becoming increasingly oriented to producing maximum yield. This plantation provides an example of the potential productivity of black cottonwood. On appropriate sites, particularly on river benches or terraces, we believe the species warrants greater consideration.

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Tree Planter's Notes, Vol. 34, No. 2 (1983)

A Cottonwood Planting Punch for 1-Year-Old, Rooted Whips

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A tractor-mounted hydraulic ram was developed for deep planting 1-year-old, rooted cottonwood whips. The ram has proved to be efficient and durable when used in rough, newly cleared areas.

In order to establish fast-growing, long-rotation cottonwood plantations in which the first thinning would remove saw-log-size material, a wide spacing of 28 feet by 28 feet has been adapted by the Anderson-Tully Co. Test plantings demonstrated that survival was excellent for deep-planted, 1-year-old, nursery-grown cottonwood whips with roots, if planting holes were completely closed. Dry sand poured into the planting holes proved to be the most efficient method to insure closure. Because planted heights are 4 feet or more, such plantings produce plantations in which the intensity of cultivation is significantly lessened, compared to conventional planting with 20-inch, unrooted cuttings.

Planting operations are usually carried out on newly cleared areas. An efficient and durable tractor-mounted hydraulic ram for punching planting holes at least 2-1/2 inches in diameter and 3 feet deep was developed by Anderson-Tully Co. The hydraulic specifications were developed by Mr. S. Vinyard[2] and personnel of the Forest Service Engineering Laboratory at Auburn, Ala. A sand hopper-equipped trailer is coupled to the tractor and carries the cottonwood whips (fig. 1). Fabrication was done by a private machine shop.

Figure 1.—*Tractor-mounted hydraulic punch with sand hopper-equipped trailer carrying whips.*

The Cottonwood Planting Punch

The tractor-mounted punch (fig. 2) consists of a double-acting hydraulic cylinder with a 60-inch stroke, 3-inch-diameter bore, and 1-1/2-inch-diameter shaft. The probe, attached to the end of the cylinder, is 52 inches long with 8 inches of ground clearance. This probe has the ability to punch a 44-inch-deep hole on even ground, while in rough ground a 36-inch hole has always been attained.

One probe is 2-7/8 inches outside diameter, while the other is 2-1/2 inches outside diameter. One is made from black iron pipe and the other is stainless steel. The black iron pipe does as well as the stainless steel probe once it becomes polished. The lateral roots

Figure 2.—*Anderson-Tully cottonwood planting punch*

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[1] At the time this unit was developed, Burkhardt was Chief Forester, Anderson-Tully Company, Vicksburg, Miss., and King was Engineer, USDA Forest Service, Engineering Laboratory, Auburn, Ala.

[2] Formerly, Mr. Vinyard was a graduate assistant, Argicultural Engineering Department, Auburn University, Auburn, Ala.

are pruned and whips are selected for straightness (fig. 3).

The punch was designed to fit the hydraulic system of an I-H 856 tractor. This tractor has a closed system, 90-quart reservoir with maximum pressure of 2,000 pounds per square inch, and maximum flow rate of 12 gallons per minute.

To date, the punch has averaged 21 seconds per hole, which includes moving time, or 2.7 to 2.8 holes per minute. This was on 24-foot spacing with an experienced operator and excludes downtime.

As each hole is punched, the person who does the planting on the rear of the tractor inserts a whip in the previously punched hole and fills the hole with dry sand from the hopper (fig. 4). The planter must be quick and efficient to complete the planting before the tractor moves on to punch the next hole. The planting punch, coupled with the sand hopper-equipped trailer, has proved to be a labor-saving device enabling the establishment of high-value sawlog plantations for the future.

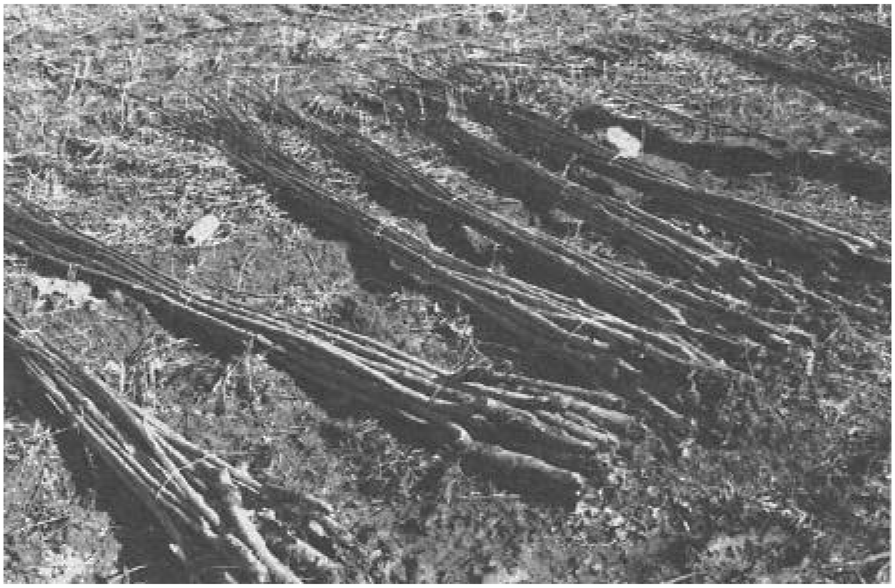

Figure 3.—*A sample of cottonwood whips, which must be as straight as possible.*

Figure 4.—*Dry sand used to fill around cottonwood whip.*

Tree Planter's Notes, Vol. 34, No. 2 (1983)

Why Nonindustrial Forest Landowners Do Not Invest in Pine Reforestation

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The results of a survey of southern, nonindustrial, private forest landowners on why their lands were not reforested to pine are reported. The most important barrier to pine reforestation was the inaccurate assumption by many landowners that adequate pine regeneration would occur naturally.

To insure a fully stocked pine stand in the South, it is generally necessary for landowners to do some sort of site preparation and reforestation activity. The practice of cutting without special regeneration measures often results in an understocked stand of pine or low-value hardwood. Since the early 1960's, however, few of the 1.5 million acres of pineland harvested annually in the South by nonindustrial, private owners have been adequately reforested with pine (*1*).

To find out why southern landowners are not investing in southern pine reforestation, 759 personal interviews were conducted in the southern pine region of Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, and the eastern parts of Oklahoma and Texas (2). The sample used in the survey was derived from the one used by the U.S. Department of Agriculture Statistical Reporting Service, for its 1981 June Enumerative Survey. This is the main survey from which the U.S. Department of Agriculture produces its estimates of agricultural production and is based on a field canvass of a sample of 1- to 2-mile-square blocks of land. In the South, a significant portion of the land within these blocks is forested. During this survey, enumerators in the 12 Southern States were asked to identify tracts within the sample units on which timber had been harvested in the preceding decade. The enumerators then conducted personal interviews with these landowners between August and October 1981.

Survey Results

The survey of harvested ownerships showed that 64 percent of the land harvested in the South was left to reforest itself. The lack of pine reforestation efforts among southern timber owners can be attributed largely to their abiding faith that cutover sites will naturally reforest themselves (table 1). On about 4 out of 5 acres in the South that were not actively reforested by planting pine seedlings or preparing the site for natural regeneration, the owners felt that their site would reforest itself.

Other important reasons for not reforesting were: high costs, 51 percent of the acres; returns from forestry occurring too far in the future, 43 percent of the acres; other uses for harvesting revenues, 40 percent of the acres; and returns from forestry being too low, 34 percent of the acres. While these reasons were offered far less frequently than relying on natural reforestation, they are nonetheless important because they highlight the extent to which several very basic problems in nonindustrial, private forestry play a role in landowner decisions. Reforestation costs can run as high as $200 per acre on cutover lands. Average reforestation costs on harvested pinelands range from $75 to $150 (*3*). This represents a cost to landowners that they may view as prohibitive. As shown in table 1, over half of all lands harvested are held by landowners who see the costs of reforestation as being too high. Compounding the problem of high costs are the alternative uses of timber harvesting revenues. High alternative rates of return are important to the owners of 2 out of 5 acres in the South. This suggests that forestry investments, while profitable on many sites, may not be perceived by landowners as the most attractive use of their harvesting revenues.

The potential returns to forestry investments have been estimated at 4 percent or greater, after inflation, on over 100 million acres of southern forest land (*4*). However, over 1/3 of the harvested forest land in the South is owned by individuals who believe returns from forestry investments are too low. Fully 43 percent of the acres are owned by individuals who do not invest because returns occur too far in the future. These economic and financial constraints on forestry management represent a second major challenge to observers of reforestation. Assuming the need to reforest was established in the minds of landowners,

Table 1.—*Landowners' reasons for not actively reforesting tract to pine by degree of importance*[1]

Reasons for not reforesting	Importance					
	High effect	Moderate effect	Low effect	No effect	Not aware of program	Total
	% of acres					
Could not get cost-sharing.	4	5	16	52	23	100
Land is not sufficiently productive for pine.	5	7	19	69	0	100
Return on reforestation investment occurs too far in the future.	15	28	24	33	0	100
Return on reforestation investment is too low.	9	25	30	36	0	100
Have not yet decided the future use of land.	10	11	13	66	0	100
Investment in reforestation is too risky because of fire, insects, and disease.	1	1	27	71	0	100
Had other use for harvest revenues.	22	18	13	47	0	100
Reforestation costs too much.	30	21	16	33	0	100
Too much red tape in obtaining technical or cost-sharing assistance.	11	16	16	42	15	100
Felt the site would reforest to pine naturally.	60	19	5	16	0	100
Logging treatment when timber was harvested left site in such poor condition that it made reforestation with pine difficult.	2	8	27	63	0	100

[1] Asked only respondents who left site to reforest itself after clearcutting and partial cutting.

would those owners elect to spend money on forestry? The data from this study show that a combination of high costs and low or delayed returns is a significant obstacle to the reforestation of pine.

Factors of lesser importance to reforestation decisions were the poor productivity of land; risks associated with fires, insects, and disease; the poor condition of the site following harvest; too much difficulty in getting technical assistance; the lack of cost-sharing; and indecision about the future uses of the site. Site productivity and site condition following harvesting were important to the owners of only 12 percent of the land harvested, and only 2 percent of the land is held by individuals who view risks from natural hazards as being too high. A larger, although modest, proportion of the acreage, 21 percent, was held by owners who had not decided the future use of their land. A still larger proportion, 27 percent, of the acres harvested was owned by individuals who consider the "red tape" associated with getting assistance on forest management as being too cumbersome. Finally, only 9 percent of the acres were held by individuals who saw the absence of cost-sharing funds as a difficulty. It should be noted, however, that almost 1 harvested acre in 4 is owned by someone who is unaware that cost-sharing is available. The combination of these minor factors points to the complexity of reasons that underlie the decisions not to reforest cutover forest land in the South.

Conclusion

The widespread perception that natural pine reforestation occurs on harvested lands raises important issues with respect to landowner decisions. Forest Service forest inventory data show that the acres of southern forest land growing pine have begun to decline in the past decade, following the extensive rotation of retired cropland to pine between 1915 and 1965 (*1, 4*). Abandoned farmland reseeds to pine with relative ease, but cutover land does not. As a rule, harvested lands require treatments such as burning, herbicide application, chopping, and planting to insure an adequate stocking of pine. This means that landowners need to make a conscious effort either to seek help in identifying the specific needs of their site or to identify those needs on their own. They must subsequently make the investments of time and money to carry out the treatments necessary to insure pine reforestation. Without the recognition of the need for forest management following harvest, little can be expected in terms of pine establishment except in highly fortuitous situations. As a result, reshaping the perceptions of the owners of some 80 percent of the harvested lands in the South is central to the question of pine reforestation. Their present perception that cutover lands will reforest themselves is only accurate in a small number of cases. Without recognition by the nonindustrial forest landowners of the need to invest in pine regeneration, the South will probably lose much of its pineland resources productivity.

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Evaluation of Zinc Phosphide for Control of Pocket Gophers on Christmas Tree Plantations

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Zinc phosphide-carrot bait was comparable to strychnine-grain bait for controlling pocket gophers. We recommend development of a 0.75-percent zinc phosphide-carrot bait for special local need registration to insure safety to wildlife or domestic animals.

Pocket gophers *(Thomomys spp.* and *Geomys spp.)* can cause serious damage to conifers grown for Christmas trees. In Minnesota, Miles (*12*) reported that pocket gophers caused 13-percent mortality to Scotch pine *(Pinus sylvestris)* and 15-percent mortality to Norway pine *(P. resinosa).* In the Pacific Northwest, a 1975 survey revealed that 2,101 hectares (5,192 acres) of Christmas tree lands were sustaining damage by gophers and that landowners expected the problem to increase (*13*). Major damage areas in the Pacific Northwest are east of the Cascade Mountain range (*14*). Other regions in the United States also experienced pocket gopher damage problems.

Kill trapping with Macabee gopher traps and poisoning with 1080, Gophacide, and strychnine alkaloid grain baits are used to reduce pocket gopher populations and damage (*3, 8, 13, 14, 16*). Currently, baiting with strychnine accounts for over 90 percent of the control efforts (*2, 13*).

Of these methods, trapping can be uneconomical and ineffective (*1, 8*); 1080 has severe State and Federal pesticide use constraints (*10, 16*); Cophacide, which was developed for pocket gopher control (*15, 16*), has limited distribution; and strychnine poses serious concerns regarding inadvertent poisoning to other animals (*2*).

A toxic bait with little nontarget hazard potential, therefore, appeared desirable for controlling gophers on Christmas tree plantations, particularly those plantations that are readily accessible for use by household pets and locally sensitive wildlife species.

Zinc phosphide, an established rodenticide from the World War II era (*6*), seemed a likely candidate for testing. It has a large data base documenting its toxicology, biological activity, and effects on wildlife (*11*). The LD_{50} of zinc phosphide to pocket gophers *(Thomomys mazama) is* 14.7 milligrams per kilogram (*2*) and to *T. talpoides,* 6.8 milligrams per kilogram (*11*). Hazards to dogs, cats, and most other animals are considered minimal (*9, 11*).

Methods

Laboratory tests. Bait acceptance tests (*2, 15*) were conducted on pocket gophers to establish baseline data on bait and toxicant intake and efficacy of zinc phosphide and strychnine baits. Individually caged gophers were each offered 20 grams of treated oats or one piece of treated carrot each day for 3 consecutive days or until death. Control animals were offered untreated oats. Supplemental food was available during the test.

Baits tested included a 1-percent zinc phosphide-oat groat bait registered for gopher control in eastern Oregon, a 0.75-percent zinc phosphide-carrot bait registered for control of nutria *(Myocastor coypus)* in the United States, and three 0.5-percent strychnine-rolled oat baits used for gopher control in the United States.

Field study. Based on the results of our bait acceptance tests and a field study with radio telemetry (2), we field tested the 0.75-percent zinc phosphide-carrot bait (EPA Reg. No. 6704-52) and the 0.5-percent strychnine-oat bait (EPA Reg. No. 6704-58) for comparative efficacy against *Thomomys mazama.* The field study was conducted during November 1981 in a 4-year-old Douglas-fir *(Pseudotsuga menziesii)* and white pine *(Pimis monticola)* Christmas tree plantation on). Hofert Co. lands near Olympia, Wash. Baiting was conducted under an experimental use permit issued by the Washington State Department of Agriculture.

We modified the open-hole procedure (3, 15) initially to identify active gopher systems and later to test treatment effects. This procedure is based on the pocket gopher's behavior of plugging any opening in its burrow system within a relatively short time. Individual 40-square-meter plots, spaced at least 20 meters apart so they represented individual pocket gophers, were sampled for gopher activity by opening two burrows per plot. *A* plot was considered active if at least one burrow was plugged with dirt within 48 hours.

Thirty active plots were baited with 1-centimeter wedges (about 2.5 g) of 0.75-percent zinc phosphide-treated carrots; another 30 active plots were baited with 0.5-percent strychnine-treated oats. Each plot was baited with three bait sets spaced at least 1 meter apart. Each zinc phosphide-carrot bait set consisted of four carrot pieces totaling about 10 grams. Each strychnine-oat bait set contained about 4 grams of grain. Baits were delivered by spoon through probe holes into gopher burrows, and the probe holes were then covered with debris such as soil clods or vegetation.

Seven days after baiting, we opened two burrows in each plot and examined them at 24 and 48 hours for plugging activity. A dirt plug at either of the open burrows indicated a live pocket gopher.

Results

Laboratory tests. We tested five groups of 10 individually caged pocket gophers on the two zinc phosphide baits and three strychnine baits. All but the zinc phosphide-oat groat formulation yielded effective kills (90 percent or

Table 1.—*Mean bait acceptance, toxicant intake, and mortality when zinc phosphide and strychnine alkaloid baits were offered to caged pocket gophers*

Formulation	Bait concentration	Consumption		Number of lethal doses consumed	Number of deaths/ number tested	Registration remarks
		Bait	Toxicant			
	%	*G*	*Mg*			
Zinc phosphide						
Crimped oat groats, petrolatum, and mineral oil	1.0	0.26	2.6	2.2[1]	7/10	Gopher bait, eastern Oregon
Cut fresh carrots and corn oil	.75	2.20	16.5	20.1	10/10	Nutria bait, nationwide
Strychnine						
Rolled oats, molasses, salt, and soda	.5	.89	4.5	4.2	10/10	Gopher bait, nationwide
Rolled oats and molasses	.5	1.12	5.6	5.1	10/10	Experimental bait—previous standard bait formula
Rolled oats and Rhoplex AC-33	.5	1.02	5.1	4.7	9/10	Gopher bait, nationwide
Control						
Untreated rolled oats	0	1.53	–[2]	–[2]	0/10	

[1] Test results indicated that some of the test animals also ingested enough zinc phosphide to cause mortality while grooming their cheek pouches after transporting bait to their nests.

[2] – = not applicable.

better) of test gophers (table 1). Efficacy of the strychnine-rolled oats formulation with molasses, salt, and soda did not differ from the experimental strychnine bait formulated with only molasses.

Field study. In our field test, 19 of 30 plots for each treatment remained unplugged, indicating a 63-percent reduction in pocket gopher activity for both the 0.75-percent zinc phosphide-carrot bait and the 0.5-percent strychnine-oat bait. This level of reduction is generally considered poor field efficacy (*1*). These results may have been caused, in part, by the abundant vegetative food supply for gophers that existed on the study site.

Discussion and Conclusions

Our toxicant application and evaluation was directed at individual pocket gophers. We did not attempt to recover poisoned gophers or to determine the impact of baiting on area populations. Previous work with radio telemetry (2) in this same Christmas tree plantation showed that virtually all poisoned gophers died in nests or burrows 51 to 160 centimeters (2 to 5 ft) underground. In that radio study, one poisoned gopher was recovered above ground, but we suspected that it died underground and was pushed out of its system by another animal. Another poisoned gopher, recovered in its nest, was partially consumed by an unidentified carnivore.

Based on cursory observations, our study sites contained a relatively high population of pocket gophers -one gopher about every 23 meters (75 ft). We estimate that tree mortality by gophers exceeded 10 percent. Most mortality was caused by root pruning (fig. 1) that occurred over a period of several years. In addition, a survey of a nearby 7-year-old plantation of noble fir (*Abies procera*) revealed that 8 percent of the trees were missing and 1 percent had died because of pocket

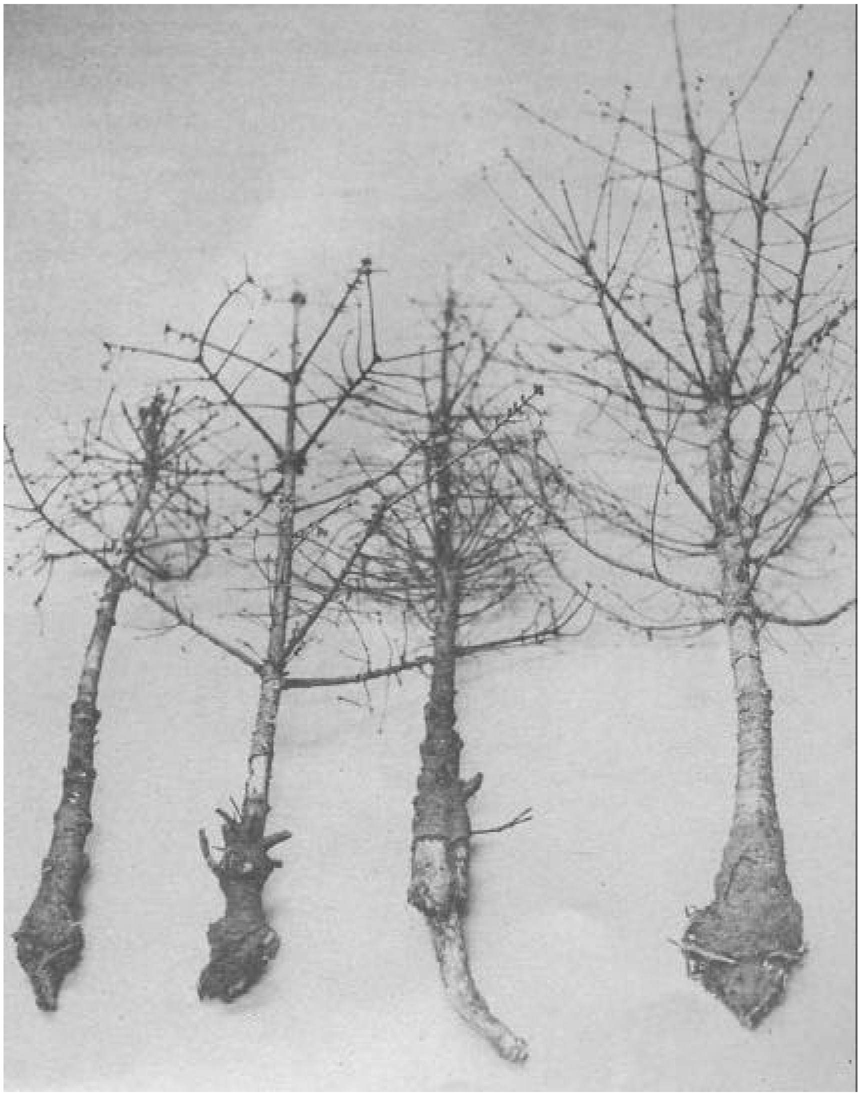

Figure 1.—*Douglas-fir Christmas trees killed by pocket gophers. The club-shaped base of these trees is characteristic of root pruning by pocket gophers.*

gophers. An additional 5 percent had gopher mounds surrounding the base of the trees indicating that root pruning by these animals was still occurring; growth of other trees was stunted. Pocket gophers were responsible for the majority of missing and stunted trees in this plantation (fig. 2).

In conclusion, our study showed that zinc phosphide was comparable to strychnine in controlling pocket gophers. Based on other studies (*4, 5, 7, 14*), vegetative control could be integrated with baiting and other pest management methods (*1*) for reducing the long-term impact of pocket gophers and competing vegetation on growth and survival of Christmas trees. Our data, therefore, supports the recommendation by Barnes and others (*2*) for further development of the 0.75-percent zinc phosphide-carrot bait for a special local need registration to control pocket gophers in Christmas tree plantations and other local areas where safety to wildlife or domestic animals must be insured.

Figure 2.—*Openings and stunted trees in this noble fir Christmas tree plantation are caused by pocket gophers.*

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Presummer Harvesting Reduces Pine Seedling Losses to Pales Weevils

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A study of pales weevil damage to planted southern pine seedlings indicates that completion of stand harvesting before July 1 in a given year results in lower subsequent seedling mortality after planting.

In several Southeastern States, insecticides are used to reduce seedling mortality from the pales weevil (*Hylobius pales* Herbst). Soon after harvesting, adult weevils are attracted to harvesting debris. Their offspring may continue emerging to feed on and kill unprotected seedlings on restocked tracts for up to a year in some instances. An alternative is to allow tracts to lie fallow for 12 to 18 months (*2*) after harvest, but timber companies are often unwilling to lose so much growth potential. Preliminary research indicated that the delay between harvesting and planting might be reduced to 6 to 7 months if harvesting was completed by late spring (*1, 3*). The primary objective of the study described here was to test this approach.

Materials and Methods

Six pairs of plots were installed and sampled in June 1980; each pair was located in the same county and not more than 20 miles apart. One of the pair had the bulk of harvesting before and the other after July 1, 1979. Although site preparation methods varied (raking and bedding, raking, burning, or windrowing), all paired plots were prepared in the same manner. Pines were planted from 3 to 12 months after harvest. Some plots were planted in 1979 and others in the spring of 1980.

Seedlings were checked in June 1980 to determine mortality that had occurred since planting in an attempt to increase the accuracy over fall surveys alone. Flags were placed by living and dead seedlings so that they could be easily located during a second mortality check in October 1980. Seedlings were sampled in a diagonal pattern[2] across each field. Twenty-five seedlings per row (or empty spaces where seedlings had been) were checked and flagged; after offsetting 1 to 2 rows, depending upon the size of the field, another 25 seedlings were checked until a total of 500 were examined. In smaller or shallower fields, the pattern was altered to examine the required number of seedlings.

Results and Discussion

Most weevil-caused seedling mortality occurred in late winter and spring because of the feeding of overwintering adults (3). These results (table 1) confirm that plots harvested after July 1 suffered more mortality than plots harvested earlier (differences significant at the 0.01 level, + 0.01 = 4.08 with 5 degrees freedom). In June, dead seedlings were easy to locate, and the cause for mortality was usually easy to identify. In the fall, many dead seedlings had disintegrated or were hidden by weeds, making assessment of mortality and its causes very difficult.

In addition to pales weevils, drought killed substantial numbers of seedlings (table 1). More seedlings died from drought than from pales weevils on 9 of 12 plots. Poor planting methods, which left exposed roots or air pockets around roots, also contributed to mortality.

Site preparation methods appeared to have little effect on the level of pales weevil-caused mortality. There was as much variation within as between methods. There was also not much effect that was attributable to the interval between harvesting and planting. Slightly higher weevil-caused mortality was evident in plots planted less than 4 months after cutting than in other plots. However, the effect of that interval was small in comparison to the effect of harvest timing.

The results indicate that completing harvesting before July 1 in a given year results in lower resident pales weevil populations and subsequent mortality when pine seedlings are replanted. It is probable that early harvesting with fall or winter regeneration will reduce requirements for extensive planting delay and pretreatment because harvesting debris tends to dry out

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[1] The author thanks Mr. Don Rogers, North Carolina Forest Service, for assisting in a portion of this work.

[2] Survey methods developed by the Forest Service, Southeastern Area, State and Private Forestry.

during the summer. Although additional testing is required, insecticide pretreatment of planted seedlings may be unnecessary except in areas heavily infested with pales weevils.

Table 1.—*Mortality of untreated loblolly pine seedlings caused by pales weevils (PW) and other factors during 1980 on areas harvested before and after July 1, 1979, and planted 3 to 12 months later*[1]

Plot location (County)	June survey				October survey			
	Harvested before July 1		Harvested after July 1		Harvested before July 1		Harvested after July 1	
	PW	Other	PW	Other	PW	Other	PW	Other
	% mortality							
Chesterfield, S.C.	1	2	–[2]	-	1	7	-	-
Chesterfield, S.C.			5	17			6	41
Halifax, N.C.	<1	10			1	21		
Halifax, N.C.			31	14			53	27
Burke, N.C.	0	6			<1	19		
Burke, N.C.			13	19			17	37
Iredell, N.C.	2	7			4	20		
Iredell, N.C.			12	1			17	21
Berkeley, S.C.	4	<1			5	1		
Berkeley, S.C.			29	14			33	17
Charleston, S.C.	2	21			3	26		
Charleston, S. C.	-	-	12	17	-	-	12	18

[1] 500 seedlings checked per plot.

[2] – = not applicable.

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Tree Planter's Notes, Vol. 34, No. 2 (1983)

Effect of Lateral Root Pruning on Development of Nursery-Grown Longleaf Pine Seedlings

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Lateral root pruning, both across and lengthwise to the bed and at 2-, 4-, 6-, and 8-week intervals, failed to stimulate new roots on the first 6 inches of longleaf nursery seedling taproots. The results indicated that, 90 days after germination, longleaf seedlings have developed basically all their potential lateral roots over the first 6 inches of the taproot. The seedlings were not undercut.

Establishment of longleaf pine *(Pinus palustris Mill.)* plantations with nursery-grown seedlings is difficult. Although many factors are important for seedling survival, a well-developed, fibrous root system is believed to enhance seedling survival probability. Seedlings with a fibrous root system are expected to have a greater probability of survival after outplanting, because more roots are available to regenerate new roots, to hold a greater nutrient pool in the seedlings, and to present a greater root surface area to absorb water.

In 1965, Shoulders (*1*) reported that undercutting of longleaf pine seedlings in the nurserybed promoted root development and increased outplanting survival. He concluded that longleaf seedlings should be undercut to a depth of 7 inches in October or November and at least 1 month before lifting. June, August, and December undercuttings were also effective in promoting survival; however, summer root-pruned stock developed new roots, which had to be repruned during grading. Shallow root undercutting (at 4 inches) also increased survival, but the short-rooted seedlings were considered to be more difficult to plant. Finally, a shallow root pruning (4 inches) in June followed by a deep root pruning (7 inches) in November was only slightly more effective than a single root pruning.

Tinus (*2*) reported that lengthwise and cross-bed lateral root pruning, in addition to undercutting the seedlings, was under intensive study in New Zealand forest tree nurseries. These studies indicate that increases in survival and initial growth are sufficient to take 1 year off a 27-year rotation.

The objective of this study was to determine whether systematic lateral pruning would stimulate lateral root development along the taproot of longleaf pine seedlings.

Materials and Methods

Two-week-old longleaf seedlings were transplanted from germination trays into a 90-foot nurserybed at the Alexandria Forestry Center. The seedlings were transplanted 3 inches apart within rows; rows were spaced 4 inches apart. The final seedling bed density was 12 per square foot. All of the seedlings were transplanted on March 11, 1980.

Lateral root pruning was initiated in mid-June and continued through October. The specific pruning treatments were: (1) a control, which was not pruned; (2) across-row pruning and no within-row pruning at the time of lifting; (3) pruning across and within rows at time of lifting; (4) pruning every 2 weeks across rows and no within-row pruning; (5) pruning every 2 weeks across and within rows; (6) pruning every 4 weeks across rows and no within-row pruning; (7) pruning every 4 weeks across rows and within rows; (8) pruning every 6 weeks across rows and no within-row pruning; (9) pruning every 6 weeks across and within rows; (10) pruning every 8 weeks across rows and no within-row pruning; and (11) pruning every 8 weeks across and within rows. Because of the nature of the beds, no undercutting was done.

Each of the 11 pruning treatments occupied a plot area of 4 linear feet along the nurserybed and were one-half of the width of the bed. Each treatment was replicated four times in randomized complete plots. Each replicate had 80 seedlings for a total of 320 seedlings per treatment. The middle row of the seedling bed was sown, but these seedlings were not used in this study in order to eliminate border effects. All pruning was done by sawing through the soil with a sharpened machete at a mid-distance between the seedling rows.

A control check on the effectiveness of lateral root pruning for stimulating root development was done on July 11 (the first pruning date) by randomly lifting 21 seedlings from the entire nurserybed. The number of lateral roots 0.5 inches or longer between the root collar and the first 6 inches of the taproot were counted.

In mid-December 1980, 25 seedlings were randomly lifted from the interior of each replicated treatment plot, and all of the secondary lateral roots exceeding 0.5 inch were counted as above.

Table 1.—*Mean number of lateral roots longer than 0.5 inch on 9-month-old longleaf seedlings subjected to different lateral root pruning regimes (Each plot mean is based on 25 seedlings randomly selected from each nursery treatment plot.)*

Treatment	Frequency	Method seedling beds pruned		Mean number of lateral roots/ plot				
code	of pruning	Lengthwise	Across	1	2	3	4	(X)
1	Not pruned	-[1]	-	18.96	15.08	12.73	15.57	15.58
2	At lifting	+[2]	-	18.52	15.44	13.00	18.00	16.24
3	At lifting	+	+	19.96	19.76	13.04	15.52	17.07
4	Every 2 weeks	+	-	20.48	17.88	17.52	14.56	17.61
5	Every 2 weeks	+	+	22.20	18.00	13.36	17.52	17.71
6	Every 4 weeks	+	-	18.52	11.81	14.44	15.08	14.96
7	Every 4 weeks	+	+	19.44	20.24	14.40	15.04	17.28
8	Every 6 weeks	+	-	18.76	16.68	13.20	21.72	17.59
9	Every 6 weeks	+	+	24.48	15.44	13.84	18.32	18.02
10	Every 8 weeks	+	-	21.00	15.92	14.92	15.52	16.84
11	Every 8 weeks	+	+	19.24	18.12	11.88	16.84	16.52

[1] – = no pruning treatment.

[2] + = pruning treatment.

Results and Conclusions

The results of lateral root pruning of longleaf seedlings in either a single parallel cut across the seedling rows or a combined across- and within-row pruning regime are given in table 1.

The effect of root pruning on the stimulation of lateral root production was not dramatic, although 9 of the 10 pruning treatments had mean lateral root counts greater than the control nonpruned seedlings. The mean lateral root count ranged from 14.96 to 18.02 for the 10 treatments, while the mean lateral root count of the control seedlings was 15.58. These differences were not statistically significant at the $p<0.05$ level. The lowest mean root count (14.96) was recorded for the seedlings root pruned only lengthwise every 4 weeks (table 1). The highest mean lateral,root count (18.02) occurred for the seedlings that were root pruned both across and within rows every 6 weeks.

The mean number of lateral roots for the 21 seedlings lifted on July 11 was 15.33 (table 2). These seedlings were considered to be a control since they were randomly removed from the entire nurserybed on the day that lateral root pruning began. They had been in the nurserybeds exactly 90 days. These data indicate that lateral root growth of longleaf pine seedlings is not stimulated by lateral root pruning. Equally important, they indicate that, after 3 months of growth in nurserybeds, secondary or lateral root development along the first 6 inches of the taproot is essentially fixed. Thus, stimulus of longleaf root growth may not be possible by lateral root pruning alone.

Although root pruning was done on a 2-, 4-, 6-, or 8-week cycle in either one or two directions, no detectable difference in lateral root development showed. This is surprising since half of the plots were root pruned in both directions and thus underwent radical root volume loss. The large loss of lateral root volume suffered by the seedlings was not sufficient to stimulate new lateral root growth. However, no root undercutting was done in this study, and possible relationships with undercutting and lateral pruning are not known.

Under the conditions of this study, the results indicate that lateral root pruning, by itself, will not significantly increase the number of lateral roots within the first 6 inches of the taproot. The current method of broadcasting longleaf seed over the nurserybed has been questioned and some nursery personnel feel that longleaf should be sown in rows to permit lateral root pruning. Row-sown longleaf beds may be preferred over broadcast beds since lateral root pruning could be easily done between the rows with coulter blades. This would reduce the labor cost of root trimming done in the packing shed following lifting, but it is doubtful that additional lateral roots will be produced by lateral root pruning alone.

Table 2.—*Mean number of lateral roots for 21 longleaf seedlings lifted 90 days after growth in a nursery bed*[1]

Seedling	Number of roots
1	17
2	13
3	25
4	13
5	19
6	17
7	13
8	15
9	22
10	12
11	18
12	19
13	17
14	10
15	21
16	10
17	13
18	19
19	9
20	11
21	9
Average	15.33

[1] The seedlings had not been undercut or lateral root pruned. Spacing between seedlings was 3 inches and between rows fl inches. All lateral roots longer than 0.5 inch were counted.

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Diagnosis and Control of Cutworm Damage on Conifer Seedlings in Nursery Seedbeds

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The article describes cutworm outbreak, damage, identification, and control in conifer nurserybeds of a Lake States nursery. How to diagnose cutworm damage is discussed.

Seedling damage at a northern Lake States nursery was first observed in the mid-1960's. The damage, from an unknown cause, was of minor importance until it became epidemic in 1976. The nursery manager estimates losing approximately 1 million seedlings a year from 1976 to 1978, the total loss valued between $150,000 and $200,000.

All conifer species were affected. Symptoms included cut or chewed cotyledons, primary needles, or stems of 1-year-old seedlings. Many times, only part of the stem was left standing in the ground. This damage was tentatively labeled "bird peck" because the seedlings appeared as if a bird had nipped off the foliage or stem. But repellants and screening failed to reduce the problem. The damage was similar to that caused by damping-off fungi, so fungicides were tried as a control, but without success. Losses were sometimes attributed to poor seed germination. Our objective was to determine the cause of seedling losses.

Methods and Results

To determine the cause of the damage, we studied affected seedbeds at the nursery, beginning in the early spring of 1979. On May 24, 1979, the sites of the most severe damage were marked, and damaged 1-0 red pine seedlings were collected. Parts of these seedlings were surface-sterilized and incubated in petri dishes on various mycological media to see if a fungal pathogen could be recovered. Most of these isolations were sterile and no pathogens were recovered.

One week later, in late afternoon, another close inspection of damaged seedlings revealed one or two cutworms feeding on the foliage. Because cutworms are normally active only at night, the seedlings were again closely observed that evening. Many cutworms were observed devouring seedling foliage and were determined to be the cause of the damage.

Cutworms were collected and reared to the adult stage in the laboratory for positive species identification. The cutworm was identified as dingy cutworm *(Feltia ducens* Lepidoptera:Noctuidae). Using the same techniques, we examined emerging red pine seedlings at other Lake States nurseries. Only a few cutworms and minor cutworm damage were observed.

Diazinon AG-500, at 4 quarts of product per 96 gallons of water, was applied on June 1 and June 6, 1979. Before control measures were begun, small plots were established to determine the effectiveness of the spray.

Seven bedrows of 1-0 red pine were designated as spray areas. The remaining two bedrows were the control (unsprayed). In each of the sprayed and unsprayed areas, four 0.6-meter-long plots (each consisting of one row of trees) were established. The number of undamaged seedlings were counted in each plot, and each damaged seedling was tallied and marked with a toothpick.

On June 12, 1979, we examined the plots and found that the spray was effective in controlling the cutworms (table 1).

Also on June 12, sprayed and unsprayed plots were observed after dark during the period when cutworms are active. No cutworms were observed feeding on seedlings in the sprayed plots, but 18 cutworms were found on unsprayed seedlings during a count period of 45 minutes for each plot. These observations confirmed the effectiveness of the chemical control.

Table 1.—*Effectiveness of a chemical spray for control of cutworms on 1-0 red pine seedlings*

Treatment[1]	Number of trees in sample[2]	Number of seedlings damaged	
		Before spray	After spray
Sprayed[3]	186	35	0
Unsprayed	148	64	27

[1] Chemical used was Diazinon AG-500 at a rate of 4 quarts of product per 96 gallons of water.

[2] Total number of trees from 0.6-meter-long plots replicated four times per treatment.

[3] Sprayed June 1 and June 6, 1979.

Discussion

Cutworm damage has been reported infrequently from Lake States nurseries. Although conifer seedlings are usually the reported host, cutworms have also been observed feeding on young, deciduous trees such as hybrid poplars. Cutworm outbreaks occur when favorable environmental conditions allow populations to build up quickly to damaging economic levels.

Cutworms generally feed at night and go underground during the daylight hours, hindering identification of the cause of damage. Heavy seedling losses can occur before damage is noticed, especially if the seedlings are under protective screens. During 1979, 1 million trees, valued at $58,000, were saved at the nursery we studied by the proper identification of the cause and quick chemical control.

Early spring is the time to watch for cutworm damage on young seedlings (*1*). To make a positive identification, growers should look for cutworms feeding on the seedlings at night where damage was noticed during the day (fig. 1). If a chemical control is used, it should be applied as soon as the cutworm damage is observed. Early detection is necessary if control is to be effective in reducing losses. Because cutworms also feed on weeds, their populations can be reduced through weed control.

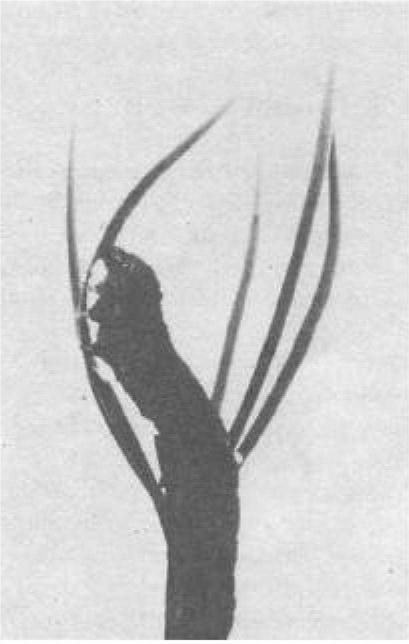

Figure 1.—*Cutworm feeding on red pine seedling.*

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Soil Texture and Bulk Density Affect Early Growth of White Oak Seedlings

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Recently germinated white oak seedlings were grown under three bulk densities and five soil textures. Root growth was significantly reduced at the highest bulk density. White oak regeneration from seed may therefore be hindered where sites are compacted from logging or other operations.

Abundant oak regeneration must be present in an understory if a future stand is to be predominantly oak (*3*). Beck (*2*) suggested a three-cut shelterwood may be effective in establishing such regeneration. However, more entries into a stand by logging equipment may increase soil compaction and thereby hinder root growth of young seedlings. When bulk densities exceed 1.55 grams per cubic centimeter in coarse soils or 1.75 grams per cubic centimeter in fine-textured soils, root penetration may be impeded (*12*). Shale and sandstone-derived soils common to upland hardwood forests of the Eastern United States tend to be droughty during portions of the growing season (*13*), making vigorous root growth vital for survival and growth of young hardwood seedlings.

In addition to bulk density, differences in soil texture can cause varying root growth patterns. For example, roots of fruit trees penetrated to a depth of 30 feet in coarse-textured soils but only 3 feet in high clay soils (*7*). The objectives of this study were to determine the effects of compaction and growing-medium texture on the early growth of white oak seedlings.

Materials and Methods

The A_1 horizon of a Calvin silt loam, a clayey, mixed, mesic, Typic Hapludult, was collected from a forested site in Montgomery County, Va., air dried and passed through a 2-millimeter screen. Fifty-five lengths of plastic PVC pipe (each 7.7 cm in diameter and 43 cm long) were plugged at one end to allow drainage, but prevent soil loss. These long containers were used as pots to allow ample room for taproot growth. The inside walls of all containers were swathed with an adhesive casting resin;[1] soil was added to the container and shaken so that a thin film of soil became "glued" to the inside walls. The containers were allowed to dry for 1 week to insure that the resin was completely dry and free of vapor. The walls were thus roughened to minimize taproot spiralling. Containers and soil were then randomly divided into two groups for the bulk density and soil texture experiments.

The desired bulk density was attained by repeatedly pouring a small amount of soil into a container, followed by tamping. When a container was filled, it was weighed and the bulk density calculated. This procedure was repeated until five replications (containers) were attained for each treatment level (1.0, 1.2, and 1.5 g/cm^3).

Five soil texture treatments were administered across five replications (25 containers). The silt loam soil was mixed with coarse sand (0.5-1.0 mm) in various percentages (volume/volume): 100 soil/0 sand, 75 soil/25 sand, 50 soil/50 sand, 25 soil/75 sand, 0 soil /100 sand. In addition, a treatment with Pro-mix BX2 (60-percent peat, 20-percent vermiculite, and 20-percent perlite) as the growth medium was used.

White oak seeds were collected from several trees in Blacksburg, Montgomery County, Va., and composited to form a single seedlot. One white oak *(Quercus alba* L.) acorn was placed in each container; and in one replication, red oak *(Quercus rubra* L.) acorns were placed alongside the white oak acorns. The red oak acorns had been in cold storage for 1 year and were included to compare freshly germinated red and white (unstored) oak seeds. Seedlings were placed in a growth chamber with 15° C nights and 25° C days under a 12-hour daylength regime. Plants were watered to field capacity at intervals of 3 to 5 days.

Seedlings were harvested 40 days after planting. Soil was washed from root systems, and shoots were separated from roots at the root collar (just below the point of acorn attachment to epicotyl). The following measurements were taken: shoot height and dry weight (including stem, leaves, and acorn); taproot

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[1] Chemco, San Leandro, Calif.

[2] Bonar-Bennis Ltd., Canada.

length and dry weight; and primary and secondary lateral root number, length, and dry weight.

The bulk density experiment was a completely randomized design with three treatments and four replications. The soil texture experiment was of similar design, but with five treatments and four replications. An analysis of variance was used to test significance of treatments. Treatment means were compared and results are reported on the basis of least significant difference at the 0.05-probability level. The single replication containing red oaks was not used in the statistical analysis.

Results and Discussion

Root growth of white oak was significantly reduced at a bulk density of 1.5 grams per cubic centimeter (table 1). Similar reduced growth was also found with Sitka spruce *(Picea sitchensis* (Boug.) Carr), western hemlock *(Tsuga heterophylla* (Raf.) Sarg.), and western red cedar *(Thuja plicata* Donn) (*11*); Scots pine (*Pinus sylvestris* L.) (*5*); and yellow-poplar *(Liriodendron tulipifera* L.) (*9*). Root growth may therefore be adversely affected on intensively used recreation sites where bulk densities may increase to 1.5 grams per cubic centimeter or higher (*8*) and on forest sites subjected to heavy equipment traffic. Bulk density may increase by 35 percent because of tractor skidding (*4, 14*), with the greatest compaction resulting from the first few tractor passes (*1, 10*). Since more than two cutting operations may be necessary to successfully regenerate oak (2), site compaction may become a problem for establishment of young white oak seedlings as advanced regeneration and as postharvest regeneration. In addition, a bulk density of 1.5 grams per cubic centimeter significantly decreased the taproot length of white oak. Because early establishment of a long taproot is essential for drought tolerance (*6*), high bulk density is likely to lower white oak seedling tolerance to water stress. This would be critical on xeric sites typical of south and southwest

Table 1.—*Growth responses of container grown white oak seedlings at three bulk densities and five soil textures*[1]

	Root length			Root number[2]		Dry weight		Shoot height
Treatment	Tap	Prim.	Sec.	Prim.	Sec.	Root	Shoot	
Sulk density (g/cm^3)	- - - - - *Cm* - - - - -					- - - - *G* - - - -		*Cm*
1.0	20	88	18	47	4	0.5	1.4	10.6
1.2	22	133	29	57	1	.7	1.6	10.2
1.5	9	43	13	19	3	.4	1.7	9.4
Least significant difference (.05)[3]	8	58	NS	21	NS	NS	NS	NS
Growing medium (% v / v)								
100 silt loam soil 0 sand	20	88	18	47	4	.5	1.4	10.6
75 silt loam soil 25 sand	22	98	38	52	4	.6	1.7	11.3
50 silt loam soil 50 sand	20	133	66	57	1	.5	1.7	9.9
0 silt loam soil 100 sand	24	244	296	93	58	.7	1.4	9.2
Pro-mix	36	92	12	65	3	.6	1.4	9.9
Least significant difference (.05)	NS	95	NS	NS	40	NS	NS	NS

[1] Values are means tar four replications.

[2] Roots 0.5 centimeter or longer were counted.

[3] Differences between two means that exceed the least significant difference are significant, NS indicates treatment means do not differ significantly.

Table 2.—*Growth responses of container-grown red oak seedlings at three bulk densities and five soil textures*

Treatment	Root length			Root number[2]		Dry weight		Shoot height
	Tap	Prim.	Sec.	Prim.	Sec.	Root	Shoot	
Sulk density (g/cm^3)	- - - - - *Cm* - - - - -					- - - - *G* - - - -		*Cm*
1.0	24	189	238	63	47	1.1	3.6	19.5
1.2	23	212	54	49	19	1.0	4.6	20.3
1.5	18	193	65	27	24	.5	3.0	10.0
Growing medium (% v / v)								
100 silt loam soil 0 sand	24	189	238	63	47	1.1	3.6	19.5
75 silt loam soil 25 sand	18	366	518	66	215	.9	4.2	20.5
50 silt loam soil 50 sand	19	208	374	56	96	1.0	3.9	12.5
0 silt loam soil 100 sand	29	308	509	308	509	1.1	3.7	13.1
Pro-mix	22	455	951	58	429	1.2	1.8	18.2

[1] Values represent one tree per treatment.

[2] Roots 0.5 centimeter or longer were counted.

aspects in the central Appalachians and most upland soils of the Piedmont where fine-textured soils are prevalent.

Generally, with an increasing percentage of sand, root growth of white oak increased. The number of secondary and length of primary and secondary roots grown in 100-percent sand were significantly greater than those growing in other soil media (table 1). The large pores and low mechanical resistance in this sandy soil enabled rapid development of the large root system. Such large root systems allow plants to exploit greater soil volumes, which may be critical, since less moisture and fewer nutrients are available with decreasing amounts of silt and clay (*12*). Differences in root growth because of soil texture also have implications for root growth studies that use different types of soil media. Because of different growth responses, such as those observed in this study, the texture of the growing medium must be considered when conclusions and recommendations are made.

Red oak growing in Pro-mix had a larger number of roots per unit volume (intensive root system) than red oaks grown in soil mixtures (table 2). Also, white oaks growing in Pro-mix were found to have longer taproots than those growing in soil mixtures (table 1). This greater root growth may have resulted from greater total porosity, better aeration, and resultant ease of root penetration. Although results are based on only one replication, it would appear that additional work should be done with intensively rooted species such as red oak and yellow-poplar to more clearly understand root growth patterns that occur in an artificial growing medium such as Pro-mix. It is evident that large numbers or lengths of new roots in Pro-mix do not indicate similar growth in soil mixtures.

Red oak responses to treatments were similar to white oak. However, red oak had 20 times the number and 4 times the length of secondary roots. Such growth may be because of greater food reserves stored in the larger red oak acorn. This early establishment of a large root system could enable red oak seedlings to compete more effectively than white oaks and may partly account for the faster growth rate of red oak.

Summary and Conclusion

Compaction, which may result from several logging operations, such as in a three-cut shelterwood, may inhibit root growth of young white oak seedlings. Root growth of freshly germinated white oak seedlings was severely curtailed in silt loam soil that had a bulk density of 1.5 grams per cubic centimeter. The inability of roots to penetrate fine-textured soils that have been compacted can therefore reduce white oak establishment on upland hardwood sites. Root growth was also found to vary at different soil textures and was notably large with seedlings grown in 100-percent sand. The significance of the soil texture used in an experiment must then be considered, particularly where new root growth is used as an index of a seedling's physiological condition and its ability to survive outplanting.

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Tree Planter's Notes, Vol. 34, No. 2 (1983)

Is It Possible To Detect Cull Trees Within 1 Year After Planting?

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On November 20, 1980, after a severe spring and summer drought, 100 low-vigor and 100 high-vigor seedlings in a plantation were selected and observed through spring 1982. The low-vigor seedlings had slower height growth and later spring bud break. There were no significant survival differences.

After a severe drought, first-year plantation survival may be marginal or insufficient to produce a satisfactory commercial return. On the other hand, stocking density following drought may be adequate, but many seedlings surviving drought may have suppressed growth in later years. This study sought to quantify such observations.

Materials and Methods

Following the severe drought of 1980, 100 seedlings that appeared to have low vigor and 100 seedlings that appeared to have high vigor were flagged for reference in a plantation established during the previous winter on a well-drained sandy loam site at the Palustris Experimental Forest in central Louisiana. Weeds and brush were bush-hogged and disked before planting at a 2- by 2-foot spacing. The seedling roots were mycorrhizal at the time of planting.

On November 20, 1980, 100 low-vigor and 100 high-vigor loblolly pine seedlings were flagged and their heights were measured. A low-vigor seedling was defined as chlorotic and having small or no branches, short secondary needles, and a small terminal bud. High-vigor seedlings were characterized as having green foliage with larger branches, long secondary needles, and a large terminal bud.

Results and Discussion

At the time of selection, the mean height of the low-vigor seedlings was 24.2 centimeters and the mean height of the high-vigor seedlings was 28.8 centimeters. These differences were small, but statistically significant at the $p \leq 0.05$ level of confidence. By August 30, 1981, the mean height and standard error of the more vigorous seedlings was 57.1 ± 10.73 centimeters, but the mean height and standard error of low-vigor seedlings was only 36.6 ± 6.98 centimeters. These differences were statistically significant at the $p \leq 0.01$ level of confidence. Thus, the vigorous seedlings had grown 55 percent more than the low-vigor seedlings in the same growth period (table 1). This represented a 91.3-percent increase in height growth for the vigorous seedlings and a 51.2-percent increase in height growth for the low-vigor seedlings.

On February 20, 1981, the seedlings were surveyed for bud break. All of the vigorous seedlings had broken bud (table 2), but only six of the low-vigor seedlings had broken bud. Most of the vigorous seedlings had also developed a flush of growth and an apparently strong bud. The low-vigor seedlings had not only failed to break bud, but, except for six seedlings, they had also retained all original low-vigor characteristics from November 20, 1980. Four of the low-vigor seedlings appeared dead, but all of the high-vigor seedlings were still living. However, all low-vigor seedlings had begun growing by March 13.

Observations were repeated in February 1982. Of the four seedlings that had previously appeared dead, two had survived. By February 20, 67 percent of the seedlings classified as vigorous in November 1980 had begun to grow, but only 9 percent of the low-vigor seedlings had initiated terminal bud break. By March 11, 93 percent of the high-vigor and 53 percent of the low-vigor seedlings had broken bud (table 3). Mean height of the two groups of seedlings had not changed since November 20, 1981; both sets of seedlings were effectively dormant between November 20, 1981, and February 22, 1982.

Perhaps the most interesting and important point is that on November 20, 1980, on consideration of foliage color, secondary needle length, and bud and branching characteristics, two classes of seedlings that would perform differently could be distinguished. This prediction was restricted to two groups of seedlings, but the prediction was surprisingly accurate; and the suppressed seedlings as of November 1980 continued to be less vigorous in 1982. Perhaps with more intensive quantification of seedlings and seedling vigor analysis, it may be possible, after the first growing season, for the plantation manager to estimate accurately the number of suppressed trees in a plantation. This information may be used to determine whether the plantation should be replanted even though the overall survival percentage is acceptable for minimum reforestation criteria.

Table 1.—*Second-year growth of low-vigor and high-vigor seedlings*

Seedling class	Mean heights of seedlings (with standard errors) November 20, 1980	Mean heights of seedlings (with standard errors) August 30, 1981	Height increase
	- - - - - - - - - - - - - - Cm	- - - - - - - - - - - - - -	%
Low vigor	24.2 ± 4.54a[1]	36.6 ± 6.98a	51.2
High vigor	28.8 ± 4.38b	57.1 ± 10.73b	91.3

[1] Data sets followed by different letters indicate a statistically significant difference at the $p \leq 0.05$ level.

Table 2.—*Percentage of surviving loblolly seedlings and percentage of surviving seedlings that had broken dormant buds on February 20, 1981 (100 low-vigor and 100 high-vigor seedlings were compared.)*

Seedling class	Date	Surviving	Bud break
		- - - - - - - - - - - - - %	- - - - - - - - - - - - -
Low vigor	2-20-82	96	6.2a[1]
	3-15-82	96	100
High vigor	2-20-82	100	100b
	3-15-82	100	100

[1] Data sets followed by different letters indicate a statistically significant difference at the $p \leq 0.05$ level.

Table 3.—*Percentage of surviving loblolly seedlings and percentage of surviving seedlings that had broken dormant buds on February 22, 1982, and March 11, 1982*

Seedling class	Date	Surviving	Bud break
		- - - - - - - - - - - - - %	- - - - - - - - - - - - -
Low vigor	2-20-82	98	9.2a[1]
	3-11-82	98	53.0a
High vigor	2-22-82	100	67.0b
	3-11-82	100	93.0b

[1] Data sets followed by different letters indicate a statistically significant difference at the $p \leq 0.05$ level.

Tree Planter's Notes, Vol. 34, No. 2 (1983)

Cherrybark and Shumard Oaks Successfully Planted on Eroded Ridges

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Eroded ridges were planted with Shumard and cherrybark oaks. Shumard had greater diameter growth and cherrybark appeared to have better form. Contour ditching to allow for added infiltration had no effect on growth.

The Brown Loam Bluffs adjacent to the Mississippi River Delta were farmed for several decades following the Civil War. Poor farming practices resulted in severe erosion. Many ridge areas completely lost their topsoil. Now abandoned, these areas are generally stocked with medium- to poor-quality timber. Loblolly pine has been widely used in reforestation programs for these types of eroded areas. Recent concern has been expressed about obtaining adequate oak regeneration after cutting (*3*). This study tested hardwood alternatives for planting on eroded ridges as one of its objectives; two of the species studied were cherrybark *(Quercus falcata* var. *pagodifolia Ell.)* and Shumard *(Q. shumardii* Buck.) oaks.

The characteristic soil, classified as Loring silt loam, has a weak fragipan at 20 to 35 inches (51 to 89 cm). Memphis, a similar soil, but without a fragipan, has a cherrybark oak site index of about 100 feet (30 m) (*2*). The pan on these ridgetops has a low permeability; and after the upper horizons are filled, much of the precipitation is lost to runoff. Ditching on the contour to catch and allow added infiltration of rainwater was proposed and tested as an aid to plantation establishment and site amelioration.

Methods

Three similar old-field ridge sites near Vicksburg, Miss:, were prepared for planting during the winter of 1961. Half of each site (90 by 90 ft (27 by 27 m), chosen at random), was disked and served as a control. The other half was ditched on the contour with a dozer blade. The ditches, which were discontinuous to prevent lateral movement of water, were 2 feet (61 cm) deep and spaced approximately 10 feet (3 m) apart. The berm was thrown downhill.

Seedlings were handplanted March 1 and 2 on the berm side next to the ditch on within-row spacings of 8 feet (2.4 m). Control plots were similarly spaced. The species tested were cherrybark oak, Shumard oak, sycamore *(Platanus occidentalis* L.), yellow-poplar *(Liriodendron tulipifera* L.), and cottonwood *(Populus deltoides* Bartr. ex Marsh.). All but the cottonwoods, which were planted as cuttings, were 1-0 stock grown at the research unit nursery from local seeds. Hoeing was done as needed to control weeds during the first growing season.

Survival was recorded and height measured annually for 5 years. At 20 years in the field, diameter and height were measured and survival recorded (fig. 1). Data were evaluated by a least-squares analysis

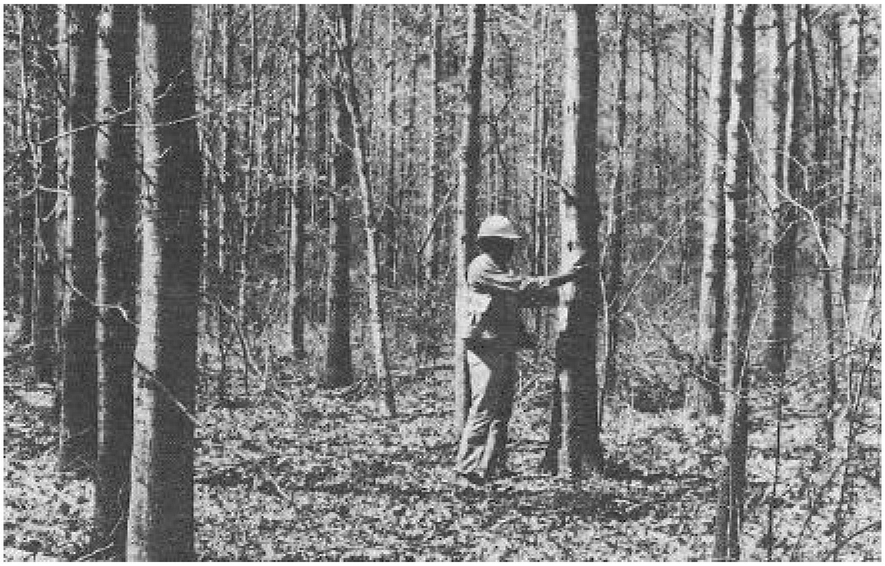

Figure 1.—*Twenty-year-old Shumard oak planted on an eroded ridgetop site.*

of variance (α = 0.05) weighted for number of surviving trees.

Results

Except for occasional survivors, sycamore and cottonwood failed on all sites. The cause of their failure is unknown. Yellow-poplar averaged 47 feet (14 m) high and 5.6 inches (14 cm) in diameter at breast height (d.b.h.) at 20 years. Survival was about 60 percent. This rate of growth was faster than that of the oaks on the plots, but poor for yellow-poplar, which usually does not occur on ridgetops in the area, preferring more mesic sides and bottoms. For this reason, the species was not included in the following comparisons.

After 20 years, the contour ditches were still intact and still caught and held rainwater. Their worth, however, was another matter. During the first growing season after establishment, soil moisture in the ditched and control areas was not significantly different. Ditching did not affect survival or height of oaks at 5 years or their survival, height, or diameter at 20 years. The interaction of treatment and species was not significant.

Comparisons of species within treatments are given in table 1. Note that Shumard oak was significantly taller than cherrybark oak at 5 years on the control (flat) plots, but not on the ditched plots. The diameters of Shumard oak at 20 years on both control and ditched plots were significantly greater than those of cherrybark oak.

Cherrybark oak appeared to have a stronger apical dominance, longer central bole, and more slender branches than Shumard oak. Thus, the slight diameter advantage of Shumard oak may be offset by better form in cherrybark oak.

Although an effort was made to select similar planting sites for this study, the height and diameter growth differences at 20 years between planting blocks (locations) are an indication of site variation. While soil tests showed N reserves to be low, there was little difference between plots. Other nutrients and soil pH appeared to be adequate. Soil texture was similar for all blocks. Soil structure or other environmental causes may have been responsible for the block differences.

Height growth and survival of the two species during the first 5 years are shown in figure 2. Initially, survival of Shumard oak was better than cherrybark oak; but by 5 years, it had decreased below that of cherrybark oak. At 20 years (table 1), there was little difference in survival of the two species. Height growth began slowly, but increased to a little over 2 feet per year (61 cm) after the third growing season. This compares favorably with growth rates reported for cherrybark elsewhere (*1, 4, 5*).

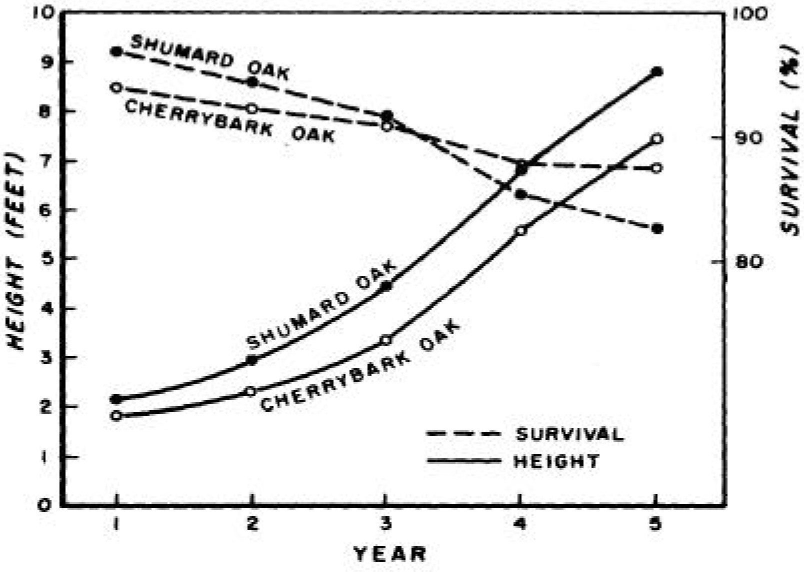

Figure 2.—*Height and survival of cherrybark and Shumard oak seedlings during the first 5 years in the field.*

Table 1.—*Survival, diameter, and height of cherrybark and Shumard oaks at 5 and 20 years with two site preparation treatments*

Treatment	Species	Survival		D. b. h.		Height	
		5 yrs	20 yrs	5 yrs	20 yrs	5 yrs	20 yrs
		- - - - - - % - - - - - -		- - - - *Inches* - - - -		- - - - - - *Ft* - - - - - -	
Disked (Control)	Cherrybark	89a[1]	76a	_[2]	4.4b	6.5b	41a
	Shumard	80a	73a	—	5.1a	8.4a	40a
Ditched	Cherrybark	86a	81a	—	4.2b	8.2a	39a
	Shumard	85a	83a	—	5.2a	9.3a	41a

[1] Weighted least-squares means within the same treatment and age followed by the same letter are not significantly different (α = 0.05).

[2] – = no measurement taken.

Conclusion

Hardwoods, as well as pines, can be grown on eroded sites in the Brown Loam Bluffs along the Mississippi River. Although Shumard demonstrated greater diameter growth and cherrybark appeared to have better form, both are excellent choices. The construction of water-trapping structures during site preparation does not pay off in better growth.

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Cost Savings From Improved Seed Germination Rates

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A procedure for establishing the economic value of increased seed quality is described and illustrated. Methods and equipment for improving seed quality can be evaluated with these procedures.

A new piece of equipment or handling technique often results in a better product. How is this improvement evaluated? If greater *quantity* is the result, the benefit can be expressed in a new average production cost figure: new total cost divided by new quantity of output. However, if the result is improved product quality, choosing an appropriate evaluation criteria is more difficult. This is the case when new equipment or handling techniques result in improved seed germination rates. For example, how can an economic value be attached to a germination rate that is improved from 50 to 60 percent?

One approach is to view the quality improvement as a *quantity* improvement. At a germination rate of 50 percent, 2.0 pounds of field-run seed will produce a pound of 100-percent viable seed. If the price plus processing costs of field-run seed is $40 per pound, a pound of viable seed would cost $80. After improving the germination rate to 60 percent, only 1.67 pounds of field-run seed will produce a pound of viable seed. The cost would then be $66.67 for a cost savings of $13.33.

Table 1 contains cost savings figures per 100 pounds of viable seed for selected seed price plus processing costs and germination rates. For example, if the market price plus processing cost of seed is $34 per pound and the current mean germination rate is 65 percent, improving the germination rate to 66 percent will decrease the cost of processing 100 pounds of viable seed by $79.30.

We can easily expand this simple example into a more realistic situation. Suppose a State forestry agency purchases a new seed dewinger to reduce the impact damage caused by the old one. The new dewinger increases the seed germination from 65 percent to 88 percent for species "A" seed and from 61 percent to 78 percent for species "B" seed. The market price of field-run seed is $31.50 per pound for species "A" and $25.75 per pound for species "B." The processing cost of each species and for each dewinger is the same: $2.60 per pound.

To determine the approximate economic benefit of this new dewinger, calculate the average cost savings per 100 pounds of viable seed for each species by averaging the tabulated cost savings for the nearest before-improvement price/cost/germination rate and the nearest after-improvement price/cost/germination rate and then multiply this figure by the number of percentage points between the initial and improved germination rates.

For species "A" the calculation would be as follows:

Price plus processing cost: $34.10 per pound.
Initial germination rate: 65 percent.
Nearest table value: $79.30 ($34 row, 65-percent column).
Improved germination rate: 88 percent.
Nearest table value: $41.50 ($34 row, 90-percent column).

$$\frac{\$79.30 + \$41.50}{2} = \$60.40$$

$60.40 X 23 (percentage point difference between 65 and 88 percent) = $1,389.20 (the approximate cost savings from processing 100 pounds of viable species "A" seed).

Following the same procedure, the approximate cost savings from processing 100 pounds of viable species "B" seed would be $1,017.45.

Note that these are only approximate cost savings. The calculations treat the table values as if they were linearly related, which is not the case; and the closest price/cost/germination rate values were used, not the exact ones. More precise cost savings figures can be calculated using the following formula:

$$\text{Cost savings per 100 pounds of viable seed} = \left[\frac{P+C}{G} - \frac{P+C^*}{G^*}\right] 100$$

where:

P = Market price (or cost) per pound of field-run seed.
C = Initial processing cost per pound of field-run seed.
C* = New processing cost per pound of field-run seed.
G = Initial germination rate (as a decimal).
G* = Improved germination rate (as a decimal).

Using this formula, the previous example of cost savings would be calculated as follows for species “A”:

P = $31.50 per pound.
C = $2.60 per pound.
C* = $2.60 per pound.
G = 65 percent.
G* = 88 percent.

$$\left[\frac{\$31.50 + \$2.60}{.65} - \frac{\$31.50 + \$2.60}{.88}\right] \times 100 = \$1{,}371.15 \text{ per 100 pounds.}$$

For species "B":

P = $25.75 per pound.
C = $2.60 per pound.
C* = $2.60 per pound.
G = 61 percent.
G* = 78 percent.

$$\left[\frac{\$25.75 + \$2.60}{.61} - \frac{\$25.75 + \$2.60}{.78}\right] \times 100 = \$1{,}012.93 \text{ per 100 pounds.}$$

Table 1.—*Cost savings from processing 100 pounds of viable seed by increasing the mean germination rate by one percentage point*

Market price (or cost) plus processing cost per pound of field-run seed	Savings per 100 pounds of seed processed at current mean germination rates (percentages)													
	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%
Dollars	***Savings in dollars***													
50	537.60	396.80	304.90	241.50	196.10	162.30	136.60	116.60	100.60	87.70	77.20	68.40	61.10	54.80
48	516.10	381.00	292.70	231.90	188.20	155.80	131.10	111.90	96.60	84.20	74.10	65.70	58.60	52.60
46	494.60	365.10	280.50	222.20	180.40	149.40	125.70	107.20	92.60	80.70	71.00	62.90	56.20	50.40
44	473.10	349.20	268.30	212.60	172.50	142.90	120.20	102.60	88.50	77.20	67.90	60.20	53.70	48.20
42	451.60	333.30	256.10	202.90	164.70	136.40	114.80	97.90	84.50	73.70	64.80	57.50	51.30	46.10
40	430.10	317.50	243.90	193.20	156.90	129.90	109.30	93.20	80.50	70.20	61.70	54.70	48.80	43.90
38	408.60	301.60	231.70	183.60	149.00	123.40	103.80	88.60	76.50	66.70	58.60	52.00	46.40	41.70
36	387.10	285.70	219.50	173.90	141.20	116.90	98.40	83.90	72.40	63.20	55.60	49.20	44.00	39.50
34	365.60	269.80	207.30	164.30	133.30	110.40	92.90	79.30	68.40	59.60	52.50	46.50	41.50	37.30
32	344.10	254.00	195.10	154.60	125.50	103.90	87.40	74.60	64.40	56.10	49.40	43.80	39.10	35.10
30	322.60	238.10	182.90	144.90	117.60	97.40	82.00	69.90	60.40	52.60	46.30	41.00	36.60	32.90
28	301.10	222.20	170.70	135.30	109.80	90.90	76.50	65.30	56.30	49.10	43.20	38.30	34.20	30.70
26	279.60	206.30	158.50	125.60	102.00	84.40	71.00	60.60	52.30	45.60	40.10	35.60	31.70	28.50
24	258.10	190.50	146.30	115.90	94.10	77.90	65.60	55.90	48.30	42.10	37.00	32.80	29.30	26.30
22	236.60	174.60	134.10	106.30	86.30	71.40	60.10	51.30	44.30	38.60	34.00	30.10	26.90	24.10
20	215.10	158.70	122.00	96.60	78.40	64.90	54.60	46.60	40.20	35.10	30.90	27.40	24.40	21.90
18	193.50	142.90	109.80	87.00	70.60	58.40	49.20	42.00	36.20	31.60	27.80	24.60	22.00	19.70
16	172.00	127.00	97.60	77.30	62.70	51.90	43.70	37.30	32.20	28.10	24.70	21.90	19.50	17.50
14	150.50	111.10	85.40	67.60	54.90	45.50	38.30	32.60	28.20	24.60	21.60	19.20	17.10	15.40

Tree Planter's Notes, Vol. 34, No. 2 (1983)

Germinative Pretreatments and Seedcoat Impermeability for the Kentucky Coffeetree

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A 150-minute acid scarification of Kentucky coffeetree seeds provided earlier and significantly greater germination than other treatments. Similar total germination resulted from water-soaked and unsoaked, acid-treated seeds. Unscarified seeds did not imbibe water.

Kentucky coffeetree *(Gymnocladus dioicus* (L.) K. Koch), is a medium-to-large, dioecious species occurring throughout much of the central hardwood region. It produces seeds with a hard, water-impermeable seedcoat, which prevents or delays germination and probably accounts for the species' infrequent occurrence throughout its extensive range (*2*).

The current pregermination procedure is based on Weisehuegel's (*4*) only account of germinative energy and germinative capacity for water-soaked, acid-treated seeds. This pregermination treatment includes a 24-hour water soak followed by an approximately 2-hour soak in concentrated sulfuric acid (*2*). If the seedcoat is water impermeable, the water presoak appears unnecessary and inconsistent with seedcoat characteristics.

This paper is a report of a study to evaluate alternative pregerminative treatments and their effect on germination and seedling development.

Methods

Seeds used in this study were collected in 1978, 1979, and 1980 near Lexington, Ky. Seedlots were washed and mixed, and 50 seeds were selected to receive each of the following six pretreatments: a control, a 24-hour water soak only, a 24-hour water soak plus a 120-minute acid scarification, a 24-hour water soak plus a 150-minute acid scarification, a 120-minute acid scarification only, and a 150-minute acid scarification only. Concentrated sulfuric acid was used to scarify seeds. All water soaks were at room temperature. The study was replicated three times.

Number 8 styroblocks were filled with a 1:1 peat moss and vermiculite mixture containing 2 teaspoons of Osmocote 14-14-14 fertilizer per gallon of medium. Twenty seeds per square foot or one seed in alternate cavities were planted approximately 2.54 centimeters deep and were watered three times weekly. Germination was tallied when any part of the plumule was visible. Germination data were collected over 30 days, adjusted by an arcsine proportion transformation and statistically examined by a chi-square test (*3*).

Seedlings were grown in a greenhouse with photoperiods of 16 hours and temperatures ranging from 20° C at night to 30° C by day. The top of the medium was sprayed lightly each week with a complete fertilizer and immediately followed with ample water to move the fertilizer throughout the root zone. The complete fertilizer contained 50 parts per million N, K, Mg, S, and Ca; 100 parts per million Cl and Na; 150 parts per million P; 10 parts per million chelated Fe; and less than 1 part per million Mn, B, Zn, Cu, and Mo. Total height in centimeters and stem diameter 2.54 centimeters above the root collar in millimeters were measured 3 months after planting. Analyses of variance for height and diameter were adjusted for germination. Treatment means were tested with Duncan's multiple range test (*3*). Data were analyzed according to the statistical analysis system (*1*).

Results and Discussion

A desirable pretreatment provides consistent and rapid germination; thus, treatments were evaluated for efficacy on germinative energy and capacity (table 1). All acid treatments exhibited maximum daily germination by 8 days after planting and total germination after 19 days. Seeds receiving 150-minute acid scarification showed maximum daily germination 1 day before seeds treated for 120 minutes in acid. A 120-minute acid treatment

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[1] The author wishes to acknowledge Dr. S. Carpenter of Oklahoma State University and N. Smith of the University of Kentucky, whose efforts made this project possible.

Table 1.—*Number of germinating seeds per day, with 150seeds planted per treatment*

Days after planting	Acid only		24-hour water soak plus acid	
	120 min.	150 min.	120 min.	150 min.
3	0	0	0	0
4	1	1	2	3
5	8	11	9	18
6	19	23	19	25
7	26	35	26	33
8	27	21	33	27
9	18	14	20	17
10	16	13	10	7
11	12	10	7	4
12	5	4	3	3
13	3	2	3	3
14	2	1	0	2
15	1	0	0	1
16	0	2	3	0
17	2	1	0	1
18	0	0	2	0
19	0	0	0	0
Total	140	139	137	144

yielded 54-percent germination after 8 days for unsoaked seeds, while 59 percent of presoaked seeds germinated during the same period. Seven days after planting, seeds receiving the 150-minute acid treatment had 47-percent germination for unsoaked seeds and 53-percent germination for presoaked seeds. A chi-square test of the proportion of germinated seeds after day 7 for 120-minute and 150-minute acid treatments was significant (α = 0.05). There was no difference after day 7 in germination of unsoaked and water-soaked seeds. A chi-square test for the proportion of germinated seeds after day 7 for 120-minute and 150-minute acid treatments was also significant for water-soaked seeds. Thus, early seed germination can be significantly increased by using a 150-minute acid treatment of seeds, and water presoaking appears unnecessary. The control and water-soaked only seedlots yielded 1-percent and 3-percent total germination. Total germination was complete after 19 days and was similar for all acid-treated seeds. Seedlings from acid-treated seeds appeared normal.

Analyses of variance were conducted on the percentage of total germination and seedling height and diameter. Significant differences were observed in treatment effects, and Duncan's multiple range tests were conducted on means (table 2). Significant differences occurred only among acid-treated and untreated seeds. Thus, there were no differences in the percentage of total germination and seedling development after 3 months for acid-treated seeds.

A second study examined seedcoat impermeability to water. Twenty-five hand-scarified seeds were weighed before and after a 24-hour water soak. Twenty-five unscarified seeds were weighed before and after soaking for 24, 36, and 48 hours. Unscarified, water-soaked seeds had an average weight of 1.95 grams, showed a nonsignificant increase in mean weight of 0.04 grams after 24 hours, and failed to germinate. Weight changes after 24 hours were not detectable. Hand-scarified seeds weighed, on the average, 1.96 grams and exhibited a highly significant 97-percent increase in mean weight from soaking. A112 5 seeds germinated. These data suggested that the seedcoat is water impermeable.

Results from these two studies indicated that 150-minute scarification of seeds with concentrated sulfuric acid can produce earlier and significantly greater germination of Kentucky coffeetrees than other treatments. All acid treatments produced normal seedlings. Water presoaking of seeds before acid treatment is unnecessary since seedcoats are water impermeable.

Table 2.—*Duncan's multiple range tests for percentage of germination, height, and diameter (Means are adjusted for germination.)*

Treatment	Germination	Height	Diameter
	%	*Cm*	*Mm*
Control	1b[1]	0.06b	0.02b
Water only	3b	.26b	.08b
120 minutes in acid	93a	7.53a	2.40a
150 minutes in acid	92a	7.84a	2.51a
Water soak plus 120 minutes in acid	91a	7.87a	2.55a
Water soak plus 150 minutes in acid	96a	7.92a	2.58a

[1] The same letter within a column is not significantly different at a = 0.05.

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Maturity and Viability of Boxelder Maple Seeds

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The viability of boxelder maple seed gradually increased during each of four weekly harvests to a maximum of 75 percent. During this period, the moisture content of the seeds fell from 65 to 50 percent. As moisture content continued to fall below 50 percent, seed viability stabilized and then declined.

Boxelder maple *(Acer Negundo* L.) is used for shelterbelt planting in the Plains region, but information on seed maturity and viability for nursery operations is limited. The seeds have been reported to ripen in the fall (*2, 3*), and harvesting on September 5 (*4*) or at 57-percent moisture content (*1*) is recommended.

Methods

Seeds were harvested in 1970 from two trees at 10 weekly intervals from August 3 to November 2. The seeds were spread to dry in the greenhouse for 2 days. All seeds that appeared abnormal were then discarded and the balance stored in polyethylene bags at 35° F (2° C).

Moisture content, as a percentage of the fresh weight of the seeds, was determined at the time of each harvest. This was done by ovendrying three samples of 10 seeds at 212° F (100° C) for 24 hours. On December 30, 350 seeds from each tree and harvest were surface-sterilized. These seeds were then stratified in moist sand at 41° F (5° C) for 90 days.

Viability of the stratified seeds was evaluated by the germination of greenhouse sowings in flats containing a sterilized 2:1 soil-to-sand medium. Ten rows of 25 seeds for each date of harvest and tree were sown in each flat and replicated six times. Sowings were watered as required. Germination was recorded twice weekly for 30 days. Percentage data were transformed for analyses of variance to determine the significance of mean differences, but are reported as percentages.

Results and Discussion

Mean moisture content of the seeds gradually and significantly decreased for the first six successive harvest dates (table 1). The moisture content increased significantly on October 13 and decreased on October 17, but then increased for the last two harvests. Moisture content of seeds for both trees had the same trends. Cram and Worden (*1*) reported similar decreases for the moisture content of boxelder maple seeds in 1956, from 67 percent on August 26 to a low of 11 percent on October 3.

Rainfall recorded during harvest intervals appeared to modify the moisture content of maple seeds. However, this occurred for some harvest dates, but not for others. Little, if any, rainfall appeared to be absorbed by maple seeds with more than 50-percent moisture, whereas significant amounts of rain were absorbed by the more mature seeds with 11- to 23-percent moisture.

Table 1.—*Moisture content and germination capacity of boxelder maple seeds for 10 consecutive weekly harvests (means for two trees)*

Dates of harvest		Moisture[1] content	Germination[2] capacity
		- - - - - - - - %	- - - - - - - -
August	31	65.1a[3]	44.7d
September	8	60.7b	55.4bc
	14	53.5c	62.7ab
	22	49.1d	74.0a
	28	21.1f	55.7bc
October	5	11.4h	56.0bc
	13	16.0g	56.4bc
	19	13.0h	33.4e
	26	23.3f	18.0f
November	2	26.8e	26.8e

[1] Moisture content as a percentage of wet weight for three samples of 10 seeds after ovendrying for 24 hours at 212 °F.

[2] Germination capacity as a percentage for six replications of 25 seeds sown after stratification for 90 days at 41 ° F.

[3] Means within a column followed by a common letter are not significantly different at the 5-percent level.

Germination capacity of the seeds gradually increased for the first four harvest dates to a maximum of 74 percent on September 22 (table 1). It then decreased to 56 percent for the next three harvests (to October 13). Germination for the last three harvests was significantly inferior. Germination of seeds for the two individual trees followed similar trends, but at different levels. Although maximum germination was recorded for the September 22 harvest of both trees, the levels were 65 percent for one tree and 83 percent for the other. The average germination of seeds for all 10 harvests of one tree was 37 percent, but 60 percent for the other. Thus, seed viability of the two trees differed greatly.

Viability of maple seeds apparently was at a maximum when the average seed moisture decreased to 49 percent (table 1). Viability then appeared to fall to 56 percent and remained constant for three subsequent harvests. During this period, the moisture content decreased to 11 percent and then increased to 16 percent. Later harvests showed lower seed viabilities.

Conclusion

Boxelder maple seeds should be harvested when the moisture content is 50 percent or less. Large-scale harvesting can be continued for several weeks, but should be terminated when the seed moisture rises above 16 percent after late fall rains.

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Fungus-Damaged Seeds Can Be Removed From Slash Pine Seedlots

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The specific gravity table was useful in removing fungus-damaged seeds from slash pine (Pinus elliottii) seedlots. This separation of fungus-damaged seeds improved germination in most, but not all, lots.

A recent report (*1*) indicates that internal seed fungi are commonly found in slash pine seeds from seed orchards. Often, these are pathogenic fungi, which are known to cause losses of flowers, cones, and seeds in seed orchards (*3*). Damping-off in the nursery is caused by some of these fungi, but it is not yet proven that this problem can be brought on by using infected seeds (*2*). However, reducing the number of infected seeds in a seedlot is a logical precaution.

Unsound seeds with internal fungi, like those shown in figure 1, are easily identified in a radiograph. Some sound seeds also contain internal fungi. However, current procedures permit removal only of the unsound seeds. Separations are possible only when there is a weight difference between sound and unsound seeds.

Separation Procedures

Advance preparations. Unsound seed with internal fungi are removed as a final step in seed processing. Before this step, all the trash and most empty seeds need to be removed. The seeds should also be sized with round-hole screens. Sizing is necessary because larger, partly deteriorated seeds might well have the same weight as smaller, sound seeds (fig. 2). Wing stubs must also be completely removed because they can adversely influence the physical properties of the seeds during the subsequent removal of seeds with internal fungi.

Steps to remove fungus-damaged seeds. The first step is to X-ray the seedlot to allow estimation of the percentage of seeds to be removed. This percentage, on a volume basis, should equal the percentage of seeds in the radiograph that look like the seeds in figure 1.

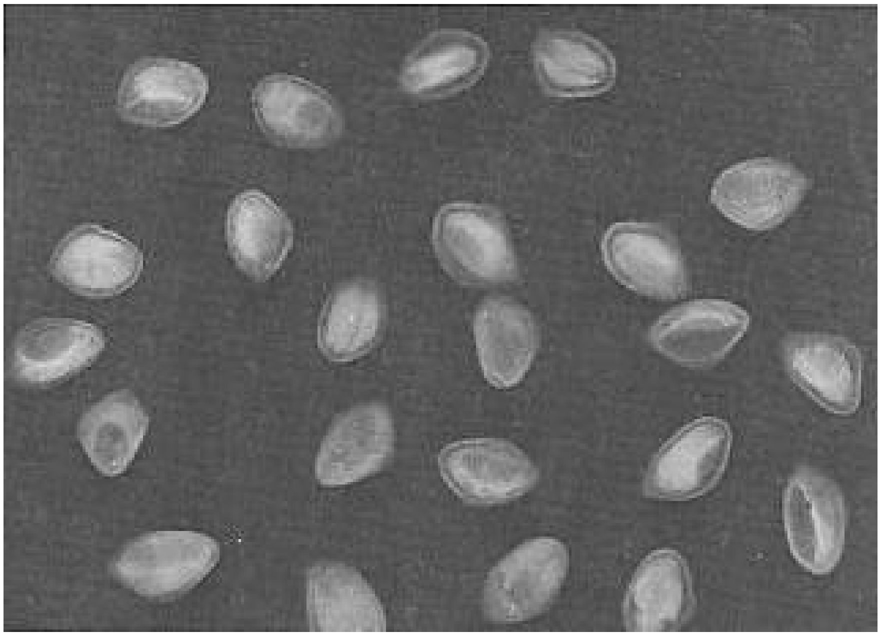

Figure 1.—*X-ray of fungus-damaged seeds.*

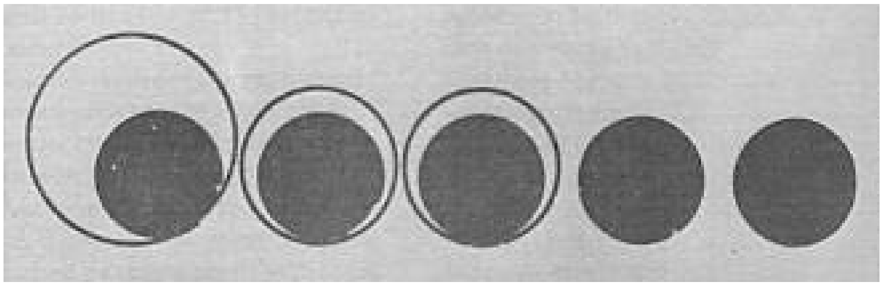

Figure 2.—*Seeds with different outside diameters can have the same weight if the larger ones are only partially filled.*

A gravity table separation should then be used to remove the fungus-damaged fraction of the seed. Detailed descriptions of the principles of gravity table use are available from equipment vendors or the author. Basically, a blast of cold air and a vibrating wire or cloth table causes seeds to separate according to their relative weights or specific gravity. As a result, heavy seeds move to the top of the table and lighter seeds to the bottom. Careful adjustment is necessary for successful seed separation. For the purpose under discussion, good and bad seeds are separated by adjustable cut off chutes as they leave the table. Radiographs are taken again to verify that the gravity table is properly adjusted. If not, the procedure is repeated and a correction is made.

Specific Examples

The National Tree Seed Laboratory has assisted two agencies in removing fungus-damaged seeds from slash pine seedlots. The seedlots are, therefore, referred to as group I and group II.

Group I. Laboratory germination improved an average of 8 percent for 37 lots, decreased an average of 5 percent in 14 lots, and remained the same for 4 lots (table 1). The largest individual lot improvement was 19 percent. The original germination tests were conducted in October 1979. The first gravity table cleaning was conducted in July 1980. Twenty lots were not satisfactorily improved in the first cleaning and were cleaned again in January 1981.

Group II. Group II was composed of two low-quality lots, with germination percentages of 50 and 60 percent. The gravity table separation procedure failed to make an obvious improvement in these lots. However, the fraction with large seeds from one lot was examined more closely. This fraction was given two treatments on the gravity table. The result was a substantial difference in viability between the best and poorest fractions (table 2). Although the general quality of the seed lot was low, the highest quality seeds could still be separated from the poorest seeds.

Discussion

Fungus-damaged seeds can be removed from many slash pine seedlots by use of a specific gravity table. However, each lot must be treated as a unique problem. Careful adjustment of machine settings, guided by X-ray test results, is required. Some lots will be in such poor condition that a good final product will be impossible.

The decrease in germination of some group I lots after cleaning is paradoxical. This decrease probably was the result of continued seed deterioration between cleanings.

Other types of precision seed separators have not been tested on this problem. These include aspirators and electrostatic

Table 1.—*Group I results from specific gravity table separations*

		Average germination percentage		
Lot types[1]	No. of lots	Before upgrading	After upgrading	Increase/ decrease
I	37	73	81	8
II	14	77	7	-5
III	4	81	81	0

[1] Type I lots increased in germination after attempting upgrading. Type II lots decreased in germination after attempting upgrading. Type III lots showed no change in germination after attempting upgrading.

Table 2.—*Group II results from specific gravity table separations*

Lot fraction[1]	How obtained	Germination
1	Top of table, 2d run	61
2	Middle of table, 2d run	61
3	Bottom of table, 2d run	43
4	Bottom of table, 1st run	48

[1] "Fraction" denotes that portion of the seedlot leaving the separator from the top, middle, or bottom part of the table.