SOUTHERN FOREST EXPERIMENT STATION

1974

U.S. FOREST SERVICE RESEARCH NOTE

SO-176

Forest Service, U. S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

PERFORMANCE OF PINE AND YELLOW-POPLAR PLANTED ON LOW-QUALITY SITES IN CENTRAL TENNESSEE

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SOUTHERN FOREST EXPERIMENT STATION

Ten years after planting on low-quality Cumberland Plateau and Highland Rim sites in Tennessee, loblolly pine averaged 26.2 feet tall and 4.4 inches in diameter, Virginia pine 22.2 feet and 3.9 inches, and shortleaf pine 19.0 feet and 3.4 inches. White pine grew slowly at first but improved considerably in the second 5 years. Yellow-poplar performed poorly where soil moisture was limiting and rooting depth restricted. Survival was 67 percent or greater for all species on all sites except where voles killed Virginia pine.

Additional keywords: *Pinus taeda, P. virginiana, P. echinata, P. strobus, Liriodendron tulipifera,* site quality.

Species selection and site evaluation are fundamental in the rehabilitation of depleted forests on Cumberland Plateau and Highland Rim in central Tennessee. Research comparing the performance of several pines and hardwoods on a range of upland sites and soils was started in 1959 by the Sewanee Silviculture Laboratory. This note reports the 10-year performance of loblolly (*Pinus taeda* L.), shortleaf (*P. echinata* Mill.), Virginia (*P. virginiana* Mill.), and white (*P. strobus* L.) pines and yellow-poplar (*Liriodendron tulipifera* L.) planted on sites with potential soil limitations.

METHODS

Plantations were established on four upland sites to study survival, growth, and yields over a 30-year period. Two sites are in the midportion of the Cumberland Plateau in south-central Tennessee, one is in the eastern section of the Highland Rim known locally as the "Barrens", and one is in the maturely dissected Highland Rim west of the Nashville Basin. Because of repeated partial cutting and other abuses, the stands—predominately oak-hickory of sapling and pole size—were too degraded to accurately reflect site potential.

Prior to planting, merchantable timber was harvested. Unmerchantable trees were treated by frilling and applying 2,4,5-T in diesel oil or injecting with undiluted 2,4-D.[2] The dense understories of hardwood sprouts and tolerant shrubs necessitated re-treatment the following year.

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[2] This publication reports research involving herbicides. It does not contain recommendations for their use nor does it imply that the uses discussed here have been registered. All uses of herbicides must be registered by appropriate State or Federal agencies before they can be recommended.

Five plots—one for each species—in each of three randomized blocks comprise the experimental design at all locations. Individual plots are one-fourth acre and originally contained 221 seedlings, bar-planted at a spacing of 6 by 8 feet. All seedlings planted were bare-rooted, 1-0 stock, except that white pine was 2-0. The plantations were established between 1959 and 1963. Planting was between mid-February and April of each year. Dead and missing seedlings were replaced after the first growing season.

Differences in average height and diameter between species within each plantation were compared by analysis of variance and Duncan's new multiple-range test. Tests of significance were made at the 5-percent level. No statistical comparisons of species' performance were made between plantations.

SITE DESCRIPTIONS

The sites for Plantations 1 and 2 (designated in table 1 as Plateau flats) are gently undulating to nearly level—typical of the topography on top of the Cumberland Plateau in south-central Tennessee. Slopes are generally 2 to 5 percent with no strong relationship between aspect and site quality. Soils are primarily of the Hartsells, Linker, and Jefferson series with small areas of local alluvium in the depressions and inclusions of the shallow Ramsey on the southerly aspects. Soil depths range from 30 inches to over 6 feet except for Ramsey, which is 20 inches or less to bedrock. These sandstone-derived soils are medium-textured, well drained, acid, and low in nitrogen, phosphorus, and calcium by agricultural standards. Moisture for tree growth is usually adequate. At the time of establishment, the condition of the oak-hickory stands was very poor due to frequent cutting, almost annual burning, and unrestricted grazing.

Plantation 3 is on a narrow, rounded ridge representative of the topography above and adjacent to the Cumberland Plateau escarpment. The plantings extended downward onto upper slopes with northerly and southerly aspects and gradients ranging from 4 to 13 percent. Soils are mainly of the Hartsells series, with total depths to sandstone bedrock ranging from 20 to 46 inches but generally less than 3 feet. Ramsey soils are also common. In addition to degradation from past abuses, ridge sites are inherently shallow, droughty, and infertile.

The site for Plantations 4 and 5 typifies the gently undulating to nearly level "Barrens" area of the eastern Highland Rim. The major question is whether low productivity is from aboriginal fire and post-settlement abuse or severe soil and site limitations. Dissection is light except near permanent streams, and surface drainage is not well developed. Common soils in the area are of the Mountview-Dickson-Sango-Guthrie series; a

Table 1.—*Performance of loblolly pine (LP), Virginia pine (VP), shortleaf pine (SP), white pine (WP), and yellow-poplar (YP) at plantation age 10 years*

Site designation, plantation number, and location	Total height					Diameter				
	LP	VP	SP	WP	YP	LP	VP	SP	WP	YP
	Feet					*Inches*				
Plateau-flat 1-Sewanee, Tn.	27.8a[1]	24.5ab	23.3ab	20.5bc	16.2c	4.4a	3.8ab	3.6b	3.3b	1.7c
Plateau-flat 2-Sewanee, Tn.	23.7a	23.1a	17.3ab	13.0b	16.6ab	3.9a	3.9a	3.0b	2.1c	1.9c
Plateau-ridge 3-Sewanee, Tn.	21.6ab	22.0a	16.0bc	10.1d	13.6cd	3.6a	3.6a	2.7b	1.5c	1.4c
Highland Rim-flat 4-Tullahoma, Tn.	28.4a	16.5b	18.6b	14.0b	8.5c	4.5a	3.8a	3.6a	2.5b	1.0c
Highland Rim-flat 5-Tullahoma, Tn.	27.3a	24.0b	18.3cd	17.5d	19.4c	4.5a	4.2b	3.2c	2.9d	2.2e
Highland Rim-ridge 6-Centerville, Tn.	28.2a	23.1b	20.4bc	12.8d	19.2c	5.2a	4.0b	4.2b	2.2c	2.0c
Average all sites	26.2	22.2	19.0	14.6	15.6	4.4	3.9	3.4	2.4	1.7

[1] In each row, all means not identified by a common letter are significantly different at the 5-percent level.

catena formed in a well-weathered silty mantle underlain by a residuum of cherty limestone or old alluvium. Principally the soil is Dickson with depths to the fragipan ranging from an average of 14 to 25 inches. Except for Mountview, these soils have well developed fragipans and slow internal drainage; all are of low inherent fertility. Site suitability for hardwoods appears to vary with depth to the fragipan ranging from poor—less than 20 inches of soil—to good on the wetter, deeper soils at the lower drainage positions. Low levels of nitrogen and phosphorus may also limit the growth of the more demanding species, especially hardwoods.

Plantation 6 is in the western Highland Rim on a narrow ridge site bounded by V-shape hollows. Topographic position and aspect influence soil features and site quality. Soils are of the Bodine series, formed mostly from very cherty limestone residuum. They are strongly acid, low in fertility, and well to excessively drained. These soils (35 to 90 percent chert by volume) are sensitive to dry periods.

SURVIVAL

Tenth-year survival averaged 76 percent or better for loblolly pine, shortleaf pine, and yellow-poplar in all plantations. White pine survival ranged from 67 to 95 percent, falling below 85 in only two plantations. Except in Plantation 4, Virginia pine survival equalled or exceeded 87 percent.

The 67 percent survival of white pine in Plantation 4 provides more than 600 trees per acre on this degraded Highland Rim site. Survival was probably affected more by the dense herbaceous and hardwood sprout competition at the time of planting than by soil limitations.

After the fifth growing season survival of Virginia pine in Plantation 4 averaged 93 percent. Feeding by meadow voles (*Microtus pennsylvanicus*) between the eighth and 10th seasons reduced survival to 31 percent. The high vole population resulted from a dense ground cover which provided a favorable habitat. Virginia pines in Plantation 5 escaped vole damage because this cover did not occur. Where vole populations are high, it is advisable to plant a less preferred species such as loblolly pine or to reduce the ground cover by site preparation.

GROWTH

Ten years after planting, loblolly and Virginia pines were generally greater in height and larger in diameter than shortleaf and white pines and yellow-poplar on all sites (table 1). Virginia pine in Plantation 4 was an exception because voles eliminated the vigorous trees. At 5 years this stand averaged 9.3 feet in height.

Loblolly pine grew best on the Highland Rim sites, where it was significantly taller than all other species. Within each plantation, loblolly heights varied only slightly and on a per-acre basis at least 640 of the surviving trees equalled or exceeded a minimum desirable total height of 20 feet at 10 years (table 2). In average diam-

Table 2.—*Trees meeting or exceeding 20 feet in total height at plantation age 10 years*

Site designation, plantation number, and location	Loblolly pine	Virginia pine	Shortleaf pine	White pine	Yellow-poplar
	Trees per acre				
Plateau-flat 1-Sewanee, Tn.	702	774	701	496	205
Plateau-flat 2-Sewanee, Tn.	648	769	207	69	337
Plateau-ridge 3-Sewanee, Tn.	588	735	146	0	173
Highland Rim-flat 4-Tullahoma, Tn.	812	60	259	52	18
Highland Rim-flat 5-Tullahoma, Tn.	640	726	277	251	389
Highland Rim-ridge 6-Centerville, Tn.	752	657	475	43	346
Average all sites	690	[1]732	344	152	245

[1] Excludes Plantation 4.

eter, loblolly was significantly larger than Virginia pine in two of the three plantations.

On the Cumberland Plateau, differences were less pronounced. Loblolly outranked Virginia pine in average height and diameter in one plantation, and then only by a small margin. Although differences in stand heights were not statistically significant, there are some indications that Virginia pine may be the preferable species for Plateau ridgetops or soils with a past history of severe disturbance. For example, in Plantation 3, 735 Virginia pines per acre—83 percent of the surviving trees—attained heights of 20 feet or greater, by comparison with 588 trees per acre or 69 percent for loblolly pine. By the same height standard, Virginia pine outperformed loblolly in Plantation 2 even though soil depth was considered adequate. On this Plateau flat, Virginia pine was apparently more tolerant of site limitations.

If 2 feet per year is acceptable growth for young pine plantations in central Tennessee, loblolly and Virginia pines performed well on all four sites. Their early superiority has been observed in other experimental and industrial plantations in the area and has probably made these pines the most widely planted species on Tennessee's Cumberland Plateau and Highland Rim. They are also favored on ridges and upper slopes on the Cumberland Plateau in northern Alabama (Smalley and Pierce 1972).

Shortleaf pine ranked third in growth, with average stand heights ranging from 16.0 feet at 10 years on the somewhat droughty Plateau ridge to 23.3 feet on the Plateau flat (Plantation 1). Statistically, shortleaf was significantly shorter than Virginia pine in only two plantations. Although it grew more slowly than loblolly and Virginia pines, its performance was good in terms of the number of trees reaching 20 feet or greater in height for the 10-year period (table 2). For example, on the Plateau ridge 146 surviving trees per acre attained desirable heights. This is a sufficient number for selection of final crop trees. In average diameter, shortleaf was significantly smaller than loblolly pine on all Plateau sites and one Highland Rim site.

Except on the Plateau ridge, differences in diameters and heights between shortleaf and Virginia pines can be traced to insufficient control of competition, which slowed the initial growth of shortleaf. During the last 5 years shortleaf increased in growth rate, averaging 11.0 feet for the period as compared to 11.5 feet for Virginia pine. The effects of competition on shortleaf seedling growth and the need for immediate and complete release have been demonstrated for Cumberland Plateau sites (Russell 1969).

Tenth-year average heights and diameters indicate that white pine was the poorest performer of the pines on all sites. With 2.0 feet per year for the first 10 years as an index of acceptable height growth, Plantation 1 can be rated as satisfactory, Plantation 5 as marginal, and the others as poor. This rating may be premature since white pine, like shortleaf pine, did not commence rapid height growth until after the third growing season. For the second 5-year period, average annual growth ranged from 1.4 to 2.9 feet, falling below 1.8 feet on only one site. On this basis, white pine compares favorably with shortleaf and Virginia pines on all sites except the Plateau ridge. Continuation of this growth trend for the next 5 years may show that white pine can be grown successfully on most low quality upland sites.

The growth and appearance of yellow-poplar indicate that it is the most sensitive of the species tested to soil-site limitations. Poorest growth was in Plantation 4, established on a Highland Rim flat where a dense fragipan occurs within 20 inches of the surface. On this site only 18 of the surviving trees per acre had growth rates averaging at least 2 feet per year (table 2). In contrast, the best 10-year average stand height, 19.4 feet, occurred on the other Highland Rim flat. During the 5th to 10th year, however, growth decreased on this site from a periodic average of 2.5 feet to 1.4 feet per year. This suggests that the fragipan, although at a greater depth than in Plantation 4, is beginning to limit growth.

After 5 years, yellow-poplar height growth on the Highland Rim site was poor, averaging less than 1.5 feet per year. During the second 5-year period, however, it increased to 2.6 feet per year. This growth acceleration suggests site suitability for long-rotation tree crops.

Yellow-poplar height growth in the Cumberland Plateau plantings ranged from 1.3 feet per year on the narrow ridge site to 1.6 feet on both of the flats. Poor performance on the ridge is attributed to limited soil moisture during much of the growing season. Not only do the sandy loam soils have low moisture holding capacity, but rainfall is rapidly removed from this convex surface by infiltration, runoff, and evapotranspiration. The presence of many multiple stems, as well as slow initial growth and poor form, indicates the site is marginal for quality saw log production.

Growth on the Plateau flats was marginal. Twenty-seven percent of the surviving trees in Plantation 1 and 39 percent in Plantation 2 attained the rate of 2 feet per year. Heights varied widely within these plantations. Groups of the tallest trees occurred in small depressions and on areas where past soil disturbance was minimal. With normal summer rainfall, the sites provide adequate moisture for yellow-poplar growth. However, there are indications that multiple nutrient deficiencies may be limiting to yellow-poplar on these sandstone-derived soils (Loftus 1971).

CONCLUSIONS

These plantations demonstrate that loblolly, Virginia, shortleaf, and white pines and yellow-poplar can survive and grow on Cumberland Plateau and Highland Rim sites with potential soil limitations. Barring unusual weather conditions and serious injury by insects, diseases, or mammals, good survival can be expected with standard planting stock and techniques.

Survival alone is not an adequate measure of species adaptability, however. For example, the capacity of yellow-poplar to sprout increased its relative survival on all sites, but average stand heights at 10 years indicate that these sites are marginal to poor for the species. The performance of yellow-poplar in this comparison serves to reinforce previous research; that is, acceptable to excellent growth can be expected only when sites are selected with care and competition is controlled (Russell *et al.* 1970).

Loblolly and Virginia pines are the preferred species to plant on narrow ridgetops where soils tend to be droughty, on sites that have been degraded through mismanagement, or on soils shallow to bedrock or a fragipan. On the drier ridgetops of the Cumberland Plateau, Virginia pine can be substituted for loblolly with little or no loss in growth. Shortleaf pine grows slower than loblolly and Virginia pines, but is a desirable species for planting and performs reasonably well when competition is controlled. Although white pine ranked below the other pines in total height, its annual growth rate increases after an initial establishment period indicating adaptability to Cumberland Plateau and Highland Rim conditions.

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Forest Service, U. S. Dept. of Agriculture

1974

U.S. FOREST SERVICE RESEARCH NOTE

SO-177

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

1973 MISSISSIPPI RIVER FLOOD'S IMPACT ON NATURAL HARDWOOD FORESTS AND PLANTATIONS

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SOUTHERN FOREST EXPERIMENT STATION

Through October, the 1973 Mississippi River flood had not caused extensive damage to natural hardwood forests or plantations that were 1 year or older and had been flooded only during the first 2 months of the growing season. New plantings of cottonwood were virtually destroyed, however, and 1-year-old sweetgum, flooded about 3 months, was killed. All yellow-poplar observed was killed. Siltation up to 5 feet deep has not caused appreciable damage, but trapped water has caused some mortality.

Additional keywords: Backwater, planting, siltation, water temperature.

A major flood occurred on the Mississippi River during the spring and early summer of 1973. Along the Mississippi and a number of smaller rivers, about 8 million acres were flooded—nearly 3 million acres were in the State of Mississippi. This report summarizes the impact, after one growing season, on planted and natural stands within the Mississippi River floodplain from about 30 miles north of Greenville to Port Gibson, Mississippi.

Research plantings of the Southern Hardwoods Laboratory were affected by Mississippi River floodwater and by backwater from the Yazoo and Sunflower Rivers. Normally the Sunflower drains into the Yazoo, a tributary of the Mississippi River near Vicksburg. When the Mississippi reached flood stage, these rivers backed up and flooded land less than 101.5 feet in elevation.

Mississippi River floodwater conditions were monitored by Southern Forest Experiment Station researchers at Stoneville. Observations were made on research and industrial plantings at Huntington and Catfish Points and Archer Island near Greenville, and at Port Gibson. Backwater conditions created by the Yazoo and Sunflower Rivers were monitored at Mahannah Plantation near Vicksburg and the Delta National Forest near Rolling Fork. Data were received on commercial plantings at Fitler and Paw Paw Island, between Greenville and Vicksburg.

Water temperatures were measured with an Atkins thermistor thermometer and oxygen contents determined with a Sargent oxygen analy-

[1] The authors are stationed at the Southern Hardwoods Laboratory, which is maintained at Stoneville, Miss., by the Southern Forest Experiment Station, USDA Forest Service, in cooperation with the Mississippi Agricultural and Forestry Experiment Station and the Southern Hardwood Forest Research Group.

zer.[2] Water depths were also measured. The general appearance of all species in an area was recorded at each visit.

FLOOD STAGE REACHED

The Mississippi River reached floodstage (48 feet) at the Greenville Bridge on March 24, 1973. Probably the beginning of the flood was in mid-October 1972. At that time a 7- to 8-inch rain fell over most of Mississippi, causing widespread flooding in low-lying areas. For the next 7 months, more than 46 inches of rainfall was recorded at Stoneville. Average annual rainfall is about 50 inches.

The initial visit to Huntington Point was on March 29, at which time about 1 foot of water covered the research plots. Most of the trees, except sweet pecan and green ash, had begun to leaf out. Maximum water depths at Huntington and Catfish Points were 6 to 7 feet. Water receded about June 1. Five more trips were made to Huntington Point, three to Mahannah, two to Archer Island, and one each to Catfish Point, Port Gibson, and the Delta National Forest, during and after the flood.

Floodwater at Huntington Point reached a maximum 6.5 feet on May 15. Water temperatures reached a high of 69°F on May 25, but oxygen contents were adequate to supply tree requirements. Data on water depths, temperatures, and oxygen contents are given in table 1. Broadfoot has concluded that lower oxygen contents in shallow-water impoundments than reported here are adequate to sustain tree growth.[3] Water conditions at Catfish Point, Port Gibson, and Archer Island, were probably the same as at Huntington Point.

[2] Mention of trade names is for information only and does not constitute endorsement by the Forest Service.

Table 1.—*Water depths, temperatures, and oxygen contents of flood- and backwater*

Date (1973)	River stage: Greenville Bridge	River stage: Vicksburg	Water depth	Water temperature	Oxygen content
	Feet	*Feet*	*Feet*	*°F*	*P/m*
		HUNTINGTON POINT			
4/4	54.0		2.5	55	7.1
4/12	54.7		3.5	54	8.4
4/27	56.0		4.5	60	7.6
5/15	57.7		6.5	65	6.0
5/25	54.9		2.0	69	5.8
		MAHANNAH			
5/3		51.8	8.5	69	6.7
5/22		52.2	10.5	76	6.1
6/7		45.4	6.0	81	4.8

Backwater at Mahannah did not reach the research plots until April 9, because the area is protected by a private levee. After the backwater went over the levee, it rose to a depth of 6 feet within 3 days. Temperatures were higher and oxygen contents lower than at Huntington Point. Maximum depths at Mahannah were about 11 feet. Water left the area between June 20 and July 1. Conditions on the Delta National Forest were about the same as Mahannah except that depths were lower.

Cottonwood was observed at Huntington and Catfish Points, and at Mahannah; sycamore at Huntington, Catfish, Archer Island, and Port Gibson; yellow-poplar at Huntington, Catfish, and Delta National Forest; sweetgum at Huntington, Catfish, Archer Island, and Port Gibson; and green ash at Huntington and Archer Island. Additionally, sweet pecan and Shumard, water, cherrybark, and Nuttall oaks were checked at Huntington; Shumard oak, black and Persian walnut, and royal paulownia at Archer; Shumard and cherrybark at Catfish; swamp chestnut oak and loblolly pine at Delta National Forest; and black willow at Mahannah.

Soil type is mostly Commerce silt loam at all locations except Mahannah and Delta National Forest, where it is primarily Sharkey clay.

Cottonwood

The flood virtually destroyed cottonwood cuttings planted from November 1, 1972, to March 15, 1973, for studies and a nursery at Huntington Point. Commercial plantings north of there and north of Vicksburg also suffered. Many cuttings had begun to leaf out when the river reached floodstage. The first several weeks after the water receded, some sprouting occurred. For example, in one study at Huntington Point, 24 percent of 768 cuttings planted had leafed out by the last week of June, although half of these were in very poor condition. The nursery area at Huntington Point was maintained for the summer, but a later sample showed only 18 percent survival for four clones. In several instances

[3] Broadfoot, W. M. Shallow water impoundment increases soil moisture and growth of hardwoods. Soil Sci. Soc. Am. Proc. 31: 562-564. 1967.

natural seeding made up for the planting failure.

In March, a 12-acre cottonwood plantation had been established near Vicksburg with seedlings rather than cuttings. Almost immediately the planting was covered with water, and remained so until mid-June. By late summer, most of the trees had evidence of top dieback, but overall survival was about 50 percent.

A previous study found that seedlings survive better than cuttings where flooding occurs prior to the start of height growth.[4] In that report, planting was in January. The site was flooded from mid-March to late May, but tops of some seedlings stayed above high water. Survival was 90 percent for seedlings and 19 percent for cuttings. Also, a publication in 1941 reported that cottonwood seedlings survived better than cuttings on a low site in a wet year.[5]

The same may be said for black willow. Nearly all cuttings planted outside the private levee at Mahannah in March were dead when examined in mid-July. At planting, the soil was soggy since it had been under water just prior to planting. Before the end of the month, the area was covered again and water remained until the end of June.

In contrast, cottonwood that was 1 year or older at Huntington Point survived in good condition. The trees were never completely covered with water (fig. 1). Most had begun to leaf out before flooding, and that part above water formed dark green, fully developed leaves and appeared healthy.

[4] Maisenhelder, L. C., and McKnight, J. S. Cottonwood seedlings best for sites subject to flooding. USDA For. Serv. Tree Plant. Notes 19(3): 15-16. 1968.

[5] Bull, H., and Putnam, J. A. First-year survival and height growth of cottonwood plantations at Stoneville, Miss. USDA For. Serv. South. For. Exp. Stn. Occas. Pap. 98, 16 p. 1941.

Figure 1.—*Cottonwood at Huntington Point on May 15, when water depth was 6-1/2 feet, still had vigorous appearance.*

Backwaters reached a maximum depth of 11 feet on a 53-acre, 1-year-old cottonwood plantation at Mahannah on May 22. Some 75 to 80 percent of the trees were inundated (fig. 2). Average heights of the 10 tallest trees per plot ranged from 8.5 to 10.5 feet. Water defoliated the trees, but as it receded they leafed out again and most appeared to do well. Three of the four clones planted in this study averaged from 1 to 7 percentage points less in survival after flooding. However, one clone in a portion of the field next to a soybean planting, had high mortality. Whether floodwater was slow in leaving this area or whether other factors were involved is not known. As an example, the plot nearest the bean planting had 90 percent survival after 1 year, but only 28 percent in September of the second year. The other eight plots had from 3 to 30 percentage points loss.

Figure 2.—*Water depth at Mahannah was about 11 feet deep on May 22, and a majority of the trees were covered.*

A slightly different situation with cottonwood plantings occurred in nurseries where stems had been cut back. At Mahannah, on Commerce soil, the rootstocks were 2 and 3 years old. Survival was 70 percent where 10-inch stumps were left, but only 20 percent where stumps were even with the ground. Part of the mortality may have resulted from high temperatures, as the water receded to about 1 foot and remained for several days. Water left the nursery about 2 weeks earlier than in the plantation. At Catfish Point, also on Commerce soil, 2-year-old rootstocks had from two-thirds to three-fourths the previous year's survival. In both nurseries, stems had been cut just prior to flooding. Late dormant season cutting, i.e., in March, may or may not have influenced survival.

Fusarium cankers were observed in several cottonwood plantations starting their second year. A sample survey at Mahannah in August indicated from 6 to 16 percent infection in three clones, while the fourth clone varied from 6 to 60 percent. The latter was next to the plot with the heavy mortality mentioned previously. The flood was not entirely responsible, as many of the cankers indicated infestation during the previous year, probably aided by mechanical damage during cultivation. However, the flood undoubtedly reduced the ability of the trees to resist the canker. If the trees prove vigorous enough, they have a chance of overcoming the infection with rapid growth. That appeared to be the case at Fitler and on Paw Paw Island. The cottonwood trees developed good color and growth, and the cankers seemed to heal. These plantations were disked as soon as the sites were dry enough, and this treatment seemed beneficial.

Yellow-Poplar

In a planting at Huntington Point, wilting of leaves on 1-year-old yellow-poplar was first observed on April 27, about 1 month after flooding began. All trees were dead by May 15. Two other yellow-poplar plantings were killed by the flood. One at Catfish Point was 11 years old, averaged 6.8 inches d.b.h., and was 55 to 60 feet tall. Floodwaters were 6 to 7 feet deep. The other was on the Delta National Forest. These trees were 15 years old and averaged 7.9 inches d.b.h.; the dominants were 72 feet tall. Floodwaters were about 4 feet deep. Water stood on both plantings about 2 months, and trees had leafed out.

Sycamore

One-year-old sycamores at Huntington Point were never completely covered with water. At least half of the trees became infected with anthracnose during the flood and looked sickly by mid-May (fig. 3). But after the water receded, the trees recovered, and were growing vigorously by the end of the season. Planted sycamore (11 years old) at Catfish Point also survived in apparently good condition. Sycamore plantings in 1962 and 1963 on Archer Island were not damaged by the 1973 flood. Many of the trees stood in trapped water at least through August, but were healthy in September.

Figure 3.—*Water was receding at Huntington Point on May 25, but sycamore had sickly appearance.*

Sprouting of coppiced sycamore at Huntington Point did not appear to be reduced by the flood, but there was no unflooded area for comparison. Stems with 3-year root systems, after field planting, were cut in January 1973, and the stumps sprouted well after the water subsided.

Sycamore seedlings planted in January 1973 on Hooker's Ridge, north of Vicksburg, died.

Sweetgum

Sweetgum at Huntington Point had begun to leaf out for their second season. Trees were completely inundated from about April 4 to June 1, but were in good shape at the end of the growing season.

In contrast, 1-year-old planted sweetgum near Port Gibson did not survive the flood. The only apparent difference was that the Port Gibson sweetgum were inundated about a month longer, from mid-March to mid-June.

Sweetgum planted with sycamore on Archer Island in 1962 and 1963 also survived even though they were in trapped water during most of the growing season.

Green Ash

One-year-old green ash at Huntington Point had not leafed out when flooding started. Tops above water leafed out during the flood. The leaves were killed when the trees were covered, but leafed out again when the water receded. The trees grew vigorously during the rest of the year.

Green ash on Archer Island, planted in 1962 and 1963, also stood in trapped water through August. As with sycamore and sweetgum, it apparently did not suffer any appreciable damage.

Other Species

Shumard oak seedlings planted at Huntington Point in January 1973 had 90 percent mortality by the middle of June. Seedlings and cuttings of species observed in this study probably need at least a year's growth in the field to withstand flooding. For example, on Archer Island, 1960-1961 plantings of green ash, sycamore, Nuttall oak, cherrybark oak, willow oak, swamp chestnut oak, sweetgum, yellow-poplar, and royal paulownia died in a 1961 flood.

A 14-year-old Shumard oak planting on Archer Island was not damaged by the 1973 flood. Trees averaged 7.5 inches d.b.h. and dominants were about 55 feet tall. During its third growing season this planting had withstood the 1961 flood. The 1973 river stage was about 10 feet greater.

Additional plantings on Archer Island in 1962 and 1963 were made with black walnut, royal paulownia, and Persian walnut. The latter two species were dead at the end of June 1973. The black walnut looked good at that time, but by the end of September all trees that had been in trapped water were dead. Trees on higher ground were in very poor condition and did not look as if they would survive.

Sweet pecan, water oak, Nuttall oak, and cherrybark oak that had gone through one growing season survived although they were inundated for 2 months at Huntington Point. Eleven-year-old Shumard and cherrybark oak at Catfish Point, and 15-year-old swamp chestnut oak and loblolly pine on Delta National Forest, were undamaged by 2 months of flooding.

Nuttall oak acorns had been direct-seeded and green ash cuttings planted horizontally on Tennessee Bar, north of Vicksburg, during winters of 1971-72 and 1972-73. The 1971-72 Nuttall seedlings survived in good condition, and a count of the 1972-73 planting made in late August showed that 65 to 70 percent of the acorns had germinated after floodwaters receded; seedlings appeared healthy and were growing vigorously. Sprouting percentages were low for the 1971-72 green ash planting, but where the cuttings had sprouted they appeared to survive. Green ash cuttings planted in 1972-73 did not sprout after the flood. Floodwaters had been about 25 feet deep in the area.

OTHER EFFECTS

Siltation occurred in nearly all flooded areas. Depths ranged from a trace to 5 feet. Observations 2 to 3 months after the floodwaters receded indicated no apparent damage either to the planted trees or species found in natural riverfront forests. Trees appeared healthy and growing well in September in portions of a 2-year-old cottonwood plantation at Catfish Point with almost pure sand deposits up to 5-foot depths (fig. 4). The only loss was by the amount the main stem was covered.

Figure 4.—*Sand deposits had not affected these 2-year-old cottonwood trees by late September.*

Floodwaters caused heavy damage to deer fences around research plots at Huntington Point. Debris broke the wire away from the posts or pushed the fence over. On commercial cottonwood plantations, where "debris fences" had been built to exclude deer, some trees were broken when the water washed tree tops and branches into the plantations. Where the current received some channeling, water movement alone appeared to have been sufficient to bend, break, or wash over plantation-grown trees. Older plantations, in the 3- to 5- and even up to 10-year age classes, suffered some blowdown in localized areas from the waterlogged soils and gusty winds.

Trapped water in low areas and former stream channels has been a problem. In the cottonwood plantation at Catfish, several such areas have water up to 4 feet deep and trees were beginning to die by August (fig. 5). Natural sycamore, up to 20 feet tall and still standing in water at the

Figure 5.—*Trapped water throughout the growing season had caused some mortality by late September in this 2-year-old cottonwood plantation.*

end of September, did not appear adversely affected. Leaf scorch from anthracnose was present, but so was it on drier sites. In another location where water was 1 to 6 feet deep, small sweetgum (4 inches d.b.h.) and dogwood were dying. Older hackberry, ash, honeylocust, and others showed no apparent damage.

DAMAGE SUMMARIZED

Trees less than 1 year old died in the 1973 flood. However, trees that were 1 year or older survived where flooding occurred in the first 2 months of the growing season—with the exception of yellow-poplar.

Cottonwood plantings established in the winter of 1972-73 were virtually destroyed. Cottonwood seedlings fared better than cuttings. One-year-old sweetgum—flooded about 3 months—was killed. Yellow-poplar, from 1 year to 15 years, was killed.

Species such as sweetgum, sweet pecan, and Nuttall, water, and cherrybark oaks survived 60 to 65 days flooding even though they had gone through only 1 growing season in the field and were only 1 to 2 feet tall. Green ash, cottonwood, and sycamore were also in good condition.

Siltation up to 5 feet deep in plantations and natural stands has not so far caused any appreciable damage.

Trapped water around trees is harmful. Probably low oxygen content and high water temperatures cause the mortality.

SOUTHERN FOREST EXPERIMENT STATION

1974

U.S. FOREST SERVICE RESEARCH NOTE

SO-178

Forest Service, U. S. Dept. of Agriculture

10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA 70113

WEIGHT, MOISTURE, AND LIPID CHANGES DURING LIFE CYCLE OF THE SOUTHERN PINE BEETLE

Stanley J. Barras and John D. Hodges[1]

SOUTHERN FOREST EXPERIMENT STATION

Insect wet weight ranged from 0.054 mg in the egg stage to 3.04 mg for the parent female adults. Parent females and males in fresh inner bark were heavier than emergent brood adults; parent females were heavier than parent males. The greatest gain in weight, a tenfold increase between the egg stage and the subsequent inner-bark larval stage, coincided with active feeding in the fungal-phloem substrate. An additional fivefold increase was recorded between the inner- and outer-bark larvae.

Moisture content ranged from 81 and 85% for outer-bark larvae and pupae in the rhytidome to 191 and 197% for parent males and females in fresh inner bark.

Percentage of lipid varied from 23 and 24% in the emergent males and females to 78 in the eggs. Lipid weight ranged from 21 µg in the egg stage to 561 µg in the outer-bark larvae, reflecting fivefold increases between the egg and inner-bark larvae and between the inner- and outer-bark larvae. Parent females contained less lipid than males.

Additional keywords: *Dendroctonus frontalis, Pinus taeda.*

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Limited data are available on the lipid content of *Dendroctonus* bark beetles. Willis and Hodgson (1970) recorded total lipid and fatty acid content of emergent southern pine beetle adults from North Carolina and Louisiana. Atkins (1966, 1967, 1969) surveyed the fat content of laboratory-reared and wild adult Douglas-fir beetles (*D. pseudotsugae* Hopkins). He also sampled pre- and post-flight females, and Thompson and Bennett (1971) did the same with males while studying the oxidation of fat during flight.

In the study reported here, changes in weight, moisture, and gross lipid of the southern pine beetle (*Dendroctonus frontalis* Zimm.) were examined at six developmental stages. The study was one of a series on the nutritional relationships between the southern pine beetle, its associated mycangial fungi (Barras and Perry 1972), and loblolly pine (*Pinus taeda* L.) phloem.

METHODS AND MATERIALS

Analyses were made of parent adults (males and females separately), eggs, inner- and outer-bark larvae (IBL and OBL), pupae, and emergent brood (male and female). All six stages were taken from sections of a naturally infested loblolly pine tree which was cut in April, when the beetle is considered to be in its most vigorous condition. Collections were made daily as the insect progressed through each stage in the host tissue. Parent adults were collected from freshly initiated inner-bark galleries while the females were ovipositing. Eggs were obtained from phloem niches 1 to 2 days following oviposition.

IBL and OBL were grouped separately in recognition of physical and chemical differences in habitat. The inner bark here refers to the functional phloem between the vascular cambium and innermost living periderm, and the outer bark consists of various layers of nonconducting, obliterated phloem (Howard 1971). Although it is generally agreed that IBL include the penultimate instar, it is not certain how many instars occur. There is evidence that some populations have three larval instars (personal communication from R. C. Thatcher, Southern Forest Experiment Station) instead of the commonly reported four (Dixon and Osgood 1961).

OBL probably included some prepupae, as many of the larvae had constructed pupal chambers. When about one-half of the pupae in a bolt had been collected, the bolt was put in a rearing can to obtain emerging brood adults.

Each daily collection was placed in a separate tared vial for determination of wet weight (WW), frozen at —8°C, and freeze-dried overnight. The moisture content was then computed and the specimens were stored at —8°C until further analysis.

The freeze-dried specimens of each stage were combined and homogenized three times in cold spectrometric grade chloroform: methanol (2:1, V/V). A total lipid (TL) extract (minus proteolipids) of each stage was prepared by modified methods of Folch *et al.* (1957) and Lambremont *et al.* (1966). Duplicate 20μL subsamples of extracts were dried with N_2 in tared aluminum pans and weighed on a Cahn electrobalance.

RESULTS

Weight and moisture.—The parent females had significantly (P = 0.05) higher WW and FDW than the parent males (table 1). This greater weight was probably the result of the females feeding during gallery construction in fresh inner bark. Parent males expend energy during mating and clearing the gallery of frass, but they seem to feed little.

Table 1.—*Weight and moisture relationships of the southern pine beetle*

Stage	Insects collected	Weight per specimen		Moisture, FDW basis[1]
		WW	FDW	
	No.	*Milligrams*	*Milligrams*	*Percent*
Parent ♀	115	3.04 (2.99-3.32)	1.02 (0.93-1.11)	197a
Parent ♂	90	2.61 (2.32-2.84)	.89 (0.58-1.01)	193a
Egg	485	.054 (0.028-0.062)	0.027 (0.013-0.044)	100b
IBL	1,333	.59 (0.033-2.14)	.27 (0.01-1.00)	123b
OBL	236	2.85 (2.60-3.32)	1.57 (1.51-1.67)	81b
Pupae	464	2.78 (2.66-2.91)	1.50 (1.24-1.89)	85b
Emergent ♀	444	2.14 (2.03-2.23)	.93 (0.83-1.21)	129b
Emergent ♂	482	2.07 (1.88-2.33)	.93 (0.79-1.30)	124b

[1] Values followed by the same letter are not significantly different at the 0.05 level.

In IBL the WW and FDW ranged widely, reflecting growth while feeding on fungal-inner bark substrate. Thus the average IBL weight increased about tenfold over average egg weight, but the larger late larvae were up to 40 times the egg weight. Average weight of OBL was about five times that of IBL. There was no overlap between the two larval groups—an indication that most if not all OBL were in the same instar.

Pupae did not differ significantly from OBL in average WW or FDW, but female and male emergent adults were significantly lower than pupae in both measures. WW decreased 23 percent in females and 25 percent in males, while the decrease in FDW was 35 percent in both sexes. The decreases were probably the result of utilization of moisture and stored nutrients during eclosion and emergence through the outer bark. It is not known if emerging beetles obtain nourishment as they bore through the outer bark, but identifiable pieces of phloem and fungal material have been observed in young adults before they begin to emerge. In older emergents, only finely divided amorphous material has been noted (Barras, unpublished).

It might be expected that the weight would be less in post-flight parents than in emergents. In this study, however, post-flight beetles were collected after they had entered fresh phloem and begun to feed.

The percentage of moisture at each life stage seemed to be influenced by the moisture characteristics of the habitat (table 1). The percentages for parent female (197) and male (193) were significantly greater than for all other stages. This high moisture content corresponds with inner-bark moisture, which is often over 200 percent (Gaumer and Gara 1967). In unpublished studies, Barras recorded inner-bark moisture (DW basis) of 172-268 percent (average 214 percent) near parent beetle galleries. Other insect stages were associated with drier habitats. For instance, phloem in areas of IBL development had moisture contents of 83-173 percent (average 137 percent), but outer bark ranged from 27-45 percent (average 35 percent).

The amount of actual moisture changed little from pupae to emergent adults, but the significant decrease in FDW caused the computed moisture percentage to increase. Moisture contents (WW basis) of 56 percent for emergent females and 55 percent for males were similar to the 52-72 percent (average 61 percent) reported for newly emerged Douglas-fir beetle adults (Atkins 1966).

Lipid content.—Lipid contents reflected the physiological state or biological activity of each stage (table 2). For instance the total lipid content ranged from 78 percent (FDW) in eggs to lows of 24 and 23 percent in emergent females and males. Although the parent adults were higher in TL than emergent adults, the heavier parent females did not contain as much lipid as the males. Several factors may be responsible for this result. Females normally find suitable host trees and initiate attack, after which their pheromone attracts male beetles, perhaps on a shorter flight line. Thus females would utilize more lipids. Reduction of fat during flight has been reported for both female (Atkins 1969) and male (Thompson and Bennett 1971) Douglas-fir beetles, but no comparisons were made between sexes in the same experiment. The female southern pine beetle may also use a greater amount of lipid during attack, oögenesis, and oviposition. Penner and Barlow (1972) showed that female scolytid *Ips paraconfusus* Lanier utilized lipids for oögenesis and contained less than the male.

Table 2.—*Lipid content of the southern pine beetle*

Stage	Weight per specimen	Proportion of insect weight	
		FDW	WW
	Micrograms	——— *Percent* ———	
Parent ♀	288	28	10
Parent ♂	338	38	13
Egg	21	78	39
IBL	103	38	17
OBL	561	36	20
Pupa	459	31	17
Emergent ♀	227	24	11
Emergent ♂	213	23	10

The concentration of lipids we observed in the egg stage was higher than that reported by Fast (1964) and Gilbert (1967) for 12 other insects, and may signify a greater dependence on lipids during embryogenesis. The subsequent increase in size and weight during larval feeding coincided with a fivefold increase in amount of lipids between the egg and IBL stages and between IBL and OBL.

In percentage composition, lipids declined (WW) by about half from the egg to OBL stages, probably in consequence of increases in other chemical components and body structure. Lipid percentages on a FDW basis were slightly lower than those published for larvae of several Coleoptera but were generally higher than those recorded on a WW basis (Fast 1964, Gilbert 1967, Mauldin *et al.* 1971). FDW percentages for IBL (38), OBL (36), and pupae (31) were greater than or equal to values for Douglas-fir beetle larvae and prepupae, and about the same as those for pupae of this beetle (Atkins 1967).

Lipids decreased by 50 percent from the pupal to the emergent stage. WW and FDW declined less than this amount (table 1), an indication that lipids serve as an energy source during emergence. The large reduction is in agreement with Gilmour's (1965) observation that pupae generally draw upon stored fat. In the typical pattern of emergent insects, the female had slightly higher lipid content than the male.

Lipid content (FDW) of both the female (24 percent) and male (23 percent) was higher than that reported by Atkins (1967) for outdoor-reared Douglas-fir beetle adults (14 percent DW) but lower than for laboratory-reared adults (28-36 percent).

Lipid content of southern pine beetle emergent adults was similar to that of other phloem- or xylem-inhabiting Coleoptera, e.g., *Trypodendron lineatum* (Oliv.) males (6-28 percent DW) and females (11-34 percent) (Nijholt 1965, 1967); *Hylobius abietis* L. emergent adults (32 percent DW) (Guslits 1970); *Lyctus planicollis* LeConte laboratory-reared emergent adults (14 percent WW) (Mauldin *et al.* 1971); and *Xyleborus ferrugineus* (F.) laboratory-reared females (8.2 percent WW) (Kok and Norris 1972).

DISCUSSION

Though information is scanty, lipid content of pine bark is considered to be low. Parkerson and Whitmore (1972) reported between 0.4-3 percent (DW) in the cambial-phloem zone of eastern white pine. A preliminary assay of uninfested loblolly pine inner bark sampled in early spring showed lipid content of 4 percent (FDW). Thus, the insect probably receives little lipid directly from bark tissue.

Many insects synthesize fats from carbohydrates, and attacking southern pine beetles may utilize the normally high carbohydrate content of the inner bark for that purpose. After successful attack, however, carbohydrates decrease rapidly (Barras and Hodges 1969) and so may not be available to the larvae. On the other hand, mycangial fungi (Barras and Perry 1972) and other less specific microorganisms (Howe *et al.* 1971) introduced by the parent beetles exhibit a complex relationship that favors growth of the mycangial fungi in phloem surrounding larval chambers. The resulting mycelium and asexual fruiting bodies are in turn ingested by the larvae. It is not known how much the fungus-phloem substrate contributes to the lipid requirements of the beetle, but absence of mycangial fungi results in poor beetle development (Barras 1973). Many fungi have a high lipid content (Cochrane 1963, Kok and Norris 1973), and for one scolytid ambrosia beetle the mycangial fungi provide a dietary sterol required for pupation (Norris 1972). A similar type of dependency may be the basis for the symbiosis of the southern pine beetle and mycangial fungi in pine phloem. The fungus-feeding characteristics of the larvae support this hypothesis.

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SOUTHERN FOREST EXPERIMENT STATION

U.S. FOREST SERVICE RESEARCH NOTE

1974

SO-179

Forest Service, U.S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

RED IMPORTED FIRE ANT A PREDATOR OF DIRECT-SEEDED LONGLEAF PINE

Thomas E. Campbell[1]

SOUTHERN FOREST EXPERIMENT STATION

The red imported fire ant destroyed an average of 32.8 percent of germinating longleaf pine seeds coated with bird, rodent, and insect repellents. Damage to established seedlings was negligible.

Additional keywords: *Solenopsis invicta, Pinus palustris* Mill., seed losses, and seedling damage.

Many species of ants are destructive to direct-seeded southern pines, but seed and seedling losses have generally been small. However, the red imported fire ant (*Solenopsis invicta* Buren)[2] destroyed 11 percent of the longleaf pine (*Pinus palustris* Mill.) seed sown on an ant-infested area near Alexandria, Louisiana, in 1970. This species of fire ant had not been observed as a pest on direct seedings previously. Although populations within timber stands are relatively low, the number of active nests increases rapidly following timber harvest and site preparation for stand regeneration. The abundance of the insect and the extent of loss it caused in 1970 suggest that it might be an important predator. Research to appraise damage caused by the fire ant was initiated in the spring of 1972 and concluded in the fall.

METHODS

The study was made near Alexandria on an open, cutover site with about eight large fire ant nests per acre. Two repellent coatings containing insecticides were applied to longleaf pine seed to compare their repellent qualities for ants. An Arasan-endrin-latex slurry[3] with 0.5-percent active endrin was used as one treatment, and in the other 2.67 percent Furadan 75-W[4] replaced endrin.

The design of the study was a randomized complete block (10 blocks) with split plots. Major plots were established around 20 ant mounds, located at least 60 feet apart. Plots were paired, one

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[2] Formerly recognized as the imported Argentine fire ant (Solenopsis saevissima richteri Forel) until a recent name change.

[3] Pesticides mentioned here were registered and recommended for the use described at the time this manuscript was prepared. A responsible State agency should be consulted as to their current status.

[4] Furadan 75-W is an experimental pesticide for the use described here. This publication does not imply that the uses discussed here have been registered, nor does it contain recommendations for the use of Furadan 75-W.

randomly chosen for endrin-coated seeds and the other for Furadan-treated seeds. Each major plot had eight radii 45 degrees apart and extending outward 20 feet from the nest. Minor plots were observation stations located at 5-foot intervals on each radial. Treated seeds were broadcast uniformly on each plot at the rate of 15,000 per acre—433 per plot—in February 1972. Seeds retrieved from near each observation station were carefully placed so that on each radial at 5, 10, 15, and 20 feet there were 1, 2, 3, and 4 seeds. This provided 80 seeds per plot for detailed observation. It was believed that depredations would be lighter as distance from the nest increased and extra seeds would yield more representative information.

All seeds at the observation stations were checked twice weekly from the sowing date through May 10. Seed or seedling damage was recorded by cause. Ants observed feeding on seeds or seedlings were collected and identified[5]. Proportions of seed and seedling damage and seedling-to-seed ratios were transformed to arcsines according to Freeman-Tukey and tested by analysis of variance at the 0.05 level of significance.

RESULTS

Of the 1,600 seeds observed in this study, 32.8 percent were destroyed by the red imported fire ant. Losses by repellent treatment averaged 38.9 percent of the endrin-treated seeds and 26.8 for those treated with Furadan (table 1). The difference was significant. Distance of seeds from the nest, up to and including 20 feet, had no significant influence on ant depredations.

Seedling damage by fire ants was low, averaging 3.8 percent for endrin- and 1.8 for Furadan-treated seeds (table 1)—no significant difference. In almost every instance, ants clipped the cotyledons just below the seedcoat and ate the megagametophyte from the fallen seed. Needle clipping of this type is usually not lethal.

Seedling-to-seed ratios averaged 34.6 percent on plots sown with Furadan-treated seeds and 26.0—significantly less—for plots with endrin-coated seeds (table 1). With regard to distances from the nest no trend was detected.

DISCUSSION

This study indicates the fire ant is a serious predator of germinating longleaf pine seed. The critical period of seed exposure is shorter for fire ants than for some other predators, however. Of the observed seed, 525 were destroyed by ants consuming the megagametophyte and embryo after seeds had cracked open to germinate. The vulnerable stage for longleaf is from the start of germination to the point at which seedcoats are lifted off the surface—about 10 days to 2 weeks under normal weather conditions. After germination, ants are of no concern. Birds and rodents will prey on seeds from the time of sowing till

[5] Identifications were made by Dr. John C. Moser, Entomologist, Southern Forest Experiment Station, Pineville, Louisiana.

Table 1.—*Seed and seedling damage by the red imported fire ant, by repellent treatment and distance from the nest*

Repellent treatment	Distance from nest	Total seeds observed	Ant-damaged seeds	Ant-damaged seedlings	Seedling-to-seed ratios
	Feet	*Number*	— — — — —	*Percent*	— — — — —
Endrin	5	80	41.3	3.3	32.5
	10	160	35.1	.9	35.0
	15	240	34.2	2.7	25.8
	20	320	43.8	7.2	20.0
	Mean	800	38.9	3.8	26.0
Furadan	5	80	23.8	.0	38.7
	10	160	20.0	3.0	43.7
	15	240	32.1	4.8	31.2
	20	320	26.9	.0	31.6
	Mean	800	26.8	1.8	34.6

they drop off the erect cotyledons—a period of about 5 weeks.

Observed ants seemed to be searching the entire area; there were no obvious trails leaving the nest. They fed on the seed where it was found, and made no effort to carry it back to the nest.

Even though seeds treated with Furadan had significantly lower losses than those with endrin, it is doubtful that any insecticide coating on the seed will give adequate protection. Ants do not feed on the whole seed as do rodents; they wait until the seed is cracked open for emergence of the radicle, then enter the opening.

It is recommended that bait in current use be applied in advance of sowing if an area appears heavily infested—3 or 4 nests per acre would be considered numerous. Guidelines for use of the bait are available through County Agents and Agricultural Research Service Animal and Plant Health specialists.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife —if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

PROTECT

Use Pesticides Safely
FOLLOW THE LABEL
U.S. DEPARTMENT OF AGRICULTURE

SOUTHERN FOREST EXPERIMENT STATION

1974

U.S. FOREST SERVICE RESEARCH NOTE

SO-180

Forest Service, U.S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA 70113

SOIL-APPLIED HERBICIDES FOR CONTROL OF RED OAKS AND HICKORIES IN THE BOSTON MOUNTAINS OF ARKANSAS[1]

Edwin R. Lawson and Edwin R. Ferguson[2]

SOUTHERN FOREST EXPERIMENT STATION

In the Boston Mountains of Arkansas, picloram, bromacil, and tert-*butylcarbamate were effective in killing hickories at the manufacturer's recommended rate. At 1.5 times the recommended rate fenuron was significantly more effective than at the suggested rate. Fenuron, bromacil, and* tert-*butylcarbamate exceeded 50 percent crown kill for red oaks at recommended rates and were more effective at the highest rate. Dicamba was ineffective for control of either species; picloram was ineffective on red oaks.*

Additional keywords: Crown kill, hardwood control.

Broadcast soil application of granular and pelleted herbicides is being researched in the Ozark Highlands of Arkansas since aerial applications have been curtailed by environmental considerations and single-stem injections are too costly. Several herbicides, including fenuron, dicamba, bromacil, *tert*-butylcarbamate, and picloram, have proven effective on some tree species, especially in sandy soil. In the present study, these five herbicides were tested at various rates in the Boston Mountains.

METHODS AND MATERIALS

The study area included several ridge-top stands of even-aged red oaks (*Quercus* spp.) and hickories (*Carya* spp.) on sandy loam and loam soils. Tree diameters ranged from 3 to 8 inches. Averaging 5.24 inches, red oaks were larger in diameter than hickories, which averaged 4.43 inches.

Chemicals and the manufacturer's recommended rate of application were: picloram (4-amino-3,5,6 trichloropicolinic acid), 10 percent pelleted-80 lbs/acre; fenuron (3-phenyl-1, 1-dimethylurea), 25 percent pelleted-70 lbs/acre; bromacil (5-bromo-3-*sec*-butyl-6-methyluracil), 10 percent pelleted-85 lbs/acre; dicamba (3, 6-dichloro-o-anisic acid), 10 percent granular-80

[1] This publication reports research involving herbicides. It does not contain recommendations for their use nor does it imply that the uses discussed here have been registered. All uses of herbicides must be registered by appropriate State or Federal agencies before they can be recommended.

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lbs/acre; and, *tert*-butylcarbamate (m-(3,3 dimethylureido) phenyl *tert*-butylcarbamate), 10 percent granular-72 lbs/acre.

Levels of application were 50, 100, and 150 percent of recommended rates. The area within the dripline of the individual test stems was used to calculate the amount of chemical broadcast under each tree. Test trees were separated by at least two times their crown widths. Each of the 15 chemical-rate combination treatments was applied to 10 randomly chosen trees of each species. Application was in the early spring of 1970, and ocular estimates of crown kill were made in June and August of 1971, 1972, and 1973. Any kill less than 80 percent was considered inadequate.

Analyses of variance at the 0.05 level determined significant differences in initial diameter and percentage of crown kill after arc-sine transformation. Duncan's multiple range test, at the same level, determined differences among transformed means.

RESULTS

Applied at the manufacturer's recommended rate, *tert*-butylcarbamate attained 100 percent crown kill on hickories (fig. 1); picloram and bromacil gave crown kills of 81 percent or better. On red oaks, the recommended rate of fenuron was most effective, killing 86 percent (fig. 2).

At 150 percent of the recommended rate, *tert*-butylcarbamate and bromacil gave 100 percent kill on hickories; fenuron killed better than 90 percent. The high rates of fenuron, bromacil, and *tert*-butylcarbamate killed 83 to 91 percent of the red oaks.

Significant differences in crown kill among chemical-rate combinations were noted with red oaks, but they occurred in the first 14 months of treatment. There was no significant difference in treatments after June 1971.

Dicamba was ineffective for control of both species at any rate tested; picloram was ineffective at any rate on red oaks. No chemicals had crown kill percentages exceeding 50 percent on either species when applied at half the recommended rate.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife —if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

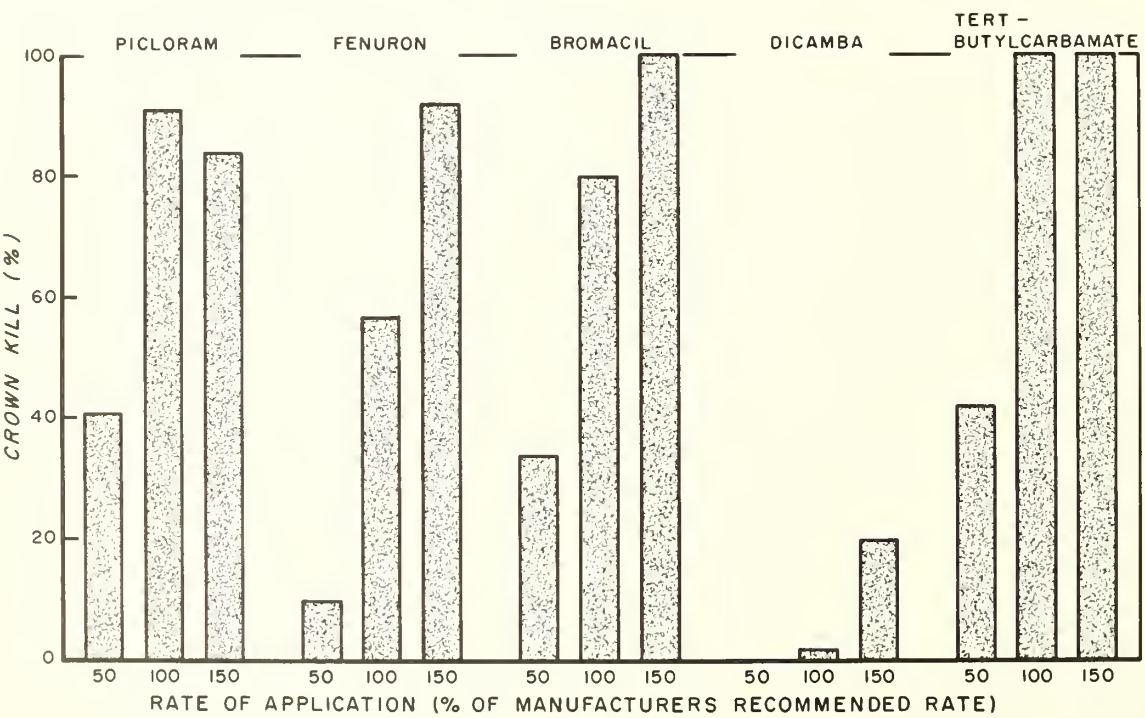

Figure 1.—*Crown kill of hickory by rate and chemical after three growing seasons.*

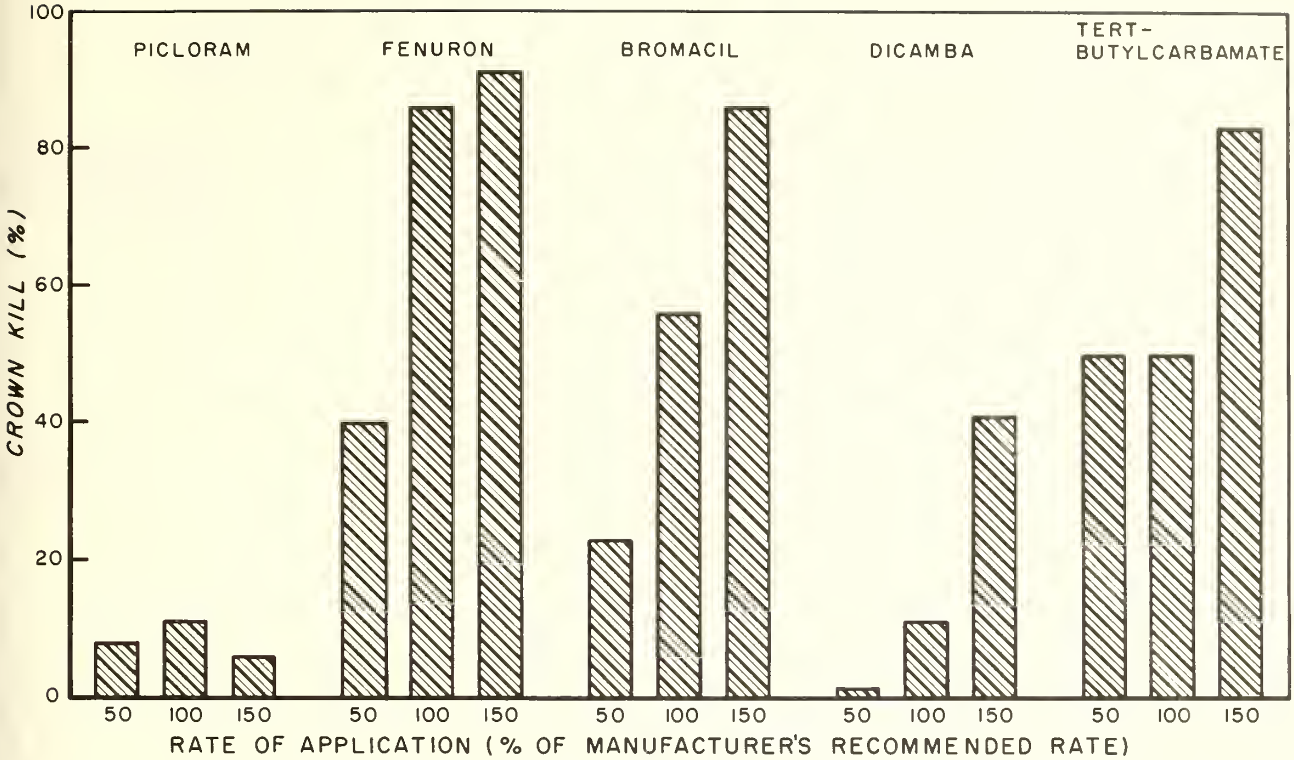

Figure 2.—*Crown kill of red oak by rate and chemical after three growing seasons.*

SOUTHERN FOREST EXPERIMENT STATION

1974

U.S. FOREST SERVICE RESEARCH NOTE

SO-181

Forest Service, U.S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

LONGLEAF PINE SEEDLING MORTALITY RELATED TO YEAR OF OVERSTORY REMOVAL[1]

William D. Boyer

SOUTHERN FOREST EXPERIMENT STATION

During the first year after overstory removal, mortality of longleaf pine seedlings was highest on plots cut in the spring after seedling establishment (71 percent) and lowest on those cut at seedling age 1 (36 percent) or age 2 (40 percent). Seedling mortality rose to 51 percent with logging at age 3 and to 54 percent with logging at age 5. Fifty-seven percent of all mortality was caused by direct logging damage. The remainder, all among seedlings apparently undisturbed by logging, amounted to 35 percent of the residual stand. This mortality rate far exceeded attrition on unlogged plots, which averaged 13 percent.

Additional keywords: *Pinus palustris*, logging damage, harvest cuts.

Natural regeneration of longleaf pine (*Pinus palustris* Mill.) can best be attained through a shelterwood system in which seedlings are established under parent overstories of medium density (Croker 1969). Most longleaf seedlings will survive prolonged overstory competition provided they are protected from fire (Smith 1961, Boyer 1963). However, if the seedlings' susceptibility to logging damage changes with age, the timing of overstory removal could have an important impact on seedling mortality. In the present study, mortality among seedlings released at various ages was compared.

METHODS

The study site in Coosa County, Alabama, contained mature stands of longleaf pines averaging over 100 years of age. Basal area of overstory pines ranged from 17 to 43 ft^2 per acre and averaged 29 ft^2; basal area of hardwoods was 2 to 13 ft^2 per acre and averaged 6 ft^2. A heavy seed crop in 1961 had resulted in excellent seedling establishment; seedlings numbered about 73,000 per acre.

The six treatments included complete overstory removal when seedlings from the 1961 crop were 0, 1, 2, 3, and 5 years old plus an unreleased check. Plots released at seedling age 0 were logged in April; all other logging was done in March. All merchantable trees were felled, limbed, and skidded tree length

[1] The study was conducted on the lands of, and in cooperation with, the Kaul Lumber Company.

with a crawler tractor. Logging procedures were normal for the area. Log landings were located outside the plots; otherwise no special protective measures were taken. All residual stems down to about 1 inch in ground-line diameter were also cut or deadened at the time of overstory removal.

Treatments were randomly assigned among six square, 1.6-acre plots in each of three blocks. Within each plot, nine square, 4-milacre subplots were located 1 chain apart. In the early spring of 1962, 12 well-spaced seedlings on each subplot (3 per milacre) were marked for study. None of the marked seedlings had begun height growth (6 inches or more in height to base of bud) at the time of clearcutting, except for about 2 percent of those in plots released at seedling age 5.

Annual winter observations included mortality of marked seedlings, milacre stocking, and a complete count of all 1961 seedlings in the northeast ¼-milacre of each 4-milacre subplot. All older seedlings had been removed from study plots at time of plot establishment.

No plots were burned after seedling establishment.

RESULTS

Year of release had a significant ($P<0.05$) impact on seedling mortality during the first growing season after logging (table 1). On plots clearcut in April after seedling establishment, 71 percent of the marked seedlings died in their first year. Mortality after logging was lowest on plots cut at seedling age 1 or 2.

Table 1.—*Mortality of longleaf pine seedlings during year of clearcutting*

Seedling age at release (years)	Mortality [1]
	Percent
0	71.3
1	36.2
2	40.3
3	51.4
5	54.4

[1] Means connected by a single line not significantly different (5 percent level).

The direct impact of logging on the seedling stand varied significantly with date of release (table 2). Logging damaged more seedlings during the first cut in April 1962 than in any later cut. The proportion of damaged seedlings that died was also greatest on plots released at seedling age 0 and lowest on those released at age 1 or 2. An average of 57 percent of the total mortality recorded during the year of logging was caused directly by the clearcutting operations. Logging damage accounted for 80 percent of the seedling deaths in plots released at age 0 and for 32 percent of those in plots released at age 1.

Among seedlings that were apparently undisturbed by logging, losses averaged 35 percent; the normal attrition rate on plots not being logged averaged 13 percent a year. The difference between the two was 22 percent. In an earlier study, this difference in mortality between undamaged seedlings on logged plots and those on check plots averaged 20 percent

Table 2.—*Longleaf pine seedling mortality through first year after clearcutting in relation to year of cut and seedling age*

Year	Seedling age at release	Seedlings disturbed by logging			Nonlogging mortality		
		Total [1]	Dead		Recently cut plots [3]	All other plots	Difference
			Total [1]	Proportion [2]			
		Percent					
1962	0	62	56	91	38	26	12
1963	1	19	12	62	30	6	24
1964	2	37	21	56	30	14	16
1965	3	43	33	78	32	12	20
1967	5	29	23	77	45	7	38
Average		38	29	73	35	13	22

[1] Based on marked seedlings alive before logging.
[2] Mortality among seedlings disturbed by logging.
[3] Mortality among residual (after logging) marked seedlings undisturbed by logging.

(Boyer 1964). This excess mortality on recently logged plots was not significantly affected by year of cut, and its causes are not known. Twelve percent of the post-logging losses were definitely attributed to insect or small mammal activity, which varied widely among treatments, years, and blocks. The rest must be associated with cutting in some way, even though none of the seedlings were directly injured by overstory removal. An average of 72 percent of these losses occurred between the first and second examinations after logging (April to July).

On undisturbed plots, 26 percent of the marked seedlings died during their first year, probably because of a severe spring drought. Three weeks in May passed without rain, and only 0.41 inch fell during the 5 weeks from April 30 to June 3. Growing season rainfall (March through August) was 18.81 inches, over 30 percent below normal for the area. Over the next 5 years, however, there were no significant year-to-year differences in natural mortality.

Except for the first year after seedling establishment and the first year after logging, differences in seedling mortality on released and on unreleased plots were negligible. Annual seedling mortality percents for all released plots (excluding those cut in the current year) and for all plots as yet unreleased are tabulated below:

	2nd year	3rd year	4th year	5th year	6th year	Avg.
Released	10.5	10.2	10.8	4.9	7.3	8.7
Unreleased	4.6	16.5	13.5	8.1	6.7	10.0

The average yearly attrition rate of nearly 10 percent is higher than the 2 to 5 percent rate observed in other studies (Boyer 1963, 1974). This higher rate may have resulted, in part, from the high initial seedling density of 73,000 per acre. By age 6 the survivors numbered 17,000 per acre.

CONCLUSIONS

This study suggests that seedling mortality associated with logging is minimal when clearcutting is done at seedling age 1 or 2. Susceptibility to logging damage is high in newly established seedling stands and also appears to increase after seedling age 2.

Much of the mortality on clearcut plots occurs among seedlings not directly disturbed by logging. These losses did not differ significantly with seedling age.

The importance of logging-related losses to the forest manager will depend mostly on the density of the seedling stand. If large numbers of seedlings are present, such losses can probably be ignored. However, optimum time of release may be a major consideration in regeneration areas with marginal stocking.

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SOUTHERN FOREST EXPERIMENT STATION

1974

U.S. FOREST SERVICE RESEARCH NOTE

SO-182

Forest Service, U. S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

IMPACT OF PRESCRIBED FIRES ON MORTALITY OF RELEASED AND UNRELEASED LONGLEAF PINE SEEDLINGS

William D. Boyer

SOUTHERN FOREST EXPERIMENT STATION

In nonfire years mortality averaged less than 4 percent for both released and unreleased grass-stage longleaf pine seedlings but with prescribed winter burns annual losses averaged as much as 19 percent among released seedlings and 41 percent among unreleased seedlings. Root-collar diameter and infection by brown-spot needle blight both affected seedlings' susceptibility to fire. Most of the unreleased seedlings larger than 0.5 inch in root-collar diameter survived the fires. Losses among released seedlings on average sites were minor provided burning was done no sooner than 2 years after logging and seedlings were 0.3 inch or more in root-collar diameter.

Additional keywords: *Pinus palustris*, brown-spot needle blight, *Scirrhia acicola*.

After a good seed crop, longleaf pine *(Pinus palustris* Mill.) seedlings are often established in abundance beneath well-stocked stands; but within a few years most of these seedlings disappear. Overstory competition alone is not responsible for the high seedling mortality, for research indicates that most longleaf seedlings can survive prolonged overstory competition if they are protected from fire (Smith 1961, Boyer 1963). Is fire, then, the principal killer of longleaf seedlings? Are seedlings beneath an overstory more susceptible to fire damage than those in the open? How big must seedlings be before a stand can be safely burned?

These questions are particularly important since natural regeneration of longleaf can best be achieved through a shelterwood system in which seedlings are established beneath parent overstories of medium density (Croker 1969). Prescribed fire may be needed in these shelterwood stands to prepare a seedbed for additional seedling establishment or to retard encroachment of hardwoods and brush.

The impact of winter prescribed fires on seedlings both under an overstory and in the open was observed during three regeneration studies in southwest Alabama.

PROCEDURES

All three study areas were included in periodic, large-scale winter fires prescribed for hazard reduction, seedbed preparation, or brown-spot control. Weather conditions desired were those associated with the passage of a cold front: an inch or more of rain followed by cool or cold temperatures and a moderate but steady northerly wind. Fast-moving head fires were normally employed. Actual conditions of weather and fuel varied from fire to fire and were seldom ideal, but they were always within the range required for careful winter burns.

Information obtained regularly on selected longleaf seedlings in each study included survival, root-collar diameter to the nearest 0.1 inch, and amount of current year's foliage destroyed by brown-spot disease, estimated to the nearest 10 percent. Examinations were made during the dormant season.

Study 1, release from a hardwood overstory.—In the first study, seedlings from the 1947 and 1951 seed crops were released from a hardwood overstory at various times ranging from 1 year before seedfall to 8 years after. The overstory contained 267 to 593 stems per acre and 27 to 42 ft^2 of basal area per acre.

The study area included six blocks of plots, two on poor sites and two on average sites on the Escambia Experimental Forest, and two on average sites on the Conecuh National Forest. Soils of the poor sites were predominantly Alaga loamy sands. Average sites on the Escambia consisted predominantly of sandy loams of the Ruston, Benndale, and Dothan series. On the Conecuh, soils were fine sandy loams of the Tifton, Benndale, and Dothan series.

The 1947 seedlings were observed on six 0.1-acre plots on each of the six blocks, and the 1951 seedlings were observed on five additional 0.1-acre plots in each of the four Escambia blocks. Each 0.1-acre plot contained a ½-chain square net plot that was subdivided into 100 ¼-milacre quadrats. The best seedling in each stocked quadrat was measured. Examinations of 1947 seedlings were made each winter through January 1951 and then at 2-year intervals through December 1957. The 1951 seedlings were examined annually through February 1953 and then every other year through December 1957. A total of 4,319 1-year-old seedlings were included in the first measurement.

At age 3 seedling stands were thinned to a maximum of three per ¼-milacre subplot, with a minimum of 1 foot between seedlings.

The 1947 series of plots was burned by winter prescribed fires when seedlings were 2, 5, and 7 years old. The 1951 series of plots was burned when seedlings were 3 years old.

Study 2, overstory density.—The effect of pine overstory density on fire losses among seedlings from the 1955 seed crop was observed in 50- to 60-year-old stands on the Escambia Experimental Forest. Early in 1957, ten 4-milacre plots were located under each of six overstory densities: 9, 27, 30, 45, 60, and 90 ft^2 of basal area per acre. Within each plot, 12 seedlings were marked for annual observation.

Study areas had been burned early in 1955 for seedbed preparation and were burned again in January 1964, when seedlings were 8 years old.

Study 3, release from a pine overstory.—The effects of overstory competition and prescribed fire on seedling survival were sampled in five 40-acre compartments on the Escambia Experimental Forest, where pine overstories ranged from 23 to 48 ft^2 of basal area per acre. Most seedlings came from the 1957 and 1958 seed crops although older ones were present. Strips 2.5 or 3.3 chains wide were clearcut along the east side of three compartments in January 1960 and along the north side of two more in February 1961. Five transects were randomly established on each of the five clearcut strips and paired with a similar transect in the adjacent forest. Transects were 2 chains long, 5 links wide, and at right angles to the long axis of the strip. Each transect formed 40 square, ¼-milacre quadrats. The seedling nearest the center of each stocked quadrat was marked for study, and the fate of the 831 marked seedlings was recorded annually.

Three compartments were burned in January 1962, one was burned in January 1964, and one was burned both times.

RESULTS AND DISCUSSION

Release from a Hardwood Overstory

Prescribed fires played a major role in longleaf pine seedling mortality, as reflected by reductions in ¼-milacre stocking on study plots (figs. 1 and 2). Overall, 90 percent of the total stocking losses of 1947 seedlings occurred during the three intervals (5 years) with a fire, and the rest occurred during the three intervals (4 years) without a fire. Eighty percent of the stocking losses of 1951 seedlings occurred during the 2-year interval with a fire, and the rest, during the 3 years without a fire.

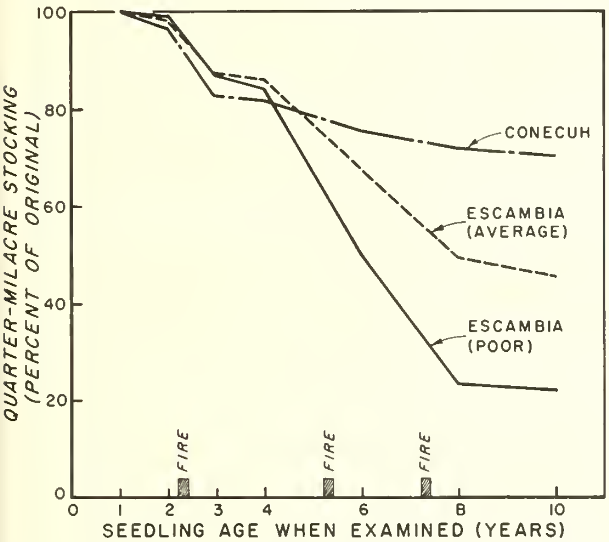

Figure 1.—*Progressive quarter-milacre stocking loss of 1947 seedlings.*

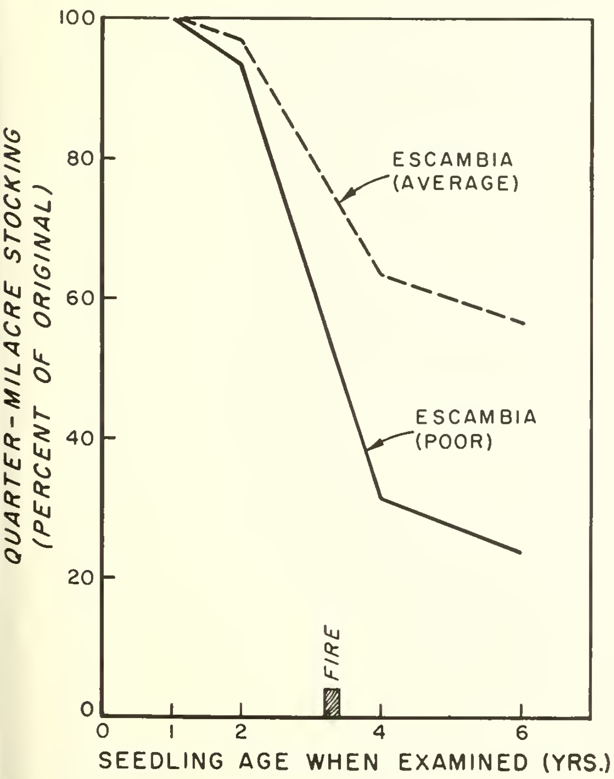

Figure 2.—*Progressive quarter-milacre stocking loss of 1951 seedlings.*

Unrecorded mortality during the nonfire year in each 2-year interval with a burn was assumed to be the same as the average annual mortality recorded for intervals without fire; and average annual ¼-milacre stocking losses in years with and without fire were determined for each seed crop, site, and release condition (table 1). Fire losses were worst for unreleased seedlings on poor sites, where they averaged 59 percent of residuals (stocked ¼-milacres) per fire.

Table 1.—*Average annual stocking losses*[1] *of released and unreleased longleaf pine seedlings in years with and without prescribed fire*

Seed crop and site	Released		Unreleased	
	Fire	No fire	Fire	No fire
	---- *Percent* ----			
1947 seedlings				
Escambia, poor	29.1	2.0	47.4	2.9
Escambia, average	13.4	1.8	24.0	5.2
Conecuh, average	1.9	1.4	18.5	2.5
1951 seedlings				
Escambia, poor	48.7	10.8	94.5	1.0
Escambia, average	22.8	4.4	64.3	4.4
All[2]	18.6	3.5	39.0	3.3

[1] Based on reduction in ¼-milacre stocking between examinations.

[2] Weighted annual average for 9 years of observation of 1947 seedlings and 5 years of observation of 1951 seedlings.

The fate of 666 seedlings from the 1947 seed crop was recorded after the winter prescribed fire at age 5, when most of the seedling mortality occurred. An analysis of variance indicated that both seedling root-collar diameter and brown-spot infection, as recorded at age 4, had a significant (0.05 level of probability) relationship to seedling fate (dead or alive) at age 6. Surviving seedlings were larger and had less brown-spot infection at age 4 than those that died (table 2).

A discriminant function analysis of seedling fate as affected by brown-spot infection and

Table 2.—*Average root-collar diameters and percent of brown-spot infection associated with seedling fate after a winter prescribed fire*

Site	Condition	Fate	Root-collar diameter	Brown-spot infection
			Inch	*Percent*
Average	Released	Lived	0.38	34
		Died	.33	52
	Unreleased	Lived	.33	17
		Died	.30	49
Poor	Released	Lived	.40	44
		Died	.34	51
	Unreleased	Lived	.34	41
		Died	.23	60

seedling size further underscored the importance of these two variables. A separate analysis was made for each of the four site-release combinations listed in table 2. Analysis of two-thirds of the data, randomly selected, provided the discriminants which were used with the remaining one-third. The discriminants for both variables combined, on the average, correctly classified the fate of 71 percent of the seedlings in the group withheld from analysis. Classification was better for the unreleased (79 percent) than the released (62 percent) seedlings. On good sites the most important discriminant was brown spot; on poor sites it was root-collar diameter. The large number of seedlings whose fate was not correctly classified indicates that other factors also are important. These would include many unrecorded variables such as topography, fuel conditions, weather, type and intensity of fire, seedling vigor, and root exposure. The fact that data on seedling size and brown-spot infection were obtained a year before burning could also have had an effect on the results.

Overstory Density

Overstory density significantly affected seedling fire mortality, which was lowest under the 9-square-foot density class and highest under the 30-square-foot class (table 3). Maple (1969), on the other hand, reported that overstory densities of 10 to 60 ft^2 of basal area per acre did not affect fire losses among selected, vigorous grass-stage seedlings between 0.3 and 0.7 inch in root-collar diameter. However, Maple's overall fire mortality was only 4.3 percent; in the present study 43.2 percent of the 428 marked 8-year-old seedlings were dead 1 year after burning—40.6 percent had been killed by the fire and 2.6 percent by other, natural causes.

Table 3.—*Seedling losses after a prescribed fire in January 1964*

Stand density (basal area/acre)	Fire [1]	Other	Total
Square feet		*Percent*	
9	16.2a	2.9	19.1
27	54.6bc	3.6	58.2
30	59.0c	3.3	62.3
45	38.3ab	0	38.5
60	41.0ab	4.8	45.8
90	38.8ab	2.5	41.3

[1] Within columns, values followed by the same letter are not significantly different at the 0.05 level.

Losses were concentrated among seedlings 0.5 inch or less in root-collar diameter, as the tabulation below indicates. The comparatively low mortality in the 0.2-inch class may be related to the low level of brown-spot infection in this class (8 percent); infection in the larger sizes averaged 14 to 22 percent.

Root-collar diameter	Fire kill
Inch	*Percent*
0.2	38
.3	49
.4	42
.5	40
.6	22
.7	16
.8	12
.9+	10

Release from a Pine Overstory

As in study 1, prescribed fire was associated with marked increases in seedling mortality, and its impact was more severe among seedlings in the forest than among those in clearcut strips. In fire years, losses averaged 10 percent among released seedlings and 40 percent among unreleased seedlings, a significant difference. In nonfire years, losses averaged only 2.7 and 3.7 percent among released and unreleased seedlings respectively; the difference was not significant.

The mortality rate for released seedlings is calculated only for the four compartments first burned 2 or 3 years after logging. The fifth compartment was burned just 1 year after overstory removal, and there mortality among released seedlings was exceptionally high (25 percent) because of fuel provided by the undecomposed needle litter and logging slash still present on the site.

The high fire mortality among seedlings in the forest can probably be attributed to both the small size of these seedlings and to the presence of pine needle litter on the forest floor. Seedlings under the overstory averaged 0.33 inch in root-collar diameter before the first fire; those in the open averaged 0.48 inch. Standard deviation for both classes of seedlings was 0.06 inch. Needle litter is probably responsible for the difference between the clearing and the forest in fire mortality among seedlings of the same size (table 4). The difference between losses among released and unreleased seedlings, however, decreased as seedling size increased. Davis (1955), too, found that both seedling size and needle litter influenced seedlings' susceptibility to fire. He reported that near overstory pines fire destroyed 50 percent of the seedlings 0.2 inch in diameter at the root collar but only 10 percent of those 0.3 inch in diameter; in a clearing mortality for these two size classes averaged 18 and 7 percent.

Table 4.—*Fire kill in relation to seedling size*

Seedling root-collar diameter	Seedling mortality	
	Released	Unreleased
Inch	– – *Percent* – –	
0.1	60	86
.2	24	62
.3	16	34
.4	7	27
.5	6	8
.6	6	16
.7	5	18
.8	0	0
.9	14	14

Bruce (1951) concluded that a higher seedling mortality near the timber edge than in the open resulted from fires being hotter when fueled with needle litter than with grass.

CONCLUSIONS

Fire was the principal factor associated with excessive mortality among grass-stage longleaf pine seedlings. The impact of fire was much greater under an overstory than in the open. Fire was also more damaging on poor sites than on average sites. Consequently, if there is a possibility that the young seedling stands will be burned, release is most urgent for those on poor sites.

Both seedling size and bown-spot infection are closely related to fire mortality. The higher average level of disease infection on poor sites may be a major factor in the site effect.

Winter prescribed fires in clearcut areas on average sites have a minor effect on seedling survival, provided burning is done no sooner than 2 years after logging and the grass-stage seedlings are 0.3 inch or more in root-collar diameter. A fire 1 year after logging may cause excessive losses in the seedling stand because undecomposed litter and logging slash are still present.

Within forest stands, healthy grass-stage seedlings larger than 0.4 or 0.5 inch in root-collar diameter are comparatively safe from loss in careful winter prescribed fires. Fire mortality will increase rapidly with decreasing seedling size below 0.5 inch in diameter, and the slow growth of seedlings under an overstory extends the period of vulnerability to fire damage.

In the absence of fire, annual mortality was low for seedlings retained under pine or hardwood overstories as well as for seedlings released from all overstory competition.

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SOUTHERN FOREST EXPERIMENT STATION

Forest Service, U. S. Dept. of Agriculture

1974

U.S. FOREST SERVICE RESEARCH NOTE

SO-183

10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

CHEMICAL COMPONENTS OF SOME SOUTHERN FRUITS AND SEEDS

F. T. Bonner[1]

SOUTHERN FOREST EXPERIMENT STATION

Fruits and seeds of 26 species were collected in central Mississippi and analyzed for crude fat, protein, total carbohydrates, phosphorus, calcium, and magnesium.

Additional keywords: Wildlife food, mast, nutrients, stored foods, hardwood seed.

It is often very useful to know the chemical makeup of fruits and seeds, especially the major storage-food components. Such information may influence choice of test methods or cleaning and storage procedures. Chemical content can also indicate value of seeds as food for wildlife. Chemical contents for 37 southern species were determined at the Forest Tree Seed Laboratory at Starkville, Mississippi, and published previously (Bonner 1971). This note presents similar data for 24 more species. In addition, new analyses of intact fruits of *Cornus florida* and *Prunus serotina* reveal the importance of the pulp on these fruits.

[1] Forest Tree Seed Laboratory, maintained at Starkville, Mississippi, by the Southern Forest Experiment Station, USDA Forest Service, in cooperation with Mississippi State University.

MATERIALS AND METHODS

All samples were collected in Mississippi, principally in Oktibbeha County, from 1970 to 1974. Most were composites from several trees or collection dates.

Samples were dried for 24 to 48 hours at 70° C in a forced-draft oven and cooled in desiccators. Seeds with low fat content were ground in a Wiley mill to pass a 40-mesh screen. Those with high fat contents were chopped finely by hand with a razor blade. Up to 10 g of tissue was prepared from each sample. All analyses were in duplicate.

Crude fat was determined gravimetrically by extraction with petroleum ether. Soluble and insoluble carbohydrate and nitrogen fractions were analyzed from samples extracted with 80-percent ethyl alcohol, and the data were combined to give total carbohydrate and total nitrogen values. Carbohydrate analyses were made by the phenol-sulfuric acid method (Nalewaja and Smith 1963). Nitrogen was determined by micro-Kjeldahl procedures, and protein was estimated as total percent N times

6.25. Solid residues from the alcohol extraction were tested for the presence of amylose by IKI staining (Jensen 1962).

Phosphorus, calcium, and magnesium were determined on acid extracts of ashed samples. Phosphorus was measured by the chlorostanous-reduced molybdophosphoric blue method (Jackson 1958). Calcium and magnesium were measured with a flame photometer. Details of the analytical methods have been described elsewhere (Bonner 1972).

RESULTS AND DISCUSSION

Data for 26 species are summarized in Table 1. Four species had crude fat contents of 25 percent or above: *Carya cordiformis, Euonymus americanus, Maclura pomifera,* and *Magnolia grandiflora.* The 41.2 percent fat in *M. grandiflora* is second only to the 46.6 percent measured previously in *Sassafras albidum* (Bonner 1971).

Total carbohydrate contents of 25 percent or above were recorded in *Acer saccharinum, Melia azedarach, Quercus lyrata, Q. macrocarpa, Q. michauxii, Q. nuttallii, Q. palustris,* and *Vaccinium arboreum.* Seeds of all these species stained positive for amylose except *Melia azedarach.* Four other species had carbohydrate contents between 20 and 25 percent: *Osmanthus americanus, Prunus caroliniana, P. serotina,* and *Q. falcata.*

Table 1.—*Chemical contents of southern fruits and seeds*

Species	Condition of seed	Crude fat	Total protein	Total Carbohydrates	Amylose [1]	P	Ca	Mg
		– – *Percent* – –				– *Percent* –		
Acer rubrum L., red maple	intact	4.6	20.7	19.5	–	0.34	0.34	0.23
A. saccharinum L., silver maple	intact	1.5	17.0	41.2	+	.48	.26	.10
Alnus serrulata (Ait.) Willd., hazel alder	clean seed	17.8	16.5	3.2	–	.29	.68	.24
Carya cordiformis (Wangenh.) K. Koch, bitternut hickory	husked	30.8	3.3	17.1	– [2]	.12	.46	.08
C. tomentosa Nutt., mockernut hickory	husked	20.0	3.7	12.7	+ [2]	.08	.22	.07
Cephalanthus occidentalis L., common buttonbush	clean seed	3.8	5.6	12.8	+	.18	.37	.08
Cornus florida L., flowering dogwood	intact	20.5	4.0	18.3	+	.13	1.19	.21
Euonymus americanus L., brook euonymus	intact	36.2	12.6	10.6	–	.28	.21	.11
Fagus grandifolia Ehrh., American beech	seed only	10.6	7.8	6.5	+	.26	1.18	.17
Maclura pomifera (Raf.) Schneid., Osage-orange	clean seed	31.3	27.7	10.6	–	.42	.09	.10
Magnolia grandiflora L., southern magnolia	intact seed	41.2	10.8	12.4	–	.28	.17	.08
Melia azedarach L., Chinaberry	intact	7.1	5.2	25.0	–	.16	.24	.04
Morus rubra L., red mulberry	intact	3.8	11.6	16.9	+	.22	.77	.21
Osmanthus americanus (L.) Benth. & Hook. f., devilwood	intact	10.6	5.0	22.7	–	.08	.18	.04
Prunus caroliniana (Mill.) Ait., Carolina laurelcherry	intact	10.9	7.8	24.6	+	.17	1.00	.14
P. serotina Ehrh., black cherry	intact	4.9	7.8	20.8	–	.16	.22	.07
Quercus falcata Michx., southern red oak	acorn	17.0	5.1	23.0	++	.08	.32	.14
Q. lyrata Walt., overcup oak	acorn	.9	4.6	49.8	++	.12	.16	.08
Q. macrocarpa Michx., bur oak	acorn	4.8	4.3	45.9	++	.10	.08	.06
Q. michauxii Nutt., swamp chestnut oak	acorn	3.3	4.1	56.1	++	.12	.08	.06
Q. nuttallii Palmer, Nuttall oak	acorn	13.2	4.5	46.2	++	.09	.04	.06
Q. palustris Muenchh., pin oak	acorn	15.4	3.8	45.4	++	.08	.04	.06
Rhus glabra L., smooth sumac	intact	14.2	2.4	16.8	–	.08	.28	.10
Taxodium distichum (L.) Rich., baldcypress	clean seed	4.6	3.4	3.1	–	.10	.32	.08
Ulmus serotina Sarg., September elm	intact	19.0	24.1	7.4	–	.31	1.23	.12
Vaccinium arboreum Marsh., tree sparkleberry	intact	2.9	3.0	33.6	+	.06	.33	.07

[1] Amylose reactions: – = absent; + = light stain; ++ = heavy stain.
[2] Kernel tissue only.

Protein contents of 20 percent and above were recorded for *Acer rubrum, Maclura pomifera*, and *Ulmus serotina*. These three species and *Acer saccharinum* had the highest phosphorus contents also. A similar relationship between protein and phosphorus contents was noted in the previous work (Bonner 1971).

The highest calcium contents (1.0 percent and above) were in *Cornus florida, Fagus grandifolia, Prunus caroliniana*, and *Ulmus serotina*. High magnesium contents were recorded in *Acer rubrum, Alnus serrulata, Cornus florida*, and *Morus rubra*.

The importance of the pulpy mesocarps on *Cornus florida* and *Prunus serotina* can be seen by comparing analyses of intact and depulped fruits in Table 2. These data suggest that most of the crude fat and magnesium of *C. florida* is in the mesocarp, and some carbohydrates and phosphorus are also there. Protein and calcium percentages, by contrast, were higher in depulped tissue, an indication that these components are found almost entirely in the endocarp and embryo. Relationships were similar in *P. serotina*, except that some calcium was in the pulp, and very little, if any, magnesium.

Table 2.—*Chemical contents of intact and depulped fruits of* Cornus florida *and* Prunus serotina. *Data for depulped fruits taken from Bonner (1971)*

Species	Crude fat	Total protein	Total carbohydrates	P	Ca	Mg
			Percent			
Cornus florida						
Intact	20.5	4.0	18.3	0.13	1.19	0.21
Depulped	6.2	5.0	14.7	.09	1.88	.05
Prunus serotina						
Intact	4.9	7.8	20.8	.16	.22	.07
Depulped	1.8	13.7	15.3	.14	.14	.09

Comparative data from other sources are few. One analysis reported for *Acer saccharinum* without pericarps (Anderson and Kulp 1921) showed about 4 percent crude fat, 27 percent protein, and 62 percent total carbohydrates. While all three components are above the values for this species in Table 1, the relative amounts are very similar. Halls and Oefinger (1969) reported 0.89 percent calcium in dogwood fruits, which is close to the 1.10 percent in Table 1. Intra-generic comparisons with the previous work (Bonner 1971) show similarities for *Carya, Quercus*, and *Ulmus* species.

These data should not be considered comprehensive, since the values for each species represent samples from only a few trees in one locality. They do provide useful indications, however, and the few comparisons available suggest that they are fairly representative.

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SOUTHERN FOREST EXPERIMENT STATION

1974

U.S. FOREST SERVICE
RESEARCH NOTE

SO-184

Forest Service, U. S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

WEEDING NORTHERN RED OAK PLANTATIONS ON THE CUMBERLAND PLATEAU

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SOUTHERN FOREST EXPERIMENT STATION

Weeding has increased diameter growth of planted red oaks on two clearcut sites in central Tennessee. Height growth was slightly poorer for released than for unreleased saplings. Over a 3-year period one weeding was just as effective as repeated annual treatments. Survival on treated plots was not significantly improved.

Additional keywords: *Quercus rubra* L., hardwood planting, control of competition.

Oak seedlings grow so slowly that they are often overwhelmed by other hardwoods and brush (Olson 1972, Russell 1973). If suppression could be controlled and growth stimulated, oak plantations could help increase southern hardwood production. This note describes studies conducted on two sites to determine whether weeding red oak plantations improves growth or survival.

METHODS

The test areas, near Sewanee, Tennessee, were originally developed to compare a variety of planting methods; details of establishment and early development are reported elsewhere (Russell 1973). The first site, designated "plateau," was planted in 1962, and the second, locally called a "cove," in 1963. Site index for northern red oak at 50 years was an estimated 67-75 feet on the plateau and 80-90 feet in the cove. Merchantable timber was cut from both areas, and remaining hardwoods over 0.5 inch d.b.h. were deadened with chemicals. One-0 bare-rooted oak was planted.

Although survival and early growth were excellent, untreated small hardwoods and brush increasingly dominated both areas. When weeding was begun, both sites supported about 70,000 stems per acre. Competition was predominately blackberry and greenbriar on the plateau and viburnum in the cove. Each area supported about 18,000 stems of timber-producing hardwood per acre, mainly oak and yellow-poplar on the plateau and sugar maple in the cove.

Weeding was begun after planted oaks had been on the plateau 6 years and in the cove 7. Two weeding intensities were tested on both sites: (1) a single initial weeding with no

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further attempt to control competing vegetation, and (2) frequent repeated weedings designed to keep crowns continuously free from overtopping or crowding vegetation. On both sites untreated plots were also observed.

Plots were hand-weeded in early spring, soon after new leaves were fully expanded. All unwanted hardwood seedlings, sprouts, shrubs, briars, and vines were cut near the groundline. On plots scheduled for repeated weeding, stumps over 0.5 inch in diameter were sprayed with herbicide to minimize sprouting, and weeding was repeated two more times the first summer and twice during each of the next 2 years.

Plots contained six rows of six saplings each, with 5 x 8 foot spacing on the plateau and 6 x 10 in the cove. Weeding was superimposed across the rows used for original planting studies, and thus all planting variables are equally represented within each seeding plot. Treatments were replicated four times on the plateau and three in the cove, in randomized blocks. Differences in survival were evaluated by analysis of variance with planned orthogonal comparisons. Growth differences were tested by covariance analysis, with initial mean total seedling height per plot used as the covariate for periodic height growth, and initial mean diameter stump height for diameters. Results significant at the 0.05 level are reported here.

RESULTS AND DISCUSSION

Weeding increased diameter growth on both sites (table 1). Repeated weedings did not produce diameters significantly larger than a single treatment. Numerical differences between a single and multiple weedings are explained by initial diameter differences.

Best height growth in the cove was on unreleased plots. On the plateau height differences between unreleased and released oaks were not significant. Although weeding may initially slow height growth, this effect is unlikely to continue after the crowns have closed. Similar results occurred in tests conducted on 7- to 9-year-old natural stands in Ohio (Allen and Marquis 1970), where complete removal of surrounding competition reduced height growth of oak saplings and increased diameters.

Table 1.—*Initial diameter-height and 3-year diameter-height growth of northern red oak saplings*

Site and weeding intensity	Diameter		Height	
	Initial	Growth in 3 years	Initial	Growth in 3 years
	– *Inches* –		– *Feet* –	
Plateau:				
Unweeded	0.69	0.42	5.7	3.2
One weeding	.75	.71	6.2	3.1
Multiple weedings	.73	.76	5.7	2.9
Cove:				
Unweeded	.72	.60	6.3	6.1
One weeding	.58	.68	5.4	4.9
Multiple weedings	.67	1.01	6.3	5.3

Weeding had little effect on survival. All weeded saplings on the plateau survived during the 3-year study, but more than 99 percent of the unreleased oaks also survived. In the cove, the 96 percent mean survival for both levels of release did not differ significantly from the 86 percent on unreleased plots.

In the southern Appalachians, successful plantations of slow-starting species probably will require either very well-prepared sites, post-planting cultural treatments, or both. During the 3 years of this study, a single thorough release was as effective as intensive annual treatments.

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SOUTHERN FOREST EXPERIMENT STATION

1974

U.S. FOREST SERVICE RESEARCH NOTE

SO-185

Forest Service, U.S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

SITE PREPARATION IMPROVES SURVIVAL AND GROWTH OF DIRECT-SEEDED PINES

Richard E. Lohrey

SOUTHERN FOREST EXPERIMENT STATION

After 10 years on a Beauregard silt loam soil, loblolly pines direct-seeded on flat-disked strips, mound-disked strips, and in furrows survived better and were 2 to 4 feet taller than trees established on a grass rough. Planted loblollies were taller than all seeded trees except those strip-sown on flat- and mound-disked plots, and they had larger diameters than all seeded trees except those sown on mound-disked strips or in furrows. Slash pine tree to seed ratios were better on prepared sites, but the trees were about the same height and diameter in all seeding and planting treatments at age 10.

Additional keywords: *Pinus elliottii, P. taeda*, direct seeding.

Prescribed burning is frequently the only site treatment needed to establish southern pines by direct-seeding on open, grassy sites. However, early tests indicated that disking or furrowing increased survival in dry years and stimulated early height growth. Loblolly (*Pinus taeda* L.) and slash (*P. elliottii* Engelm.) pines sown on disked seedbeds were about as tall as adjacent nursery-grown seedlings planted in a grass rough (Hatchell 1961, Russell and Rhame 1961). In these tests, however, planted and seeded trees were from different seed sources. This note compares stand densities, heights, and diameters at age 10 years for loblolly and slash pines established by planting seedlings on a grass rough and by direct-seeding on several seedbeds by different sowing methods.

METHODS

The study area, located in central Louisiana, was open and grassy, typical of cutover longleaf pine land in the West Gulf Region. Soil is a Beauregard silt loam with slow internal drainage. The gently rolling topography provides adequate surface drainage, however.

Seven treatments were tested:

1. Planting 1–0 nursery stock at 6- by 8-foot spacing on a 1-year grass rough.
2. Broadcast sowing 1.0 pound of seed per acre on a 1-year grass rough.
3. Broadcast sowing 1.0 pound of seed per acre on an area with flat-disked strips 6.9 feet wide and alternate undisked balks of equal width.

4. Broadcast sowing 1.0 pound of seed per acre on an area with mound-disked strips 7.0 feet wide and alternate undisked balks of equal width.
5. Sowing at a rate of 0.5 pound per gross acre with seed confined to flat-disked strips.
6. Sowing at a rate of 0.5 pound per gross acre with seed confined to mound-disked strips.
7. Machine sowing at a rate of 0.6 pound per acre in plowed furrows spaced at 8-foot intervals.

The site was burned in May 1961 and disked 5 months later. Furrowing was done at the time of sowing in February 1962. Planted and seeded trees were from the same seed lots.

The two species were tested in separate experiments. All treatments were replicated three times in randomized block designs. Gross treatment plots were 0.4 acre, and measurements were confined to the central 0.1 acre. Stocking at age 1 year was estimated from seedling counts on randomly spaced subplots. At age 10 years all trees were counted and their diameters measured to the nearest 0.1 inch. However, diameters of all trees were influenced so much by stand density that seedbed effects were obscured. Density had less effect on the dominant stand; so diameters of the 100 largest trees per acre were compared. Total height at age 10 was measured to the nearest 1.0 foot on 10 or more dominants and codominants per plot. Data were analyzed for statistical significance at the 0.05 level by Duncan's multiple range test.

RESULTS

Loblolly Pine

Planted stands averaged 859 trees per acre after 1 year in the field and 815 trees per acre after 10 years. Survival was high: 95 percent at the first inventory and 90 percent at the second.

Stand density on seeded plots ranged from 1,635 to 3,507 trees per acre at age 1 and from 1,480 to 3,434 trees per acre at age 10 (table 1). The ratio of seedlings to seed (tree ratio) varied from 12 to 15 percent at age 1 and from 8 to 16 percent at age 10. The uniform initial success in direct-seeded treatments probably resulted from ample and generally well-distributed rainfall during the first growing season. Most mortality occurred during the second and third years. Losses were heaviest in the grass rough, where they averaged about 1,000 seedlings per acre. On broadcast plots, stocking on flat- and mound-disked strips was almost double that on grassy balks after 10 years. The increased stocking in one treatment from age 1 to 10 was attributed to sampling error in the first inventory.

At age 10, dominant and codominant trees on strip-sown plots that had been flat-disked or mounded were as tall as those planted on the grass rough (table 1). Pines in all other seeding treatments were 2.5 to 4.8 feet shorter than planted ones, which averaged 30.7 feet. Seeded trees on the grass rough were smaller than those in all other treatments except broadcasting on flat-disked strips. Pines on undisked balks were about 1 foot shorter than those on adjacent prepared strips.

Mounding did not increase height growth over

TABLE 1.—*Loblolly pine stocking, tree ratio, height, and diameter by seedbed and sowing method*[1]

Seedbed and sowing method	Trees per acre		Tree ratio		Height, age 10, dominants and codominants	Diameter, age 10	
	Age 1	Age 10	Age 1	Age 10		All trees	100 largest per acre
	— — — *No.* — — —		— — — *Percent* — — —		*Feet*	— — — *Inches* — — —	
Grass rough, broadcast	2,937	1,920	12	8	25.9d	2.8bc	4.8c
Flat-disked, broadcast	3,507	3,423	15	14	27.5cd	2.5c	4.8c
Mound-disked, strip-sown	3,034	2,623	13	11	28.2bc	2.8bc	5.2bc
Flat-disked, strip-sown	1,721	1,953	14	16	28.8abc	3.1bc	5.2bc
Mound-disked, strip-sown	1,635	1,480	14	12	30.0ab	3.5b	5.8ab
Furrowed, strip-sown	2,083	1,917	15	13	28.2bc	3.1bc	5.5ab
Planted in grass rough	859	815	[2]95	[2]90	30.7a	4.7a	6.1a

[1] Within a column, means followed by the same letter are not significantly different at the 0.05 level.

[2] Survival for planted trees.

flat-disking on this soil. Average tree heights were comparable on both mounded and flat-disked plots. These two site treatments resulted in equal heights for planted pines on a similar soil (Derr and Mann 1970).

On seeded plots, diameters of the dominant stands ranged from 4.8 to 5.8 inches. Average diameter of the 100 largest planted pines per acre was 6.1 inches, which was superior to diameters in four of the six seeding treatments. Only strip sowing on furrowed or mounded plots produced a dominant stand with diameters comparable to those of the planted pines and significantly better than those of trees in the two poorest treatments, broadcasting on grass rough or on flat-disked sites.

Slash Pine

Planted slash pine averaged 694 stems per acre at age 1 and 595 at age 10. During the 9-year period survival dropped from 76 to 66 percent.

Stand density on seeded plots ranged from 849 to 2,704 trees per acre at age 1 and from 807 to 1,410 at age 10 (table 2). At 1 year, stocking was lowest where seed was confined to mound-disked strips, but subsequent losses in this treatment were small. At 10 years, tree ratio was lowest on the grass rough (7 percent), highest where sowing was confined to disked and furrowed strips (11 to 13 percent), and intermediate where seed was broadcast on prepared seedbeds (9 to 10 percent). On broadcast plots, flat-disked strips had 39 percent more trees than adjacent balks, but stocking on mounded strips was no better than on untreated areas.

Heights of dominants and codominants at age 10 did not differ among treatments. Planted trees averaged 28.1 feet. Seeding treatments ranged from 26.1 to 28.5 feet.

Mean diameters of all trees in direct-seeded plots ranged from 3.2 to 3.7 inches. The differences were not significant. Planted trees averaged 4.1 inches, significantly larger than all seeded trees except those on plots that were disked and strip-sown. But the difference between planting and seeding treatments was not significant when only the 100 largest trees per acre were compared. Average diameter of the dominant stand ranged from 5.1 to 5.6 inches for seeded plots. For planted trees it was 5.7 inches.

CONCLUSIONS

Response of planted and seeded pines to mechanical site treatments varies by species and soil type. This study is the first time growth of direct-seeded loblolly pine has been compared among different seedbeds on a Beauregard silt loam. Seeded slash pines and planted trees of both species have previously been tested on this soil type but not always with the same results.

At age 10 years, loblolly pines sown on flat- or mound-disked strips and in furrows were taller, larger in diameter, and had survived better than trees established in a grass rough. Planted pines were taller and larger in diameter than trees on broadcast plots but no taller than those sown on flat- or mound-disked strips. Mean diameters of the 100 largest planted trees were not significantly better than those of trees strip-sown on furrowed or mounded plots.

Slash pine tree to seed ratios were better on prepared sites, but the trees were about the same height and diameter in all seeding and planting treatments at age 10. However, previous studies

TABLE 2.—*Slash pine stocking, tree ratio, height, and diameter by seedbed and sowing method*[1]

Seedbed and sowing method	Trees per acre		Tree ratio		Height, age 10, dominants and codominants	Diameter, age 10	
	Age 1	Age 10	Age 1	Age 10		All trees	100 largest per acre
	——— *No.* ———		——— *Percent* ———		*Feet*	——— *Inches* ———	
Grass rough, broadcast	1,875	963	14	7	27.4a	3.5b	5.5a
Flat-disked, broadcast	2,008	1,410	15	10	26.1a	3.2b	5.1a
Mound-disked, broadcast	2,704	1,283	20	9	26.4a	3.2b	5.3a
Flat-disked, strip-sown	1,402	900	20	13	28.5a	3.7ab	5.6a
Mound-disked, strip-sown	849	807	12	12	27.2a	3.6ab	5.4a
Furrowed, strip-sown	1,653	930	20	11	26.7a	3.5b	5.2a
Planted in grass rough	694	595	[2]76	[2]66	28.1a	4.1a	5.7a

[1] Within a column, means followed by the same letter are not significantly different at the 0.05 level.
[2] Survival for planted trees.

have shown that mechanical seedbed preparation increases both survival and growth of slash pine (Campbell and Mann 1971, Russell and Rhame 1961).

Flat-disking is the recommended site preparation treatment for both loblolly and slash pines on Beauregard soils to prevent excessive mortality of seedlings from drought during the first growing season. Both disking and furrowing improved survival and growth of loblolly, but furrowing is risky because seeds may be washed away during heavy rains, submerged, or silted over. Mounding is not recommended because it is more expensive but no more effective than flat disking and it leaves the site rough.

No important differences in stand development between broadcast or strip sowing on disked plots were apparent at age 10. When this study was installed some landowners considered hand-sowing prepared strips on areas up to several hundred acres in size. Strip seeding by hand then cost about the same as broadcasting by aircraft and saved 50 percent on the cost of seed. Now, with increased labor rates, mechanical methods are usually cheaper than hand seeding.

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SOUTHERN FOREST EXPERIMENT STATION

Forest Service, U. S. Dept. of Agriculture

1975

U.S. FOREST SERVICE RESEARCH NOTE

SO-186

10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

EVALUATION OF ANIMAL HAZARDS TO SPOT-SEEDED BLACK CHERRY IN CENTRAL TENNESSEE

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SOUTHERN FOREST EXPERIMENT STATION

On forested sites of the Cumberland Plateau, unprotected seedspots have yielded satisfactory black cherry (Prunus serotina *Ehrh.) seedling establishment. Screen protection limited depredations, but losses of exposed seed were usually too light or spotty to cause stocking failures. Since risks of serious animal damage appear slight, protection is not needed to achieve acceptable stands of direct-seeded black cherry on the Cumberland Plateau. Fall sowing of unstratified seed gave better results than spring seeding with stratified seed.*

Additional keywords: *Prunus serotina*, direct seeding, regeneration of hardwoods.

Black cherry grows well on a variety of sites throughout central Tennessee, but occurs mainly as scattered single trees or in small groups. Because a seed source is lacking on most productive sites, artificial regeneration is needed to establish this valuable species. Where steep slopes, rocky soils, or heavy logging slash increase the difficulty of planting, direct seeding is a useful regeneration alternative. Since few attempts have been made to direct-seed black cherry, the impact of animal depredations on seedling establishment is largely unknown. Studies identifying black cherry as a choice summer food of gray squirrels have not specified whether cleaned seeds are eaten as readily as the whole fruit (Davison 1964). In the mountains of east Tennessee, cherry is presumably a major food of golden mice *(Ochrotomys nuttallii)*, since seeds are found in a high proportion of their nests (Linzey 1968).

In direct-seeding trials on the Allegheny Plateau, rodents caused little damage to black cherry seed or seedlings (Huntzinger 1972), but these results may not apply to the Southern Appalachians, where variations in soil, climate, vegetation, and animal populations might produce different animal hazards. The study reported here evaluated animal hazards to spot-seeded black cherry on the Cumberland Plateau.

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METHODS

Three levels of seedspot protection were tested at 10 widely dispersed locations near Sewanee. Sowing was conducted in both fall and spring for 3 years (1965-66, 1966-67, and 1967-68) on two sites—shallow U-shaped hollows on top of the Plateau, and northerly slopes of the Plateau escarpment known locally as "coves." Soils in the hollows are mainly fine sandy loams of the Hartsells-Ramsey association that support fair-quality stands of oak and hickory with an occasional yellow-poplar or other miscellaneous species. Cove soils are dark, friable loams of the Allen or Bouldin series. Here timber types vary from oak-hickory on the dry aspects to mixed-mesophytic hardwoods on cool slopes.

The areas were partially cut at intervals for almost a century and were last logged 5 to 15 years before seeding. Since our purpose was to define the potential for animal damage, we did not deaden residual hardwoods. Deadening would have triggered a succession of herbaceous and woody vegetation and might have produced different cover types and densities for each yearly trial.

Treatments were replicated fives times in a completely randomized, split-plot design. Ten major plots—five hollows and five coves—were used. Each was in a separate hollow or cove at least 0.5 mile from all other installations and from radically different cover types such as old fields or cultivated areas. Each plot contained six subplots with 16 seedspots 6 feet apart. Hardwood litter was removed, and 10 black cherry seeds were sown ½-inch deep in mineral soil.

Each year for 3 consecutive years, unstratified seeds were sown in November and stratified seed in March. The same seedlot was used for a single fall-spring series, but different lots were sown each year. Prior to sowing, seeds were treated with dilute citric acid to enhance germination (Jones 1963). The same subplots were resown for all annual trials, after seeds or seedlings left from a previous year were removed by raking. Gross normal germination of the seedlots used for the three annual trials averaged 41 percent in the laboratory and varied little between lots.

On randomly selected subplots, seeds received one of three levels of protection from animal depredations: (1) no protection, (2) covering with 1-inch mesh wire screens that allowed passage of small rodents such as mice but barred squirrels and larger animals, and (3) covering with ¼-inch mesh hardware cloth that prevented animal access. Preliminary trials in spring 1965 had determined that the screens would provide the desired levels of protection and that seed damage could be reliably detected.

Results were expressed as percent of seedspots disturbed, as the number of seedlings obtained per 100 seed (tree percents), and as the proportion of seedspots producing one or more seedlings (initial stocking). Animal depredations are reported but not analyzed. Differences in tree percents and stocking were tested by analysis of variance after arcsine proportion transformation with separate calculations for each year. Results significant at the 0.01 level are reported. Data from the preliminary trial were not analyzed but are summarized.

RESULTS

Depredations

Animal depredations were usually light and spotty. For the 3 years combined animals disturbed 8 percent of the unprotected and 6 percent of the partially protected seedspots; totally protected plots had depredations of 1 percent or less. Losses of unprotected seeds averaged 3 percent in Plateau hollows and 14 percent on cove sites. Depredations were widespread only in spring 1968 averaging 18 percent in the hollows and 58 percent in the coves. Squirrels were unusually numerous during this period and possibly caused the depredations.

Seedling Establishment

Results expressed as tree percents paralleled depredation observations. Over the 3 years tree percents averaged 28 on unprotected seedspots, 23 under 1-inch mesh screens, and 33 on spots protected with ¼-inch mesh screens (table 1). Differences between both levels of protection and exposed seed were not significant in any year.

Fall was significantly superior to spring seeding in all annual trials, with fall catches averaging 33 percent and spring 23 percent. In 1965-66, fall seeding was better on cove

Table 1.—*Seedling establishment and seedspot stocking (data for fall and spring combined)*

Observation and type of seedspot screen	Year of test		
	1965-66	1966-67	1967-68
	– – *Percent* – –		
Tree percents [1]			
None	38	14	34
1-inch mesh	32	8	30
¼-inch mesh	36	24	39
Stocking [2]			
None	96	61	87
1-inch mesh	92	41	84
¼-inch mesh	96	76	98

[1] Number of seedlings produced during the first growing season per 100 seed sown.

[2] Percent of seedspots having one or more seedlings.

sites, while in the hollows spring was superior. No other differences related to sites and their interactions with seasons and levels of protection were statistically significant.

Seedling establishment may be influenced by such factors as seed quality and weather, as well as by animal damage. In the field, germination under ¼-inch mesh screens was only 8 percentage points lower than the potential indicated by laboratory tests. Poorer overall seedling establishment in 1966-67 was mainly because of low germination on spring-seeded plots. For this particular lot of seed, stratification prior to spring seeding was not fully effective in breaking dormancy.

With the spring 1965 trial included, the ability of seedlings to survive their first summer was evaluated in 4 consecutive years. Survival averaged 53 percent, with a 2 percentage point difference between unprotected and protected seedspots. Evidently browsing animals rarely damage newly germinated black cherry seedlings on the Cumberland Plateau.

Stocking

Stocking based on total field germination averaged 81 percent on exposed seedspots, 72 percent under 1-inch screens, and 90 percent under ¼-inch mesh screens. Stocking was not significantly different between unprotected and protected spots in any year. Fall seeding was better than spring seeding in 1966-67 and in 1967-68.

If each season of sowing at each location, including spring 1965, is considered a separate test, the study included 70 small trials. The proportion of these trials yielding various specified levels of stocking with unprotected and protected seeds are shown here:

Proportion of trials yielding seedspot stocking	No protection	¼-inch mesh screens
	– *Percent* –	
Based on total germination		
65 percent or better	80	90
50 percent or better	87	96
35 percent or better	93	99
Based on seedlings surviving one growing season		
65 percent or better	47	53
50 percent or better	63	76
35 percent or better	67	80

On unprotected spots initial stocking was 35 percent or better in 93 percent of the trials and 65 percent or better in 80 percent of the trials. Although excluding animals always increased the proportion of trials yielding a specified level of stocking, improvement was not sufficient to justify the expense of mechanical seedspot protection.

Seedling mortality during the first summer after seeding usually reduces stocking, particularly for intolerant species that are not promptly released from competing hardwoods. Even so, a stocking of 65 percent or better was obtained in nearly half the trials, and 35 percent or better was achieved in two-thirds of the trials. With adequate control of unwanted timber and brush, success in seeding cherry on cutover sites should fall somewhere between the extremes represented here by total germination and by surviving seedlings.

DISCUSSION

Animals had little effect on spot-seeded black cherry on the Cumberland Plateau. Although scattered and occasionally heavy depredations occurred, animals were not a serious or consistent threat. A cheap and environmentally acceptable repellent would help against unusual animal pressures.

The good seedling establishment obtained in these tests indicates that black cherry can be direct-seeded successfully over a range of sites in this region. Since fall sowing produced higher tree percents than spring in all 3 years, and better stocking in 2 years, fall is probably the preferred sowing season.

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SOUTHERN FOREST EXPERIMENT STATION

1975

U.S. FOREST SERVICE RESEARCH NOTE

SO-187

Forest Service, U. S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

GROWTH OF LOBLOLLY PINE FROM VARIOUSLY SELECTED PARENTS

Hoy C. Grigsby [1]

SOUTHERN FOREST EXPERIMENT STATION

During the first 10 years after planting, progenies of control-bred plus trees from Mississippi grew best, averaging 5 feet taller than the progenies of woodsrun and pole and piling quality trees from Arkansas.

Additional keywords: Heritability, additive genes, *Cronartium fusiforme*, *Pinus taeda.*

This note reports a study to compare growth of loblolly *(Pinus taeda* L.) progeny from woodsrun trees with those from parents representing some degree of selection.

Parents were (1) mixed seed of wind-pollinated woodsrun trees whose progeny are designated A, (2) wind-pollinated pole and piling quality trees, dominant or codominant, suitable for long poles and free of fusiform rust (progeny B), (3) 10 wind-pollinated plus trees (progenies CDEFGHIJKL), and (4) a control-pollinated cross of plus trees K and L, whose progeny are designated M. The ratios of select trees to all saw log size trees were 1:64 for pole and piling quality and 1:95,000 for plus trees. Progenies A-J were from southeastern Arkansas; K, L, and M (the controlled cross of K and L) were from eastern Mississippi.

Woodsrun and pole and piling progenies were grown in Arkansas State Nursery at Baucum; plus-tree seedlings were grown at Crossett, Arkansas. Methods at the two nurseries are similar, and the seedlings showed no apparent size differences when outplanted.

Progenies were planted near Crossett in a randomized block design. Each lot was replicated four times in 121-tree plots. Spacing was 8 by 8 feet.

Heights in tenths of feet were taken at the end of the first, third, and fifth growing seasons and to the nearest half foot at the end of the tenth year. Incidence of fusiform rust *(Cronartium fusiforme* Hedgc. and Hunt ex Cumm.) was recorded, and diameters breast high (d.b.h.) in tenths of inches were recorded after the tenth year. Volumes were computed by the method of Schmitt and Bower (1970).

Plot means were subjected to analyses of variance and to Duncan's test. Differences at the 0.05 level were considered significant.

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RESULTS

Survival.—After 10 years, survival among the 13 progenies ranged from 81 to 45 percent (table 1). Rigor of selection had little or no effect on survival, but progeny source had a pronounced effect. The woodsrun (A) and pole and piling (B) progenies were intermediate in survival. Survival of the three Mississippi lots (K, L, M) was poorest and differed significantly from six Arkansas progenies. Variation in survival of the 10 local lots was 22 percentage points, but few of the differences were significant. Mortality increased from 1 to 4 percentage points after age 1 for progenies of most local trees. Mississippi progenies, however, had losses of 6 to 9 percentage points between ages 1 and 10, and mortality of L and M was significantly greater than that of most of the local progenies for the period. Late mortality was caused by fusiform rust.

Growth.—Diameter of woodsrun progeny (A) ranked lowest, and that of pole and piling progeny (B) ranked third from lowest (table 1). Trees from the controlled plus-tree cross (M) ranked among the largest in diameter. Diameters breast high tended to vary directly with rigor of selection and indirectly with survival percentage.

Heights ranged from 30 to 35 feet and tended to increase with rigor of selection, although woodsrun progeny grew as well as the pole and piling progeny. Progeny M from the cross of the Mississippi plus trees grew tallest and were significantly taller than the progenies of seven other plus trees, including one of the parents. All plus tree progenies were significantly taller than offspring of woodsrun and pole and piling quality trees. The progeny of the controlled cross were 16.2 percent taller than the progeny of woodsrun trees and 5.9 percent taller than the average height of wind-pollinated plus tree progenies.

Both tree and plot volumes increased with rigor of selection. Average individual volumes at age 10 ranged from 2.33 cubic feet for the pole and and piling progeny to 3.35 cubic feet for the controlled cross. Progenies of K and M had significantly more volume per tree than eight others, but were low in plot volume because of poor survival. Progenies of the woodsrun and pole and piling parents ranked third and fifth from the bottom. Progeny J had significantly more volume per plot than six others, including the controlled cross. The plus-tree progeny averaged 7.8 percent more volume per plot than the woodsrun progeny.

Rust.—Fusiform rust incidence varied from 7 to 64 percent and appeared to be associated with seed origin rather than selection intensity. Trees from the Mississippi lots were most frequently galled. Progenies L and M had more

Table 1.—*Performance of progenies at age 10*

Progeny [1]	Percent	Diameter breast high		Height		Volume per plot		Fusiform rust	
		Progeny	Inches	Progeny	Feet	Progeny	Cubic feet	Progeny	Percent
D	81.4 [2]	K	6.83	M	35.3	J	278.4	D	7.0
G	77.7	H	6.80	J	34.8	D	271.9	F	12.8
F	74.6	M	6.68	L	34.4	G	251.9	A	15.0
J	74.0	J	6.50	I	33.9	I	248.1	G	15.1
B	72.1	L	6.38	D	33.8	H	240.1	E	16.8
I	71.7	E	6.38	K	33.7	C	227.8	I	21.0
A	70.0	C	6.33	G	33.6	F	226.5	H	21.5
C	66.5	I	6.30	C	33.0	M	216.1	C	23.8
H	62.2	G	6.20	E	32.5	B	203.3	J	28.4
E	59.5	D	6.20	H	32.5	E	202.3	B	29.1
L	54.8	B	6.05	F	31.8	A	199.2	K	45.8
M	53.3	F	6.03	A	30.4	L	198.1	M	54.2
K	45.5	A	6.00	B	30.1	K	183.7	L	64.4

[1] Progeny identification

A: From woodsrun trees, mixed sced

B: From pole and piling quality trees, mixed seed

C-J: From individual local wind-pollinated plus trees

K & L: From individual Mississippi wind-pollinated plus trees

M: From controlled cross of K × L.

[2] Means not opposite the same line differ significantly (0.05 level) by Duncan's test.

rust than all local progenies. Differences among progenies of Arkansas parents were usually minor.

DISCUSSION

Survival of the Arkansas progenies was highest in this test and has been among the highest in previous studies (Grigsby 1973, Wells and Wakeley 1966).

Some of the growth superiority of the Mississippi progenies may be due to geographic seed source. Results from a previous test showed that trees from three Mississippi loblolly pine sources averaged 8 percent better growth at age 10 than Arkansas trees.

Mississippi progenies K and L are being evaluated in another Arkansas planting. Ten-year results confirmed the superior vigor of the Mississippi trees, which had 76.6 percent survival and only 3.5 percent rust infection. The progeny of their controlled cross (M in the present study) had 71.6 percent survival, compared to 71.4 percent for the woodsrun, and produced 35.8 percent more volume per tree than the woodsrun progeny. After the 8 percent gain from geographic seed source was subtracted, the controlled cross still produced 27.8 percent more volume than woodsrun trees. Progeny K were also tested in Georgia (Sluder 1973), where they were the most vigorous of the six lots planted. These data, plus results from seed-source studies that included Mississippi stock, indicate that in the present study survival was lower and incidence of rust higher than what might normally be expected for Mississippi trees planted in Arkansas.

The fact that the seedlings were grown in two nurseries might have influenced the results, but a previous experiment showed that nursery effects were no longer meaningful 3 years after planting.[2] In another planting at Crossett, the woodsrun progeny and progenies K, L, and M, all grown in the same nursery, showed even greater differences in growth performance than in the present study.

[2] Grigsby, H. C. The survival and growth of loblolly pine as influenced by nursery source. Final office report, FS-SO-1107-11.14 August 31, 1961.

Because individual tree diameters were influenced by spacing variation brought about by survival differences, height variation—which is less affected by spacing—should show the most valid genetic influence. Progeny of the controlled cross were significantly taller than most of the progenies of the wind-pollinated plus trees. More controlled crosses might have produced different results, but when inheritance is conveyed additively, the progeny of a controlled cross usually perform better in the traits for which the parents were selected than wind-pollinated progeny.

Controlled-cross progeny were superior in tree volume, but ranked eighth in plot volume. However, the Mississippi parents were somewhat susceptible to fusiform rust, which caused the poor survival. Parents with both growth potential and rust resistance should produce progeny with superior plot volume as well as tree volume.

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SOUTHERN FOREST EXPERIMENT STATION

1975

U.S. FOREST SERVICE RESEARCH NOTE

SO-188

Forest Service, U. S. Dept. of Agriculture

-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

LONGLEAF SEEDLINGS SURVIVE FIRE IN CLEARCUT STRIPS

Thomas C. Croker, Jr. [1]

SOUTHERN FOREST EXPERIMENT STATION

Large grass-stage longleaf pine (Pinus palustris *Mill.) seedlings in clear-cut strips suffered little mortality (maximum 6 percent) from prescribed burns of three intensities. Losses were higher on the east than on the west sides of openings.*

Additional keywords: *Pinus palustris,* prescribed fire, clearcuttings.

Large even-aged units are efficient for longleaf pine management, but on many ownerships recreation, or aesthetic objectives limit openings to small areas or narrow strips. Too small to be economically excluded from fires prescribed for control of understory brush and other purposes, such areas are prone to seedling losses unless burning is done under favorable circumstances. Earlier research [2,3,4] points to seedling diameter, fire intensity, and proximity to standing timber as major factors in determining seedling survival in such fires.

This note reports mortality when longleaf pine seedlings of fire-resistant sizes were subjected to burns at three intensity levels. The seedlings were at varying distances from north-south timber walls on the Escambia Experimental Forest in southern Alabama.

METHODS

Selected 1-0 seedlings from the Atmore nursery of the Alabama Forestry Commission were planted in six blocks, three on deep Alaga loamy sand and three on Bowie sandy loam with sandy clay subsoil. In each block planting was on a 120-foot-wide north-south cleared strip within a longleaf pine stand of saw log size. Four strips were clearcut in December 1970; the other two had been cleared earlier. Each strip was divided into four segments, to which three intensities of fire and an unburned check were assigned randomly. In each segment four rows of planting locations three feet apart extended from the east and west timber walls to the strip centerline (fig. 1). Locations within rows were at 6-foot spacings.

[1] Principal Silviculturist, recently retired, at the Southern Forest Experiment Station, Brewton, Alabama.

[2] Davis, V. B. Don't keep longleaf seed trees too long! USDA For. Serv., South. For. Exp. Stn., South. For. Notes 98. 1955.

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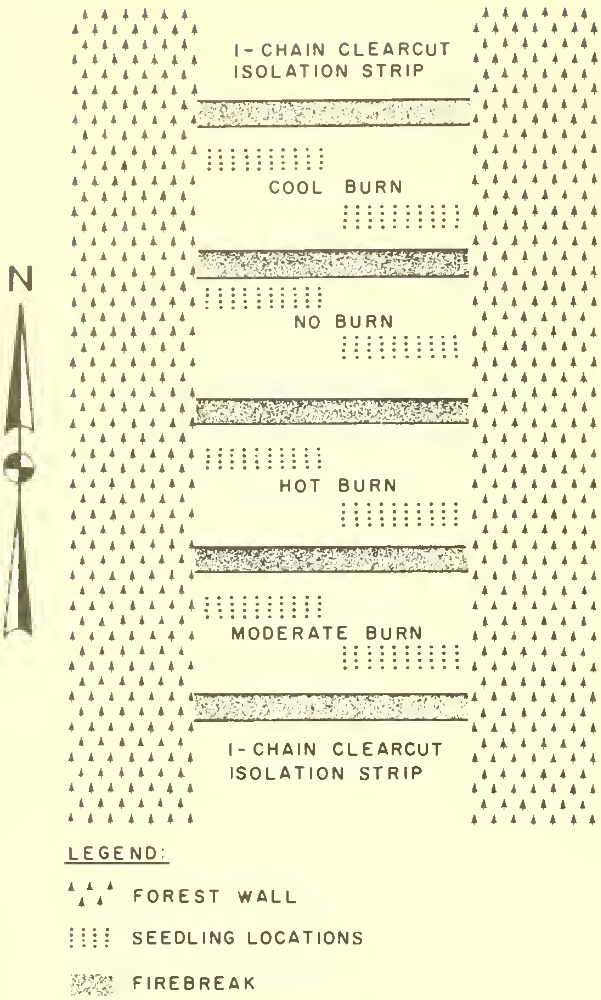

Figure 1.—*Typical block layout.*

Seedlings were planted, and their locations permanently marked, in February 1971. All were vigorous and over ½ inch in diameter at the rootcollar. Mortality due to pales weevil (*Hylobius pales* Herbst.) in the freshly cut blocks necessitated replacement of many seedlings with similar stock in February 1972. When burns were applied, beginning in January 1973, the younger seedlings had been in place one full growing season; seedlings from both years were between 0.6 and 1.0 inch in diameter; none had started height growth.

Burning conditions are summarized in table 1.

Mortality was recorded in November 1973. For each block, mean mortality rate in the unburned segment was deducted from total mortality in each burned segment to estimate mortality due to burning.

RESULTS

Fire losses were light, averaging 4 percent (table 2). Mortality from the hot fires appeared to be higher than that from the cool and moderate fires, but the difference was not significant at the 0.05 level of probability. Mortality was not significantly related to soil type (losses averaged 4 percent on Bowie and 3 percent on Alaga) or distance from the timber walls. Mortality in the hot burn on eastern sides of cleared strips, 8 percent, was significantly greater than that (2 percent) on western sides.

Low mortality reflects the fire resistance of large (>0.5 inch diameter) grass-stage longleaf pine seedlings; all were of large size when planted and none had been in place long enough to be greatly affected by site differences or competition. Absence of high mortality nearest timber walls suggests that where such effects have been observed [2,3] they may have resulted primarily from seedling suppression rather than from hotter fire due to needle fall. Higher mortality in the eastern half of

Table 1.—*Weather conditions when burns were made*

Item	Cool	Moderate	Hot
Date	1-11-73	1-15-73	5-10-73
Time	12 noon-1:30 pm	10:00 am-1:00 pm	1:00 pm-3:35 pm
Last previous rain			
Date	1-11-73 (before the burn)	1-12-73	5-8-73
Amount, inch	0.12	0.02	0.50
Humidity, percent	55	65-32	40-35
Temperature, °F	48	55	85
Sky	Cloudy	Clear	Clear
Wind			
Mph	2-5	0-7	Light
Direction	NE	NW	Variable

Table 2.—*Fire losses in relation to fire treatment, soil, and exposure*

Exposure, soil type, and block number	Cool burns	Moderate burns	Hot burns	Mean
	Percent			
Eastern side				
Bowie 1	0	0	20	7
Bowie 2	5	0	3	3
Bowie 3	0	0	3	1
Alaga 4	0	13	7	7
Alaga 5	0	0	0	0
Alaga 6	16	0	13	10
Mean, eastern	4	2	8	5
Western side				
Bowie 1	0	8	5	4
Bowie 2	8	0	0	3
Bowie 3	22	2	10	11
Alaga 4	8	10	0	6
Alaga 5	0	0	0	0
Alaga 6	0	0	0	0
Mean, western	6	3	2	4
Mean, both sides	4	2	5	4

north-south strips probably reflected drying of fuels by afternoon insolation; the western halves of the test strips were progressively shaded after noon. A similar effect is likely on east-west strips, whose northern sides receive more insolation, especially in winter.

These results suggest that after seedlings have reached resistant sizes, prescribed burns can be run through small openings or narrow strips without excessive seedling losses.

SOUTHERN FOREST EXPERIMENT STATION
Forest Service, U. S. Dept. of Agriculture
1975
U.S. FOREST SERVICE RESEARCH NOTE
SO-189
T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS LA. 70113

CHEMICAL INJECTIONS FOR THINNING POLE-SIZE HARDWOODS IN THE OZARKS [1]

Edwin R. Ferguson and Edwin R. Lawson [2]
SOUTHERN FOREST EXPERIMENT STATION

A combination of picloram and 2,4-D was more effective than 2,4-D alone. With both herbicides, dormant-season injections gave slower and less complete kills than applications during the growing season.

Additional keywords: Herbicides, Tordon 101, picloram, 2,4-D.

This note reports on the effectiveness of injected 2,4-D and Tordon 101 (picloram + triiscopropandlamine salt of 2,4-D) on a variety of hardwood species in the Ozark Mountains of Arkansas. The trees averaged between 4.4 and 9.6 inches in diameter and were on north slopes generally considered suitable for hardwoods. They were overdense and needed thinning.

In most of the Southeastern U. S., a ready market exists for pole-size hardwoods. In the Ozarks, by contrast, such trees usually cannot be sold. Thinning is consequently an expense rather than a source of income, and management of the stands is seldom attempted. The purpose of the research was to determine if chemical injections—which are reasonably economical by comparison with other methods—would deaden the unwanted trees.

PROCEDURES

The data are from 36 widely scattered half-acre plots on the Ozark National Forest. A total of about 850 trees were treated, but all species were not equally represented.

Metered injections of 1 ml of the concentrated formulations were made at 3-inch spacings during the dormant season (February 1970) and the growing season (late May and early June, 1970) by experienced research personnel. In the late summers of 1970, 1971, and 1972 each treated stem was evaluated and the

[1] This publication reports research involving herbicides. It does not contain recommendations for their use nor does it imply that the uses discussed here have been registered. All uses of herbicides must be registered by appropriate State or Federal agencies before they can be recommended. Commercial products are mentioned for information only; such mention does not constitute recommendation by the U. S. Department of Agriculture.

[2] Principal Silviculturist and Research Hydrologist, Southern Forest Experiment Station, Forest Service, USDA, Fayetteville, Arkansas.

proportion of crown reduction (top-kill) was estimated visually to the nearest 5 percent, then averaged by species and treatment. Crown reductions of 90 to 100 percent were considered satisfactory, 80 to 89 percent marginal, and under 80 percent unsatisfactory.

RESULTS

Within the first growing season after treatment, satisfactory control was achieved by all treatments on six species—southern red oak, black oak, blackjack oak, white oak, post oak, and elm (table 1).[3] Black walnut was satisfactorily controlled with all combinations except 2,4-D injected in the dormant season; here marginal control was achieved in the first year and subsequent evaluations showed no change.

Cherry was satisfactorily controlled during the first year by growing-season injections of both chemicals and by winter injection of Tordon 101, but was not satisfactorily controlled by dormant-season injections with 2,4-D until the second growing season (18 months after treatment).

Growing-season injections of both chemicals on persimmon gave satisfactory control within 3 months. No sample stems were injected with 2,4-D during the winter but Tordon 101 injected at that period resulted in only marginal control after 18 months.

Black locust was satisfactorily controlled during the first year by growing-season injection of 2,4-D and dormant-season injection of Tordon 101.

Growing-season injections of Tordon 101 were effective on mulberry within 3 months. The only other combination investigated, winter injection of 2,4-D, achieved satisfactory control after 18 months.

On blackgum stems, the only satisfactory treatment for early control was 2,4-D injected during the growing season. Tordon 101 was satisfactory by the second year regardless of the season of injection, but trees receiving 2,4-D in the winter were only marginally controlled after 18 months.

Dormant-season injections with Tordon 101 provided early control of hickory, essentially a verification of previously reported data by Ferguson and Lawson.[4] All of the other combinations gave satisfactory control by the second year.

Dogwood was controlled only with Tordon 101 injected in the dormant season.

Maple stems were highly resistant to all treatments except Tordon during the growing season.

No ash stems were injected with Tordon, but 2,4-D had absolutely no effect.

CONCLUSIONS

Overall, the most effective combination was growing-season injection of Tordon 101, which by the end of 18 months had achieved in excess of 90 percent crown kill of all species except dogwood and maple and on these gave crown kill exceeding 80 percent.

In contrast, the poorest combination was 2,4-D injected in the dormant season. It gave poorer kill than Tordon on eight species as well as being virtually a total failure on dogwood, maple, and ash.

[3] No important changes occurred after the second growing season (15 and 18 months) and data are not shown in the table.

[4] Lawson, Edwin R., and Edwin R. Ferguson. Chemical for winter kill of hickories in the Ozark-Ouachita Highlands. Ark. Farm Res. 23(2): 16. 1974.

Table 1.—*Percent of crown-kill by chemical, season of application, time after injection, and species*

Species	Dormant season								Growing season							
	Tordon 101				2,4-D				Tordon 101				2,4-D			
	No. stems	Avg. d.b.h.	6 mos.	18 mos.	No. stems	Avg. d.b.h.	6 mos.	18 mos.	No. stems	Avg. d.b.h.	3 mos.	15 mos.	No. stems	Avg. d.b.h.	3 mos.	15 mos.
Southern red oak, *Quercus falcata* Michx.	20	8.1	99	100	25	7.7	94	94	45	9.9	97	100	38	9.9	99	100
Black oak, *Q. velutina* Lam.	22	9.6	100	100	45	11.3	97	97	22	7.2	99	100	15	7.7	99	100
Blackjack oak, *Q. marilandica* Muenchh.	2	9.3	100	100	1	4.6	100	100	1	15.6	100	100	2	9.3	100	100
White oak, *Q. alba* L.	54	7.2	100	100	44	7.3	94	100	33	7.7	92	100	39	6.7	94	99
Post oak, *Q. stellata* Wangenh.	11	7.4	100	100	15	10.6	100	100	13	7.7	99	100	19	7.3	99	100
Elm, *Ulmus* spp.	1	4.4	100	100	3	6.1	100	100	4	7.0	100	100	7	6.5	100	100
Black walnut, *Juglans nigra* L.	2	6.1	100	100	3	5.8	87	87	2	5.9	100	100	2	5.2	100	100
Cherry, *Prunus serotina* Ehrh.	6	8.9	100	100	2	11.1	25	90	1	5.3	100	100	3	8.4	100	100
Persimmon, *Diospyros virginiana* L.	3	6.5	63	83	0				2	4.5	100	100	4	8.3	95	100
Black locust, *Robinia pseudoacacia* L.	3	7.4	100	100	4	6.7	78	98	3	8.2	88	100	3	6.5	100	100
Mulberry, *Morus rubra* L.	0		...		2	5.5	90	90	1	6.0	100	100	0		...	
Blackgum, *Nyssa sylvatica* Marsh.	11	7.6	79	96	17	8.7	58	88	10	7.8	86	91	11	6.6	95	100
Hickory, *Carya* spp.	58	6.8	93	94	31	6.4	35	96	49	6.5	76	100	45	6.6	81	100
Dogwood, *Cornus florida* L.	4	4.4	100	100	3	4.1	7	3	9	4.6	79	84	11	4.1	47	55
Red maple, *Acer rubrum* L.	15	6.3	0	1	27	5.7	0	5	9	5.2	82	89	7	5.1	6	9
Ash, *Fraxinus* spp.	0		...	...	2	7.0	0	0	0			...	2	4.6	0	0

☆U.S. GOVERNMENT PRINTING OFFICE: 1975- 673-420/50 Region No. 7

SOUTHERN FOREST EXPERIMENT STATION

1975

U.S. FOREST SERVICE
RESEARCH NOTE

SO-190

Forest Service, U. S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

SIX-STATE TEST OF ARKANSAS LOBLOLLY PINE

Hoy C. Grigsby [1]

SOUTHERN FOREST EXPERIMENT STATION

Loblolly pines from a Crossett, Arkansas, seed source were tested against trees from the local seed source in 16 plantations in six Southern States. Trees from some of these areas were also tested against local stock at Crossett. After 10 years, Crossett trees survived better than certain other sources in six plantations and had less rust in three. In cubic-foot volume per plot, trees from the Crossett source were inferior to those of other sources in six plantations and superior in two.

Additional keywords: Geographic variation, *Cronartium fusiforme*, *Pinus taeda*.

Do the vigorous, high-quality stands of loblolly pine *(Pinus taeda* L.) in the vicinity of Crossett, Arkansas, represent a superior geographic race? As interest in seed-source testing increased during the 1950's, visitors frequently asked this question about the pines in the general area bounded on the west by the Saline and Ouachita Rivers and on the east by Bayou Bartholomew.

A cooperative study was begun in 1953 to gain information on the subject. Ten cooperators,[2] at several locations, established plantations to compare Crossett materials with stock from local sources. Some cooperators, in turn, sent samples of their local seed for testing at Crossett. This note reports 10-year results from 16 plantations in six Southern States.

METHODS

The 16 plantations were established over a period of 3 consecutive years: seven during the first winter (1953-1954), three during the second winter, and six during the third. Locations are shown in figure 1.

Seed lots were those available to the cooperators at the time the study was initiated, and the exact origin of certain lots is unknown. All seed was collected from woodsrun trees, and seedlings planted at each site were grown in the same nursery. Planting sites were mostly abandoned fields. Experimental design was patterned after the Southwide Pine Seed Source Study (Wells and Wakeley 1966).

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[2] Georgia-Pacific Corporation, Tennessee Valley Authority, Continental Can Company, Louisiana Forestry Commission, Arkansas Agricultural Experiment Station, Louisiana State University School of Forestry, Mississippi Forestry Commission, Louisiana Tech University Department of Forestry, Auburn University Department of Forestry, and West Virginia Pulp and Paper Company.

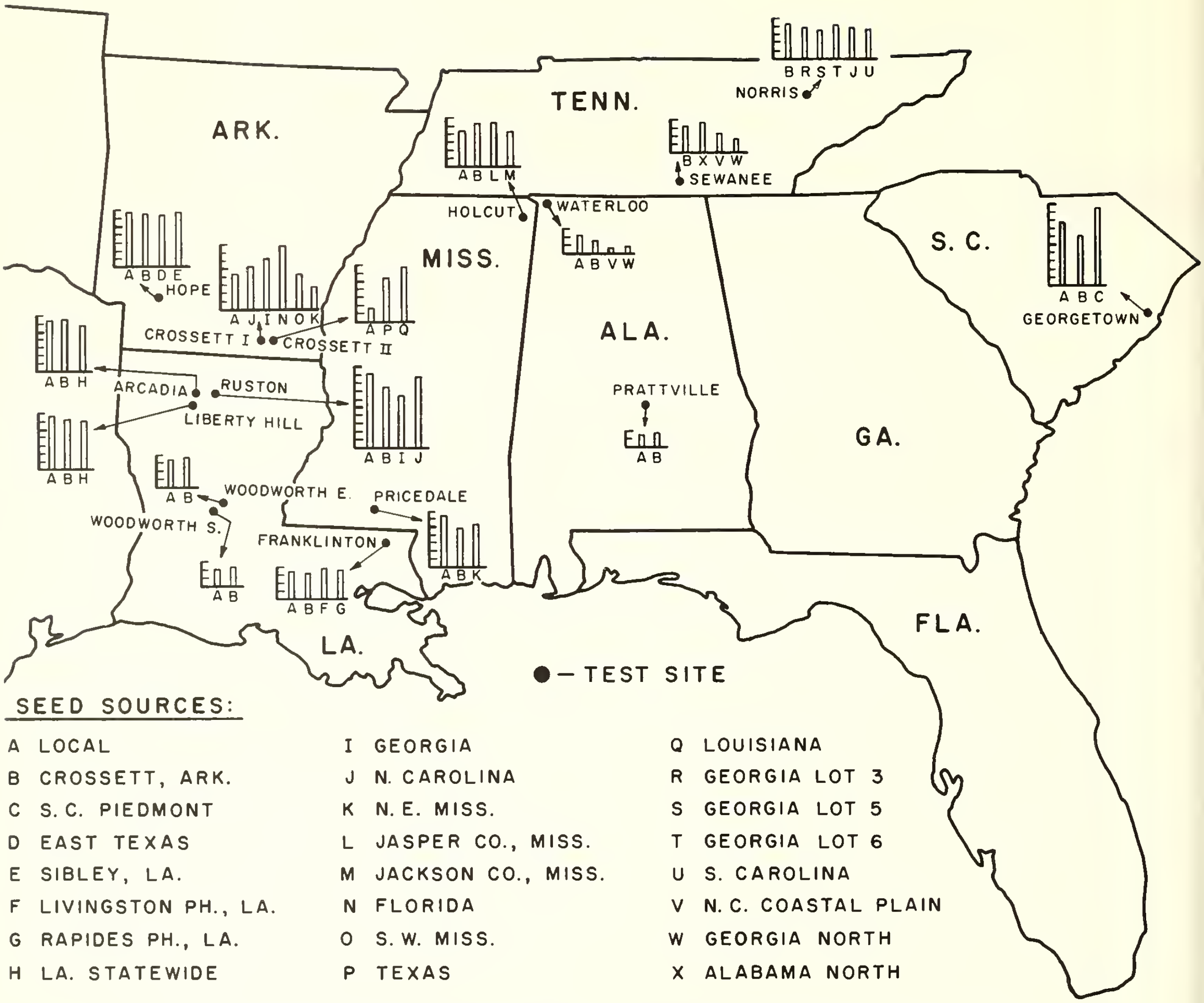

Figure 1.—*Relative cubic foot volume per plot by seed source at each test location after 10 years. Each segment of graduated columns equals 10 cubic feet.*

Plantings were arranged as randomized blocks, with each source replicated four to six times in 121-tree plots. Spacing was 6 by 6 feet. The inner square of 49 trees was measured.

Analyses of variance were computed on 10-year data for each recorded trait at each location. Heights were measured in tenths of feet and diameters at breast height in tenths of inches. Absolute volumes per plot were based on the size of the average tree and were computed by the method of Schmitt and Bower (1970). Arc sin $\sqrt{\text{proportion}}$ transformations were made on percentages expressing survival and incidence of the southern fusiform rust (*Cronartium fusiforme* Hedgc. and Hunt ex Cumm.). Trees were considered to have rust if either stems or branches were infected. Differences among seed-source means were appraised by Duncan's multiple range test. All tests were at the 0.05 probability level.

RESULTS

Survival.—Survival of trees from the Crossett source was 76 percent, as compared to an average of 70 percent for all others. Crossett trees survived significantly better than certain other sources in six plantations and had the highest numerical average in 12 of the 16 plantations (table 1).

Height.—In three plantations, including one at Crossett, trees from other sources were taller than Crossett trees, while Crossett trees were superior to none. In all plantations, Cros-

Table 1.—*Data summary by plantation* [1]

Plantation	Seed source	Survival	Rust infection	Height	D.b.h.	Volume per plot
		Percent	*Percent*	*Feet*	*Inches*	*Cubic feet*
Georgetown, S. C.	S. C. Lot 6	69.4a	23.5a	36.4a	5.3a	79.9a
	S. C. Piedmont	67.4a	32.4a	38.2a	5.8a	95.9a
	Crossett, Ark.	66.3a	6.2a	32.6b	5.1a	61.1a
Hope, Ark.	Crossett, Ark.	95.4a	2.1a	29.9a	4.7a	66.8a
	La. (Sibley)	92.4a	2.8a	31.2a	4.7a	68.8a
	Local	91.8a	2.2a	30.9a	4.8a	68.8a
	E. Texas	72.5b	2.8a	32.5a	5.1a	63.9a
Woodworth, La. (East)	Crossett, Ark.	90.8a	10.1a	25.5a	3.9a	36.9a
	La.	84.0a	10.5a	25.2a	3.8a	32.9b
Woodworth, La. (South)	Crossett, Ark.	56.1a	24.9a	23.6a	4.0a	23.1a
	La.	53.4a	20.8a	23.1a	3.8a	20.3a
Franklinton, La.	Crossett, Ark.	74.0a	50.0b	24.7a	4.1a	31.4a
	Liv. Parish, La.	67.0a	48.9b	29.5a	4.4a	39.3a
	Local	66.0a	78.6a	27.0a	4.3a	33.2a
	Rap. Parish, La.	64.0a	45.7b	27.8a	4.5a	36.2a
Arcadia, La.	Crossett, Ark.	90.2a	18.1a	29.5a	4.8a	65.9a
	Local	89.8a	23.2a	29.7a	4.8a	64.7a
	La. (statewide)	80.8a	21.2a	29.2a	4.8a	58.5a
Liberty Hill, La.	Local	95.1a	9.8a	31.1a	4.7a	68.7a
	Crossett, Ark.	90.2a	10.8a	30.2a	4.6a	61.4b
	La. (statewide)	86.1a	9.5a	31.0a	4.6a	60.4b
Ruston, La.	Crossett, Ark.	95.4a	0.0a	26.9ab	5.3bc	75.7b
	La.	91.8ab	3.2a	29.0a	5.7ab	90.4a
	N. C.	87.8b	0.0a	28.7a	5.8a	89.0a
	Ga.	87.2b	0.0a	25.5b	5.1c	64.1b
Pricedale, Miss.	Crossett, Ark.	91.4a	4.0a	27.8b	4.2b	48.4b
	S. W. Miss.	90.6a	6.8a	32.1a	4.5a	63.1a
	N. E. Miss.	85.3a	11.5a	28.9b	4.4a	51.4b
Holcut, Miss.	Crossett, Ark.	90.6a	0.0b	27.2ab	4.6a	54.2a
	Jasper Co., Miss.	88.2a	4.2a	29.0a	4.5a	54.4a
	Local	81.6ab	3.5a	25.6b	4.4a	42.8b
	Jackson Co., Miss.	66.9b	3.1a	26.3b	4.7a	41.7b
Prattville, Ala.	Crossett, Ark.	35.9a	3.3b	22.9a	4.2a	16.0b
	Local	25.4b	33.3a	22.7a	4.4a	17.6a
Crossett, Ark. Test I	Crossett, Ark. (Local)	98.8a	18.6a	26.5b	5.8b	41.8bc
	Ga.	86.3ab	62.8a	28.6b	4.9b	62.6ab
	N. C.	80.2b	19.5a	26.7b	4.8b	51.5abc
	Fla.	59.7b	43.3a	33.2a	6.2b	78.4a
	S. W. Miss.	19.5c	21.9a	31.7ab	7.6a	40.8bc
	N. E. Miss.	12.4c	37.5a	29.6ab	8.5a	27.6c
Crossett, Ark. Test II	La.	94.9a	18.1a	29.2a	4.9a	69.7a
	Texas	87.0a	10.4a	27.8a	4.6a	53.6a
	Crossett, Ark. (Local)	48.1b	18.6a	28.8a	3.0b	15.7b
Norris, Tenn.	Crossett, Ark.	91.3a	0.0	24.7a	4.1a	41.2a
	Ga. Lot 6	85.7ab	0.0	26.4a	4.1a	40.7a
	N. C.	85.2ab	0.0	26.8a	4.0a	39.7a
	Ga. Lot 3	84.7ab	0.0	25.8a	4.2a	39.8a
	Ga. Lot 5	81.6ab	0.0	26.3a	4.0a	36.4a
	S. C.	75.5b	0.0	26.0a	4.3a	38.8a
Waterloo, Ala.	Crossett, Ark.	29.6a	22.4a	25.4a	4.6a	15.5a
	Ala. N.	29.6a	32.8a	27.6a	4.9a	20.7a
	N. C. Coastal Plain	10.2a	25.0a	25.4a	6.1a	6.8a
	Ga. N.	8.7a	17.7a	27.1a	5.7a	9.4a
Sewanee, Tenn.	Ala. N.	80.6a	0.6a	26.6a	4.0a	37.1a
	Crossett, Ark.	70.4a	3.6a	27.7a	3.9a	31.0a
	N. C. Coastal Plain	50.0a	0.0a	26.7a	4.1a	22.0a
	Ga. N.	48.0a	3.3a	24.9a	3.6a	17.9a

[1] Within a particular plantation, values followed by the same letter do not differ significantly (0.05 level) by Duncan's test.

sett trees averaged less tall than trees from 29 other sources and equal to or slightly taller than trees from 12 sources.[2] Greatest height (37.3 feet average) was attained by trees from the two South Carolina sources in the plantation at Georgetown, South Carolina. Slowest average height growth was made at Prattville, Alabama, by local and Crossett sources.

Diameter.—In line with the pattern for height growth, the Crossett source did not significantly excel in any plantation. In four plantations—including the two at Crossett—seven other sources had significantly larger diameters. In one of these tests, however, poor survival gave the remaining trees of two sources an advantage in growing room. If this single instance of bias is excluded, trees with the largest average diameters were attained by the Florida source at Crossett, by a South Carolina source at Georgetown, South Carolina, and by a North Carolina source at Ruston, Louisiana.

Volume.—The Crossett trees had significantly greater volume than trees from one or more other sources in two of the 16 tests. In six plantations, Crossett trees produced significantly fewer cubic feet of wood per plot than one or more other sources. In four of these, the two Crossett tests being the exceptions, the local trees produced the greatest average volume.

Greatest average volume per plot (95.9 cubic feet) was attained by the South Carolina Piedmont source at Georgetown, South Carolina, and by the Louisiana (90.4 cubic feet) and North Carolina (89.0 cubic feet) sources at Ruston, Louisiana (table 1, fig. 1).

Fusiform rust.—Rust incidence was generally low, but varied significantly in three of the plantations. In all of these, Crossett trees had less rust than the local trees. In no case did the Crossett trees have significantly more rust than others. The Franklinton, Louisiana, plots had the greatest average incidence of rust, ranging from 46 to 79 percent. Next in severity of infection were the plantations at Crossett; Prattville and Waterloo, Alabama; and Georgetown, South Carolina. The plantation at Norris, Tennessee, had no rust. Trees from Alabama, Georgia, Florida, and eastern Mississippi were most frequently infected.

[2] Some sources occur in more than one plantation.

DISCUSSION AND CONCLUSIONS

Trees from the Crossett seed source tended to excel in survival and resistance to fusiform rust. But in volume per plot they were more often inferior than superior to other sources, even in plantations where they were the local source.

The overall good survival of the Crossett trees in comparison to that for other sources agrees with findings of the Southwide Pine Seed Source Study (Wells and Wakeley 1966). Results further suggest that survival would not be a limiting factor in moving trees from some East Coast sources to Arkansas.

Wakeley (1961) found that sources of loblolly pine increased in susceptibility to fusiform rust from west to east. In an Arkansas study, I tested trees from more than twice as many sources and found similar clinal variation; stock from eastern Alabama, western Georgia, and northern Florida was most susceptible (Grigsby 1973). The same study also showed susceptibility decreasing from south to north along the Atlantic Coast. Wells and Switzer (1971) tested many Mississippi loblolly pine seed sources in southeastern Louisiana and found a decrease in rust susceptibility to the north and west. In the present study, the incidence of rust on stock from eight sources suggested a similar trend in trees grown at Crossett, although the differences were not significant. In extensive testing in Georgia, Kraus (1967) found trees from an Arkansas loblolly pine source more resistant than trees from Florida and Georgia.

Local trees produced significantly more volume in only four of the 16 plantations, an indication that more detailed seed source testing may be needed for some areas.

Trees from the Atlantic coastal States were among the fastest growers. This finding reinforces earlier data indicating that sources from coastal areas perform well when moved inland (Grigsby 1973, Goggans *et al.* 1972, Lantz and Hofmann 1969, Kraus 1967, Wells and Wakeley 1966). These reports, however, are based on data from plantations no more than 10 years old. Ranking may change in the future as height growth of all sources slows.

How close to the northern boundary of the natural range can coastal sources be moved?

The answer remains uncertain, but locations near or just north of the species' range appear too severe. In the present study, trees from Crossett and north Alabama outperformed North Carolina Coastal Plain trees at Sewanee, Tennessee, and at Waterloo, in northern Alabama. Farther north in the Cumberland Mountains trees from the North Carolina Piedmont grew better than those from the coastal plains of North and South Carolina (Thor 1967). In plantations near the northern edge of loblolly's range, Zarger (1961) reported that inland sources made better diameter growth than coastal trees. Wells and Wakeley (1966) also found that inland and local sources grew fastest in the two northernmost plantings of the Southwide Study.

On the basis of this study, there appears to be little reason for moving Crossett stock to other locations.

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☆ U.S. GOVERNMENT PRINTING OFFICE 1975—673-489

SOUTHERN FOREST EXPERIMENT STATION

1975

U.S. FOREST SERVICE RESEARCH NOTE

SO-191

Forest Service, U. S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

RELATIONSHIP OF PERSONNEL CHARACTERISTICS TO FIRE PREVENTION EFFECTIVENESS

M. L. Doolittle, M. H. Kootsher, and C. V. Mercer [1]

SOUTHERN FOREST EXPERIMENT STATION

In a study of North Carolina Forest Service personnel, effectiveness appeared related to the ability to communicate, acceptance of self and others, achievement orientation, and motivation toward self-improvement.

Additional keywords: Recruitment, placement.

The most effective forest fire prevention programs in the rural South convey information by means of face-to-face contact between fire prevention personnel and individuals in a community (Griessman and Bertrand 1967, Dickerson and Bertrand 1969, Doolittle 1972, Doolittle and Welch 1974). Both the personality of the communicator and the content of his message may influence a community's reception of the prevention program. We are attempting to determine the influence of a communicator's personal traits on his effectiveness, as such information might prove useful for the selection and placement of employees.

METHODS

The initial study was conducted within the North Carolina Forest Service. Two positions in that organization (county ranger and assistant county ranger) require the employee to conduct face-to-face fire prevention activities with local citizens One-hundred thirty-seven employees who continuously filled these positions in 94 counties from 1968-1972 comprised the sample population. All were white males with similar demographic, residential, and military backgrounds.

We attempted to quantify fire prevention effectiveness in each county by computing an effectiveness ratio, based on the assumption that each employee's performance was influencing the occurrence of fires in his county.

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We divided the number of man-caused fires in a county in 1968 and 1969 into the number of fires in 1971 and 1972:

$$\text{Effectiveness Ratio} = \frac{\text{Man caused fires 1971-72}}{\text{Man caused fires 1968-69}}$$

Each ranger and assistant ranger was assigned the effectiveness ratio of his county.

Members of the study population completed a questionnaire that contained 63 items about attitudes and values. They were randomly arranged and required a dichotomous response (yes-no). The questions were adapted from eight scales used in previous studies of employee effectiveness.[2] The qualities evaluated were:

Conformity. Adherence to norms of the work group (Peterson 1964).

Communityness. Identification with community and participation in its activities (Fanelli 1956).

Self-improvement. Motivation to strive toward the expansion of mental potentialities (Dean 1964).

Extroversion. Direction of interests and energies toward people and events (Peterson 1964).

Occupational primacy. Importance placed on occupation (Kahl 1965).

Acceptance of self and others. Acceptance of own social-psychological position and that of others (Berger 1952).

Communication. Ability to convey ideas effectively (Dean 1964).

Achievement orientation. Attitudes toward success (Rosen 1956).

An employee's score on each scale was determined by counting the number of responses indicating a high position on that scale. Correlations between fire prevention effectiveness and scale scores were evaluated by path analysis (Blalock 1967, Li 1956, Duncan 1966).

RESULTS AND DISCUSSION

Fire-prevention effectiveness ratios ranged from 0.11 to 4.26, with low ratios indicating greater effectiveness than high ones. For example a ratio of 0.5 represents a 50 percent reduction in fires, 1.0 represents no change, and 2.0 represents twice as many fires in 1971-72 as in 1968-69.

[2] The questionnaire is not presented in this paper because additional tests of validity and reliability are needed before publication.

The path coefficient of each scale is the proportion of variation in the effectiveness ratios explained by that personnel characteristic. Coefficients between scale scores and effectiveness ratios were:

Communication	.19
Acceptance of self and others	.17
Achievement orientation	.15
Self-improvement	.13
Occupational primacy	.10
Communityness	.06
Extroversion	.05
Conformity	.02
Total	.87

The eight scales accounted for 87 percent of the variation. Communication, acceptance of self and others, achievement orientation, and self-improvement appeared closely related to fire-prevention effectiveness, but communityness, extroversion, and conformity did not.

We are currently modifying our technique for evaluating fire prevention effectiveness to overcome weaknesses in the present method. The North Carolina Forest Service is screening applicants for county ranger and assistant ranger with an operational version of the 63 questions on attitudes and values. By studying the performance of the employees selected, we hope to establish the relationship of their scores to their effectiveness as fire-prevention personnel.

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SOUTHERN FOREST EXPERIMENT STATION

1975

U.S. FOREST SERVICE RESEARCH NOTE

SO-192

Forest Service, U. S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

VEGETATIVE RESPONSE TO TWELVE YEARS OF SEASONAL BURNING ON A LOUISIANA LONGLEAF PINE SITE

Harold E. Grelen [1]

SOUTHERN FOREST EXPERIMENT STATION

*After 12 years of biennial burning in March, May, or July, no significant differences in herbage yield and composition were found among the three burning treatments and an unburned control. Longleaf pines (*Pinus palustris *Mill.) were larger on the May burn than on other plots; few pines, hardwoods, or shrubs remained on the July-burned plots.*

Additional keywords: Prescribed burning, herbage yield, botanical composition.

How does repeated burning in March, May, or July affect vegetation on longleaf pine-bluestem range? On a site near Alexandria, Louisiana, burns in 1962 and 1963 boosted herbage quality in midseason without seriously depleting yield (Grelen and Epps 1967). Since then, treatments have been repeated in even-numbered years only; and observations through 1973 indicate that herbage yield and composition are similar on unburned controls and on plots burned in winter, spring, or summer. However, May fires proved most beneficial to pine growth, and July fires increased pine mortality and reduced hardwood and shrub cover.

METHODS AND MATERIALS

The study area is in a 250-acre stand of longleaf pine. After natural regeneration in 1955, grazing was excluded. The soil is a Ruston fine sandy loam, but the site gradient ranges from a dry ridge to a fairly moist lower slope. Pinehill bluestem *(Andropogon scoparius* var. *divergens* Anderss. ex Hack.) and slender bluestem *(A. tener* (Nees) Kunth) constituted over half the herbage. Prominent shrubs were southern waxmyrtle *(Myrica cerifera* L.), shining sumac *(Rhus copallina* L.), and American beautyberry *(Callicarpa americana* L.).

In 1962 all pines, hardwoods, and shrubs above grass height were removed from study plots. Four treatments—annual burns in winter (March 1), spring (May 1), or summer

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(July 15), and mechanical herbage removal—were applied to four randomized blocks containing plots about ¼-acre square. During the next 2 years, plots produced little but herbage.

Beginning in 1964, burning treatments were scheduled every other year, and the date for summer fires was changed to July 1. Plots were burned with headfires as close as possible to the scheduled date. Climatic and fuel conditions, unless excessively wet, did not influence timing of fires. Mechanical herbage removal was discontinued after March 1963, and these undisturbed plots served as controls.

Annual herbage yield and botanical composition were measured in 1967 and 1973, years without burns. All herbage on nine systematically located 2.4 ft^2 quadrats per plot was clipped, separated by species or species groups, ovendried, and weighed. In 1971 all forb stems on the quadrats were counted.

All shrubs and hardwood stems were tallied by species and by size class in 1972. The amount of canopy cover was determined in 1973 on four milacre quadrats per plot.

Although initial stocking of longleaf pines was not recorded, trees were counted in 1972. To evaluate growth differences among treatments, heights and breast-height diameters of 10 dominant longleaf pines were measured on each plot in 1973. On plots with fewer than 10 dominants, all trees above 4.5 feet in height were measured.

All treatment comparisons were tested by analysis of variance at the 95 percent confidence level.

RESULTS

Herbage

After a full season's undisturbed herbage production, yields averaged about 2,100 pounds per acre in 1967 and 1,800 pounds per acre in 1973 (table 1). In both years differences among treatments were not significant.

On all plots bluestem grasses predominated, as they generally do on cutover longleaf pine range in excellent condition (Duvall and Hilmon 1965). In both 1967 and 1973, more than half the herbage on all plots was provided by pinehill bluestem and slender bluestem. However, control plots had significantly less slender bluestem than other plots. In addition, the lower percentage of pinehill bluestem and higher percentage of forbs on July-burn plots than on other treatments suggested that forage condition on these plots was declining.

Thirty-five forb species were recorded on the study area in the 1971 forb survey. Treatments did not differ significantly in number of species; the average was 27 per treatment. Generally, the same species were most plentiful on all plots. A legume, pencil flower *(Stylosanthes biflora* (L.) BSP.), and a composite, swamp sunflower *(Helianthus angustifolius* L.) were the most abundant forbs. Besides pencil flower, other common legumes recognized as important quail or turkey food plants were showy partridge-pea *(Cassia fasciculata* Michx.) and littleleaf tickclover *(Desmodium ciliare* (Muhl.) DC.). No species was found

Table 1.—*Herbage yield and botanical composition in 2 years without burns*

	Treatments							
	Control		March burn		May burn		July burn	
	1967	1973	1967	1973	1967	1973	1967	1973
	Percent							
Composition								
Pinehill bluestem	52	50	56	49	48	46	43	40
Slender bluestem	13	4	23	21	36	22	33	19
Other bluestems	1	9	3	2	4	2	4	6
Other grasses	28	30	13	20	9	21	13	21
Grasslikes	1	t[1]	t	1	t	t	t	1
Forbs	5	7	5	7	3	9	7	13
	Lbs/acre							
Total herbage yield	2,230	1,752	2,289	2,026	1,953	1,785	1,954	1,785

[1] "t" = less than ½ of 1 percent

in significant numbers on only burned or unburned plots. However, single stems of several species, including pineweed St. Johnswort *(Hypericum gentianoides* (L.) BSP.), occurred only on July-burn plots. Although the numbers of species were comparable, burned plots averaged about twice as many forb stems as the unburned check.

Hardwoods and Shrubs

Twenty-two species of shrubs, vines, and scrub hardwoods were listed in the 1972 inventory (table 2). Of these, one, *Ceanothus americanus* L., was found only on burned sites. Three species were found only on unburned plots: eastern baccharis *(Baccharis halimifolia* L.), eastern redcedar *(Juniperus virginiana* L.), and sweetgum *(Liquidambar styraciflua* L.). These three plants are desirable deer browse species but are uncommon on regularly burned longleaf pine-bluestem range. Southern waxmyrtle, blackjack oak, and shining sumac occurred on more plots than any other species. In addition, southern red oak *(Q. falcata* Michx.), post oak *(Q. stellata* Wangenh.) and summer grape *(Vitis aestivalis* Michx.) were found on at least half the plots of all treatments. Many hardwood stems were sprouts from plants cleared from plots when the study was installed.

Table 2.—*Hardwoods and shrubs on treated plots in 1972 (Number indicates plots occupied out of a total of 4 per treatment.)*

Species	Treatments			
	Control	March burn	May burn	July burn
	– – *No. of plots* – –			
Baccharis halimifolia L.	1			
Callicarpa americana L.	4		2	3
Carya sp.	1	1		
Castanea alnifolia Nutt.	1	1		
Ceanothus americanus L.		2	1	1
Cornus florida L.	4	1	2	1
Diospyros virginiana L.	1			1
Hypericum stans (Michx.) Adams & Robson	2	1		
Juniperus virginiana L.	1			
Liquidambar styraciflua L.	1			
Myrica cerifera L.	4	4	4	2
Prunus serotina Ehrh.	3	1		
Quercus falcata Michx.	3	3	2	4
Q. marilandica Muenchh.	4	3	3	4
Q. stellata Wangenh.	2	2	2	4
Rhus copallina L.	3	4	2	4
R. toxicodendron L.	1	1		
Rubus sp.	1	2		2
Sassafras albidum (Nutt.) Nees	1	1	1	2
Vaccinium arboreum Marsh.	2		1	
V. elliottii Chapm.	3	2	1	2
Vitis aestivalis Michx.	2	2	3	2

Maximum height of southern red oak on unburned plots was 20 feet in 1972; tallest individuals of other oak species averaged 10 to 15 feet. A few tall individuals were found on burned plots, but most were below 4.5 feet. Shrubs such as waxmyrtle and shining sumac were 6 to 8 feet tall on control plots but about knee-high on burned plots. Hardwood and shrub cover on July-burn plots (1 percent) was significantly lower than the average for all other treatments (12 percent). However, most species occuring on other burning treatment plots were also represented on July burns.

Pines

In October 1972 stocking averaged 252 longleaf pines per acre on unburned plots, and 475, 287, and 77 trees per acre, respectively, on March, May, and July burns. The average for March-burn plots was high because one plot contained over 1,000 trees per acre. Over. 60 percent of the pines on unburned plots were still grass-stage seedlings in 1972; 13 percent on March-burn plots and less than 1 percent on the May burn were in the grass stage. July-burn plots contained no grass-stage seedlings.

In October 1973, 12 growing seasons after treatments began, trees on May-burn plots averaged 35 feet in height and 6.0 inches in d.b.h., significantly larger than those of other treatments (table 3, fig. 1). Seedling height-growth on May-burn plots was already obvious in June 1964 (fig. 2).

Table 3.—*Average height and d.b.h. of 10 dominant longleaf pines, October 1973*

Treatment	Height	D.b.h.
	Ft	*In*
Unburned control [1]	21.3	3.8
March 1 burn	27.1	4.3
May 1 burn	34.6	6.0
July 1 burn [1]	22.8	4.2

[1] One of the four plots had fewer than 10 measurable trees.

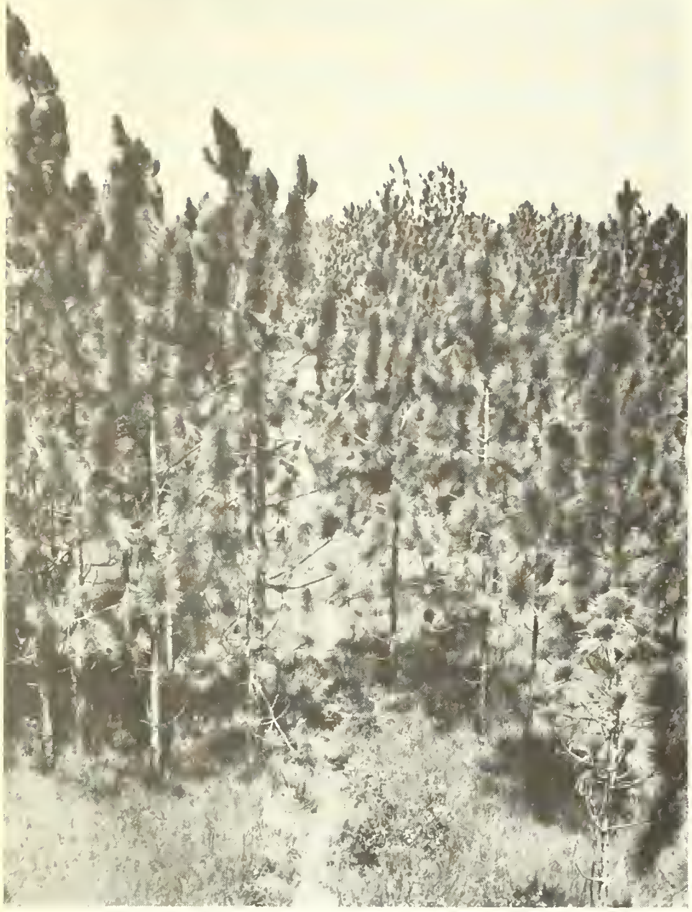

Figure 1.—*In 1973 longleaf pines on May-burn plots (left) averaged about 8 feet taller and 2 inches greater in diameter than March-burned trees (right).*

All unburned plots contained several loblolly pines *(P. taeda* L.) up to 17 feet tall; one control plot had a single 15-foot shortleaf pine *(P. echinata* Mill.). These two pine species were absent from all burned plots.

CONCLUSIONS

Herbage production and botanical composition were similar on May burns and March burns. May burning, however, apparently stimulated initiation of height growth of longleaf pine seedlings. Both March and May burning kept hardwood and shrub growth well within reach of browsing animals. Although July fires did not significantly reduce herbage yield or seriously alter herbaceous or woody species composition, pine mortality was high, and hardwood and shrub cover was drastically reduced.

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Figure 2.—*Study area in June 1964 after the third annual March and May fires had been applied. In foreground is a July-burn plot as yet unburned in 1964. Note longleaf pine seedlings in height growth in light-colored May-burn plot in center. Plot to left of May burn is is a March-burn plot.*

SOUTHERN FOREST EXPERIMENT STATION

1975

U.S. FOREST SERVICE RESEARCH NOTE

SO-193

Forest Service, U. S. Dept. of Agriculture

-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

INFLUENCE OF CUTTING CYCLE AND SPACING ON COPPICE SYCAMORE YIELD

H. E. Kennedy, Jr. [1]

SOUTHERN FOREST EXPERIMENT STATION

Cutting cycle significantly affected total aboveground dry-weight yields, which were greater with the 2-, 3-, and 4-year cycles than with the 1-year. For all cutting cycles, significantly higher yields were obtained with 2- by 5-foot spacings than with 4 by 5. Dry-weight yields ranged from 3,229 pounds per acre per year for the 1-year cutting cycle spaced at 4 by 5 feet to 7,210 pounds for the 3-year cycle at 2 by 5 feet. No interaction was detected between spacing and cutting cycle.

Additional keywords: *Platanus occidentalis*, "silage sycamore," short-rotation, juvenile wood.

As the demand for cellulose fiber from natural and planted forests exceeds the supply, the pulpwood industry must find new methods to increase production rapidly. Intensive culture of hardwoods under short rotation cycles may help supplement conventional pulpwood sources. The technique is sometimes referred to as the "silage concept" because the cut wood resembles crops harvested for silage. This note reports the effects of various cutting cycles and spacings on the growth and yield of coppice sycamore planted for pulpwood.

METHODS

In March 1970, unrooted sycamore cuttings were planted in subsoiled trenches at Huntington Point, near Greenville, Mississippi. The soil was Commerce silt loam, a favorable sycamore site.

Plots were eight rows wide by 1 chain (66 feet) long and were divided into two subplots, each four rows wide. Two spacings were randomly assigned on the subplots—2 by 5 and 4 by 5 feet. Early in the growing season, all blanks in the 4-foot spacings and consecutive blanks (two or more) in the 2-foot spacings were replanted with extra 16-inch cuttings

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established when the study was installed. Plots were weeded during the first growing season, and survival was noted.

Four replications of four cutting treatments were randomly installed on the plots. Cutting cycles were 1, 2, 3, or 4 years; thus, the 1-year cycle received four cuttings; the 2-year cycle, two cuttings; and the 3- and 4-year cycles, one cutting each. Cutting was in January for each year except 1974, when floodwaters from the Mississippi River delayed the operation until early March. Resprouting was noted after each cutting.

For each subplot, growth and yield were measured for the central 50 feet of the two center rows; the remainder of the plot formed a border.

When the plants were cut, stems plus branches of all trees within each measurement area were weighed on a platform balance at the study site. Fresh-weight yields per acre were calculated from these data.

Fresh and dry weights of stems and of branches, stump diameter at the point of cut, and stem length were measured for five trees from each subplot. Dry weights were determind after 48 hours of drying in a forced-air oven at 105°C. Total aboveground weights were obtained, and the ratios of total dry to fresh weight and of stems to branches (fresh and dry) were established.

Dry-weight yield per acre per year was calculated for each subplot by multiplying the fresh weight per acre by the ratio of dry weight to fresh weight in the sample. Data were analyzed by analysis of variance and Duncan's multiple range test. Differences significant at the 0.05 level are reported here.

RESULTS AND DISCUSSION

First-year survival was about 95 percent for all treatments. No insect or disease problems were noted during the 4 years of testing. Approximately 90 percent of the stems resprouted after harvesting.

Spacings of 2 feet produced higher fresh and dry weight yields than those of 4 feet (table 1). For all cutting cycles combined, average annual dry weight yield was 6,430 pounds per acre per year for the 2-foot spacing and 5,253 pounds for the 4-foot spacing. However, the greater cost of establishment and harvesting in the denser spacing may offset the advantages of the greater yield.

Table 1.—*Average annual fresh and dry weight, ratio of fresh to dry weight, and dry weight percentages of stems and branches by spacing and cutting cycle*

Spacing (feet) and cutting cycle (years)	Fresh weight	Dry weight	Ratio (dry to fresh)	Dry weight	
				Stem	Branches
	Pounds per acre per year		*– – Percent – –*		
2 by 5					
1	9,806	4,349	44	81	19
2	15,528	7,001	45	90	10
3	17,583	7,210	41	92	8
4	15,518	7,161	46	95	5
4 by 5					
1	6,915	3,229	46	85	15
2	12,566	5,167	41	86	14
3	14,484	6,175	43	91	9
4	15,636	6,441	42	95	5

For both spacings the 2-, 3-, and 4-year cutting cycles had higher fresh and dry weight yields than the 1 year cycle but did not differ greatly from each other (table 1). Annual dry-weight yields ranged from 3,229 pounds per acre per year in the 1-year cutting cycle with a 4-foot spacing to 7,210 pounds for the 3-year cycle with a spacing of 2 feet. These results are similar to those of Steinbeck and May (1971) and Kormanik, Tyre, and Belanger (1973). Since growth during the fourth year was not measured for the 3-year cutting cycle, third-year yields were not affected by flooding, which may have lowered average annual yields for the 1-, 2-, and 4-year cycles.

In both spacings of the 1-year cycle, yields were low the first year as the tree established a new root system, increased during the second and third years, but decreased the fourth year after flooding reduced the growing season by 2 months.

Cutting cycle and spacing did not affect the ratio of total dry weight to fresh weight. For both spacings dry weights ranged from 41 to 46 percent of the total weights (table 1), a finding similar to that of Steinbeck and May (1971), who reported 50 percent.

Cutting cycle apparently influenced the proportion of total fresh and dry weights in the stems. In the 1-year cycle stems comprised 81 percent of the dry weights in the 2-foot spacing and 85 percent in the 4-foot. In the 4-year cycle (both spacings), the stem accounted for about 95 percent of the total—somewhat more than the 70 and 78 percent reported by Steinbeck and May (1971). Thus, although the longer cutting cycles do not seem to increase the ratio of total dry weight to fresh weight, they result in greater yields of stem wood, which may produce a better fiber and a lower proportion of bark than the 1-year cycle.

No interaction was detected between spacing and cutting cycle. Average annual dry weight yields and diameter and height growth are shown by cutting cycle in table 2. Neither diameter nor height growth changed markedly during the first 3 years, but both diminished slightly during the fourth year. Diameters ranged from slightly less than 1 inch for sprouts cut each year to about 2.4 inches in 4-year-old trees. Heights ranged from 9.0 feet at 1 year to 24 feet after 4 years.

Table 2.—*Average annual dry weight yields and diameter and height growth by cutting cycle*

Cutting cycle (years)	Dry weight [1]	Stump diameter	Height
	Pounds per acre per year	*Inches*	*Feet*
1	3,789 a	0.95	9.1
2	6,084 b	.90	8.4
3	6,692 b	.75	7.3
4	6,801 b	.55	5.9

[1] Means followed by the same letter are not significantly different at the 0.05 level.

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SOUTHERN FOREST EXPERIMENT STATION

1975

U.S. FOREST SERVICE RESEARCH NOTE

SO-194

Forest Service, U. S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

RESPONSE OF YELLOW-POPLAR SEEDLINGS TO SIMULATED DROUGHT

Nelson S. Loftus, Jr.[1]

SOUTHERN FOREST EXPERIMENT STATION

Yellow-poplar seedling growth can be inhibited at soil moisture tensions considerably less than 15 bars, generally regarded as the permanent wilting point for most soils. Diameter growth was best when tensions did not exceed 2 bars. Height growth was reduced, root development was drastically inhibited, and the seedlings wilted when tensions increased to an average of 4 bars. Soil moisture content below 20 percent of available water is likely to be inadequate for newly planted yellow-poplar seedlings.

Additional keywords: *Liriodendron tulipifera*, soil moisture, seedling growth, moisture tension.

Unsatisfactory growth of yellow-poplar (*Liriodendron tulipifera* L.) seedlings on many Cumberland Plateau forest sites in Tennessee has been attributed to recurrent soil water deficits during the growing season (Russell *et al.* 1970). Good survival of planted seedlings on all sites and the infrequency of severe summer droughts (Vaiksnoras and Palmer 1973) suggest that soil moisture is rarely reduced to the permanent wilting point. The soil moisture tension at which deficits inhibit growth is not known. This note reports the effects of increasing periods of simulated drought and resulting soil-moisture tensions on the growth of yellow-poplar seedlings.

METHODS AND MATERIALS

Forty 1-0 yellow-poplar seedlings were individually potted in a Hartsells soil (typic Hapludult)—5 kg of sandy loam from the A horizon on top of 6 kg of a sandy clay loam from the B_2 horizon. The two soil horizons were used to simulate field conditions (Loftus 1971). Seedlings were dormant when planted. Soil moisture was maintained near field capacity until June, when the first flush of growth was completed and treatment started. At that time seedlings assigned to the various treatments did not differ significantly in height or root collar diameter.

Seedlings were subjected to soil moisture tensions induced by 7, 14, or 21 days of simulated drought. Controls were also grown at field capac-

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ity. At the end of each dry-down period, the pots (soil + seedling + water) were weighed, moisture content was determined, and enough water was added to return the soil to field capacity. Weight increases from growth were disregarded because they were found to have little effect on the calculated soil moisture content. Moisture content at the end of each dry-down period was assumed to be uniform throughout the soil mass, except possibly at the soil-root interface (Zahner 1968). It was also assumed that the addition of water returned the entire volume to field capacity. Regardless of the validity of these assumptions, the procedure followed simulated the periodic wetting and drying of soils under field conditions.

Ten replications of the four treatments were placed in a shadehouse in a randomized complete-block design. Here the seedlings received approximately 50 percent of full sunlight. Relative humidity was generally high, ranging from 100 percent on most mornings to 40 percent during dry sunny afternoons. Treatments began in June 1970, and resumed in June 1971 for a total of two full growing seasons. The 7-, 14-, and 21-day dry-down periods were repeated 36, 18, and 12 times. Seedlings were mulched with straw during the dormant season to protect them from freezing. Several weeks before the resumption of treatment in June 1971, soil moisture content of all pots was adjusted to field capacity.

Shoot lengths and root collar diameters were measured to the nearest 0.1 cm and 0.1 mm at the start of treatment and at the end of each growing season. At the conclusion of the study, October 1971, seedlings were washed from the soil, and ovendry weights of shoots (excluding leaves) and roots were determined. Bulk and core soil samples were obtained from the A and B_2 horizons of five randomly selected pots. From these samples, texture was determined by the Bouyoucos hydrometer method, and bulk density and total porosity were estimated. Soil moisture retained at 0.1, 0.3, 1, 2, 5, 10, and 15 bars was determined by a pressure-membrane apparatus according to standard procedures. Resulting moisture retention curves were used to compare the soil materials and determine tensions for moisture percentages obtained gravimetrically.

Differences in height and diameter growth and ovendry weights were compared by analysis of variance and Duncan's new multiple-range test. All differences discussed here were significant at the 0.05 level.

RESULTS AND DISCUSSION

Seedling height growth was slightly reduced by increasing soil moisture tensions and lower volumes of available soil water resulting from 7, 14, and 21 days of simulated drought. Two-year height growth was best, 29.3 cm, when soil moisture was maintained near field capacity (table 1). Height growth was poorest (23.2 cm) when water was withheld for 21 days. Where soils were dried for 7 and 14 days, growth did not differ from that of the controls.

Table 1.—*Seedling growth and weights after 2 years of simulated drought*

Treatment	Height growth	Diameter growth	Ovendry weight	
			Shoots	Roots
	Cm	*Mm*	*Grams*	
Control	[1] 29.3a	2.9a	8.3a	18.5a
7 day	26.6ab	2.6a	7.9a	19.0a
14 day	26.7ab	1.9b	6.1b	15.3a
21 day	23.2b	2.0b	5.9b	10.2b

[1] In individual columns, values followed by the same letter do not differ significantly at the 0.05 level.

It is uncertain whether differences would be similarly small if droughts had been longer and soil moisture tensions correspondingly higher. The reduced light within the shadehouse in combination with high relative humidity and cool nights may also have contributed.

Root collar diameter growth was sensitive to increasing periods of drought. Seedlings grown at field capacity and watered at 7-day intervals grew larger in diameter than those subjected to longer droughts. Extending the drought from 7 to 14 days reduced diameter growth 27 percent, with no further reduction after 21 days. Sensitivity of annual diameter increment to moisture changes has been demonstrated by Tryon *et al.* (1957) for 30-year-old yellow-poplars in West Virginia and is well known in southern pines (Kramer and Kozlowski 1960).

As a corollary to the diameter response, shoot dry weights were reduced when the drought was extended beyond 7 days. Seedlings subjected to 21-day droughts had lower root weights and therefore less absorbing surface than those grown under the less severe treatments. Incipient wilting, with some loss of older leaves, occurred each time the drought period approached 21 days (usually by 18 days). It is likely that extension of the drought beyond 21 days would have seriously limited growth and might have resulted in seedling mortality.

The growth data suggest that soil moisture tensions not exceeding 2 bars are optimum for yellow-poplar seedling establishment. During the first 7 days of drying, 50 percent of the available water was desorbed from this loamy soil, and moisture tensions increased to an average of 1.4 bars (table 2). By the fourteenth day, available water had been reduced by 68 percent, and tensions increased to 2.4 bars. The least desirable moisture conditions occurred on the twenty-first day: available water was reduced by 80 percent, and average tensions of 4 bars were measured. The available water holding capacity (between 1/3 and 15 bars of pressure) was 0.203 inch per inch of soil depth.

Table 2.—*Mean soil moisture contents, mean tensions, and residual available water averaged over 2 years of simulated drought*

Treatment	Moisture content	Tension	Remaining available water
	Percent by volume	*Bars*	*Percent*
Control	29.2	0.3	100
7 day	19.0	1.4	50
14 day	15.4	2.4	32
21 day	12.8	4.0	20

These data agree with other findings indicating that seedling growth may be inhibited by soil moisture tensions between 0.3 and 5 bars. Stransky and Wilson (1964) found that height growth of loblolly and shortleaf pine seedlings was inhibited at 2 bars and was prevented as tensions increased to 3.5 bars. In this study, diameter growth and shoot dry weight were reduced at 2.4 bars, and shoot growth and root development were inhibited at 4 bars. Yellow-poplar height growth continued even with tensions of 4 bars, a finding in agreement with that of Doley (1970).

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SOUTHERN FOREST EXPERIMENT STATION

1975

U.S. FOREST SERVICE
RESEARCH NOTE

SO-195

Forest Service, U.S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

MORTALITY OF LONGLEAF PINE SEEDLINGS FOLLOWING A WINTER BURN AGAINST BROWN-SPOT NEEDLE BLIGHT

William R. Maple[1]

SOUTHERN FOREST EXPERIMENT STATION

After burning, mortality increased with percentage of infection but usually declined with increased height, root collar diameter, and time since overstory removal. Burning is recommended when the infection level of the best seedlings reaches 20 percent and when root collar diameters are between 0.3 to 0.7 inch in the grass stage or larger than 1.5 inches in the height-growth stage.

Additional keywords: *Pinus palustris* Mill., *Scirrhia acicola* (Dearn.) Siggers, prescribed burning, mass selection.

Prescribed burning is the most practical method for controlling brown-spot needle blight (*Scirrhia acicola* (Dearn.) Siggers) in longleaf pine (*Pinus palustris* Mill.) seedling stands (Siggers 1944), but fire is justifiable only after potential damage to seedlings has been estimated and judged acceptable (Croker 1967). The present study discusses guidelines for such appraisals.

METHODS

A block of six 1.6-acre plots was randomly selected from three blocks established during a previous study in the Mountain Province (Hodgkins 1965) of Coosa County, Alabama. The shelterwood overstory had been left undisturbed or had been removed 1, 3, 4, 5, or 6 years earlier. For each plot, 50 seedlings 6 years of age or older were selected from each of four size classes for measurement of mortality after a prescribed burn: (1) grass-stage seedlings less than 0.5 inch in root collar diameter, (2) grass-stage seedlings 0.5 to 1.0 inch at the root collar, (3) height-growth seedlings at least 1.1 inches at the root collar and 1.0 foot tall or less (to the base of the terminal bud), and (4) height-growth seedlings 1.1 to 4.5 feet tall. Immediately before burning, heights were measured to the nearest 0.1 foot and root collar diameters to the nearest 0.1 inch; for each seedling, the percentage of the current year's infected needles was estimated to the nearest 10 percent.

A fire was set March 13, 1968, 2 days after a general 0.95 inch rainfall. The wind was from the

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northwest at 5 miles per hour with gusts of up to 20. The fire was set at 12:30 p.m. when ambient temperature was 52 degrees F; relative humidity was 50 percent but dropped to 24 percent by the completion of burning at 3:00 p.m. The National Fire Danger Buildup Index (Nelson 1964) was 4; the Spread Index varied from 8 to 22 and changed with wind speed.

Seedling mortality from fire was determined at the end of the growing season following the prescribed burn.

RESULTS AND DISCUSSION

This study supported previous observations that mortality after burning usually increases with brown-spot infection (Bruce 1954, Boyer 1974). Approximately half of the seedlings (571) were lightly infected (0 to 40 percent of the needles infected), and about half (626) were heavily infected (over 40 percent) (table 1). Seedlings with 20 percent of their needles infected or less had the lowest mortality; for those with more than 40 percent infected needles, mortality exceeded survival.

Table 1.—*Influence of brown-spot infection on longleaf pine seedling mortality after fire*

Range of infection (percent)	Seedlings	Mortality after fire
	Number	*Percent*
0–20	40	39
21–40	531	44
41–60	397	53
61–80	209	67
81–100	20	90

Although the presently accepted practice is to burn when the best seedlings show 35 percent infection on the current year's needles (Croker 1967), this study indicated that fire losses would decrease if burning were conducted when the mean infection level of crop seedlings reaches 20 percent. This practice would be advantageous to superior and apparently disease-resistant seedlings suitable for regeneration and would remove inferior, disease-prone seedlings from the stand by a relatively inexpensive mass selection process.

Mortality from fire usually decreased with height, root collar diameter, and time since overstory removal.

For the heavily infected seedlings, mortality after burning apparently peaked when height was about 1.5 feet but diminished rapidly afterward (fig. 1).

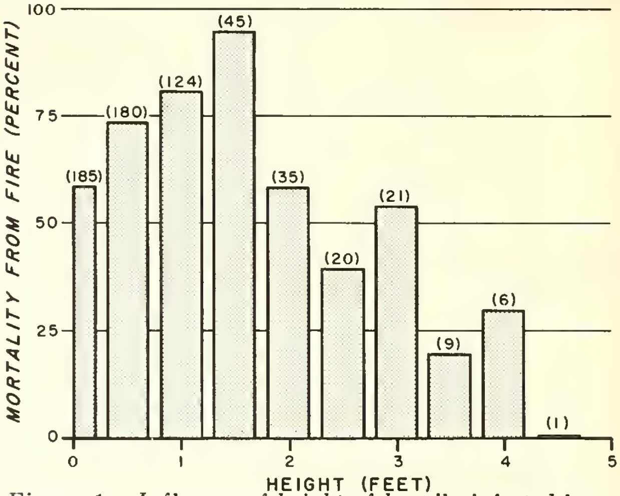

Figure 1.—*Influence of height of heavily infected longleaf pine seedlings (over 40 percent infection) on mortality from fire. Numbers in parentheses indicate number of seedlings.*

The data suggested that seedlings are susceptible or resistant to mortality from fire according to four root collar size classes (fig. 2): (1) susceptible grass stage (less than 0.3 inch root-collar diameter), (2) resistant grass stage (0.3 to 0.7 inch), (3) susceptible height-growth stage (0.8 to 1.4 inches), and (4) resistant height-growth stage (1.5 inches or larger). These classes are useful guidelines for burning.

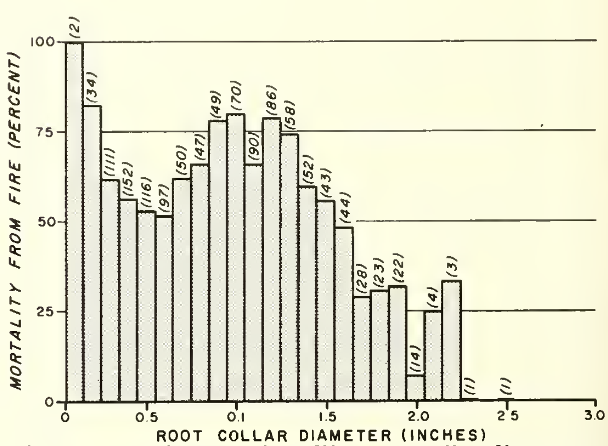

Figure 2.—*Influence of seedling root collar diameter on mortality from fire. Numbers in parentheses indicate number of seedlings.*

However, the results were apparently affected by infection levels (fig. 3). For highly infected seedlings, survival did not reach 50 percent until root collar diameters were larger than 1.7 inches; seedlings with low infection had 50 percent survival when root collar diameters were about 0.4 inch.

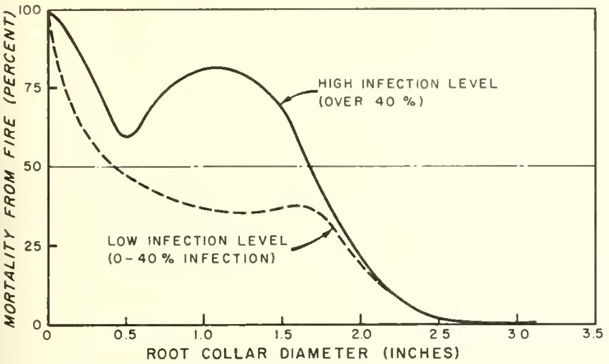

Figure 3.—*Influence of seedling root collar diameter and brown-spot infection on mortality from fire.*

Mortality generally decreased with time since overstory removal (fig. 4). Even with light infection levels, mortality was greater for seedlings released only a year before burning or left undisturbed than for those released for 3 years

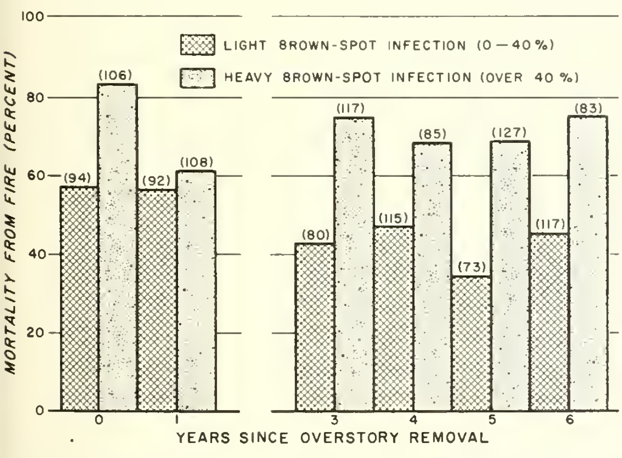

Figure 4.—*Influence of time since overstory removal and brown-spot infection on seedling mortality from fire. Number in parentheses indicate number of seedlings.*

or longer. This finding supports Boyer's (1974) observation that a fire 1 year after logging causes heavy seedling losses because undecomposed logging slash on the site acts as heavy fuel and intensifies the fire. However, highly infected seedlings released for 3 years or more still showed markedly higher mortality than those with low infection levels. Losses from burning are undoubtedly increased by the presence of dry infected needles still attached to the seedlings, and dead needles on the ground from previous growing seasons. These needles create higher temperatures of longer duration than the fine, grassy fuels normally found around released seedlings.

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SOUTHERN FOREST EXPERIMENT STATION

Forest Service, U. S. Dept. of Agriculture

1975

U.S. FOREST SERVICE RESEARCH NOTE

SO-196

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

PERFORMANCE OF LARGE LOBLOLLY AND SHORTLEAF PINE SEEDLINGS AFTER 9 TO 12 YEARS

Hoy C. Grigsby[1]

SOUTHERN FOREST EXPERIMENT STATION

Tall loblolly pine seedlings selected from nursery beds were superior to average seedlings in volume on plots measured at age 9 years but not on plots measured at age 12 years. Large seedlings survived at least as well as small or average seedlings. Differences in height lessened with age, but about 1 percent of the tall seedlings in the 27 loblolly plantings remained 50 percent or more taller than the average and short selections. These will provide material for additional selection and breeding. Nursery selection was less effective in shortleaf pine.

Additional keywords: Seedling selection, seed size, *Pinus taeda*, *P. echinata*, *Cronartium fusiforme*.

Tree vigor may manifest itself at an early age. The ease with which vigorous seedlings can be identified in uniform beds makes nursery selection attractive as a method of isolating superior germplasm.

This note reports a study made to compare the performance of exceptionally tall loblolly (*Pinus taeda* L.) and shortleaf pine (*P. echinata* Mill.) seedlings with that of small and average-size nursery stock. Also discussed are growth trends with age and effects of seed size on selection efficiency.

METHODS

Selections of 1-0 loblolly and shortleaf pine seedlings were made from nurseries maintained by the Louisiana Forestry Commission at Sibley, the Arkansas Forestry Commission at Bluff City, and the Southern Advance Bag and Paper Company at Jonesboro, Louisiana.

Height was the only criterion. Tall seedlings averaged 1.0 foot, average seedlings 0.6, and small seedlings 0.3 foot. Selection ratios for tall seedlings were 1:49,000 for loblolly and 1:40,000 for shortleaf. An average and a small seedling were taken from the immediate vicinity of each tall seedling. Seedlings of each triad were tied together when lifted and were planted together.

Seed size may influence seedling growth, but such effects are usually temporary. To appraise the impact on selection efficiency, some samples were drawn from beds that had been sown with sized seed. Sizes for loblolly were: (1) too large for passing a No. 12 screen, (2) passing a No. 12 screen but larger than a No. 10, and (3) passing

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a No. 10. Shortleaf seeds were graded into two classes, depending on whether they would or would not pass a No. 8 screen.

Some loblolly selections were from beds sown with seed that had been kept separate by place of origin—i.e., southern Arkansas, and near the northern perimeter of the range in that State.

Over 4 years, 1,643 loblolly pine triads were selected and planted at 18 locations in southern Arkansas and northern Louisiana.[2] During the same period, 289 tall shortleaf triads were planted in five of these locations. Large, average, and small seedlings were planted in separate but adjacent rows; three such rows, in random arrangement, comprised a plot. Number of triads within a plot varied with size and shape of the planting site, and number of plots per plantation depended on quantity of triads available. Seedlings from different species, seed size classes, geographic sources, and nurseries were put in separate plantings. There were 32 plantings in all, with loblolly plantations averaging 91 triads and shortleaf plantations 58 triads. One row of woodsrun seedlings was planted between plots and two rows surrounded each plantation to minimize border effects.

Survival, height, and incidence of fusiform rust (*Cronartium fusiforme* Hedgc. & Hunt ex Cumm.) were measured at the end of the third and fifth growing seasons after planting and again when the oldest plantations had completed 12 growing seasons. Because installation was spread over 4 years, the records include 12 years of growth for the oldest and 9 years for the youngest. Diameters at breast height were recorded with the last height measurements. In each plantation, relative conical volume was computed for the average tree in each selection class

$$(V = \frac{1/4\,\pi\, d^2 h}{144 \times 3}).$$

Mean survival, height, diameter, volume, and rust incidence for each seedling size and plantation were subjected to variance analysis for the randomized block design and to Duncan's multiple range test. All statistical tests were at the 0.05 level of probability.

[2] Cooperating planting agencies were Ozan Lumber Company (now Ozan Unit, Potlatch Forests, Inc.), The Crossett Company (now Georgia-Pacific Corp.), Southern Advance Bag and Paper Company (now Continental Can Company), Union Producing Company (now Pennzoil United, Inc.), Deltic Farm and Timber Company, Fordyce Lumber Company (now Georgia-Pacific Corp.), and Louisiana Tech University.

RESULTS

A combined analysis of all loblolly data showed no difference in the survival of large and average trees, but average trees survived significantly better than small ones (table 1). In shortleaf, there were no survival differences. Size for size, loblolly mean survivals were slightly higher than those for shortleaf and also varied more.

In the combined analysis for loblolly, size classes differed from each other in diameters, heights, and relative volumes (table 1). For shortleaf, the large and average seedlings differed in volume but not in diameter or height, while the large differed from the small in all three measurements.

Among loblolly pines from beds sown with size-graded seed, large and average trees differed in volume for seed sizes 1 and 2 but not for size 3, the smallest seed. The large were different from the small in all three seed sizes. The analyses indicated that differences decreased with seed size. Large shortleaf seedlings were not found in beds sown with graded seed.

In loblolly pines from the northern edge of the range in Arkansas, all three size classes differed from each other in volume. In the southern Arkansas source, large trees differed from small but not from average. Advantage of the large seedlings appeared to differ with nursery source, but statistical tests were not made.

In loblolly plantations 9 years old at time of last measurement, trees from large seedlings were superior in volume to those from average and small stock. But in 12-year-old stands, the large were superior only to the small. There were insufficient shortleaf plantations for separate analyses at these two ages.

Rust infection was light on all three loblolly selection classes ranging from 7.5 to 10.8 percent; differences were not significant.

DISCUSSION AND CONCLUSIONS

The present data corroborate Hatchell *et al.* (1972), who found no significant differences in survival between large and control seedlings of loblolly and slash pine. Several workers have reported significant differences in growth between large and control seedlings at ages 5 to 10 years (Zobel *et al.* 1957, Bengtson 1963, Zarger 1965, Hunt 1967), while others have reported early declines in superiority of large seedlings

Table 1.—*Performance by seedling selection class at ages 9-12 years*

Variable	Loblolly pine			Shortleaf pine		
	Plantations	Seedling selection class[1]	Value[2]	Plantations	Seedling selection class	Value
	No.		*Percent*	*No.*		*Percent*
Survival	27	A	77.8	5	A	72.1
	27	L	73.6	5	L	69.3
	27	S	72.0	5	S	68.3
			Inches			*Inches*
D.b.h. (combined ages 9-12 years)	27	L	6.43	5	L	6.07
	27	A	6.15	5	A	5.91
	27	S	5.87	5	S	5.76
			Feet			*Feet*
Height (combined ages 9-12 years)	27	L	32.6	5	L	29.7
	27	A	31.6	5	A	29.2
	27	S	30.8	5	S	28.6
			Cu. ft.			*Cu. ft.*
Volume per tree (combined ages 9-12 years)	27	L	2.59	5	L	2.09
	27	A	2.30	5	A	1.94
	27	S	2.06	5	S	1.85
Seed size						
> No. 12 screen (avg. age 9.4 years)	5	L	1.81			
	5	A	1.62			
	5	S	1.42			
< No. 12 screen but > No. 10 (avg. age 10.0 years)	8	L	2.38			
	8	A	2.02			
	8	S	1.83			
< No. 10 screen (avg. age 10.6 years)	5	L	2.62			
	5	A	2.46			
	5	S	2.17			
Seed origin						
Central Arkansas (avg. age 9.9 years)	7	L	2.07			
	7	A	1.73			
	7	S	1.57			
Southern Arkansas (avg. age 9.8 years)	8	L	1.96			
	8	A	1.78			
	8	S	1.59			
Nursery source						
(age 12 years only) Jonesboro, La.	2	L	[3]3.20			
	2	A	[3]2.97			
	2	S	[3]2.69			
Sibley, La.	1	L	[3]4.10			
	1	A	[3]3.56			
	1	S	[3]3.11			
Bluff City, Ark.	1	L	[3]3.70	1	L	[3]2.72
	1	A	[3]3.59	1	A	[3]2.57
	1	S	[3]3.24	1	S	[3]2.49
Overall volume averages						
Age 9 years only	9	L	1.68	2	A	[3]1.18
	9	A	1.44	2	L	[3]1.16
	9	S	1.29	2	S	[3].93
Age 12 years only	4	L	3.55	1	L	[3]2.72
	4	A	3.27	1	A	[3]2.57
	4	S	2.94	1	S	[3]2.49

[1] L, A, S = large, average, and small seedling, respectively.
[2] Values not opposite the same line are significantly different at the 0.05 level by Duncan's multiple range test.
[3] Not tested.

(Foulger 1960, Hatchell *et al.* 1972). In the present study, trends with age have remained moderately stable, but growth differences between seedling size classes have narrowed.

Loblolly pines from large seedlings had a significant 16.7 percent superiority in volume over average seedlings at age 9, but in 12-year-old plantations volume superiority was a nonsignificant 8.6 percent. When plots of ages 9 and 12 were analyzed together, shortleaf pines from large seedlings were not superior to those from average stock in diameter and height, but they were superior in volume. In both species, large stock outgrew small stock.

As outstanding shortleaf pines were not found in beds from sized seed, sizing apparently eliminated selection errors due to temporary fast growth from large seed. In loblolly selections from sized beds, by contrast, large seedlings outgrew average and small ones. The inference is that grading seed by size will facilitate and increase the efficiency of nursery selection in shortleaf but not in loblolly.

The volume differences noted in shortleaf (9-12 years combined) were significant but not large. There may be less variation in this species than in loblolly, or perhaps a greater selection differential is required. Too, the present tests contained fewer plots and therefore were not as sensitive as those for loblolly.

While the large loblolly selections were superior in volume to their average size controls at age 9, differences were not significant on plots 12 years old. But about 1 percent of the large trees grew 50 percent or more taller than the average size controls over the 27 tests. The occurrence of these exceptionally large trees makes the plantations valuable for further selection.

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SOUTHERN FOREST EXPERIMENT STATION

1975

U.S. FOREST SERVICE RESEARCH NOTE

SO-197

Forest Service, U. S. Dept. of Agriculture

-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

SOUTHERN PINE SITE-INDEX COMPUTING PROGRAM

Robert M. Farrar[1]

SOUTHERN FOREST EXPERIMENT STATION

Describes a FORTRAN program whereby site index (or height) tables for southern pines may be computed for any index age and array of integer age and height (or site index). The program uses interpolation equations developed for the site index curves in USDA Miscellaneous Publication 50.

Additional keywords: *Pinus taeda, P. palustris, P. echinata, P. elliottii,* site quality.

Foresters often use the curves in USDA Miscellaneous Publication 50[2] to estimate site index (SI) or height (HT) of natural even-aged stands of the four major southern pines. To facilitate such use, the curves have been expressed as equations[3] that can be incorporated directly into computer programs for inventory summary or prediction of growth and yield. For occasional use, the equations can be evaluated with logarithm tables or simple computers. For producing tables, however, full-scale computers are probably most efficient. This note describes a FORTRAN program for printing an array of SI (or HT) for any given index age and array of integer age and HT (or SI).

The curves in Miscellaneous Publication 50 are anamorphic, i.e., any given SI curve in a species set is a fixed percentage of another curve in that set. Because of this relationship, I selected as a guide for loblolly, longleaf, and slash pine the curve representing the most plots of each species. For these three species, total heights by 5-year age (A) increments were scaled from this guide curve to the nearest 0.1 foot. For shortleaf pine the height-age data for SI 70 (table 97) seems most appropriate, since they start at age 10 while the SI curve starts at age 15. Then I fitted the guide curve for each species by least-squares multiple regression techniques in which logarithm (base 10) of HT was the dependent variable and a fourth-order polynomial in terms of 1/A was the right hand side of the model. The final equations were those with minimum standard errors of the regression ($S_{y.x}$), which I transformed to SI or HT equations and expressed in exponential form for computer solution. Table 1 gives the statistics of the guide equation for each species. Methods of equation development are detailed in the earlier publication, which gives the same coefficients for lob-

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[2] USDA Forest Service. Volume, yield, and stand tables for second-growth southern pines. USDA Misc. Publ. 50, 202 p. 1929.

[3] Farrar, R. M., Jr. Southern pine site index equations. J. For. 71: 696-697. 1973.

Table 1.—*Statistics and limits for species guide curves*[1]

Item	Loblolly	Longleaf	Shortleaf	Slash
b_1	−2.41737	−11.8701	−11.104909	−8.80405
b_2	−273.824	0	−83.244961	22.7952
b_3	4,227.7	1,263.79	2,239.6780	0
b_4	−19,758.5	−12,409.5	−11,260.453	0
$S_{y.x}$ (feet)	.40	.56	.27	.18
R^2	.99983	.99931	.99990	.99993
Age limits (years)	10–80	15–100	10–100	10–60
SI limits (feet)	60–120	40–120	40–100	60–100

[1] Model: $\log_{10}(HT) = b_0 + b_1(1/A) + b_2(1/A)^2 + b_3(1/A)^3 + b_4(1/A)^4$ b_0 is omitted above since it does not appear in the final prediction equations.

lolly, longleaf, and slash as those shown herein. For shortleaf only, the regression analysis was performed again to take advantage of the additional data at the younger ages. Thus, the coefficients in table 1 are different for this species.

To gauge the accuracy of the equations, heights for trees at 5-year age and 10-foot SI increments were predicted to the nearest foot within the limits indicated in table 1 and checked against the corresponding values in Miscellaneous Publication 50. Observed heights for loblolly, longleaf, and slash were scaled to the nearest foot from the published SI curves, except that observed data for longleaf SI 40 were necessarily read from table 65. Observed heights for shortleaf were read from table 97. For loblolly, shortleaf, and slash none of the errors exceed ±1 foot (table 2). In about 98 percent of the cases for longleaf the errors did not exceed ±1 foot and none exceeded ±2 feet. This accuracy should be adequate for most purposes.

The program with explanatory comment cards is appended. It requires about 9 K storage and will run on any machine with this capacity and a FORTRAN compiler. Any index age may be selected, but index ages 25 and 50 are most commonly used. Also, any desired integer steps

Table 2.—*Cumulative proportion of predicted heights within specified error ranges of heights from published data*

Species	±0 foot	±1 foot	±2 feet
	Percent		
Loblolly	66.7	100.0	...
Longleaf	56.2	97.5	100.0
Shortleaf	82.0	100.0	...
Slash	83.6	100.0	...

for age, SI, or HT may be chosen along with any desired integer limits on SI or HT. The maximum array for a species may be generated by specifying 1-year age and 1-foot HT or SI steps on the input card. Computed SI or HT less than 10 or greater than 170 feet is not printed. This program should be used only for the age limits shown in table 1.

Tables 3 and 4 are examples of program printout. Table 3 presents index age 25 SI for ages 15 to 50 by 5-year age increments and 10-foot HT increments. Table 4 presents index age 50 HT for ages 15 to 100 by 5-year age increments and 10-foot SI increments. Note that table 4 represents table 65 and most of the longleaf SI curves in Miscellaneous Publication 50.

Table 3.—*Longleaf pine site index, index age = 25*

M.P.50 SI OR HT. PROGRAM, SFES. 2/6/74

LONGLEAF PINE, INDEX AGE= 25.

TOT.AGE (YRS.)	TOT.HT. (FT.)	SI (FT.)
15.	10.	17.
15.	20.	34.
15.	30.	52.
15.	40.	69.
15.	50.	86.
15.	60.	103.
15.	70.	121.
15.	80.	138.
15.	90.	155.
15.	100.	*****
15.	110.	*****
15.	120.	*****
15.	130.	*****
15.	140.	*****
20.	10.	12.
20.	20.	24.
20.	30.	37.
20.	40.	49.
20.	50.	61.
20.	60.	73.
20.	70.	86.
20.	80.	98.
20.	90.	110.
20.	100.	122.
20.	110.	135.
20.	120.	147.
20.	130.	159.
20.	140.	*****
25.	10.	10.
25.	20.	20.
25.	30.	30.
25.	40.	40.
25.	50.	50.
25.	60.	60.
25.	70.	70.
25.	80.	80.
25.	90.	90.
25.	100.	100.
25.	110.	110.
25.	120.	120.
25.	130.	130.
25.	140.	140.
30.	10.	*****
30.	20.	17.
30.	30.	26.
30.	40.	35.
30.	50.	43.
30.	60.	52.
30.	70.	61.
30.	80.	69.
30.	90.	78.
30.	100.	87.
30.	110.	95.
30.	120.	104.
30.	130.	113.
30.	140.	122.
35.	10.	*****
35.	20.	16.
35.	30.	23.
35.	40.	31.
35.	50.	39.
35.	60.	47.
35.	70.	55.
35.	80.	62.
35.	90.	70.
35.	100.	78.
35.	110.	86.
35.	120.	94.
35.	130.	101.
35.	140.	109.
40.	10.	*****
40.	20.	14.
40.	30.	22.
40.	40.	29.
40.	50.	36.
40.	60.	43.
40.	70.	50.
40.	80.	57.
40.	90.	65.
40.	100.	72.
40.	110.	79.
40.	120.	86.
40.	130.	93.
40.	140.	101.
45.	10.	*****
45.	20.	13.
45.	30.	20.
45.	40.	27.
45.	50.	34.
45.	60.	40.
45.	70.	47.
45.	80.	54.
45.	90.	60.
45.	100.	67.
45.	110.	74.
45.	120.	81.
45.	130.	87.
45.	140.	94.
50.	10.	*****
50.	20.	13.
50.	30.	19.
50.	40.	25.
50.	50.	32.
50.	60.	38.
50.	70.	45.
50.	80.	51.
50.	90.	57.
50.	100.	64.
50.	110.	70.
50.	120.	76.
50.	130.	83.
50.	140.	89.

***** SI OR HT. LESS THAN 10 FT. OR GREATER THAN 170 FT.

Table 4.—*Longleaf pine mean dominant and codominant heights, index age = 50*

M.P.50 SI OR HT. PROGRAM, SFES. 2/6/74

LONGLEAF PINE, INDEX AGE= 50.

TOT.AGE (YRS.)	SI (FT.)	TOT.HT. (FT.)	TOT.AGE (YRS.)	SI (FT.)	TOT.HT. (FT.)	TOT.AGE (YRS.)	SI (FT.)	TOT.HT. (FT.)	TOT.AGE (YRS.)	SI (FT.)	TOT.HT. (FT.)
15.	40.	15.	55.	60.	63.	95.	80.	102.	45.	110.	104.
20.	40.	21.	60.	60.	65.	100.	80.	103.	50.	110.	110.
25.	40.	25.	65.	60.	67.	15.	90.	33.	55.	110.	115.
30.	40.	29.	70.	60.	69.	20.	90.	47.	60.	110.	120.
35.	40.	33.	75.	60.	71.	25.	90.	57.	65.	110.	124.
40.	40.	35.	80.	60.	73.	30.	90.	66.	70.	110.	127.
45.	40.	38.	85.	60.	74.	35.	90.	73.	75.	110.	130.
50.	40.	40.	90.	60.	75.	40.	90.	80.	80.	110.	133.
55.	40.	42.	95.	60.	77.	45.	90.	85.	85.	110.	136.
60.	40.	43.	100.	60.	78.	50.	90.	90.	90.	110.	138.
65.	40.	45.	15.	70.	26.	55.	90.	94.	95.	110.	140.
70.	40.	46.	20.	70.	36.	60.	90.	98.	100.	110.	142.
75.	40.	47.	25.	70.	45.	65.	90.	101.			
80.	40.	48.	30.	70.	51.	70.	90.	104.			
85.	40.	49.	35.	70.	57.	75.	90.	107.			
90.	40.	50.	40.	70.	62.	80.	90.	109.			
95.	40.	51.	45.	70.	66.	85.	90.	111.			
100.	40.	52.	50.	70.	70.	90.	90.	113.			
15.	50.	18.	55.	70.	73.	95.	90.	115.			
20.	50.	26.	60.	70.	76.	100.	90.	116.			
25.	50.	32.	65.	70.	79.	15.	100.	37.			
30.	50.	37.	70.	70.	81.	20.	100.	52.			
35.	50.	41.	75.	70.	83.	25.	100.	64.			
40.	50.	44.	80.	70.	85.	30.	100.	73.			
45.	50.	47.	85.	70.	86.	35.	100.	82.			
50.	50.	50.	90.	70.	88.	40.	100.	89.			
55.	50.	52.	95.	70.	89.	45.	100.	95.			
60.	50.	54.	100.	70.	91.	50.	100.	100.			
65.	50.	56.	15.	80.	30.	55.	100.	105.			
70.	50.	58.	20.	80.	42.	60.	100.	109.			
75.	50.	59.	25.	80.	51.	65.	100.	112.			
80.	50.	61.	30.	80.	59.	70.	100.	116.			
85.	50.	62.	35.	80.	65.	75.	100.	118.			
90.	50.	63.	40.	80.	71.	80.	100.	121.			
95.	50.	64.	45.	80.	76.	85.	100.	123.			
100.	50.	65.	50.	80.	80.	90.	100.	126.			
15.	60.	22.	55.	80.	84.	95.	100.	128.			
20.	60.	31.	60.	80.	87.	100.	100.	129.			
25.	60.	38.	65.	80.	90.	15.	110.	41.			
30.	60.	44.	70.	80.	92.	20.	110.	57.			
35.	60.	49.	75.	80.	95.	25.	110.	70.			
40.	60.	53.	80.	80.	97.	30.	110.	81.			
45.	60.	57.	85.	80.	99.	35.	110.	90.			
50.	60.	60.	90.	80.	100.	40.	110.	97.			

***** SI OR HT. LESS THAN 10 FT. OR GREATER THAN 170 FT.

MP-50 SI or HT Program Listing

```
C     THIS PROGRAM COMPUTES OPTIONS = (1) SI ARRAY FOR ARRAY OF INTEGER SOH  101
C     AGE AND HT.  (2) HT. ARRAY FOR ARRAY OF INTEGER AGE AND SI.       SOH  102
C     EQUATIONS FOR SI OR HT. WERE DEVELOPED FROM USDA MISC. PUBL. 50   SOH  103
C     CURVES FOR NATURAL STANDS OF 4 MAJOR SO. PINES AND FOR ANY DESIREDSOH  104
C     INDEX AGE (SEE- JOUR. FOR.(71)696-697).                           SOH  105
C     ANY NO. OF OPT.-SPECIES-INDEX AGE COM8. CAN 8E RUN.               SOH  106
C DATA INPUT FOR A OPT.-SPECIES-INDEX AGE COMB.IS A CARD WITH FOLLOWING.SOH  201
C  ITEM   COLUMNS      DEFINITION                 EXPLANATION           SOH  202
C  ----   -------   ------------------  ------------------------------- SOH  203
C  IOP     1-4      OPTION              1=COMPUTE SI ARRAY FOR ARRAYS OF SOH  204
C                                       AGE AND HT.  2=COMPUTE HT. ARRAY SOH  205
C                                       FOR ARRAYS OF AGE AND SI.       SOH  206
C  ISP     5-8      SPECIES             1=LO8LOLLY, 2=LONGLEAF, 3=SHORT- SOH  207
C                                       LEAF, 4=SLASH.                  SOH  208
C  AI      9-12     INDEX AGE           DESIRED INDEX AGE, YRS.         SOH  209
C  I8A    13-16     MINIMUM AGE         DESIRED MIN. AGE, YRS.          SOH  210
C  ITA    17-20     MAXIMUM AGE         DESIRED MAX. AGE, YRS.          SOH  211
C  IAS    21-24     AGE STEP            DESIRED AGE INCREMENT, YRS.     SOH  212
C  I8SH   25-28     MIN.HT.(IOP=1) OR   DESIRED MIN. HT. FOR OPTION 1 OR SOH  213
C                   MIN.SI (IOP=2)      MIN.SI FOR OPTION 2, FT.        SOH  214
C  ITSH   29-32     MAX.HT.(IOP=1) OR   DESIRED MAX. HT. FOR OPTION 1 OR SOH  215
C                   MAX.SI (IOP=2)      MAX.SI FOR OPTION 2, FT.        SOH  216
C  ISHS   33-36     HT.STEP (IOP=1) OR  DESIRED HT. INCREMENT FOR OPTION SOH  217
C                   SI STEP (IOP=2)     1 OR SI INCREMENT FOR OPTION 2,  SOH  218
C                                       FT.                             SOH  219
C DATA CARD FORMAT IS (2I4,F4.0,6I4)                                    SOH  220
C     A TRAILER WITH 0000 IN COLS. 1-4 FOLLOWS LAST DATA CARD.          SOH  112
C     SI OR HT. ARRAY PRINTOUT FORMAT IS F5.0                           SOH  113
C     SI OR HT. UNDER 10 FT. OR OVER 170 FT. IS NOT PRINTED.            SOH  114
C     NOTE- AGE IS TOTAL AGE, HT. IS TOTAL HEIGHT (MEANS FOR DOM. AND   SOH  115
C     CODOM. TREES).                                                    SOH  116
C                                                                       SOH  117
C     M.P.50 SI OR HT. PROGRAM                                          SOH  118
C                                                                       SOH  119
  201 FORMAT(2I4,F4.0,6I4)                                              SOH  120
      COMMON ARRAY(44,3,4),8(4,7)                                       SOH  121
      DATA ((8(I,J),J=1,7),I=1,4)/                                      SOH  122
     1 -2.417370,-273.82400, 4227.7000,-19758.500,                      SOH  123
     26HLO8LOL,6HLY PIN,5HE,    ,                                       SOH  124
     3-11.870100,  0.000000, 1263.7900,-12409.500,                      SOH  125
     46HLONGLE,6HAF PIN,5HE,    ,                                       SOH  126
     5-11.104909,-83.244961, 2239.6780,-11260.453,                      SOH  127
     66HSHORTL,6HEAF PI,5HNE,   ,                                       SOH  128
     7 -8.804050, 22.795200,    0.0000,     0.000,                      SOH  129
     86HSLASH ,6HPINE, ,5H      /                                       SOH  130
    7 READ(5,201) IOP,ISP,AI,IBA,ITA,IAS,I8SH,ITSH,ISHS                 SOH  131
      IF(IOP.EQ.0) STOP                                                 SOH  132
      IF(IOP.EQ.1) GO TO 45                                             SOH  133
      IF(IOP.EQ.2) GO TO 85                                             SOH  134
   45 KK=0                                                              SOH  135
      NO=1                                                              SOH  136
      DO 49 LAP=I8A,ITA,IAS                                             SOH  137
      DO 47 KHT=I8SH,ITSH,ISHS                                          SOH  138
```

```
      HT=KHT
      AP=LAP
      CALL SIHT(SI,HT,AI,AP,ISP)
      KK=KK+1
      IF(KK.LE.44) GO TO 46
      IF(NO.EQ.4) CALL PRINT(KK,NO,IOP,ISP,AI)
      KK=1
      NO=NO+1
   46 ARRAY(KK,1,NO)=AP
      ARRAY(KK,2,NO)=HT
      ARRAY(KK,3,NO)=SI
   47 CONTINUE
   49 CONTINUE
      CALL PRINT(KK,NO,IOP,ISP,AI)
      GO TO 7
   85 KK=0
      NO=1
      DO 89 ISI=IBSH,ITSH,ISHS
      DO 87 LAP=IBA,ITA,IAS
      SI=ISI
      AP=LAP
      CALL SIHT(HT,SI,AP,AI,ISP)
      KK=KK+1
      IF(KK.LE.44) GO TO 86
      IF(NO.EQ.4) CALL PRINT(KK,NO,IOP,ISP,AI)
      KK=1
      NO=NO+1
   86 ARRAY(KK,1,NO)=AP
      ARRAY(KK,2,NO)=SI
      ARRAY(KK,3,NO)=HT
   87 CONTINUE
   89 CONTINUE
      CALL PRINT(KK,NO,IOP,ISP,AI)
      GO TO 7
      END
```

```
      SUBROUTINE SIHT(X,Y,AI,AP,ISP)
      COMMON ARRAY(44,3,4),B(4,7)
      X=Y*10.**(B(ISP,1)*(1./AI-1./AP)+B(ISP,2)*((1./AI)**2-(1./AP)**2)+
     1B(ISP,3)*((1./AI)**3-(1./AP)**3)+B(ISP,4)*((1./AI)**4-(1./AP)**4))
      IF(X.LT.10..OR.X.GT.170.) X=10.**10
      RETURN
      END
```

```
      SUBROUTINE PRINT(KK,NO,IOP,ISP,AI)                                PRT  101
    1 FORMAT(6X,3(F5.0,4X,F5.0,4X,F5.0,9X),F5.0,4X,F5.0,4X,F5.0)        PRT  102
    2 FORMAT(6X,3(F5.0,4X,F5.0,4X,F5.0,9X))                             PRT  103
    3 FORMAT(6X,2(F5.0,4X,F5.0,4X,F5.0,9X))                             PRT  104
    4 FORMAT(6X,F5.0,4X,F5.0,4X,F5.0)                                   PRT  105
  200 FORMAT(1H1,4X,39HM.P.50 SI OR HT. PROGRAM, SFES., 2/6/74//)       PRT  106
  202 FORMAT(1H0,4X,2A6,A5,10HINDEX AGE=,F4.0/)                         PRT  108
  206 FORMAT(1H0,4X,23HTOT.AGE   TOT.HT.    SI,9X,23HTOT.AGE   TOT.HT.  PRT  109
     1 SI,9X,23HTOT.AGE   TOT.HT.    SI,9X,23HTOT.AGE   TOT.HT.    SI/6PRT  110
     2X,24H(YRS.)     (FT.)     (FT.),8X,24H(YRS.)     (FT.)     (FT.),8X,24PRT  111
     3H(YRS.)     (FT.)     (FT.),8X,24H(YRS.)     (FT.)     (FT.)/5X,25(1H-PRT  112
     4),7X,25(1H-),7X,25(1H-),7X,25(1H-)/)                              PRT  113
  208 FORMAT(1H0,4X,25HTOT.AGE    SI      TOT.HT.,7X,25HTOT.AGE    SI   PRT  114
     1 TOT.HT.,7X,25HTOT.AGE    SI      TOT.HT.,7X,25HTOT.AGE    SI     TPRT  115
     2OT.HT./6X,23H(YRS.)    (FT.)     (FT.),9X,23H(YRS.)    (FT.)     (FT.)PRT  116
     3,9X,23H(YRS.)    (FT.)     (FT.),9X,23H(YRS.)    (FT.)     (FT.)/5X,25PRT  117
     4(1H-),7X,25(1H-),7X,25(1H-),7X,25(1H-)/)                          PRT  118
  210 FORMAT(1H0,4X,56H***** SI OR HT. LESS THAN 10 FT. OR GREATER THAN PRT  119
     1170 FT.)                                                          PRT  120
      COMMON ARRAY(44,3,4),B(4,7)                                       PRT  121
      WRITE(6,200)                                                      PRT  122
      WRITE(6,202) (B(ISP,J),J=5,7),AI                                  PRT  123
   45 GO TO (50,60),IOP                                                 PRT  124
   50 WRITE(6,206)                                                      PRT  125
      GO TO 65                                                          PRT  126
   60 WRITE(6,208)                                                      PRT  127
   65 IF(KK.GT.44) KK=44                                                PRT  128
      DO 100 I=1,44                                                     PRT  129
      IF(NO.EQ.4.AND.I.LE.KK) WRITE(6,1) ((ARRAY(I,J,K),J=1,3),K=1,4)   PRT  130
      IF(NO.EQ.4.AND.I.GT.KK) WRITE(6,2) ((ARRAY(I,J,K),J=1,3),K=1,3)   PRT  131
      IF(NO.EQ.3.AND.I.LE.KK) WRITE(6,2) ((ARRAY(I,J,K),J=1,3),K=1,3)   PRT  132
      IF(NO.EQ.3.AND.I.GT.KK) WRITE(6,3) ((ARRAY(I,J,K),J=1,3),K=1,2)   PRT  133
      IF(NO.EQ.2.AND.I.LE.KK) WRITE(6,3) ((ARRAY(I,J,K),J=1,3),K=1,2)   PRT  134
      IF(NO.EQ.2.AND.I.GT.KK) WRITE(6,4)  (ARRAY(I,J,I),J=1,3)          PRT  135
      IF(NO.EQ.1.AND.I.LE.KK) WRITE(6,4)  (ARRAY(I,J,1),J=1,3)          PRT  136
      IF(NO.EQ.1.AND.I.GT.KK) GO TO 105                                 PRT  137
  100 CONTINUE                                                          PRT  138
  105 NO=0                                                              PRT  139
      WRITE(6,210)                                                      PRT  140
      RETURN                                                            PRT  141
      END                                                               PRT  142
```

USDA Forest Service Southern Forest Experiment Station Research Notes SO no. 198 is missing from library and can not be obtained.

SOUTHERN FOREST EXPERIMENT STATION

1975

U.S. FOREST SERVICE RESEARCH NOTE

SO-199

Forest Service, U. S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

YIELDS OF DIRECT-SEEDED LOBLOLLY PINE AT AGE 22 YEARS

Thomas E. Campbell[1]

SOUTHERN FOREST EXPERIMENT STATION

The average d.b.h., height, basal area, and volume of 22-year-old direct-seeded loblolly pine were only slightly lower than those in an adjacent planted stand.

Additional keywords: *Pinus taeda*, growth, regeneration, pine management.

An exploratory study on how to direct seed loblolly pine (*Pinus taeda* L.) was installed near Glenmora, Louisiana, in March 1952. Results from the study made a substantial contribution to development of the direct-seeding technique, and since that time about 200,000 acres in the State have been seeded to loblolly. This Note summarizes growth and yield of the trees at age 22 and compares them with a demonstration planting of loblolly on a ¼-acre plot located at one end of the study area.

METHODS

The study area was a cutover longleaf (*P. palustris* Mill.) site that had been burned the year before. Its topography is nearly level, and its Bowie very fine sandy loam has slow internal drainage.

Twelve 0.1-acre plots—six on light grass rough and six on disked strips—were sown at the rate of 1 pound of seed per acre. Disked strips were 6 feet wide and 6 feet apart, and seeds were confined to the disked areas. Unstratified seeds were used on some plots and 90-day cold stratified seeds on others, but seed treatments did not produce measurably different stands; so, results were combined. Nursery seedlings were planted at 6- by 6-foot spacing on the adjacent plot.

At age 22, diameters at breast height (d.b.h.) of all trees on three grass roughs, four disked strips, and the plantation were measured to the nearest 0.1 inch. The other five seeded plots did not have acceptable stocking of at least 550 trees per acre. Poor initial catches, a severe drought during the first year, and the fact that seeds were not protected with predator repellents caused the low stocking.

Sample trees were selected so that all trees in each 1-inch d.b.h. class on each plot were represented by a proportionate number of sample trees. Total heights of the sample trees were measured, and their volumes were computed by the height accumulation method described by Lohrey and Dell (1969). Plot volumes were cal-

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culated by multiplying the volume/basal area ratio of sample trees by plot basal area.

RESULTS AND DISCUSSION

Stocking averaged 845 trees per acre on the grass rough, 969 on disked plots, and 729 in the plantation (table 1). These levels are considerably lower than initial stocking and stocking at 9 years (Hatchell 1961).

The average d.b.h. of all trees was 6.6 inches on the grass rough, 6.3 inches on disked strips, and 7.2 inches on the planted plot. However, approximately 18 percent of the trees on grass roughs and 23 percent of those on disked strips were below merchantable size (smaller than 3.6 inches d.b.h.); only 2 percent of the trees on the planted plot were too small. Clustering suppressed the growth of many seeded trees and some of them will never become merchantable. For planted trees, close initial spacing caused some suppression. However, severe fusiform rust (*Cronartium fusiforme* Hedgc. and Hunt Ex Cumm.), which has caused most of the mortality since age 9, was the principal growth retardant. Trunk cankering was much less prevalent in seeded stands.

Seeded plots had a broader range of diameters than the planted one because of erratic spacing (table 1). Open-grown seeded trees reached 11 to 14 inches, whereas many trees in clusters were less than 3 inches. There were no planted trees in the two extremes of the range. The two sowing methods produced similar numbers of trees and basal area measurements in the diameter classes above 4 inches, while the plantation trees excelled in numbers and basal area in the 5- to 9-inch classes. Only when smaller, mostly unmerchantable trees were included did the seeded stands close the gap.

Heights of seeded trees averaged 48 feet on grass roughs and 49 feet on disked strips. Planted trees, 1 year older from seed, averaged 55 feet tall, giving them the equivalent of about 2 years of additional growth. Dominants and codominants averaged 6 to 7 feet taller than all trees for each treatment.

Total volume averaged 49.6, 53.1, and 55.7 cords per acre for seeded-rough, seeded-disked, and planted plots. Merchantable yields were 43.4, 46.5, and 50.1 cords. Volume differences between rough and disked seedbeds were caused by the greater number of trees, and to a lesser extent, greater heights of trees on disked plots.

Certain factors need to be considered in using these data as a basis for choosing a regeneration technique. The high sowing rate on seeded plots resulted in stands that were too heavily stocked. That problem can be partially alleviated by prescription sowing in which the rate is adjusted to site and climate conditions; often as little as 0.4 pound of seed per acre is needed. The 6- by 6-foot planting spacing resulted in higher initial yields than can be expected from the wider spacing in current use. Since planting

TABLE 1.—*Cumulative number of trees and basal area per acre in descending order of 1-inch d.b.h. classes*

D.b.h.	Trees per acre			Basal area		
(inches)	Seeded-rough	Seeded-disked	Planted	Seeded-rough	Seeded-disked	Planted
		No.			Ft^2	
14	0	4	0	0	5	0
13	6	4	0	5	5	0
12	17	4	0	15	5	0
11	29	20	0	22	14	0
10	53	65	57	35	38	32
9	124	128	143	66	66	70
8	225	217	313	103	98	132
7	327	358	428	131	136	162
6	482	460	557	162	157	188
5	577	590	657	176	175	201
4	690	750	714	186	189	206
3	760	880	729	190	196	207
2	817	920	729	191	197	
1	845	969	729	192	197	
Total	845	969	729	192	197	207

was not replicated, valid statistical comparison with seeding yields is not possible. However, these are the only data available that compare yields of seeded with planted stands at this age, and they do provide indications of what to expect.

The suitability of a regeneration method depends upon the situation of the individual landowner. Planted stands have uniform distribution of the stems, which allows easy access for fire suppression and mechanical harvesters. Despite these obvious advantages, direct seeding may be preferable. A small landowner may not have the labor or equipment for planting, or the present-day cost of about $30 per acre may be beyond his budget. He can, however, purchase seed for $4 or $5 per acre and sow them himself. The industrial landowner also might have a labor problem, or the planting task might be larger than he can accomplish in an allotted time. In either case, direct seeding is now a reliable and profitable alternative, and any landowner should consider the advantages of both regeneration methods.

LITERATURE CITED

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SOUTHERN FOREST EXPERIMENT STATION

1975

U.S. FOREST SERVICE RESEARCH NOTE

SO-200

Forest Service, U. S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

WOOD MOISTURE AND DECAY PROBLEMS IN RECENTLY CONSTRUCTED, SINGLE-FAMILY HOUSES

R. C. DeGroot and T. W. Popham[1]

SOUTHERN FOREST EXPERIMENT STATION

A survey of Federally constructed houses in three Mississippi counties investigated errors in design or construction that might lead to moisture or decay problems. The houses were generally free of interior defects, but problems were found with groundlines, roofs, and doors. The defects were significantly related to developers.

Additional keywords: Wood products, termites, wood deterioration, building inspection.

The Bureau of the Census' continuing study of residential properties indicates that many properties with one to four units require annual maintenance and repairs (U. S. Department of Commerce 1972). States bordering the Gulf of Mexico are particularly prone to wood deterioration in above-ground construction (Johnston *et al.* 1972, Scheffer 1971). A study in Alabama showed that 15 percent of the single-family houses built after 1969 had damage caused by moisture or decay (DeGroot and Dickerhoof 1975). Wood decay apparently begins shortly after construction if errors in design or building have permitted untreated wood to become wet. This paper reports the impact of moisture and decay on recently constructed single-family houses, describes errors in design or construction that might lead to decay problems, and recommends changes to reduce errors in future construction.

METHODS

One-hundred-seventy-five wood-frame houses with slab-on-ground foundations and central heating were examined in three Mississippi counties bordering the Gulf of Mexico. Most had been built as part of a program conducted by the U. S. Department of Housing and Urban Development (HUD); all were managed by HUD or by the USDA Farmers' Home Administration.

Most of the houses were randomly selected from Federal lists and were visited in order of selection during the summer of 1973; the sample also included all houses added to the property manager's rolls during that summer.

The year that each house was built was estimated from the date on the plumbing fixtures, a procedure that does not overestimate the actual age by more than 1 year. All of the houses were

[1] DeGroot is principal plant pathologist stationed at Gulfport, Mississippi, and Popham is biometrician, Forest Service—USDA, Southern Forest Experiment Station, New Orleans, Louisiana.

built after 1960; most were built between 1968 and 1972 as shown below:

Earlier than 1965	*1965*	*1966*	*1967*
2	3	4	2

1968	*1969*	*1970*	*1971*	*1972*
15	17	67	62	3

Inspection procedures were identical for each house. The major concern was to identify potential problems associated with interior components, groundline, roof construction, and exterior doors. Structural terminology follows that of Anderson (1970).

The interior of each house was examined for evidence of plumbing failures, for mildew on walls, and for evidence of wood-destroying beetles in interior doors, casings, and jams.

Groundlines were inspected for drainage patterns that might move soil against the house, for proximity of soil to sills and siding, for wood forms or stakes left adjacent to the foundation, and for fire ant mounds and termites.

Wood moisture content was measured to the nearest percent with a Delmhorst meter. Decay occurs in nondurable or untreated wood when moisture content is above the fiber-saturation point, which varies with species and physical properties (Spalt 1958). Wood with a moisture content below 20 percent is ordinarily considered safe from decay, and wood with a moisture content above 30 percent is considered susceptible.

Moisture contents at the bases of wooden carport and porch posts were analyzed for possible association with improper grading of lawns. Moisture content at midlength of one sill plate was determined for carports and attached garages.

Each roof was examined for condition of the covering and possible errors in shingle application. Attics were inspected for evidence of leaks, and soffits and facia were examined for decay, mildew, blistering or peeling paint, and wood moisture content. Defects were studied for possible associations with roof design or construction details such as attic ventilation and the presence of flashing or molding around roof edges.

The moisture content of wood in front and rear doorways was measured at the bottom of the door, the top of the exterior casing, the exterior base of the jamb, and at the base of the interior casing.

One-hundred-fifty-five of the houses were in subdivisions where the developers could be identified. These developers were individuals or institutions identifiable either by their directly employed labor pool or by the contractors and subcontractors consistently utilized. The term developer thus denotes a labor group and does not refer to individual entrepreneurs. The nine developers were labeled A through I, and their houses were then grouped and compared for frequency of specific problems or defects.

Chi-square tests were made to determine association of several combinations of classificatory variables. The significance of differences among developers was evaluated with Friedman's test. All statistical tests were at the 0.05 level of significance.

RESULTS

Visible wood decay, wood with a moisture content of 30 percent or above, and construction defects that would probably develop into decay problems within 5 years were present in 21 percent of the sample (table 1). Thus, one of every five buyers of these Federally supervised houses will probably encounter wood moisture or decay problems early in ownership.

Table 1.—*Number and percentage of houses with wood decay caused by moisture, with excessive wood moisture content, or with construction defects condusive to moisture problems*

Defect	Number	Percent
Moisture content of 30 percent or above in porch or carport posts	17	10
Roof sheathing exposed	7	4
Decayed wood in facia or soffit	3	2
Wood moisture content of 30 percent or above in doorways	9	5
Total	36	21

Although no developer was outstanding in the ability to produce houses free of conditions likely to necessitate early expenditures for maintenance and repairs, the frequency of specific problems varied among developers, and some defects were entirely developer related (table 2).

Interiors

Interiors showed no evidence of moisture, insect, or decay problems in wood.

Table 2.—*Developer related defects and ranking of developer performance*[1]

Defect	Developer								
	A	B	C	D	E	F	G	H	I
Soil contacting brick veneer	8	7	[2]5	3	[2]5	9	1	2	4
Wood forms and stakes left by house	5	6	4	2	9	7	1	3	8
Fire ant mounds by house	9	6	8	[2]1	[2]1	[2]1	7	[2]1	5
Exposed roof sheathing	8	[2]1	[2]1	9	[2]1	6	[2]1	[2]1	7
Paint failure on eaves	3	[2]1	4	7	6	[2]1	8	5	9

[1] Quality decreases with ascending rank.
[2] Equivalent performance indicated by equal ranking.

Groundline

Surface drainage was away from most of the houses, and the grade level was below the sill plate of all. However, several developer-related groundline problems were noted in many houses. Allowing the grade level of the lawn to rest high against the foundation presents a long-term termite hazard. Soil contacted one or more tiers of brick on 60 houses, and the lawn completely obscured the slabs of nine and nearly covered the slabs of four others (table 3). Seventy-seven houses showed less than 6 inches of slab between the exterior wall covering (brick veneer, asbestos shingles, wood, or composite wood siding) and the groundline. Of the 14 houses with exterior wood or composite wood siding, six had a grade level less than 8 inches below the siding. Weeper holes at the base but not necessarily the bottom of exterior brick veneer walls were above the lawn in all but one house.

These houses did not meet all of the FHA minimum property standards, which require that the bottom of wood sills or sleepers below the top of slabs be at least 8 inches above exterior finish grade and which specify that concrete foundations are not adequate protection against termites in masonry veneer construction when the brick facing or veneer extends below the top of the foundation and is less than 8 inches above finish grade (USDHUD 1966).

Stakes and construction forms were left adjacent to 28 houses; all developers were prone to this practice (table 3). Stakes and forms may promote the establishment of termite colonies, especially if the soil around the perimeter of the house has not been adequately treated with pesticides.

Fire ant mounds were next to 20 percent of the houses built by two developers but were completely absent from houses built by several others (table 3). Where ants were able to build mounds adjacent to the slab foundations, antitermitic treatments were probably inadequate.

Table 3.—*Percentage of developer's houses with existing or potential wood deterioration problems*

Developer (number of houses)	Soil contacting brick veneer[1]	Wood forms and stakes left by house[1]	Fire ant mounds by house[1]	Porch or carport post moisture content above 30 percent	Exposed roof sheathing[1]	Paint failure on eaves[1]	Moisture content of doorways above 30 percent
	Percent						
A (24)	75	17	21	0	4	8	0
B (39)	36	18	5	21	0	10	5
C (15)	33	13	20	20	0	13	7
D (12)	25	8	0	8	42	42	17
E (9)	33	33	0	11	0	33	22
F (10)	90	20	0	0	10	10	0
G (13)	8	8	8	8	0	38	8
H (17)	12	12	0	0	0	18	0
I (16)	31	25	6	6	6	50	0
Total (175)	34	16	7	10	5	19	5

[1] Defect significantly associated with developer.

Of the 69 houses that had porches or carports with wood support posts resting directly on slabs or sidewalks, 17 had posts or columns with a moisture content of 30 percent or above at the base. No association was detected between high moisture content in posts and grade level of lawns. The excessive moisture content was caused by water accumulation on porches and carport slabs, a defect in the design of the house.

The average moisture content of sill plates in the 83 houses with carports or garages was 14 percent, and moisture never exceeded 30 percent. Six of these sill plates rested on the slab; the rest were on concrete walls 6 inches high.

Roof

In eight houses, the roofer's failure to overlap two courses of shingles at the roof edge permitted water to flow between the shingles and thereby contributed to early paint failure and decay in the cornices. Seventy-five percent of these errors were associated with one developer (D); 40 percent of the sample houses built by this developer revealed the defect (table 3).

Of the four houses that had decayed wood in the soffits or facia boards, all had shingle molding.

Blistering or peeling paint on soffits or facia boards may result from intermittent and excessive wetting of the wood and is conducive to decay. The condition occurred in 34 houses, was developer-related, and was unrelated to the presence of shingle molding or metal flashing at the upper edge of the facia or to air conditioning, roof and attic ventilation, and house age.

Doors

Solid wood exterior doors were rarely observed. About 90 percent of the exterior doors had no storm sash. In nine houses, wood components in doorways had moisture contents of 30 percent or above. Three doorways had excessive moisture at the exterior base of the jamb; seven had moisture contents greater than 30 percent at the base of the interior casing. None of the high moisture contents was related to rainfall. Although no significant association was found between moisture-prone doorways and developers, several of the developers constructed houses completely free of this problem (developers A, F, H, and I) (table 3).

DISCUSSION

The differences between developers in avoiding specific defects is important because some problems are more costly to repair than others. For example, faulty roof construction in one development will cause roof decay in approximately 40 percent of the houses within 5 years; yet several developments revealed no defects in roof construction (table 3).

Problems associated with porch posts might be easily corrected, but defective doorways may require major repairs, since the defects often lead to swelling and deterioration of adjacent wall materials. Therefore, performance standards requiring that wood moisture content in doorways be less than 30 percent at the time of final inspection may justifiably be added to building codes and standards. Building inspectors might easily monitor this facet of construction by checking wood moisture content at the bases of door casings.

The use of either molding or metal flashing at the top of facia boards increases the cost of eaves construction but did not appear to reduce decay or paint problems in the eaves. The association of paint failure with developer may reflect differences in paint quality. Although we did not measure the length of shingle extension beyond the outermost edge of facia or shingle molding, we observed that the amount of shingle overhang is extremely important in protecting paint on facia boards and probably provides long-term protection against wood decay.

Because of limited time and resources, field inspections of houses in a development often do not uncover errors. We suggest that building code officials do not have to examine every house in order to detect problems. The high percentages of specific problems within certain developments and the absence of those defects in others suggests that builders tend to repeat both positive and negative construction practices. Defects might therefore be more accurately detected if building officials conducted detailed inspections of a sample of houses within a development rather than performing a cursory inspection of all houses. By directing his attention to specific problems in a development, the building official would have greater influence on construction practices and would be able to inspect for maximum quality with minimum interruptions.

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SOUTHERN FOREST EXPERIMENT STATION

1975

U.S. FOREST SERVICE RESEARCH NOTE

SO-201

Forest Service, U. S. Dept. of Agriculture

-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

EXOTIC GRASS YIELDS UNDER SOUTHERN PINES

H. A. Pearson[1]

SOUTHERN FOREST EXPERIMENT STATION

Kentucky 31 and Kenwell tall fescue, Pensacola bahia, and Brunswick grasses yielded nearly three times more forage under an established pine stand than native grasses 7 years after seeding. Introducing exotic grasses did not significantly increase total grass production but did enhance range quality since the cool-season grasses are green during winter and are higher in crude protein, ether extract, phosphorus, and Vitamin A than the warm-season grasses. Prescribed burning was neither detrimental nor beneficial to the exotic grass yields.

Additional keywords: Introduced grasses, perennial, forage yields, multiple-use, forest range, cool- and warm-season grasses.

The problem of providing adequate forage on southern pine range can be solved by establishing sufficient perennial forages which tolerate shade and prescribed burning. Although there are several studies concerning exotic grass species on southern ranges (Burton 1973, Halls *et al.* 1957), little information (Hart *et al.* 1970) exists regarding introduced forages beneath pines. Moreover, most forest range improvement studies have not investigated the use of cool-season grasses, which provide green forage during winter and reduce the need for supplemental feed. The present study was initiated to determine the productivity of selected warm- and cool-season exotic grasses under an established, well-stocked 15-year-old pine stand.

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METHODS

The study was on the Palustris Experimental Forest in central Louisiana, where annual precipitation averages 58 inches. In 1952 about 0.2 acre of cutover land was burned and planted with slash (*Pinus elliottii* Engelm.) and loblolly (*P. taeda* L.) pine seedlings at a spacing of 6 by 6 feet. By the fall of 1974, the pines had a basal area of 210 ft^2 per acre and averaged 6.6 inches in d.b.h. Pine density was 885 trees per acre, but because the plantation was small, forage responses were expected to be somewhat higher than normally found under trees this dense.

The area was not grazed after pine establishment. Pinehill bluestem (*Andropogon scoparius* var. *divergens* Anderss. ex Hack.) and slender bluestem (*A. tener* (Nees) Kunth) originally dominated the herbaceous vegetation; however, by 1971 switchgrass (*Panicum virgatum* L.), spreading panicum (*P. rhizomatum* Hitchc. & Chase), and pinehill bluestem dominated.

In November 1967, 14 plots (10 by 20 feet) were burned and randomly assigned to be seeded with one of six exotic grass species or left unseeded as a control.[2] No soil disturbance or vegetation control methods were used other than burning. Four varieties of tall fescue (*Festuca arundinacea* Schreb.), all cool-season perennials, were seeded in December 1967 at a rate of 25 pounds per acre; varieties were Fawn, Goar, Kentucky 31, and Kenwell. Two warm-season grasses, Brunswick (*Paspalum nicorae* Parodi) and Pensacola bahia (*P. notatum* Flügge), were seeded in May 1968 at a rate of 15 pounds per acre.

Since cast pine needles covered the understory vegetation, half of each plot was prescribed burned in February 1970. In 1974 pine litter accumulations were measured on four 2.4 ft^2 quadrats per split plot.

During 1971 and 1974, grasses were clipped once in summer from two 9.6 ft^2 quadrats in each split plot. The grasses were separated by species, ovendried, and weighed. Total yield and yields of exotic and native grasses were evaluated with analysis of variance; significant (0.05 level) means were separated by Duncan's multiple range test. Chemical analysis[3] and *in vitro* dry matter digestibility (Pearson 1970) were determined from forages harvested in June 1971.

RESULTS AND DISCUSSION

Four years after seeding (tree age 19 years), Kentucky 31 and Kenwell tall fescue yielded significantly more forage than any of the other exotic grasses (table 1), but residual native grasses on each plot outproduced the exotics. Native grass production averaged 159 pounds per acre; exotic grasses averaged 42 pounds per acre. Warm-season exotic grass yields were not significantly greater than zero.

After 7 years (tree age 22 years), Kentucky 31 and Kenwell tall fescue, Pensacola bahia, and Brunswick yielded 3 to 14 times more forage than at 4 years; Brunswick showed the greatest proportionate increase (table 1). Precipitation during winter, spring, and early summer of 1974 was 33 percent higher than it had been in 1971, which at least partially explains the increased yields. Average yield of these four exotics was 342 pounds per acre, or nearly three times more forage than the native grasses yielded (117 pounds per acre average). Kentucky 31 tall fescue yielded 83 percent of the total grass production on its plots, Kenwell tall fescue 75 percent, Pensacola bahia 64 percent, and Brunswick 73 percent. The other fescues essentially disappeared.

Chemical analyses indicated that cool-season Kentucky 31 and Kenwell tall fescues were higher in crude protein, ether extract, ash, phosphorus, and Vitamin A than the warm-season Pensacola bahia or native pinehill bluestem (table 2). Crude fiber and nitrogen-free-extract were higher in the warm-season grasses. Digestibility was higher for the exotics than the native bluestem. Nutritional differences between warm- and cool-season forages in winter are probably greater than these June analyses show since warm-season plants are dormant.

Total yields did not significantly increase on any of the plots, even those with significantly high exotic yields. Consequently, the only apparent benefit to be derived from seeding exotic

[2] Plots established by V. L. Duvall and L. B. Whitaker.

[3] Chemical analyses were conducted by the Feed and Fertilizer Laboratory, Louisiana State University, Baton Rouge, La.

Table 1.—*Grass production under a slash-loblolly pine plantation*

Species	Tree age 19 years			Tree age 22 years		
	Exotic grasses	Native grasses	Total	Exotic grasses	Native grasses	Total
	Pounds/acre[1]					
Kentucky 31 tall fescue	88a	160a	248a	542a	111a	653a
Kenwell tall fescue	100a	137a	237a	260b	86a	346a
Pensacola bahia	36b	197a	233a	304b	171a	475a
Brunswick	19b	146a	165a	261b	99a	360a
Fawn tall fescue	8b	225a	233a	4c	286a	290a
Goar tall fescue	1b	147a	148a	4c	178a	182a
Control	0b	101a	101a	0c	230a	230a

[1] Within columns, means followed by unlike letters are significantly different at 0.05 probability level.

Table 2.—*Chemical analysis and in vitro dry matter digestibility of forages under pines*

Chemical analysis	Pinehill bluestem	Pensacola bahia	Kentucky 31 tall fescue	Kenwell tall fescue
Digestibility (%)	34.9	46.1	44.5	49.8
Crude protein (%)	8.0	8.9	12.9	11.6
Ether extract (%)	2.3	3.9	4.9	4.4
Crude fiber (%)	36.9	40.1	31.9	30.5
Nitrogen-free-extract (%)	46.7	44.6	36.9	39.8
Ash (%)	6.1	2.5	13.4	13.7
Calcium (%)	.32	.20	.27	.29
Phosphorus (%)	.09	.10	.15	.18
Vitamin A (IU)	1,081	4,615	12,521	15,917

grasses under dense stands of pine is the green forage that cool-season exotics provide during winter which is higher in some nutrients than native grasses.

Prescribed burning 1 and 3 years before measurement neither increased nor decreased the productivity of the exotic grass species. Native grasses and total yields were similarly unaffected. Burning did not have a significant effect on litter accumulations; however, at 5,000 pounds of litter per acre, burned plots averaged 1,000 pounds per acre less than unburned plots. More frequent burnings may reduce litter sufficiently to increase grass yields.

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SOUTHERN FOREST EXPERIMENT STATION

1976

U.S. FOREST SERVICE RESEARCH NOTE

SO-202

Forest Service, U. S. Dept. of Agriculture

-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

GIRDLING AND APPLYING CHEMICALS PROMOTE RAPID ROOTING OF SYCAMORE CUTTINGS

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SOUTHERN FOREST EXPERIMENT STATION

*Shoots of 6- and 13-year-old sycamore (*Platanus occidentalis *L.) were girdled and treated with rooting powder 4 weeks before cuttings were taken. The powder, which contained auxins, sucrose, and captan, was also applied basally to nongirdled cuttings immediately before insertion in a rooting medium. Thirteen days later, 100 percent of the girdled cuttings had rooted; they produced an average of 21 roots per cutting. Only 22 percent of the nongirdled cuttings rooted during this period; the average number of roots per cutting was four.*

Additional keywords: Vegetative propagation, growth substances, *Platanus occidentalis* L.

INTRODUCTION

Sycamore improvement programs would be facilitated by reliable techniques of asexual propagation. Sycamore cuttings root readily when taken from juvenile ortets (Nelson and Martindale 1957, McAlpine et al. 1972, Briscoe 1973) or from rejuvenated stump sprouts of mature trees (Kormanik and Brown 1974), but little is known of the rooting potential of nonjuvenile material (Farmer 1974). For most forest trees including sycamore, successful rooting decreases with age, and satisfactory methods for rooting cuttings of older material have not been reported. Rooting cuttings of older trees is important because juvenile characteristics are not reliable for selecting superior trees and because grafting presents incompatibility problems and affects rootstock. For 12-year-old slash pine, girdling and applying chemicals to shoots 2 months before taking cuttings proved to be a promising method of stimulating rooting (Hare 1975). The treatment, which is similar to air-layering, improves rooting by forcing the shoot to accumulate food reserves and by inducing callus formation. Unlike air-layering, however, this system promotes rapid rooting by removing the cutting to an optimal environment once callus is formed. It also eliminates damp moss, which is known to leach out growth substances (Cameron 1968). The procedure offers tree

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breeders a way to avoid grafting when building up clone banks and seed orchards.

The present experiment describes an attempt to use the girdling technique to root cuttings from 6- and 13-year-old sycamore.

MATERIALS AND METHODS

The rooting powder applied was developed previously for sycamore and other hardwoods. It contained 1 percent each IBA (indolebutyric acid) and PPZ (1-phenyl-3-methyl-5-pyrazalone), 20 percent powdered sucrose, and 5 percent captain in talc (1-1-20-5). Cuttings were obtained from twenty-two 6-year-old trees and from three 13-year-old trees growing in southern Mississippi. On May 7, 1975, when the leaves had fully expanded, two pairs of shoots were tagged in the middle and lower crown of each tree. Each pair consisted of shoots of similar size from the same branch or from one nearby. One member of each pair was girdled by removing a ring of bark 1 to 2 cm wide from the previous year's wood about 25 cm below the tip of the shoot. An aqueous slurry of the rooting powder was applied to the distal portion of each wound with a camel's hair brush; next, the girdles were covered with saran film and then with tinfoil. Although aluminum foil, which is cheaper than tinfoil, would probably be satisfactory, tinfoil has better wrapping properties.

On June 3, cuttings were taken at the distal end of the girdled shoots and 25 cm below the shoot tip of the nongirdled ones. On the same day, cutting pairs were tied together and transported to the greenhouse in plastic bags where they were dipped in water, treated basally with rooting powder, and inserted side-by-side in the propagating bed. Nongirdled cuttings received the 1-1-20-5 powder. Girdled ones were given 0-0-20-5; IBA and PPZ were omitted to avoid possible auxin inhibition of root growth where pre-formed roots were present. The cuttings were inserted 7 cm deep in perlite-vermiculite rooting medium; spacing was 15 by 15 cm. Misting nozzles automatically controlled by evaporation from a screen supplied moisture; bottom heat was provided to maintain temperatures of 24° to 27° C in the medium. Greenhouse temperatures ranged from 18° to 32° C. The experimental design was appropriate for a paired observation t-test; each of the 50 pairs consisted of one girdled and one nongirdled cutting taken from the same ortet and crown position and placed adjacent to one another in the propagating bed. All cuttings were removed after 13 days and tallied for survival, number of roots, and the presence of callus. Because of the overwhelming response to girdling, no statistical analysis was necessary.

RESULTS AND DISCUSSION

The cuttings were all living when lifted after 13 days. All of the girdled cuttings had rooted (table 1); the average number of roots per cutting was 21.5 (fig. 1). In contrast, only 22 percent of the nongirdled cuttings rooted during this time; they averaged 4.3 roots each. Although all girdled cuttings rooted, there was evidence of clonal differences in response to treatment. Girdled cuttings from the four best trees averaged 49 roots per cutting; those from the four worst averaged only seven. Only two trees showed 100 percent rooting of cuttings that did not receive the girdling treatment.

Table 1.—*Rooting responses of girdled and nongirdled sycamore cuttings after (13) days in the propagating bed*

Ortets		Girdled cuttings		Nongirdled cuttings	
Age (years)	Number	Rooted (percent)	Roots [1]	Rooted (percent)	Roots [1]
6	22	100	22.4	22.7	4.1
13	3	100	15.2	16.7	6.0

[1] Average number of roots per rooted cutting.

At the time they were taken from the tree, all girdled cuttings were heavily callused, and some had small roots. By lifting time, half of the nongirdled cuttings that had not rooted showed some callus. Although some of these might have rooted after a longer period in the propagation bed, their root systems would be smaller than those on girdled cuttings, and survival after planting would probably be poorer.

Girdled cuttings from 13-year-old trees usually had fewer roots than those from 6-year-old trees (table 1). However, root systems of cuttings from the older trees were adequate for planting (fig. 1).

Figure 1.—*Cuttings from a 13-year-old sycamore after 13 days in the propagating bed (girdled left, nongirdled right).*

With this technique, rapid greenhouse rooting of nonjuvenile foliated sycamore cuttings appears feasible if the shoots are accessible. However, for large trees whose branches are difficult to reach, it may be necessary to shoot the cuttings from the tree without girdling. These cuttings will require more time in the propagating bed and will have sparser root systems than girdled cuttings. Using 1-1-20-5 rooting powder, we obtained 22 percent rooting within 13 days for nongirdled cuttings; possibly, 50 percent would have rooted if given more time. Improved chemical treatments are being investigated to induce adequate and rapid rooting without girdling. Another possibility is to build up clones by rooting girdled cuttings from previously grafted material.

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SOUTHERN FOREST EXPERIMENT STATION

1976

U.S. FOREST SERVICE RESEARCH NOTE

SO-203

Forest Service, U. S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

GRAZING POTENTIAL OF LOUISIANA PINE FOREST-RANGES

Herbert S. Sternitzke[1]

SOUTHERN FOREST EXPERIMENT STATION

Louisiana's 5 million acres of pine forest-range have an estimated forage potential for 135,776 yearlong cow-calf units. Two-thirds of the units can be sustained on loblolly-shortleaf pine ranges; the rest, on longleaf-slash pine ranges.

ADDITIONAL KEYWORDS: Animal unit months, cow-calf units, forage potential, understory herbage.

Grazing cattle on pine forest-ranges may offer some Louisiana cattlemen an alternative to paying rising feed grain prices. Most projections indicate strong future export demands for grain and continued upward pressures on feed prices (Hodgson 1974). By providing readily available forage, herbage understories on pine ranges can help to reduce ruminant livestock production costs.

Louisiana now has 5,096,000 acres of pine forest-range (Earles 1975). An important question for land managers and agricultural policymakers is, what is the grazing potential of this range under prevailing timber management practices? To help answer the question, a special range analysis was undertaken in 11 southwestern parishes[2] during the recent statewide timber inventory (Sternitzke and Pearson 1974). Information was evaluated from more than 3,000 sample plots that were systematically distributed over a test area of some 7 million acres.

In the parishes sampled, annual herbage production on longleaf-slash pine range is about 1,529 pounds per acre, and an average of 24 acres are needed for yearlong grazing of one animal unit (a mature cow with calf or their equivalent). Loblolly-shortleaf range produces about 816 pounds per acre, and 44 acres are needed for grazing one cow-calf unit. Fewer acres are needed in open stands than in dense ones. In pine stands classified by the Forest Survey as fully stocked with trees, only 1 in every 3 acres had herbage cover on at least half of the site. In understocked stands, 2 acres in 3 were at least half covered with herbage. Under dual beef-timber management strategies, density of the overstory is clearly a critical factor.

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[2] Allen, Beauregard, Calcasieu, Evangeline, Grant, Jefferson Davis, La Salle, Natchitoches, Rapides, Sabine, and Vernon.

The most plentiful native forage grasses are the bluestems (table 1), and they also are the most valuable as foodstuffs. The panicums are second to the bluestems in abundance and desirability. On loblolly-shortleaf forest-ranges, uniola, a cool season plant (Leithead, Yarlett, and Shiflet 1971), is particularly important in that it provides considerable forage in winter.

Table 1.—*Botanical composition (%) of understory herbage by type of pine forest-range*

Understory [1] herbage	Longleaf-slash pine	Loblolly-shortleaf pine
Slender bluestem	9.4	3.3
Broomsedge bluestem	7.0	3.2
Other bluestems	14.0	15.7
Panicums	17.6	13.4
Uniolas	.4	8.0
Carpetgrass	4.2	4.8
Threeawn	2.7	2.4
Cutover muhly	3.8	2.0
Other grass	10.3	12.4
Grasslike	8.0	8.0
Legumes	5.5	7.0
Other forbs	17.1	19.0
All herbage	100.0	100.0

[1] Based upon sample of 11 southwest Louisiana parishes.

An animal unit month (AUM) is the amount of feed or forage required by an animal unit for 1 month. In the southwestern parishes, the 737,900 inventoried acres of longleaf-slash pine had a forage potential of 376,187 animal unit months each year; the 1,574,600 acres of loblolly-shortleaf pine had a potential of 428,326 AUMs. Projected statewide, these data indicate that 135,776 cow-calf units could be grazed yearlong on Louisiana's pine forest-range. About 15 percent of the projected total is in the Florida Parishes; the rest is on ranges west of the Mississippi River.

Besides the acreage currently in pine, Louisiana has 3,722,700 acres of potential pine sites that are dominated by hardwoods. These stands are a serious hindrance to forest-range grazing (Campbell and Peevy 1945). Existing markets cannot profitably absorb the tremendous supply of low-quality hardwoods from these sites, and outright disposal is often costly (Murphy and Knight 1974). New techniques of utilization may open markets for a significant portion of this hardwood inventory and give impetus to converting the stands to pine, but the potential yields for timber and range livestock are generally not being realized at present.

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SOUTHERN FOREST EXPERIMENT STATION

1976

U.S. FOREST SERVICE RESEARCH NOTE

SO-204

Forest Service, U. S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

FATTY AND WAXY COMPONENTS OF SOUTHERN PINE BARK–AMOUNTS PRESENT AS FREE EXTRACTIVES

Elaine T. Howard [1]

SOUTHERN FOREST EXPERIMENT STATION

Whole bark from six mature trees of each of the four major southern pines was extracted with petroleum ether and with toluene. Trees were 20 to 58 years old and 8.0 to 11.8 inches in d.b.h. Percentages of petroleum ether-solubles were: slash pine, 1.94; loblolly, 2.29; longleaf, 2.64; and shortleaf 3.05. Percentages obtained by toluene extraction were: loblolly, 3.04; slash, 3.18; longleaf, 3.38; shortleaf, 3.77. Extractives were light to medium yellow, resinous in odor, and slightly tacky. Several procedures for removing these components from aqueous and ethanolic alkali extracts were tried, including organic solvent extraction of basic and acidified extracts, and acidification and filtration followed by solvent extraction. None of the methods increased the yield of lipids, and products were generally softer and stickier than those obtained by direct extraction.

ADDITIONAL KEYWORDS: Bark utilization, chemical composition, extractives, fatty acids, neutrals, *Pinus echinata*, *P. elliottii* var. *elliottii*, *P. palustris*, *P. taeda*.

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Although much work has been done on oleoresin and tall oil constituents in wood, and a considerable amount of organic-solvent solubles from barks of other species, information specific to southern pine bark is meager. Knowledge of such components is essential not only to possible commercial applications of these substances, but also because their presence will affect various possible uses of whole or fractionated bark in pulping systems, board products, pyrolysis, extracts, or other products. Because some of these compounds may also be obtained by alkaline processes, inclusion of barky chips in pulping will probably modify the composition of tall oil if bark differs considerably from wood in this respect.

Most investigations on organic-solvent extracts have dealt with the bark of Douglas-fir and western pines. For bark of other pines, various researchers list extractable lipid contents ranging generally from 3 to 8 percent. Several authors have reported alcohol-benzene extractive contents of southern pine bark, but because ethyl alcohol is polar these extracts also contain substances other than those of interest in the present study. Data from southern pine bark extractions with solvents that are nonpolar or of low polarity are very limited. Hall and Grisvold (1935) and Hall (1936) reported that 5.5 percent of the phloem from slash pine saplings was extractable in petroleum ether, and they identified some of the components. Martin and Brown (1952) obtained 4.6 percent ether solubles and 7.2 percent alcohol-benzene solubles from shortleaf pine bark. Rowe (1965) found that the benzene extract of loblolly pine was 4.6 percent of ovendry bark, and he examined the sterols.

The present study determined the amounts of fatty and waxy material available as free extractives when southern pine bark is extracted with nonpolar solvents. Petroleum ether and toluene were the solvents chosen. Because of health hazards associated with continued exposure, benzene was not used; toluene gives similar results and is less toxic.

METHODS

Six trees each of loblolly *(Pinus taeda* L.), longleaf *(P. palustris* Mill.), shortleaf *(P. echinata* Mill.), and slash pine *(P. elliottii* Engelm. var. *elliottii)* were selected from sites scattered through central Louisiana. The trees ranged from 20 to 58 years old and 8.0 to 11.8 inches d.b.h. Diseased, injured, or severely suppressed trees were avoided. In mid-October, trees were felled and hand-peeled up to a 4-inch top (o.b.). Inner bark was included. The material was segregated according to position on the stem (lower, middle, or upper third), sealed immediately in vapor-proof bags, and placed in a freezer.

To subdivide the bark into a smaller sample representative of each tree, bags were weighed and a proportionate weight was taken from each bag to yield approximately 25 pounds per tree. While still frozen, samples were run through a garden mulcher, then returned to the freezer. Before final grinding to pass a 1-mm screen, the bark was freeze-dried for 2 to 3 days to avoid the oxidation and polymerization that oven- or air-drying would produce.

Soxhlet apparatus was used for extraction with toluene and with 30-60° petroleum ether. The total number of extracts was 144: (4 species) (6 trees/species) (3 replications/tree) (2 solvents). Solvent flasks containing the waxy material were vacuum-evaporated (under 50°C), flushed with nitrogen, and weighed. Yields are expressed as a percent of bark dry weight. In an attempt to determine the amount of extractives removed, the bark was weighed before and after extraction. This approach proved unsatisfactory, presumably because of difficulty in completely removing solvents from the bark residue.

RESULTS

Extractives from both solvents were light to medium yellow; the petroleum ether-solubles were paler in color than toluene-solubles and contained a whitish waxy component that solidified earlier than the other compounds as the material cooled. A resinous odor and somewhat tacky texture were observed for all species, probably resulting from the presence of resin acids.

Tree averages for free extractives obtained by the two solvents are given in table 1. Individual trees within a species showed considerable variation. Because of its slightly greater polarity, toluene removed additional material not soluble in petroleum ether (33 percent more from loblolly; 28 percent more from longleaf; 24 percent more from shortleaf; and 64 percent more from slash pine). By two-way analysis of variance, the differences between solvents and between species were significant at the 0.05 level.

When toluene treatments were appraised by Duncan's multiple range test at the 0.05 level, extractive yield from shortleaf bark was greater than that from loblolly and slash pines, but not greater than that from longleaf. In the following summary, means underscored by the same line do not differ significantly:

Loblolly	Slash	Longleaf	Shortleaf
3.04	3.18	3.38	3.77

For petroleum-ether extracts, differences were:

Slash	Loblolly	Longleaf	Shortleaf
1.94	2.29	2.64	3.05

Table 1.—*Free extractives (in percent of ovendry weight of bark) obtained by solvent extraction of whole bark from southern pines 8 to 12 inches in d.b.h.*

Tree	Slash		Loblolly		Longleaf		Shortleaf	
	Petroleum ether	Toluene	Petroleum ether	Toluene	Petroleum ether	Toluene	Petroleum ether	Toluene
1	1.92	3.21	3.06	3.68	2.63	3.81	3.04	3.10
2	2.00	3.33	1.95	2.96	2.04	2.64	3.43	3.49
3	1.79	3.06	2.35	3.27	2.46	3.54	3.24	4.27
4	1.77	2.79	1.92	3.15	3.49	3.65	3.20	4.81
5	2.12	3.29	1.67	2.44	3.21	4.00	2.84	3.58
6	2.06	3.41	2.80	2.77	2.04	2.65	2.56	3.38
Avg.	1.94	3.18	2.29	3.04	2.64	3.38	3.05	3.77

REMOVAL OF LIPIDS BY REACTION

In hopes of increasing the yield of fatty components, and because it was felt that some problems of caustic extracts for phenolic products might be caused by soap formation, several procedures for removing these components were tried.

Aqueous caustic extracts prepared by cooking bark with 16 percent NaOH (based on ovendry bark) at 90°C were used, both in original basic form (pH greater than 10) and after acidification (to pH 4 or lower to precipitate acids and wax salts). Three recovery methods were tried:

Treatment of basic extract with organic solvents—hexanol, toluene, cyclohexane, chloroform.

Acidification, then extraction with chloroform and cyclohexane.

Acidification and filtration, followed by solvent extraction of both precipitate and filtrate.

Ethanolysis extracts were prepared by refluxing bark with 17 percent NaOH in absolute ethanol; a similar cook was made with KOH as the alkali. The liquor was drained into water (one-fifth of ethanol volume) and chilled. Lipid recovery methods were:

Filtered while basic, precipitate and filtrate acidified, then solvent extraction of filtrate.

Acidification, evaporation of ethanol, extraction with solvent.

Ethanol evaporated, acidification, solvent extraction.

Acidification, filtration, solvent extraction of filtrate.

Emulsions formed during extractions generally required centrifuging to separate the phases. None of the methods increased yields of lipids or gave more fatty or waxy material than could be obtained by direct extraction of untreated bark. Further, the products usually appeared inferior to those obtained by direct extraction. They were soft and sticky and included mixtures of free fatty acids, fatty acid salts, free fatty alcohols, various esters and waxes, and some phenolic compounds.

CONCLUSIONS

The materials studied constitute useful classes of compounds. At present, however, extraction of southern pine bark for the sole purpose of recovering the fatty and waxy products probably is economically unattractive because of the costs of solvents and material preparation and the low yields. On the other hand, extraction might well become feasible if other fractions of the bark were simultaneously processed for other products, if a particular component were found to have a high-value use (such as sterols for pharmaceuticals) or if difficulties with primary products would be alleviated by removal of lipids.

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SOUTHERN FOREST EXPERIMENT STATION

1975

U.S. FOREST SERVICE RESEARCH NOTE

SO-205

Forest Service, U. S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

MATURATION OF BLACK CHERRY FRUITS IN CENTRAL MISSISSIPPI

F. T. Bonner[1]

SOUTHERN FOREST EXPERIMENT STATION

*Black cherry (*Prunus serotina *Ehrh.) in central Mississippi grew in size and weight from early May until maturity in late June. In early June, crude fat, protein-nitrogen, and calcium concentrations increased; moisture content decreased; endocarps hardened; and embryo tissues became firm. From mid-June to maturity mesocarp growth was prominent as moisture content increased again, carbohydrates were converted from insoluble to soluble forms, and crude fat and protein-nitrogen concentrations decreased.*

Additional keywords: *Prunus serotina* Ehrh., chemical analysis, germination.

INTRODUCTION

Black cherry (*Prunus serotina* Ehrh.), a valuable hardwood species, occurs from Canada to the Gulf of Mexico (Hough 1965). It flowers from March to early June, and fruits mature from June to October, depending on latitude (Sargent 1965). The small, white, perfect flowers are in 10- to 15-cm long racemes, and fruits are single-seeded drupes. The number of cleaned seeds averages 10,500 per kg (Hough 1965).

This paper examines changes that occur in gross physical and chemical characteristics of black cherry fruits as they mature. The study was conducted in central Mississippi where black cherry usually flowers in early April, fruits mature in late June, and the number of cleaned seeds per kg averages 16,500. The species does not reach its highest value in Mississippi, but the data should help seed collectors elsewhere to secure high quality seeds at the proper time.

METHODS

Four trees were selected near Starkville, Mississippi, in 1971. Starting in late April, 10 fruits were collected from each tree every 2 weeks until late July. In 1972 and 1973 similar collections were made from three of the same trees and from a fourth tree that was not included in the earlier year.

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The fruits were collected early in the morning and transported to the laboratory in polyethylene bags for measurements of diameter, fresh weight, dry weight, and moisture contents. Dry weights were obtained after 24 hours of drying in an oven at 105°C. Moisture contents were calculated as percentages of fresh weights.

Beginning in June of 1971 and 1972, extra fruits were collected from the trees for germination tests. These fruits were depulped by hand and stratified for 90 days at 3°C before being placed on moist blotters of Kimpak under diurnally alternating temperatures of 20° and 30°C (I.S.T.A. 1966).

In 1973 extra fruits were collected from one of the trees for chemical analyses. The fruits were dried for 24 hours at 70°C and then ground in a Wiley mill to pass a 20-mesh screen. The material was analyzed for crude fat, soluble and insoluble carbohydrates, soluble nitrogen, protein-nitrogen, phosphorus, calcium, and magnesium. Details of the analytical methods are in Bonner 1972 and 1974.

RESULTS AND DISCUSSION

Physical Characteristics

The fruit crop was excellent in 1971 and poor in 1972 and 1973. In 1971 average weights increased more than five-fold from May 3 until maturity (fig. 1). Fruits from the 1972 and 1973 crops averaged half the weight, both fresh and dry, of the 1971 fruits. The average diameter was 10 mm in 1971, 8 mm in 1972, and 7 mm in 1973. In 1971, diameters were stable until early June, then almost doubled by July when dispersal began.

During each year, moisture content was about 80 percent in early May, then decreased to a low of 65 percent in early June as endocarps became hard, and the embryos changed from a watery pulp to firm, white tissues (fig. 1). After early June, the mesocarps became succulent, and moisture content increased until it ranged from 70 to 75 percent.

A low percentage of seeds germinated, especially in 1972, probably because the alternating 20° and 30°C temperatures prescribed by I.S.T.A. (1966) rules are too high for *P. serotina* (table 1). Farmer and Barnett (1972) got good germination with alternating 10° and 15.6°C temperatures, and we have been successful with a 15° and 25°C regime. Suszka (1967) and Huntzinger (1968) recommend warm-cold stratification, but recent tests in our laboratory show this does not aid germination of Mississippi seeds.

Maturity, the capability of a seed to germinate normally, was best indicated by fruit color. Huntzinger (1968) reported that seeds from green fruits could germinate, but very few did in this study. Most fruits changed from green to light

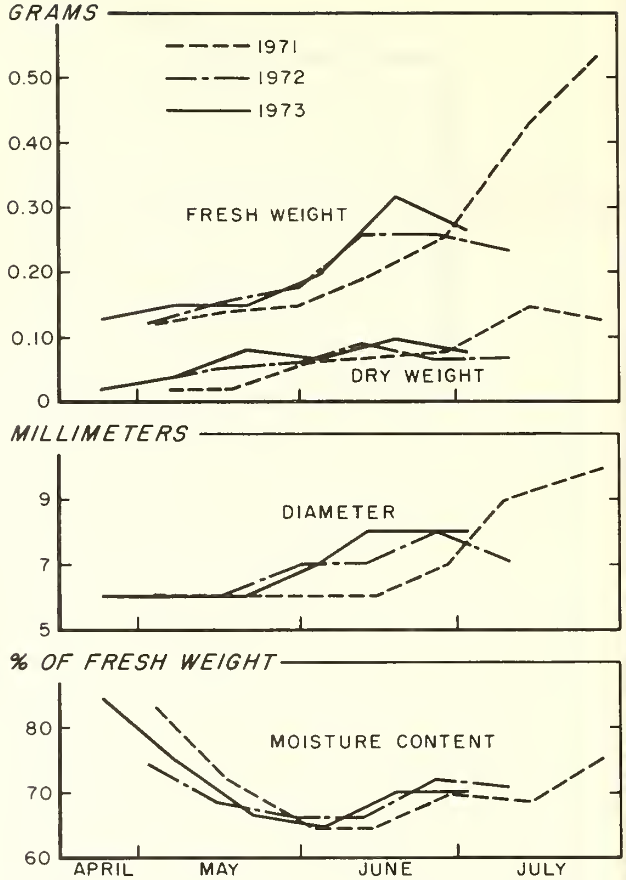

Figure 1.—*Seasonal changes in fresh weight, dry weight, diameter, and moisture content of black cherry fruits.*

Table 1.—*Germination after 30 days of black cherry seeds from 1971 and 1972 collections*

Collection date	Sample tree 1	2	3	4
	Percent			
1971				
June 14	0	15	0	2
June 28	43	23	30	8
July 14	25	6	11	3
July 28	48	9	8	4
1972				
June 6	3	0	7	0
June 26	20	...	3	0

red by the end of May and from light to dark red in early June. Seeds picked in early June that germinated probably were individuals that matured early. In late June, some exocarps were dark purple, but most were reddish purple, and there was variation in color among fruits from the same tree and within single fruit clusters. A higher percentage of seeds collected in late June germinated than seeds collected at other times, which suggests that this was when most reached physiological maturity.

Chemical Characteristics

The concentration of crude fat and protein-nitrogen decreased slightly in early May, then increased sharply to a maximum on June 5 (fig. 2). A slow decline followed the June 5 peak. Soluble nitrogen decreased from 13 mg per g of fruit on April 23 to a low of 0.6 mg per g on June 18 and then increased slightly.

Insoluble carbohydrates increased from 90 mg per g of fruit in over 150 mg per g on May 21 (fig. 2). After May 21 the concentration of soluble carbohydrates increased sharply to over 250 mg per g of fruit on June 18, which indicates that insoluble carbohydrates were converted to soluble forms. At the final collection on July 2, soluble carbohydrate concentration had fallen, and the insoluble carbohydrate concentration had increased again.

Dry weights of fruit increased from April to July, and although phosphorus and magnesium concentrations decreased, the actual amounts of the elements remained about the same (fig. 2). Calcium levels followed a pattern similar to crude fat and protein-nitrogen.

Carbohydrates were the most important stored foods (20.8 percent of dry weight); protein totaled only 7.8 percent and crude fat only 4.9 percent.

Comparing the chemical contents of depulped mature *P. serotina* with the contents of whole fruits shows that the mesocarp contains much of the crude fat, carbohydrate, and calcium (table 2). Protein appears to be concentrated in the endocarp and embryo. Percents of phosphorus and magnesium differed little between intact and depulped fruits.

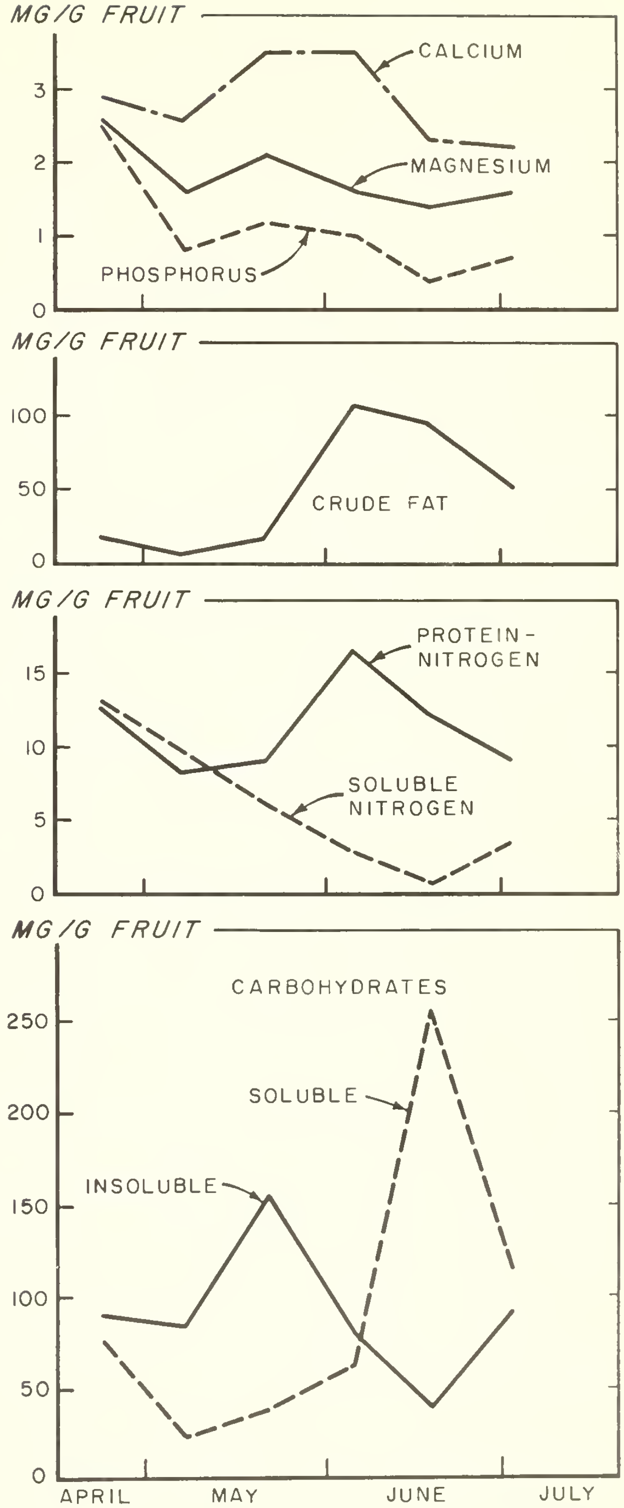

Figure 2.—*Seasonal changes in phosphorus, calcium and magnesium; crude fat; soluble nitrogen and protein-nitrogen; and soluble and insoluble carbohydrates in black cherry fruits.*

Table 2.—*Chemical contents of intact and depulped fruits (Data for depulped fruits taken from Bonner 1971)*

Condition	Crude fat	Total protein	Total carbo-hydrates	P	Ca	Mg
	Percent					
Intact	4.9	7.8	20.8	0.16	0.22	0.07
Depulped	1.8	13.7	15.3	.14	.14	.09

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SOUTHERN FOREST EXPERIMENT STATION

1975

U.S. FOREST SERVICE RESEARCH NOTE

SO-206

Forest Service, U. S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

BLACK TURPENTINE BEETLE INFESTATIONS AFTER THINNING IN A LOBLOLLY PINE PLANTATION

D. P. Feduccia and W. F. Mann, Jr.[1]

SOUTHERN FOREST EXPERIMENT STATION

Black turpentine beetle infestations can be reduced substantially by minimizing injuries to residual trees during logging and avoiding harvesting on waterlogged soils to prevent excessive root damage. After thinning, losses can be minimized by spraying visibly injured trees with lindane immediately, checking susceptible stands frequently for infestations, and applying lindane as soon as beetles are discovered.

Additional keywords: *Dendroctonus terebrans* Oliv., *Pinus taeda* L., logging damage, beetle infestation.

More than a million dollars is spent annually in the Southeast for detection and control of bark beetles, as these insects can severely reduce volume increment and kill trees (U.S. Forest Service 1975). Most control measures are directed against the southern pine beetle (*Dendroctonus frontalis* Zimm.) because it damages trees over extensive areas. The less conspicuous black turpentine beetle (*D. terebrans* Oliv.) receives comparatively little attention. Black turpentine beetles frequently attack after thinning, since stumps and residual trees injured by harvesting equipment may attract the insects and become centers of infestation (Kucera et al. 1970). If precautions are not taken, heavy mortality may result; the insect has reportedly killed more than one-fourth of a stand within a year of attack (Smith et al. 1972).

Spraying an insecticide on residual trees with visible damage and subsequently spraying attacked trees as soon as infestations are discovered can substantially reduce infestation. This paper describes black turpentine beetle attacks after thinning and spraying in a 22-year-old loblolly pine (*Pinus taeda* L.) plantation.

METHODS

The 80-acre plantation is a spacing-thinning study established in winter 1951-52 in southwest Beauregard Parish, Louisiana. Soils are mainly Caddo and Beauregard silt loams with slow internal drainage; thus, the water table is near the

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surface in winter. Estimated site index ranges from 78 to 107 feet at age 50. The plantation was divided into four 20-acre blocks for installation of five initial spacings (6 by 6, 8 by 8, 9 by 9, 10 by 10, and 12 by 12 feet). At age 17, 88 plots, each 0.4 acre in size, were created for thinning to four residual densities (60, 80, 100, and 120 square feet of basal area per acre) and an unthinned control. Some areas were bypassed because of low survival. Thinnings were scheduled at 5-year intervals.

Immediately after the second thinning (age 22) in April and May 1974, all trees with aboveground logging damage (approximately 125 trees) were sprayed with a 0.5 percent solution of lindane in diesel fuel to discourage beetle attacks; stumps were not sprayed. For the next 7 months, the study area was checked biweekly for beetle infestation; attacked trees were sprayed immediately. Information documented for each tree included month of attack, crown class, d.b.h., height of attack, and number of entrance holes. All infested trees were checked for mortality in November 1974 and in April and September 1975.

RESULTS AND DISCUSSION

Spraying immediately after thinning apparently prevented black turpentine beetles from attacking visibly damaged trees, as none of the 125 trees initially sprayed became infested during the 7-month observation period. The 184 trees that were attacked comprised only about 3 percent of the trees in the study area (table 1). These trees may have suffered undetectable root damage during logging and may therefore have been susceptible to attack. Sixteen of the attacks occurred in May; none occurred in June and July; and only five occurred in August. Almost all of the infestation was in September; attacks declined drastically in October and November.

Table 1.—*Black turpentine beetle infestations on loblolly pine after thinning in April/May, 1974*

Month of infestation	Number of trees attacked	Average number of entrance holes per tree	Average height of attack
			Feet
May	16 (87)[1]	7.1 (1-25)[2]	2.6
June	0	...	...
July	0	...	...
August	5 (100)	26.8 (16-38)	3.6
September	149 (83)	23.8 (1-70)	4.7
October	12 (75)	26.3 (9-69)	4.6
November	2 (100)	9.0 (7-11)	2.8

[1] Numbers in parentheses indicate percentage of dominants or codominants.

[2] Range.

Beetles tended to attack trees of superior size and quality. Most of the infested trees were dominants or codominants, ranging from 7 to 15 inches d.b.h. The number of entrance holes on individual trees ranged from 1 to 70, and height of attack was directly related to the number of holes per tree. Growth was probably reduced substantially for trees with as many as 70 entrance holes.

Attacks were evenly distributed over plots and were not related to spacing-thinning treatments. However, the fact that the plots were small and in close proximity to each other may have obscured a possible relationship between stand density and beetle attack, as harvesting machinery was operated on or near all plots.

When the infested trees were checked for mortality in mid-November, there were no deaths, and none of the trees showed yellowing crowns or evidence of ambrosia beetle (*Platypus* sp.) infestations. By April 1975, 35 trees had died, and by September, nine more were dead; 98 percent of the dead trees were attacked from August through October, the peak infestation period. The number of pitch tubes in dead trees varied by size and crown class: dominants averaged 36 (range 20 to 64), codominants 25 (range 10 to 48), and intermediates 15 (range 7 to 26). Dominants and codominants appeared better able to survive attack than other trees.

Treating freshly cut stumps as well as trees with visible damage might reduce infestations by eliminating favorable brooding locations. However, this practice may be economical only for seed orchards, seed production areas, and long-term growth and yield studies.

Spraying damaged trees after thinning cannot completely eliminate black turpentine beetle attacks because some of the injuries are underground and are therefore undetectable. Managers can reduce infestations by following these recommendations:

—Minimize logging damage to residual trees during thinning

—Avoid harvesting on water logged soils to prevent excessive root damage

—Spray visibly injured trees immediately with lindane

—Check susceptible stands for infestations frequently for 1 to 4 months after cutting, and spray infested trees as soon as beetles are discovered.

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CAUTION

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key — out of the reach of children and animals — and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the U. S. Department of Agriculture, consult your county agricultural agent or State Extension specialist to be sure the intended use is still registered.

PROTECT

Use Pesticides Safely

FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE

SOUTHERN FOREST EXPERIMENT STATION

1975

U.S. FOREST SERVICE
RESEARCH NOTE

SO-207

Forest Service, U. S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

SITE INDEX TABLES FOR SHORTLEAF PINE IN THE OZARK HIGHLANDS OF NORTHERN ARKANSAS AND SOUTHERN MISSOURI

Edwin R. Ferguson and David L. Graney[1]

SOUTHERN FOREST EXPERIMENT STATION

Field guides are presented for estimating site index on each of the three major soil groups in the Ozark Highland Province: limestone-dolomite, sandstone, and fragipan soils. Factors utilized vary by soil groups but include aspect, township, slope shape and depth to pan, with adjustments for hardwood competition. Tabular predictions were within ± 3 feet of measured site values on 83 percent of 41 limestone-dolomite sites, 81 percent of 37 sandstone sites, and 91 percent of 42 fragipan soils.

Additional keywords: *Pinus echinata*, fragipan, hardwood competition.

This note presents tables for estimating shortleaf pine index[2] on the three major soil groups of the Ozark Highlands in Arkansas and Missouri. Site index estimates are based on aspect, slope shape, depth to fragipan, and degree of oak and hickory competition—information that can be determined readily in the field.

Site index values were derived from equations developed by the authors and reported earlier (Graney and Ferguson 1972). Application of the tables should be restricted to the area indicated in Figure 1, where the data for deriving and testing the equations were collected.

Field Measurements Needed

Hardwood competition.—Experience in another area (Ferguson and Graney 1972) indicated that the number of oak and hickory stems and sprout clumps within 40 feet of the plot center could be in frequency classes which were positively correlated with measured loss-on-ignition (organic content) values. A similar relationship between oak and hickory stems and sprouts was also observed for the Ozark Highland sites. These frequency classes essentially reflect prior land use and presence or absence of hardwoods during the life of the stand. For management application, effective control of

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[2] Site index for shortleaf pine is the total height in feet of dominant and codominant trees at 50 years of age.

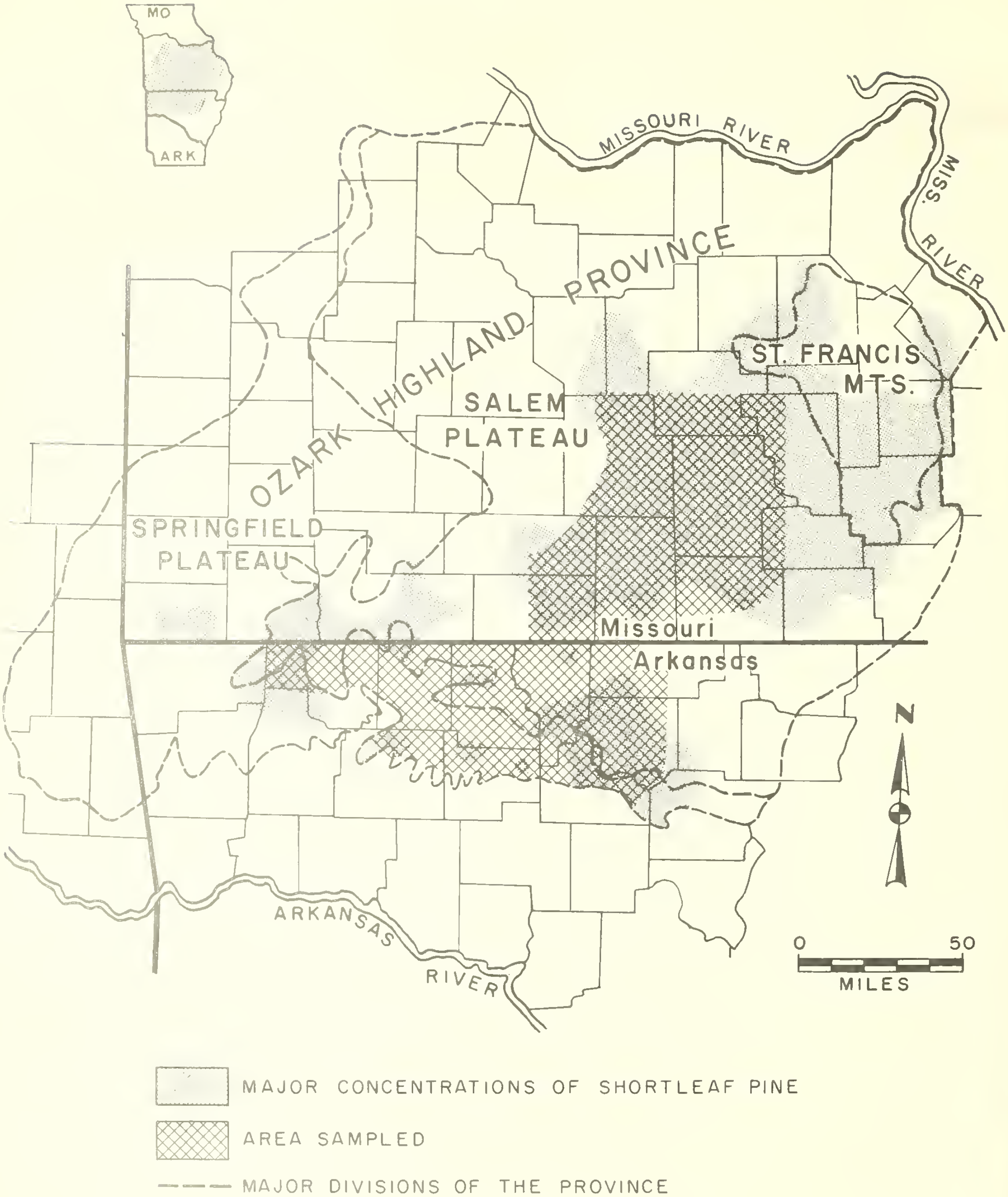

Figure 1.—*Location of area sampled within the Ozark Highlands of Arkansas and Missouri.*

competing hardwoods during establishment and early life of pine stands will reduce or eliminate the negative influence of hardwood competition on height growth of the pine. However, levels of hardwood competition have been included as modifiers in these site index tables to quantify the relative effect of hardwood competition on pine height growth.

Slope shape.—Determine whether the general configuration of the slope in the immediate vicinity of the plot is (1) convex, where the general area tends to have a rounded surface sloping away from the plot proper; (2) linear, sloping but neither rounded nor cup shaped; or (3) concave or cupshaped, where the general area tends to drain inward toward the plot. Site index increases as slope shape changes from convex through linear to concave.

Aspect.—This indicates the dominant slope-facing direction, measured in degrees azimuth on sites with slopes of 3 percent and greater. Ridge and upper slope positions with slopes of less than 3 percent are considered as neutral. For each soil grouping, northeast facing slopes are the more productive shortleaf pine sites, while southwest exposures are the poorer sites. Northwest and southeast exposures are intermediate in productivity between the better and poorer slope aspects.

Depth to pan.—Site index increases with greater depth to pan within the range of 14 to 28 inches. Fragipan layers may aid tree growth by reducing movement of water down through the profile during wet periods. Watt and Newhouse (1973) indicated that the soil above fragipan layers will hold about the same volume of available water as the upper 36 inches (zone of maximum rooting) of the nonpan soils. Thus the range in productivity for the pan soils would be similar to that of the nonpan soils, but the limiting factor would be the effective soil moisture storage capacity above the fragipan layer.

Township.—Climatic changes with latitude would seem to explain this variable. Length of growing season, together with average annual and May-September precipitation, increase from north to south throughout the Province.

Construction and Testing of Tables

Separate analyses of the three major soil groups resulted in individually unique prediction equations. Site index tables were constructed for each soil group by semigraphical extrapolation of the appropriate prediction model. These tables were developed by holding all but a single predictor variable constant in the equation and computing site indexes for various levels of the free predictor. After this step was completed for each predictor variable, the data were plotted and curves drawn. Curve values were then incorporated into the tables.

The Tables

Predicted site index for the limestone and dolomite soils are provided in Table 1. The table predicts within a rather narrow range of site index, varying from 53 to 65 feet—a difference

Table 1.—*Predicted site index in feet at age 50, by aspect, township and slope shape for Arkansas and Missouri limestone-dolomite soils*[1]

Township	Slope shape	Aspect (degrees azimuth)[2]				
		0–80	326–359 81–115	296–325 116–145	261–295 146–180	181–260
T13N–T19N	Concave	65	64	63	62	61
	Linear	63	62	61	60	59
	Convex	61	60	59	58	57
T20N–T26N	Concave	63	62	61	60	59
	Linear	61	60	59	58	57
	Convex	59	58	57	56	55
T27N–T33N	Concave	61	60	59	58	57
	Linear	59	58	57	56	55
	Convex	57	56	55	54	53

[1] For existing stands adjust predicted site index as follows: Where the number of oak and hickory stem and sprout clumps within a 40-foot radius of plot center is between 76 and 150, drop 2 feet; where the number exceeds 151, drop 4 feet.

[2] Ridge and upper slope sites with slopes of less than 3 percent are considered as neutral or within the 296–325 and 116–145 azimuth range.

of only 13 feet. However, when maximum adjustment for hardwood competition is applied, the range is extended to 17 feet. Site indexes were estimated with this table on 41 Arkansas and Missouri limestone and dolomite pine sites which had not been included in the analyses or development of the table. On all but one plot, the tabular value was within ± 5 feet of measured site index, while 83 percent of the sites were estimated within ± 3 feet.

Table 2 covers sandstone-derived soils. Although the site index range for the sandstone soils was greater than that for the limestone-dolomite soils, both tables predict within the same site index range. Thirty-seven additional sandstone soil sites were used to determine the accuracy of the table and, again, only one prediction exceeded the measured value by more than 5 feet. Site index on 81 percent of the sites was estimated within ± 3 feet of measured values.

Table 3 covers the pan soils. The 16-foot span of predicted site index in this table was slightly greater than those of the other two soil groups. On the 42 additional sites used to test site index estimates, none of the predictions missed by more than 5 feet and 91 percent were within ± 3 feet of the measured site index values. Although not significant in fitting the model and thus not included in the site prediction table, the observed relationship between site index and competing hardwoods on the pan soils was generally similar to that indicated in Tables 1 and 2.

The values in the tables do not predict over as wide a range in site index as individual soil group equations, primarily because they were derived from averages. Consequently the tables will tend to overestimate site index potential on very poor sites and will underestimate site indexes on particularly good sites (table 4). However, field application indicates that the tables should be accurate enough for classifying site potential into at least poor, medium and good categories.

Table 4.—*Ranges in predicted site index for original soil group equations and derived site index tables*

Soil group	Predicted site index range: Equation High	Equation Low	Table High	Table Low
Limestone-dolomite soils	69	45	65	49
Sandstone soils	66	48	65	49
Fragipan soils	67	47	65	50

Table 2.—*Predicted site index at age 50, by aspect and slope shape for Arkansas and Missouri sandstone soils*[1]

Slope shape	Aspect (degrees azimuth)[2]				
	0–80	326–359 81–115	296–325 116–145	261–295 146–180	181–260
Concave	65	63	61	59	57
Linear	63	61	59	57	55
Convex	61	59	57	55	53

[1] For existing stands adjust predicted site index as follows: Where the number of oak and hickory stem and sprout clumps within a 40-foot radius of plot center is between 76 and 150, drop 2 feet; where the number exceeds 151, drop 4 feet.

[2] Ridge and upper slope sites with slopes of less than 3 percent are considered as neutral or within the 296–325 and 116–145 azimuth range.

Table 3.—*Predicted site index in feet at age 50, by aspect and depth to pan for Arkansas and Missouri pan soils*

Depth to pan (inches)	Aspect (degrees azimuth)[1]				
	0–80	326–359 81–115	296–325 116–145	261–295 146–180	181–260
26–28	65	64	63	62	61
23–25	62	61	60	59	58
20–22	59	58	57	56	55
17–19	56	55	54	53	52
14–16	53	52	51	50	49

[1] Ridge and upper slope sites with slopes of less than 3 percent are considered as neutral or within the 296–325 and 116–145 azimuth range.

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SOUTHERN FOREST EXPERIMENT STATION

1976

U.S. FOREST SERVICE RESEARCH NOTE

SO-208

Forest Service, U. S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

GROWTH AND BRANCHING OF YOUNG COTTONWOODS AFTER PRUNING

R. M. Krinard[1]

SOUTHERN FOREST EXPERIMENT STATION

Although spring and summer pruning to various heights reduced diameter growth for the treatment year, diameter increment of most pruned trees did not differ significantly from that of controls 2 years after treatment. Total diameter growth during the test period was significantly less for pruned trees than for controls. Epicormic branching increased with spring treatments and with greater pruning heights. Pruning is apparently necessary to obtain high-quality stems. Summer prunings are preferable to spring ones, and no more than one-third of the total height measured during the dormant season should be pruned.

Additional keywords: *Populus deltoides*, wood quality, epicormic branching, sawtimber, veneer.

Stumpage value of cottonwood (*Populus deltoides* Bartr.) saw logs and veneer logs may be 16 times greater than that of pulpwood on a cubic-foot basis. Trees to be used as sawtimber or veneer should therefore be managed for wood quality as well as growth. The most desirable trees have large diameters, a minimum of corewood, and no stem defects. Wide planting spacings result in rapid diameter growth, and pruning both reduces defect and minimizes core size. However, pruning at an early age may reduce diameter growth and stimulate epicormic branching. This study compared growth and branching of pruned and unpruned cottonwood trees planted on two sites.

METHODS

The two plantations are at Catfish Towhead, which is about 20 miles northwest of Greenville, Mississippi, and Georgetown Towhead, located in Arkansas about 12 miles southwest of Catfish. Soils are chiefly Commerce. The sites were cleared before planting in 1968; initial spacings were 9 by 9 feet at Catfish and 10 by 10 feet at Georgetown.

During the second growing season (May and June 1969), residual trees were pruned to about 5 feet in height. The plantations were then selectively thinned to an 18- by 18-foot spacing at Catfish and a 20- by 20-foot spacing at Georgetown.

During the third year, three replications of four pruning treatments were installed in a randomized complete block design. There were

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24 trees per plot. Treatments consisted of no pruning (control) and pruning to 9-, 13-, or 17-foot heights in either March-April (spring pruning) or in June-July (summer pruning). The 17-foot pruning at Catfish was delayed until the fourth year to allow the trees to grow tall enough to treat. At that time, the 9-foot pruning on both sites was increased by 8 feet (to 17 feet).

Heights and diameters of all trees were measured after the second and third years. Diameters were remeasured after the next two seasons, although final measurements on the Georgetown plots were delayed for several months because of high water.

The number of pruned trees with epicormic branches was recorded for all pruned plots after the third growing season and in the fifth growing season on Catfish plots pruned the fourth year. Branches were tallied by length as 3 feet or less or as greater than 3 feet.

Differences in diameter and height growth between pruning treatments were evaluated by analysis of variance at the 0.05 level.

RESULTS AND DISCUSSION

After 2 years, mean height for Catfish plots was 20 feet and mean diameter was 3.0 inches; at Georgetown, mean height was 27 feet and mean diameter, 4.2 inches. Third-year pruning to 9 and 13 feet removed 45 and 65 percent of the mean second-year height at Catfish. The 9-, 13-, and 17-foot prunings at Georgetown removed 33, 48, and 63 percent of the average second-year height.

During the third growing season, control trees grew significantly taller than some of the pruned trees, although the differences were of no practical importance. Average tree heights at the end of the season were 31 feet for Catfish and 39 feet for Georgetown.

Although pruning reduced diameter growth during the year of treatment, diameter increment of pruned trees was about the same as that of controls in the fifth growing season (table 1). Total diameter increment during the 3-year test period was significantly greater for controls than for pruned trees; however, the effects

Table 1.—*Diameter growth of pruned trees on two sites for the third, fourth, and fifth growing seasons*

Site, season, and pruning height	Growing season			Total
	Third	Fourth	Fifth	
	— — — — — — — — *Inches* — — — — — — — —			
Catfish[1]				
Control	2.46 a[2]	1.55 a	1.27 a	5.28 a
Spring				
9 feet	2.13 b	1.10 c	1.28 a	4.51 bc
13 feet	1.97 bc	1.48 a	1.30 a	4.75 b
17 feet	2.44 a	0.99 c	1.22 ab	4.65 b
Summer				
9 feet	1.99 bc	1.11 c	1.04 b	4.14 c
13 feet	1.91 c	1.35 b	1.20 ab	4.47 bc
17 feet	2.34 a	1.24 b	1.20 ab	4.78 b
Georgetown[3]				
Control	2.37 a	1.60 a	1.62 abc	5.59 a
Spring				
9 feet	2.19 b	1.31 d	1.63 abc	5.12 bc
13 feet	1.97 d	1.54 ab	1.66 ab	5.17 bc
17 feet	1.56 f	1.45 bc	1.64 abc	4.65 d
Summer				
9 feet	2.25 b	1.46 bc	1.55 bc	5.26 b
13 feet	2.09 c	1.51 ab	1.54 c	5.14 bc
17 feet	1.82 e	1.39 cd	1.71 a	4.92 c

[1] Catfish trees pruned to 9 and 13 feet in third year, 17 feet in fourth year, and 9 feet increased to 17 feet in fourth year.

[2] Means followed by same letter not significantly different at 0.05 level.

[3] Georgetown trees pruned to 9, 13, and 17 feet in third year, and 9 feet increased to 17 feet in fourth year.

of pruning on diameter increment would probably be negligible after 15 or 20 years.

By the end of the third year, the percentage of trees with epicormic branching increased with pruning height and with spring pruning (table 2). Minimum branching occurred with pruning to 9 feet in summer; 79 percent of the trees receiving this treatment had no epicormic branching at Catfish and 99 percent at Georgetown. At the Catfish site, the level of branch-free stems decreased to 35 percent when pruning height was increased from 9 to 17 feet in the fourth year.

Spring prunings produced longer epicormic branches than summer treatment, probably because of differences in the length of the growing season. For trees with one or more epicormic branches, 86 percent of the trees pruned in spring had at least one branch longer than 3 feet compared to 16 percent for trees pruned in summer.

Control trees showed no tendency toward natural pruning; therefore, pruning is apparently necessary to obtain high-quality stems at the spacings used, despite some losses in diameter growth. To obtain minimum epicormic branching, summer pruning is advantageous as is pruning no more than one-third of the total height measured during the dormant season.

Table 2.—*Percentage of trees producing a given number of epicormic branches during third year after spring and summer pruning to indicated heights*

Site, season, and pruning height	Number of branches		
	None	One, two, or three	Four or more
	— — — *Percent* — — —		
Catfish			
Spring			
9 feet	29	52	19
13 feet	20	41	39
Summer			
9 feet	79	14	7
13 feet	39	45	16
Georgetown			
Spring			
9 feet	45	43	12
13 feet	31	42	27
17 feet	4	19	77
Summer			
9 feet	99	1	...
13 feet	59	36	5
17 feet	24	54	22

SOUTHERN FOREST EXPERIMENT STATION

1976

U.S. FOREST SERVICE RESEARCH NOTE

SO-209

Forest Service, U. S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

INFLUENCE OF SPACING ON GROWTH OF LOBLOLLY PINES PLANTED ON ERODED SITES

D. C. McClurkin[1]

SOUTHERN FOREST EXPERIMENT STATION

At age 20, survival, height growth, diameter growth and volume were poorer for trees with initial planting spacings of 4 by 4 feet than for those planted at 6 by 6 or 8 by 8 feet. The strong correlation (r^2 = 0.82) found between site index and spacing suggests that for these plantations, height and ultimately site index classification were correlated with stocking density rather than with the actual quality of the site. Therefore, for trees planted at close spacings, the use of the height of dominant trees as the index of site quality may underestimate potential site productivity.

Additional keywords: *Pinus taeda* L., site index, height growth, diameter growth, yield.

A long-standing mensurational question is whether stand density affects height growth, thereby influencing the site index classification of a given forest site. In natural stands, Chisman and Schumacher (1940) observed no correlation between site index and stand density, but in plantations, Gilmore and Gregory (1974) noted reduced height growth among closely spaced loblolly (*Pinus taeda* L.) and shortleaf (*P. echinata* Mill.) pines after 13 growing seasons. The present paper reports the influence of initial planting spacing on survival and growth in plantations of loblolly pines established on eroded sites in northern Mississippi.

METHODS

The plantations—located on the Tallahatchie Experimental Forest—are part of a reforestation project to restore badly eroded areas once planted to agricultural crops but later abandoned. Surface soils are silt loams of loessial origin, which grade into loamy Coastal Plain sedimentary material on side slopes. In some places, erosion had removed the surface soils to expose heavy loess or Coastal Plain subsoils.

Three 256- by 312-foot blocks were laid out on sheet-eroded ridges and upper slopes. Ridge lines ran east-west. Each block was divided into three contiguous strips running the full width of the block from north to south. One of three planting spacings was randomly assigned to each strip: spacings were 4 by 4, 6 by 6, or 8 by 8 feet; thus, three site aspects (north, ridge, and south) as well as three spacings were tested.

In February 1954, the strips were planted

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with 1-0 loblolly pine seedlings 12 rows wide at the assigned spacing; the area was then surrounded with an isolation planting 50 feet wide. After planting, each strip was subdivided into three square 64-tree plots representing a north, ridge, south aspect. Centers for the north- and south-aspect plots were 80 feet downslope from those of ridge plots.

At the end of the 1955 growing season, all dead seedlings on the plots were replaced by transplants from the isolation strips; the replacements were not included in mensurational computations. Plantation development was monitored at 2-year intervals for the first 10 years of the study and again after 15 and 20 years. For the first 10 years, only survival and height growth were measured; after 15 and 20 years, survival, height of five dominants per plot, and d.b.h. of all trees were measured; form classes were determined for the same five dominants per plot after the twentieth growing season. After heights of representative intermediate or suppressed trees for each diameter class were measured, volumes at age 20 were computed according to Minor's (1950) total height tables.

The influence of spacing and aspect on 20-year survival, diameter growth, height growth, and yield was evaluated by analysis of variance. The relationship of the height of dominant trees to both basal area and stems per acre was determined by regression analysis.

To test whether chance had consigned closely-spaced plantings to poor sites and widely-spaced plantings to the better sites, a soil site index predictive equation, developed from the soil physical property data of the nine plots planted at 8 by 8 feet, was used to calculate soil-based site index values for all plots. The differences between soil site index and tree site index on each plot were then computed and subjected to analysis of variance. The influence of site index, aspect, and spacing on yield was then evaluated by regression analysis. Site indices were based on the heights of 20-year-old dominants at age 50 years (Schumacher and Coile 1960). Results significant at the 0.05 level are reported here.

RESULTS AND DISCUSSION

Survival

Stand density significantly affected survival at all three spacings (table 1). After 20 years, survival averaged 18 percent lower on the 4- by 4- than on the 6- by 6-foot plots and 30 percent lower than on the 8- by 8-foot plots. Survival was better on ridge plots than on side slopes.

Table 1.—*Survival, height, and diameter at breast height of 10-, 15-, and 20-year-old loblolly pines planted on three spacings*[1]

Plantation age	Spacing	Height[2]	D.b.h.[2]	Survival
Years	*Feet*	*Feet*	*Inches*	*Percent*
10	4 by 4	23.0	...	89
	6 by 6	26.9	...	92
	8 by 8	28.0	...	93
15	4 by 4	38.3	4.7	76
	6 by 6	43.9	6.3	86
	8 by 8	44.2	7.1	90
20	4 by 4	46.2	5.7	56
	6 by 6	53.1	7.6	74
	8 by 8	53.2	8.3	86

[1] Each value is the average of 9 plots.
[2] Data based on five dominants per plot.

Height Growth

A comparison of the 4- by 4-foot spacing with the two wider spacings showed that height growth decreased as the number of stems per acre increased (table 1). After 20 years, heights on the 4- by 4-foot spacings were 7 feet shorter than on the two wider spacings. However, there was no significant difference between the heights of trees planted at 6- by 6- and 8- by 8-foot spacings; therefore, planting density apparently has little influence on height growth as planting spacing approaches 8 by 8 feet.

The analysis of variance of soil site index as opposed to tree site index indicated that the dominant and co-dominant trees on the 4 by 4 spacings averaged 15 feet shorter than the height predicted by soil properties. Spacing, not site quality, apparently reduced tree growth on the closely-spaced plots. Soil-site work on well-stocked, even-aged natural stands of loblolly pine has repeatedly shown no correlation between stocking density and height growth. For the plantations evaluated here, however—in which specific stocking densities were forced on the land—height growth apparently decreased with high stand density. Therefore, for trees planted at close spacings, the use of height of dominant trees as the index of site quality may underestimate potential site productivity, since height growth rates may have been reduced by dense stocking.

For all three spacings combined, there was no correlation between height and basal area ($r^2 = 0.04$), although when spacings were analyzed individually, the 8- by 8-foot spacing showed a strong correlation ($r^2 = 0.89$).

Regardless of spacing, heights of dominant trees on ridge plots averaged 5 feet less than those on north or south slopes, a condition reflecting the greater erosion on the ridges. There was no significant difference between the heights of trees on north and south slopes.

Diameter Growth

Stocking density significantly affected tree diameter at all three spacings (table 1). After 20 years, diameters of dominants and co-dominants on the 4- by 4-foot plots averaged 1.9 inches smaller than those on the 6 by 6, and 2.6 inches smaller than the 8- by 8-foot plots. Diameters on ridge positions were 0.6 inch smaller than those on side slopes; no difference was noted between spacing treatments on north and south slopes.

Volume Growth

Volume growth of trees at the 4- by 4-foot spacing averaged 1.5 cords per acre per year, significantly less than the 2.3 cords per acre per year recorded for the wider spacings. There was no significant difference between the 6- by 6- and 8- by 8-foot plantings (table 2). The

Table 2.—*Yields of 20-year-old loblolly plantations by diameter class*

Planting spacing (feet) and aspect (by block)[1]	Site index	Form class	Stems per acre	D.b.h. 5	6	7	8	9	10	11	Volume total
			Number	*Standard cords per acre*							
4 by 4											
N	[2]83	77	[3]1233	[4]10.7	19.1	...	...				29.8
R	70	77	1616	16.1	19.2	3.0	...				38.3
S	74	77	1701	9.4	21.2	6.1	4.0				40.7
N	63	72	1871	5.3	4.8	...					10.1
R	58	67	1999	7.9	...	2.1					10.0
S	67	77	1786	11.7	9.2	...					20.9
N	88	82	1021	13.3	15.5	11.4	5.1				45.3
R	77	77	1403	12.1	10.6	3.0	4.0				29.7
S	77	77	1191	17.5	12.7	3.1	4.0				37.3
6 by 6											
N	88	77	794	5.4	7.4	15.1	12.3	5.2	...		45.4
R	77	77	945	7.8	10.4	10.8	10.8	2.2	...		42.0
S	83	77	926	6.6	11.3	14.8	14.5	2.2	2.9		52.3
N	90	77	945	6.2	11.3	15.1	12.3	2.6			47.5
R	68	77	1002	7.3	15.5	8.0	1.8	...			32.6
S	83	77	908	4.7	11.3	20.2	7.3	...			43.5
N	88	77	851	3.6	12.3	24.3	8.3	2.6	...		51.1
R	84	77	908	6.6	14.2	16.2	5.5	...	2.9		45.4
S	88	82	813	5.9	14.4	16.8	16.1	3.0	3.8		60.0
8 by 8											
N	88	72	638	1.2	5.6	7.3	21.8	10.5	3.3		49.7
R	77	72	606	1.6	2.3	10.6	20.2	4.5	...		39.2
S	84	82	606	.7	8.6	13.4	16.0	11.6	1.9		52.2
N	81	77	564	0.9	7.4	15.2	10.1	5.1	3.2		41.9
R	67	72	596	2.7	6.8	8.5	4.6	1.0	...		23.6
S	77	72	596	.8	7.4	12.5	13.8	2.3	...		36.9
N	94	77	553	1.7	2.4	9.4	15.0	16.0	11.2	4.4	60.1
R	92	77	574	1.1	4.2	11.0	18.5	17.4	1.9	...	54.1
S	90	77	511	.7	2.4	8.5	17.4	17.4	7.6	2.1	56.1

N = north, R = ridge, S = south.
Based on projected height of dominants at age 50.
Includes stems less than 5 inches d.b.h.
Cubic-foot volumes converted to cords: 1 cord = 75 cubic feet.

lower growth rates of the 4 by 4 plots were not due to low form class, which was independent of spacing, but to low average diameters and heights. Fifty percent of the 4 by 4 stems were below merchantable diameter (5 inches d.b.h.) as compared to 14 percent of the 6- by 6- and 2 percent of the 8- by 8-foot plantings. The strong correlation ($r^2 = 0.82$) between site index and spacing reinforces the finding that for these plantings, height and ultimately site index classification are correlated with stocking density rather than with the actual quality of the site.

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SOUTHERN FOREST EXPERIMENT STATION

1976

U.S. FOREST SERVICE RESEARCH NOTE

SO-210

Forest Service, U. S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

BARK THICKNESS OF 17-YEAR-OLD LOBLOLLY PINE PLANTED AT DIFFERENT SPACINGS

Donald P. Feduccia and William F. Mann, Jr.[1]

SOUTHERN FOREST EXPERIMENT STATION

Diameter at breast height was the only variable affecting double bark thickness at d.b.h. and midpoint of the merchantable stem for young loblolly pine planted at five initial spacings on plots with site indices of 77 to 111 feet. Bark thickness at the 4-inch top was not correlated with breast-height diameter.

Additional keywords: *Pinus taeda* L.

Estimates of bark thickness are necessary for determining the volume of peeled wood and may be useful for calculating quantity of bark, a material now used for many purposes. This paper presents estimates of double bark thickness (DBT) and diameter inside bark to diameter outside bark ratios at breast height and the 4-inch top for 17-year-old loblolly pines.

METHODS

Data were collected during the first thinning of a 17-year-old loblolly pine (*Pinus taeda* L.) plantation growing on a cutover area in southwest Louisiana. Plots were planted by machine at spacings of 6 by 6, 8 by 8, 9 by 9, 10 by 10, and 12 by 12 feet. Estimated site indices (50-year base) range from 77 to 111 feet.

Measurements of double bark thickness at breast height, midway between breast height and the 4-inch top, and at the 4-inch top were taken with a Swedish bark gage on opposite sides of each of 106 randomly selected felled trees. The trees were 4 to 11 inches in diameter at breast height (d.b.h.) and represented all spacings and site classes. Regressions that used site index, initial number of trees planted, and d.b.h. as independent variables were screened by Grosenbaugh's combinatorial process (1967) to develop the prediction equations.

RESULTS AND DISCUSSION

Double-bark thickness at breast height (DBTBH) was correlated with diameter at breast height outside bark (DBHOB); there were no well-defined curvilinear trends, and a linear model of the relationship was adopted. Use of site index, initial density, or both as independent variables did not improve the fit

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appreciably. The equation, DBTBH = 0.3989 + 0.1284DBHOB (in inches), was significant at the 0.01 level and accounted for 48.9 percent of the variation in DBTBH among the trees. The standard error is 0.20 inch. Values derived from the equation were within 15 percent of actual measurements for slightly more than two-thirds of the trees. Burton's (1962) estimates of DBTBH for unthinned loblolly pine plantations that were 5 to 25 years old are similar to those presented here (fig. 1).

Double bark thickness midway between breast height and the 4-inch top (DBTM) increased 0.04 inch for each 1-inch increase in DBHOB (fig. 1). The equation, DBTM = 0.5368 + 0.0387DBHOB ($r^2 = 0.13$), is significant at the 0.01 level, and the standard error is 0.15 inch. DBTM ranged from 0.31 to 0.85 inch less than DBTBH, and the difference increased directly with diameter.

Double bark thickness at the 4-inch top averaged 0.53 inch for the 106 trees and did not vary with diameter at breast height.

The DIB/DOB ratios at breast height, calculated from predicted values, were:

D.b.h. class	*Ratio*
4	0.77
5	.79
6	.81
7	.81
8	.82
9	.83
10	.83
11	.84

The ratio at the 4-inch top was 0.87 for all diameter classes. DOB midway between breast height and the 4-inch top must be known to determine a ratio for that point. With an average ratio for the three points on the tree, volume inside bark for the merchantable bole can be determined using the STX or height accumulation computer programs (Mesavage 1971, Lohrey and Dell 1969). The ratios can also be used to develop inside bark taper curves.

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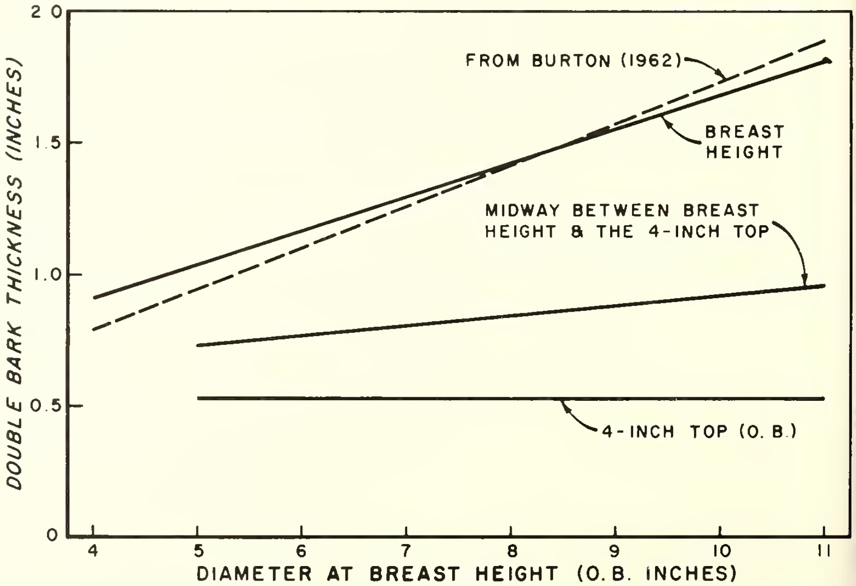

Figure 1.—*Relationship of double bark thickness at three locations on the (o.b.) at breast height.*

SOUTHERN FOREST EXPERIMENT STATION

1976

U.S. FOREST SERVICE RESEARCH NOTE

SO-211

Forest Service, U. S. Dept. of Agriculture

T-10210 FEDERAL BLDG. 701 LOYOLA AVENUE NEW ORLEANS, LA. 70113

ANOTHER ARKANSAS COLONY OF NEVIUSIA

Herbert A. Yocom and Elbert L. Little, Jr.[1]

SOUTHERN FOREST EXPERIMENT STATION

Neviusia alabamensis *A. Gray (Rosaceae), snow-wreath or neviusia, was found in 1971 on the Henry R. Koen Experimental Forest in Newton County, Arkansas. This species, classed as threatened, has been reported at 8 other locations: 4 in Alabama, 3 others in Arkansas, and 1 in Missouri.*

Additional keywords: Snow-wreath, *Neviusia alabamensis*, Rosaceae.

Neviusia alabamensis A. Gray is a shrub of the rose family (Rosaceae) that reaches a height of 3-6 feet, produces many slender stems, and has a growth habit like that of *Spiraea*. When in full bloom *Neviusia* resembles a wreath with snow. The snowlike flowers have numerous spreading white stamens but no petals. The shrub was discovered in 1857 by Reuben Denton Nevius and W. S. Wyman along shaded sandstone cliffs on the east bank of the Black Warrior River a few miles above Tuscaloosa, Alabama. The history of its discovery was reviewed by Moore (1956). Asa Gray (1859) described the distinctive shrub as a new genus and species, and named it in honor of the first collector and the State. Three sheets collected by Nevius, apparently isotypes, are in the National Herbarium of the U.S. National Museum of Natural History (US).

We report here discovery of a colony in northern Arkansas. In addition to the colony discovered by Nevius and our colony the species has been found growing naturally at six locations.

KNOWN COLONIES

Harper (1928) reported that *Neviusia* grew on bluffs and slopes of limestone and shale, usually in shady places, in four counties in northern and central Alabama: Madison, Jackson, Morgan, and Tuscaloosa (both banks of Black Warrior River).

A single plant of this species was found in 1918 by Uphof (1922, p. 7) about 7 miles west of Poplar Bluff, Butler County, in southeastern Missouri. It was growing on a southwestern sandy loam slope of a small hill near a creek bank. He made and published a drawing, but his specimens were not preserved. Steyermark (1963, p. 843), among others, failed to find this species at that locality or elsewhere in Missouri but predicted its eventual rediscovery. His plants grown in northern Illinois tended to spread vegetatively in shaded places.

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Moore (1956) found some shrubs of this species on a low sandstone ridge 200 yards long about 6 miles northwest of Conway in southeastern Conway County at about 300 feet altitude in the Ozark Plateau of northern Arkansas. In the University of Arkansas Herbarium he found filed under *Physocarpus* four other sheets collected in 1925 by Delzie Demaree along sandstone cliffs of Cove Creek in northern Faulkner County about 20 miles northeast of the other station. In 1971 a colony of *Neviusia* was found in Pope County, Arkansas, by Gary E. Tucker of Arkansas Polytechnic College (personal communication).

Mohr (1901), who knew only the type locality, cited *Neviusia* as a paired genus with *Stephanandra* of Japan. He concluded that this and several other species with isolated distribution were descendants of an ancient flora that had survived changes in geological history and found a refuge in their present localities. Fernald (1931, p. 29, map 3) cited *Neviusia* as a relative of *Kerria* of China. Before the range extensions were found, Cain (1944, p. 114) considered the species an example of local endemism. Moore (1956) concluded that *N. alabamensis* is a relatively old relic species. He noted that the species was found only beyond the margin of the Coastal Plain and on uplands exposed since late Paleozoic or early Mesozoic geologic periods.

Because it is an attractive ornamental, the species was cultivated soon after its discovery. It proved to be hardy north to eastern Massachusetts and at Kew, England. In Washington, D.C., *Neviusia* was distributed by a nurseryman by 1880 and, according to herbarium specimens (US), was grown in the Agricultural Grounds in 1885 and afterwards. Propagation is by seed and by cuttings. Index Londonensis (1930) cited 12 published illustrations as evidence of its popularity. Trelease (1931, p. 116) published a drawing for identification in winter.

NEW COLONY

We found the colony of *Neviusia alabamensis* while collecting for a list of the woody plants on the Henry R. Koen Experimental Forest. This 700-acre tract on the Ozark National Forest is in northern Newton County. The colony is beside a small, intermittent stream at an altitude of 940-1,000 feet.

Sterile plants collected in September 1971 *(Yocom 138)* were not recognized. Additional specimens with sufficient old fruits for identification were collected on August 28, 1972 *(Little and Yocom 25961)* and will be deposited in several herbaria (US, USFS, UARK).

The colony extends adjacent to the intermittent streambed on the northwest side in a strip about 1,000 feet long and about 60 feet wide. No plants were found on the other side of the streambed. The exposed bedrock in the stream bottom is limestone of Paleozoic age. The limestone extends up the slope on the northwest side about 66 feet to an outcrop of sandstone about 10 feet thick and overlain by more limestone. Shrubs 3-6 feet high grow in soil only a few inches deep over the limestone bedrock from the sandstone outcrop to the exposed bedrock at the bottom. The mean pH of 20 samples was 6.95 with a standard error of 0.12. The sandstone upslope may affect the properties of the soil in which the plants are found. The sparse forest stand in the area is mixed upland hardwoods, primarily oaks and hickories, with some eastern redcedar.

The combination of environmental factors that preserved this newly found colony from extinction is not known. The sandstone outcrop above the colony may provide more than average moisture and some nutrients. The rocks and cliffs may reduce plant competition and may offer some protection from fire.

It would be interesting to study further the site requirements and reproductive mechanisms of this rare species. The plants are readily propagated vegetatively and by seeds, yet they are not spreading in nature. The restricted colonies and absence of seedlings both imply that natural reproduction is largely vegetative.

The discovery of this additional station and range extension gives further support to the observation that *Neviusia alabamensis* is an ancient relic species. It has persisted in two ancient land masses that have been above the seas since the latter part of the Paleozoic era, about 225 million years ago according to geologists. The Alabama stations are near the southern end of the southern Appalachians; the Arkansas and Missouri stations are in the Ozark Plateau up to 450 miles to the northwest.

Several other plant species have a similar disjunct distribution pattern in the southern Appalachians and Ozarks. Ten tree species occur separately in both regions, as shown in range maps of Little (1971).

Also, the monotypic genus *Neviusia* is one of many plant genera of the southern Appalachians that have persisted from the Arcto-Tertiary flora of more or less uniform forests which extended through Eurasia and North America in late Mesozoic and early Cenozoic eras and which have their closest relatives in eastern Asia. The most closely related genera are two monotypes that have persisted in eastern Asia: *Kerria japonica* (L.) DC., kerria, of central and western China (not native in Japan but cultivated there), and *Rhodotypos scandens* (Thunb.) Mak., jetbead, of both Japan and central China. All three have the same chromosome number ($2n = 18$). A fossil species of *Kerria* from western Kamchatka of Middle Pliocene age has been described. No fossil records of the other two genera have been discovered.

Neviusia alabamensis is included in the list of endangered and threatened plant species compiled by the Smithsonian Institution (1975). This species is classed as threatened. That term, as defined, means likely to become endangered, or in danger of extinction in the wild, within the foreseeable future in all or part of its range. The wild colonies are so small and local that they could be destroyed accidentally. For example, most of the plants at the type locality were removed by quarrying. Since the newly discovered colony is on public land within the Ozark National Forest, the shrubs will be given special protection by the U.S. Forest Service. Survival of these wild plants for future observation and study is assured. Also, seeds have been spread through cultivation by nurseries and botanical gardens in the United States and Europe. Thus this species would survive in cultivation and would not disappear.

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Southern Forest Experiment Station

Research Note

SO-212

1976

Nursery Selection of Loblolly Pine

E. BAYNE SNYDER

SUMMARY

Selecting exceptionally tall loblolly pine seedlings from nursery beds is a promising and low-cost means of tree improvement, according to this 10-year study.

From 1962 to 1971, 2,800 outstandingly tall seedlings were chosen from a nursery in south Mississippi and outplanted. Selected seedlings were about twice as tall as average-height controls. When the trees were measured, the 10 plantings were 3 to 10 years old.

Selected seedlings generally survived as well as controls and had better height and volume growth. Height growth superiority declined somewhat with age, but superiority in volume growth remained fairly high. Thus, in the three 10-year-old plantings, selects were only 4 to 7 percent taller than controls, but they produced 20 to 46 percent more volume.

Fusiform rust infections were somewhat more prevalent among selects than controls, possibly because fast-growing selects reveal the weakness better than slower-growing seedlings. Nevertheless, for every 1,000 seedlings initially chosen, there were at least 10 rust-free plus trees with twice the volume of controls.

Costs of nursery selections are small compared to most tree improvement ventures. The tree breeder needs only a three-man crew for 1 week to select and plant up to 500 trees—50 controls and 450 selects. Documentation, measurement, and analyses will require less than an additional week.

This test involved more selections and plantations than had been tried in the past. The next step in evaluating nursery selection is to compare progeny from selects with those of controls to see how much of the phenotypic gain is truely genetic.

Additional keywords: Survival, *Cronartium fusiforme*, volume growth, height growth, *Pinus taeda*.

Analysis of benefits from selecting exceptionally tall seedlings from nursery beds have generally led investigators to recommend this method of tree improvement (Barber and VanHaverbeke 1961). Others (e.g., Foulger 1960) contend that height growth advantages are too small to recommend nursery selection. Before the method is routinely adopted, therefore, conflicting findings must be weighed, and the efficiency of the method must be evaluated. This experiment, in which selections of loblolly pine (*Pinus taeda* L.) were made annually for 10 years, supplements information from previous work involving fewer selections and plantations.

METHODS

From 1962 to 1971, 2,800 outstandingly tall seedlings were selected from a Forest Service nursery in south Mississippi. The selected proportion was 1:50,000 (one per nursery bed). Average-sized neighboring seedlings lifted with

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every 10th selection served as controls. Selected seedlings were about twice as tall as controls. Seedlings were planted in a completely randomized design at 1.8 by 3.6 m spacing. Plantings were mowed periodically for weed control.

Survival, seedling size, and incidence of fusiform rust were observed in the first three plantings at age 10 years and in subsequent plantings, at younger ages (table 1). Heights were measured to the nearest 0.03 m, and diameters, to the nearest 0.25 cm. For trees 6 years and older, individual tree volumes were calculated according to Schmitt and Bower (1970). For quantitative traits, differences between treatments were tested by the t-test; for qualitative traits the chi-square contingency test with correction for discontinuity was used. All tests were at the 0.05 probability level.

RESULTS AND DISCUSSIONS

Survival was generally excellent, and selected seedlings tended to survive as well as controls—in two cases significantly better (table 1). In one 5-year-old planting 99 percent of the selected trees survived. In only the 1964 and 1966 plantings was survival of selects appreciably (but not significantly) lower than that of controls.

Heights and individual tree volumes of selected trees were significantly greater than those of controls in all but two of the plantings measured. These results confirm previous findings by Hatchell et al. (1972). Height growth superiority declined somewhat with age as it did for Grigsby (1975), but superiority in volume growth remained fairly high. Thus, in the three 10-year-old plantings selects were only 4 to 7 percent taller than controls, but they produced 20 to 46 percent more volume.

Fusiform rust infections were almost always more prevalent among selects than controls, and in three plantings the differences were striking (though not always statistically significant): 52 vs. 29, 62 vs. 20, and 22 vs. 8 percent (table 1). Other researchers have suspected a higher incidence of rust in selected seedlings than in controls but have been unable to consistently demonstrate this (Wakeley 1969).

Variability among the annual plantings was large. Survival varied from 53 to 93 percent, and infection, from 1 to 46 percent. Such variation implies that results of an individual test

Table 1. *Nursery selections compared with controls*

Year planted	Age (yrs)	No. selects	Survival: Control mean	Survival: Select mean	Survival: Difference as proportion of control	Rust: Control mean	Rust: Select mean	Rust: Difference as proportion of control	Height: Control mean	Height: Select mean	Height: Difference as proportion of control	Tree volume: Control mean	Tree volume: Select mean	Tree volume: Difference as proportion of control
			Percent						*Meter*			$M^3 \times 100$		*Percent*
1962	10	697	71	90	+27s	29	52	+79s	10.4	11.1	+7s	5.5	8.1	+46s
1963	10	483	73	70	−4	42	50	+18	11.2	11.9	+6s	8.0	10.7	+33s
1964	10	151	59	47	−20	30	62	+107	9.8	10.2	+4s	6.6	7.9	+20
1965	9	288	68	64	−6	0	14	+∞	9.0	9.4	+5	4.8	6.0	+26
1966	8	285	86	71	−17	12	19	+58s	6.3	8.0	+26s	1.8	3.1	+69s
1967	7	359	90	87	−3	8	22	+175	7.1	7.9	+11s	1.9	2.8	+50s
1968	6	132	93	92	−1	0	2	+∞	4.6	5.2	+12s	0.5	0.8	+68s
1969	5	111	85	99	+16s	3	3	−1	3.2	4.2	+31s	...	...	...
1970	4	104	91	95	+4	38	39	+1	3.6	4.3	+18s	...	...	...
1971	3	144	62	74	+19	43	44	+1	2.7	3.3	+23s	...	...	...

NOTE: s indicates that the difference was significant at the 0.05 probability level.

are inconclusive. Only when the series of years is considered do strong trends emerge.

Although the results of the present experiment are valuable, the breeder contemplating nursery selection must ponder as well the cost per breed tree produced. He needs only a three-man crew for 1 week to select and plant up to 500 trees—50 controls and 450 selects. Documentation, measurement, and analyses will require less than an additional week. Thus, costs are small compared to most tree improvement ventures.

Admittedly, such a program yields only a small number of final plus-tree candidates. C. R. Gansel[1] selected for further breeding only two candidates from 1,000 original selections and pronounced the method inefficient for his dry, flatwood site in Florida. On our sites, however, for every 1,000 seedlings initially chosen, there were at least 10 rust-free trees with twice the volume of controls. Perhaps fast growth of selects exaggerates and reveals weaknesses present in the general population. If so, this exaggeration should be considered a benefit. Our final decision as to efficiency of nursery selection awaits comparison of progeny from chosen selects with those from similarly chosen controls to see how much of the phenotypic gain is truly genetic.

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Southern Forest Experiment Station

Research Note

SO-213

1976

Evaluation of Animal Hazard to Spot-Seeded White Ash In Central Tennessee

T. E. RUSSELL [1]

Screen protection of seedspots more than doubled white ash seedling establishment on orested sites of the Cumberland Plateau. For 3 years seeds were sown in fall and spring and iven either no protection, or covered with 1-inch mesh screen, or covered with ¼-inch mesh hardvare cloth. Unprotected seeds and those covered with 1-inch mesh screen suffered heavy depredaions each year.

Although white ash can be protected from animals, successful seeding will require improved eed treatments and seedling techniques. Even where animals were excluded, poor germination aused unsatisfactory seedspot stocking in a number of trials.

Additional keywords: *Fraxinus americana,* artificial regeneration of hardwoods, direct seeding, nimal damage.

White ash is an excellent species for a varity of sites throughout central Tennessee but sually occurs in small groups or as scattered rees. Because of the scattered seed source, artiicial regeneration will be required if ash is to e established on many productive sites. Where teep slopes, rocky soils, or heavy logging slash nake planting difficult, direct seeding could be useful regeneration method.

Few attempts to direct seed white ash have een made, and the factors that influence sucess are largely unknown. Loss of seeds to birds r small mammals to some extent limits seeding establishment for most hardwoods. On the Cumberland Plateau, risks differ between species, and, for example, are high for oaks and lack walnuts (Mignery 1975, Russell 1968), noderate for yellow-poplar (Russell 1973), and low for black cherry (Russell 1975). The study reported here was installed to evaluate animal hazards when spot-seeding white ash.

METHODS

Three levels of seedspot protection were tested at 10 widely dispersed locations near Sewanee. Sowing was done in both fall and spring for 3 years (1970-71, 1971-72, and 1972-73) on two sites—shallow U-shaped hollows on top of the Plateau and northerly slopes of the Plateau escarpment known locally as "coves." Soils in the hollows are mainly fine sandy loams of the Hartsells-Ramsey association that support fairquality stands of oak and hickory with an occasional yellow-poplar or other miscellaneous species. Cove soils are dark, friable loams of the Allen or Bouldin series. Timber types vary here from oak-hickory on dry, south and west facing

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slopes to mixed-mesophytic hardwoods on northerly aspects.

The areas had all been logged within the past 15 years. Since my main purpose was to define the potential for animal damage to white ash seedings, I did not deaden residual hardwoods. Deadening would have initiated a succession of herbaceous and woody vegetation that would have produced different cover types and densities for each yearly trial.

Treatments were replicated five times in a completely randomized, split-plot design; the five installations on each site were major plots. Each major plot was in a separate hollow or cove and at least 0.5 miles from other installations or from radically different cover types such as old fields. At all locations, protection and season of sowing treatments were tested on six subplots, each containing 16 seedspots spaced about 6 feet apart. Hardwood litter was removed, and 20 white ash seeds per spot were pressed into the surface of the mineral soil.

Unstratified seeds were sown in November and stratified seeds in March for 3 consecutive years. The same subplots were resown for all annual trials after seeds or seedlings from a previous year were removed by raking.

On randomly selected subplots, seeds received one of three levels of protection from animals: (1) no protection, (2) covered with 1-inch mesh screens that allowed passage of small rodents such as mice but barred squirrels and larger animals, and (3) covered with 1/4-inch mesh hardware cloth that prevented animal access. A preliminary trial in spring 1970 had determined that the screens would provide the degree of protection desired and that seed damage could be reliably detected.

Results for each year were expressed as percent of seedspots disturbed, as the number of seedlings obtained per 100 seeds (tree percents), and as the proportion of spots producing at least one seedling (initial stocking). Differences were tested by analysis of variance after arcsine proportion transformation.

RESULTS

Depredations

Animal depredations fluctuated from year to year, but damage to exposed seedspots was severe each year in all trials (table 1). Losses under 1-inch mesh screens were also heavy, indicating that mice or other small forest rodents may feed freely on white ash seeds. The 1/4-inch mesh screens significantly (0.01 level) limited depredations in all years; seed was damaged only on a few plots where animals burrowed under the screens.

Table 1.—*Seedspot depredation by animals and seedspot stocking (data for fall and spring sowing and for cove and plateau sites combined)*

Type of seedspot screen	Year of test		
	1970-71	1971-72	1972-73
	Percent		
	Spots robbed		
None	94	68	81
1-inch mesh	90	75	87
1/4-inch mesh	0	0	3
	Stocking		
None	12	34	32
1-inch mesh	12	15	15
1/4-inch mesh	39	47	48

More seedspots were robbed in the fall than in the spring in 1970-71; in 1971-72 depredations were heaviest in the spring. Animal activity did not vary significantly with season of sowing in 1972, nor between sites in any year.

The ability of seedlings to survive their first summer was observed each year. Survival averaged 84 percent with only a 2 percentage point difference between unprotected and the fully protected seedspots. Browsing animals are evidently not a serious threat to newly germinated white ash on the Cumberland Plateau.

Seedling establishment

Over the 3 years, tree percents averaged 1.8 on unprotected seedspots, 0.8 under 1-inch mesh screens and 4.0 on spots protected with 1/4-inch mesh screens. Differences between both levels of protection and exposed seed were significant in 1970-71; differences between the 1-inch and 1/4-inch mesh screens were significant in all years. Spring was superior to fall seeding in two annual trials while results were unaffected by season of sowing in the third year. None of the differences between sites or their interactions with levels of protection and seasons were statistically significant.

Results expressed as tree percents generally paralleled those based on depredations. However, seedling establishment is influenced by seed quality and weather as well as by seed losses. Seedlots used in this study contained over 90 percent full seed and had a proven germinability of 24 percent for the seeedlot sown in 1970-71 and 37 percent for the lot used in the 1971-72 and 1972-73 trials. Even under ¼-inch mesh screens, field germination was invariably much poorer than the potential indicated by laboratory tests.

Stocking

Stocking averaged 26 percent on exposed spots, 14 percent under 1-inch screens, and 44 percent under ¼-inch mesh screens and was significantly improved by the ¼-inch screen in all years (table 1). Stocking was higher on spring seeded than on fall seeded plots in 1970-71 and in 1971-72 but was not affected by season in 1972-73.

If each season of sowing at each location, including spring 1970, is considered a separate test, the study included 70 small-scale trials. The proportion of these trials yielding various specified thresholds of stocking with unprotected and fully protected seeds were:

Proportion of trials yielding initial seed-spot stocking of:	No protection	¼-inch mesh screens
	Percent	
65 percent or better	3	24
50 percent or better	17	47
35 percent or better	36	61

Excluding animals increased the odds for obtaining a stocking of 50 percent or better by almost threefold; stocking of 65 percent or better occurred eight times more often with protected than with unprotected seeds. Although the residual hardwoods were not deadened, the tolerant white ash seedlings survived well and stocking changed little during the first growing season after seeding.

DISCUSSION

On the Cumberland Plateau, foraging animals can limit spot seeding of white ash on two characteristic hardwood sites. Spring sowing produced better seedling establishment and stocking than fall sowing in 2 of 3 years; spring is probably the preferred season for sowing white ash in this region.

As a result of protection, tree percents were increased an average of three times, and the proportion of stocked spots was more than doubled. Mechanical devices as used in this study, while effective, are too costly for general use. A cheap and environmentally acceptable repellent is needed as a more practical way to minimize animal depredation.

White ash seeding was only marginally successful in many trials, even where seeds were fully protected. A major factor contributing to poor seedling establishment was the low rate of germination in the field. This may be compensated for to some extent by increasing the sowing rate. But consistent success in seeding white ash will require the development of better seeding techniques and pre-sowing seed treatments to increase field germination.

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SO-214

Southern Forest Experiment Station

Research Note

1976

Key to Mites Commonly Associated With the Southern Pine Beetle[1]

BY D. N. KINN

This paper outlines a method of preparing mites for microscopic examination and contains a simple key to the 15 species of mites commonly associated with the southern pine bark beetle. Research workers wanting to identify these mites and others curious about them, but untrained in acarology, should find little difficulty in making identifications.

Additional keywords: Acari, phoresy, *Dendroctonus frontalis.*

Current interest in the biology and ecology of the southern pine beetle, *Dendroctonus frontalis* Zimm., has created a need for a key that will help novices identify the minute organisms associated with the beetle. The Acari, or mites, are a group of associates that are unfamiliar to many investigators. The relationship between the mites and these pine beetles is a special form of commensalism called phoresy: the mites cling to the beetles to disperse themselves but do not directly harm the beetle. Moser and Roton (1971) list 96 species of mites associated with bark beetles in the southern United States, but only 15 species (table 1) are commonly phoretic on *D. frontalis.*[2] The key is to the life stage (nymph or adult) that occurs on the adult beetle. Other life stages of the mite occur in the beetle galleries.

A good hand lens or dissecting microscope will reveal characteristics that allow one to identify the families and superfamilies, but mounted specimens are needed for species identification. Color and behavior characteristics have been described, and illustrations of each specimen have been included. Few morphological terms are used, and the reader will find it easy to become familiar with those that are.

MOUNTING SPECIMENS

Specimens to be mounted on slides should be cleared in a lacto-phenol solution held at room temperature for 24 hours or placed in a 60°C (140°F) oven for 12 hours. The clearing agent is prepared by mixing:

Lactic acid . . . . 50 parts
Phenol crystals . . . . 25 parts
Distilled water . . . . 25 parts.

Berlese's solution is a convenient mounting medium and contains:

Gum acacia (crystals of gum arabic) . . . . 40 g
Distilled water. . . . . 40 ml
Glycerin . . . . 25 ml
Chloral hydrate . . . . 350 g
Glacial acetic acid. . . . . 15 ml.

This medium is prepared in the following manner:

1. Completely dissolve gum acacia in distilled water. This process is slow

[1] The work herein reported was funded in part by the U. S. Department of Agriculture's Southern Pine Beetle Research and Development Program.

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[2] Moser, J. C. 1976. Personal conversation. South. For. Exp. Stn., Pineville, La.

Table 1.--*Species and stages of mites commonly phoretic on the southern pine beetle.*

Order Parasitiformes
  Suborder Mesostigmata
    Superfamily Parasitoidea
      Ascidae - females phoretic
        Proctogastrolaelaps libris McGraw and Farrier 1969
        Proctolaelaps dendroctoni Lindquist and Hunter 1965
      Digamasellidae - deutonymphs phoretic
        Longoseius ciniculus Chant 1961
        Dendrolaelaps neodisetus (Hurlbutt 1967)
      Macrochelidae - females phoretic
        Macrocheles boudreauxi Krantz 1965

    Superfamily Uropodoidea
      Uropodidae - deutonymphs phoretic
        Trichouropoda australis Hirschmann 1972
        Trichouropoda hirsuta Hirschmann 1972

Order Acariformes
  Suborder Astigmata
    Superfamily Acaroidea
      Acaridae - deutonymphs (hypopi) phoretic
        Histiogaster arborsignis Woodring 1963

    Superfamily Anoetoidea
      Anoetidae - deutonymphs (hypopi) phoretic
        Anoetus sordida Woodring and Moser 1970
        Anoetus varia Woodring and Moser 1970

  Suborder Prostigmata
    Superfamily Tydeoidea
      Ereynetidae - adults phoretic
        Ereynetoides scutulis Hunter 1964

    Superfamily Tarsonemoidea
      Pyemotidae - females phoretic
        Pygmephorus bennetti Cross and Moser 1971
      Tarsonemidae - females phoretic
        Heterotarsonemus lindquisti Smiley 1969
        Tarsonemus ips Lindquist 1969
        Tarsonemus krantzi Smiley and Moser 1974

and may take as long as 5 days but can be shortened to about 3 hours with constant agitation. Add more water if solution does not dissolve.

2. Dissolve other ingredients in the order listed above.
3. Strain the solution through several layers of cheese cloth using a wide-mouth funnel, and then centrifuge at high speed for 45 minutes.
4. The final solution should have the consistency of honey, which is produced by heating the solution in an oven at 50°C (122°F).

The following procedure for mounting mite specimens on microscope slides is suggested:

1. Place a small drop of Berlese's medium on a clean slide.
2. Remove mite from lacto-phenol with a

needle forceps, transfer it to the slide, and carefully push it to the bottom of the droplet.

3. Carefully place a clean coverslip over the droplet with a forceps; the medium should just reach the edge of the coverslip. Attempt to center the specimen and extend its legs by gently applying pressure to the cover slip.
4. Place the slide in a drying oven overnight at 60°C (140°F).
5. Remove the slide from the oven and scrape off the excess medium with a scalpel, then seal the coverslip by ringing with a compound such as Glyptal®[3] electrical paint.

Baker and Wharton (1952) describe other mounting media, as do Evans, Sheals, and MacFarlane (1961) and Krantz (1970). Specimens mailed to specialists should not be cleared or mounted, but preserved in alcohol.

KEY TO MITES

1. Discernible without the aid of a lens; often red-brown in color; body hardened, with many shields or plates; stigmata (respiratory openings) located lateral to the bases of legs III and IV; tritosternum present; special sensory hairs not present on dorsal surface (fig. 1)... Order Parasitiformes--- Suborder Mesostigmata . . . . . . 2.

- Usually small and light in color; body without numerous plates; stigmata not located lateral to bases of legs III and IV; tritosternum absent; special sensory hairs may be present on the anterior dorsal surface (fig. 4)... Order Acariformes . . . . 8.

2. Turtle shaped; legs can be withdrawn into grooves (fig. 2); attached to beetle by anal pedicle...Superfamily Uropodoidea--- Family Uropodidae . . . . 3.

- Not turtle shaped; leg grooves absent; attached to beetle by the mouthparts and/or leg claws... Superfamily Parasitoidea . . . . . 4.

3. Anal shield with 14 hairs (fig. 2a); length about one-tenth of host's length . . . . *Trichouropoda australis*

- Anal shield with 10 hairs (fig. 2b); length about one-third of host's length . . . . *Trichouropoda hirsuta*

4. Large red-brown mite lacking claws on leg I; peritremes looped, joining stigmata posteriorly (fig. 1c)...Family Macrochelidae . . . . *Macrocheles boudreauxi*

- Leg I with claws; peritremes not looped, joining stigmata anteriorly (fig. 1b) . . . . 5.

5. Dorsal shield entire; posterior end rounded (fig. 3a)...Family Ascidae . . . . 6.

- Dorsal shield divided into two plates; posterior end more or less truncated (fig. 3b)...Family Digamasellidae . . . . 7.

6. Ventral surface with four shields (sternal, genital, ventral, and anal) (fig. 1a) . . . . . . *Proctogastrolaelaps libris*

- Ventral surface with three shields (sternal, genital, and anal) (fig. 1b) . . . . . . *Proctolaelaps dendroctoni*

7. Body about two times longer than wide (fig. 3b) . . . . . . *Dendrolaelaps neodisetus*

- Body about four times longer than wide (fig. 3c) . . . . *Longoseius cuniculus*

8. Mouthparts functional; anal suckers absent; special sensory hairs present on anterior dorsal surface (fig. 4)... Suborder Prostigmata . . . . 9.

- Mouthparts vestigial; anal suckers present; special sensory hairs not present on anterior dorsal surface (fig. 5)... Suborder Astigmata . . . . 13.

[3] Trade names are included to identify materials used and do not constitute endorsement by the U. S. Department of Agriculture.

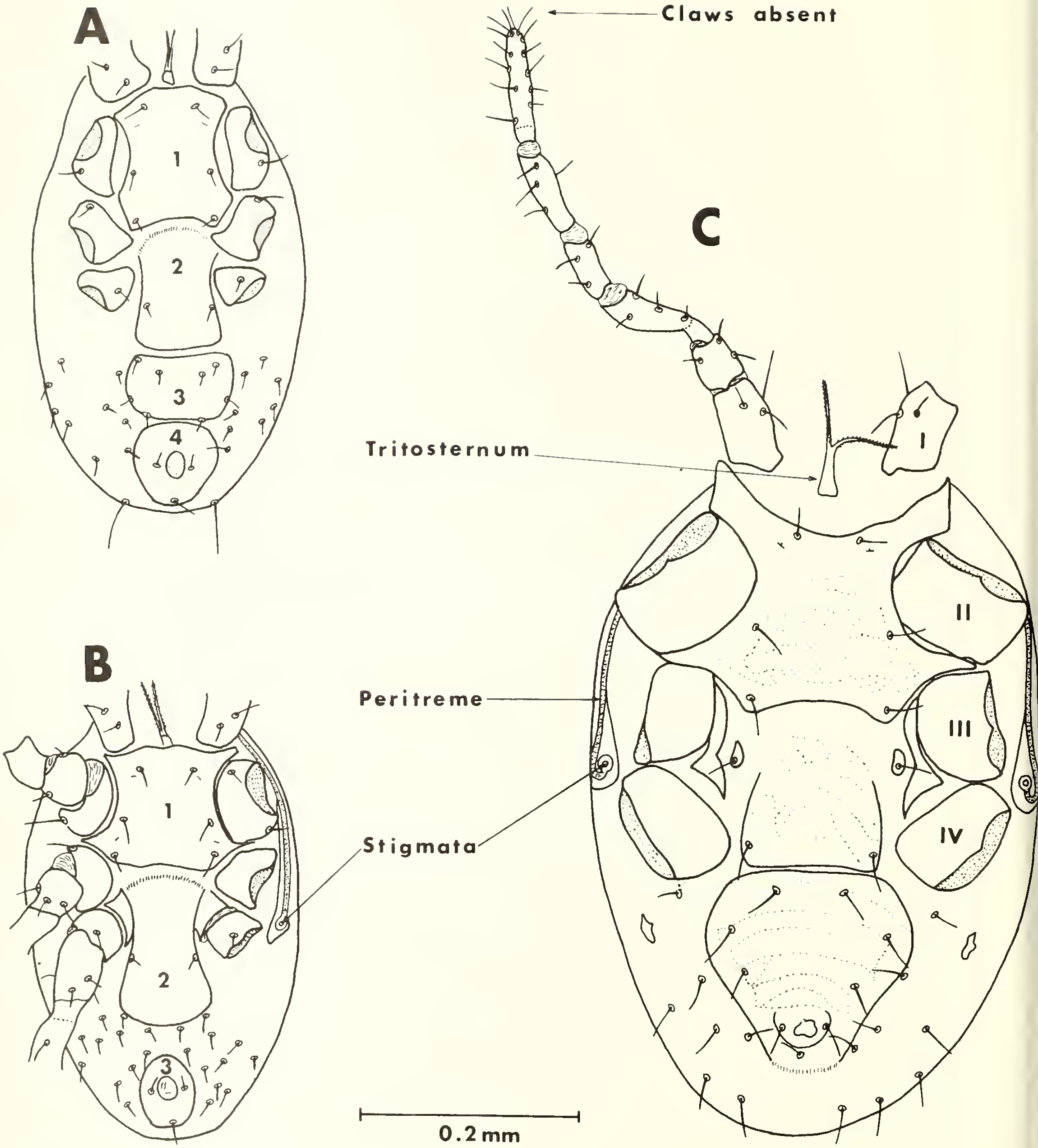

Figure 1.--Ventral aspect of (A) *Proctogastrolaelaps libris*, (B) female *Proctolaelaps dendroctoni*, (C) female *Macrocheles boudreauxi*.

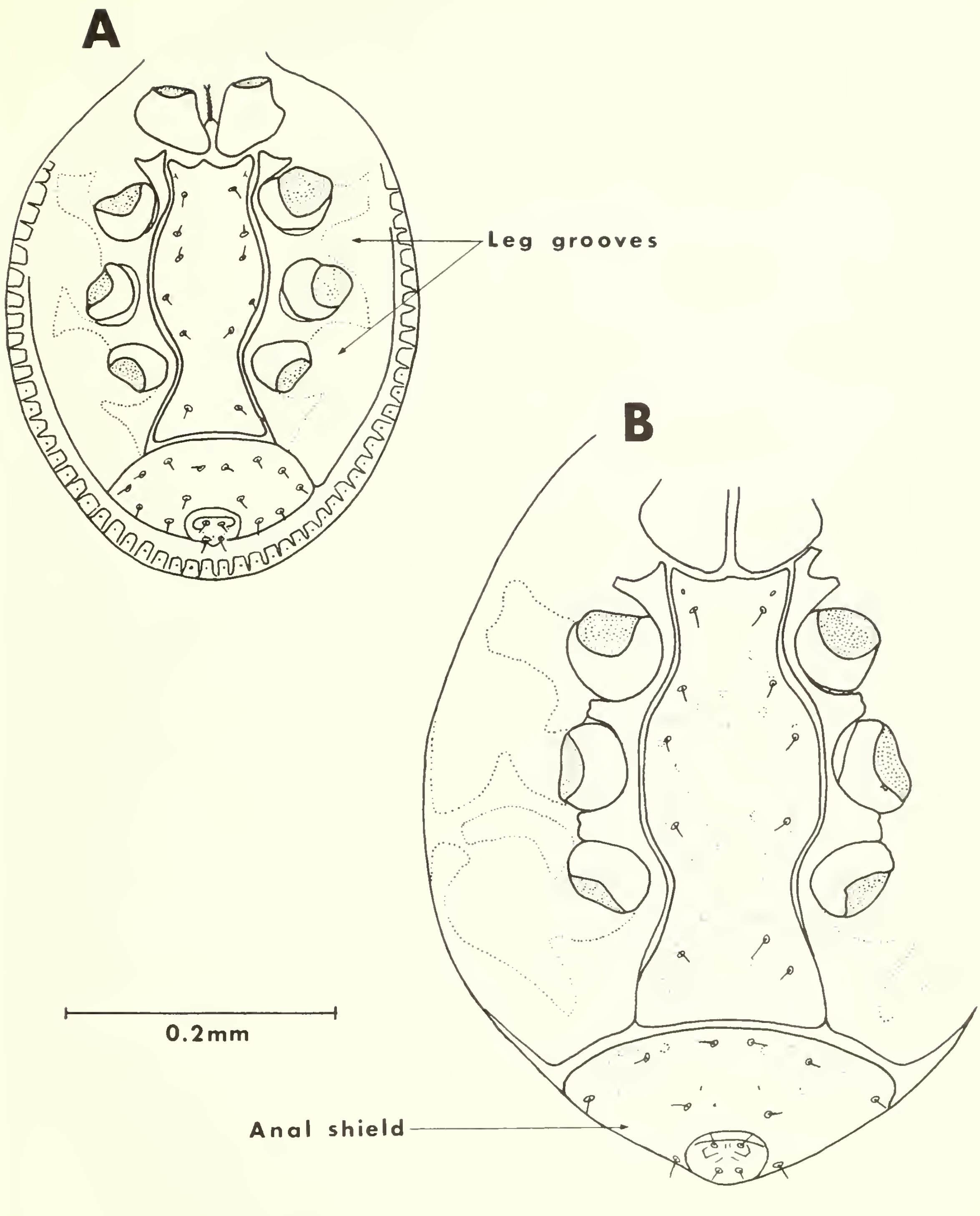

Figure 2.--Ventral aspect of (A) *Trichouropoda australis* deutonymph, (B) *T. hirsuta* deutonymph.

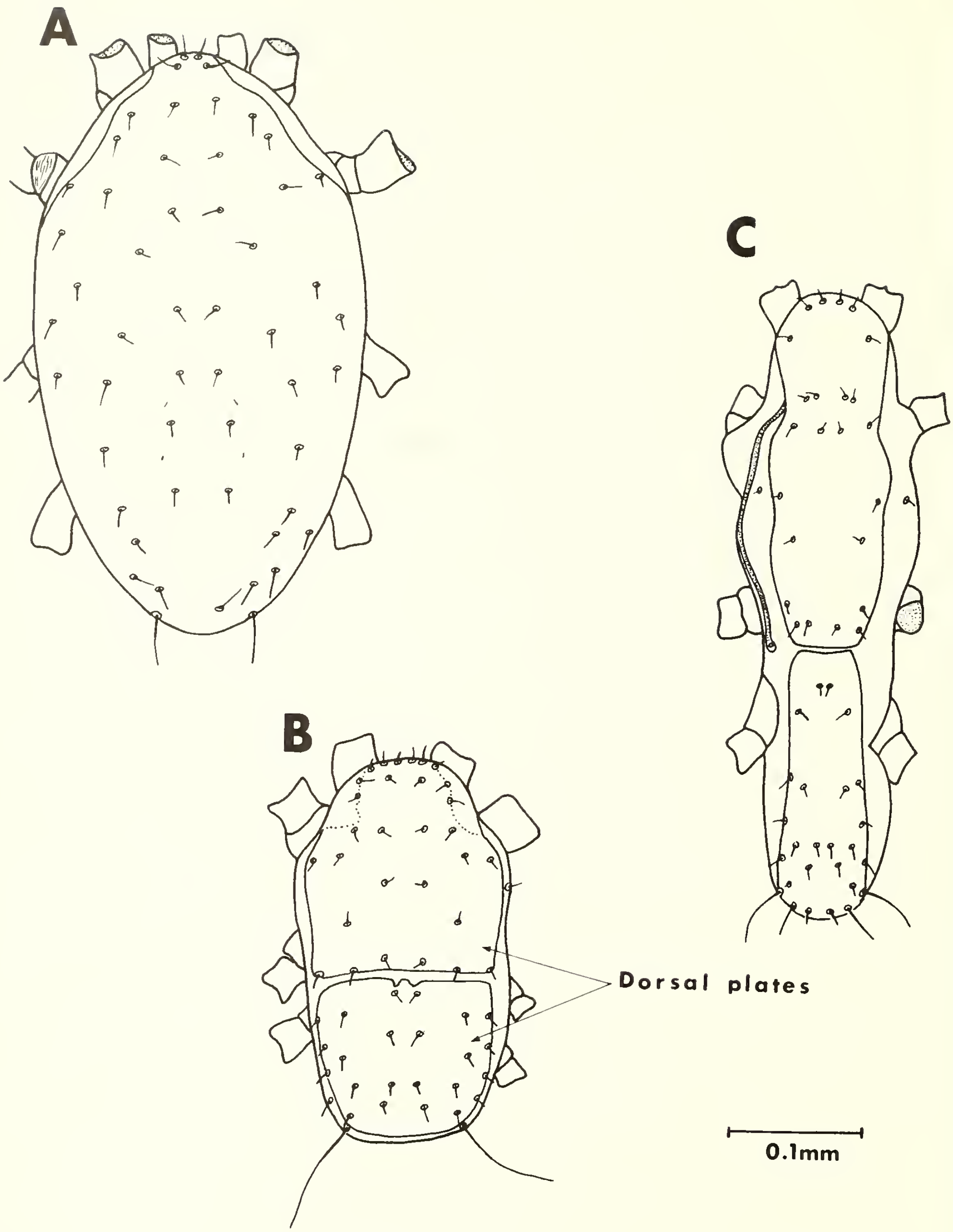

Figure 3.--Dorsal aspect of (A) *Proctolaelaps* sp., (B) *Dendrolaelaps neodisetus* deutonymph; (C) *Longoseius cuniculus* deutonymph.

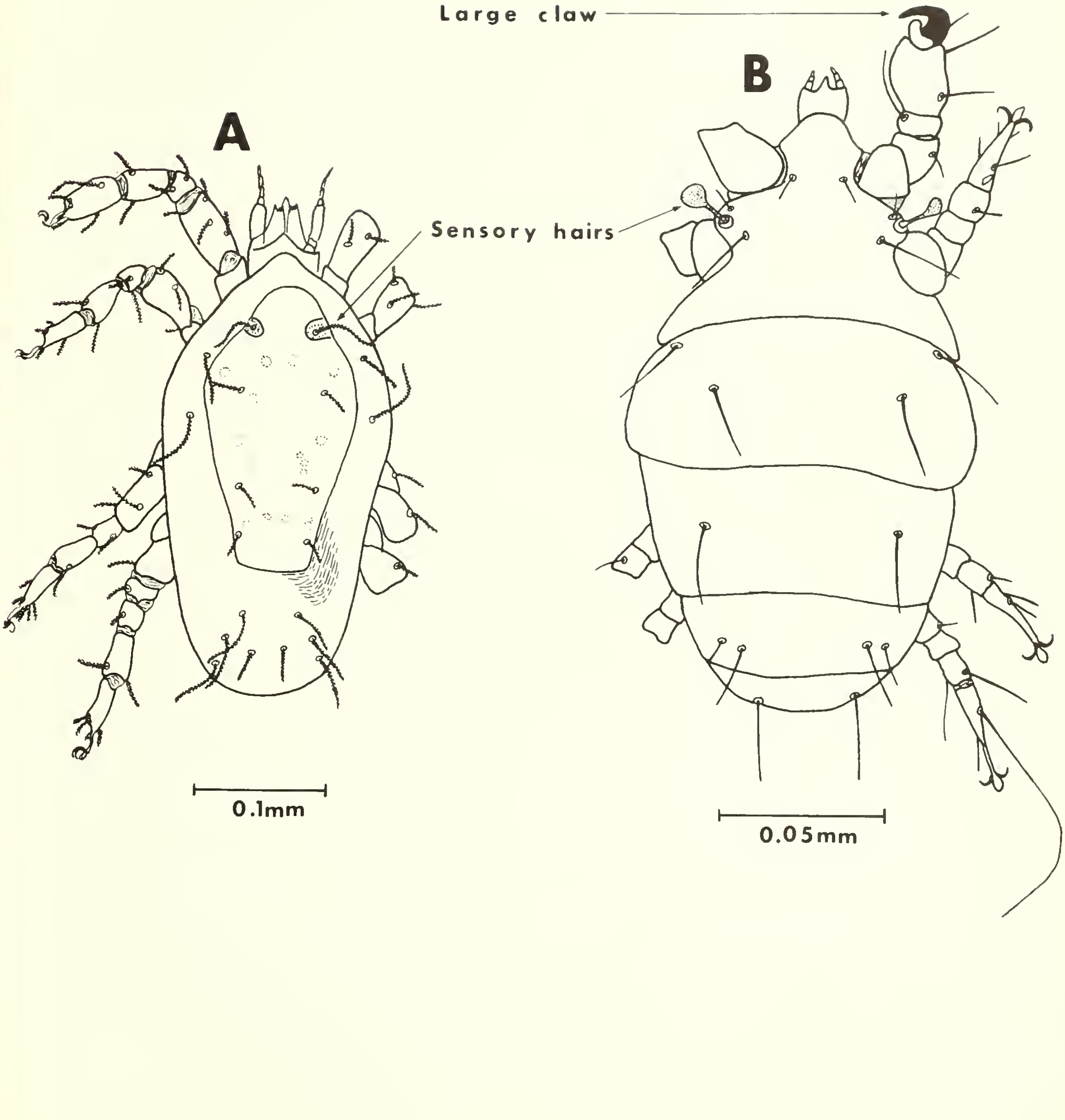

Figure 4.--Dorsal aspect of (A) *Ereynetoides scutulis*, (B) *Pygmephorus bennetti*.

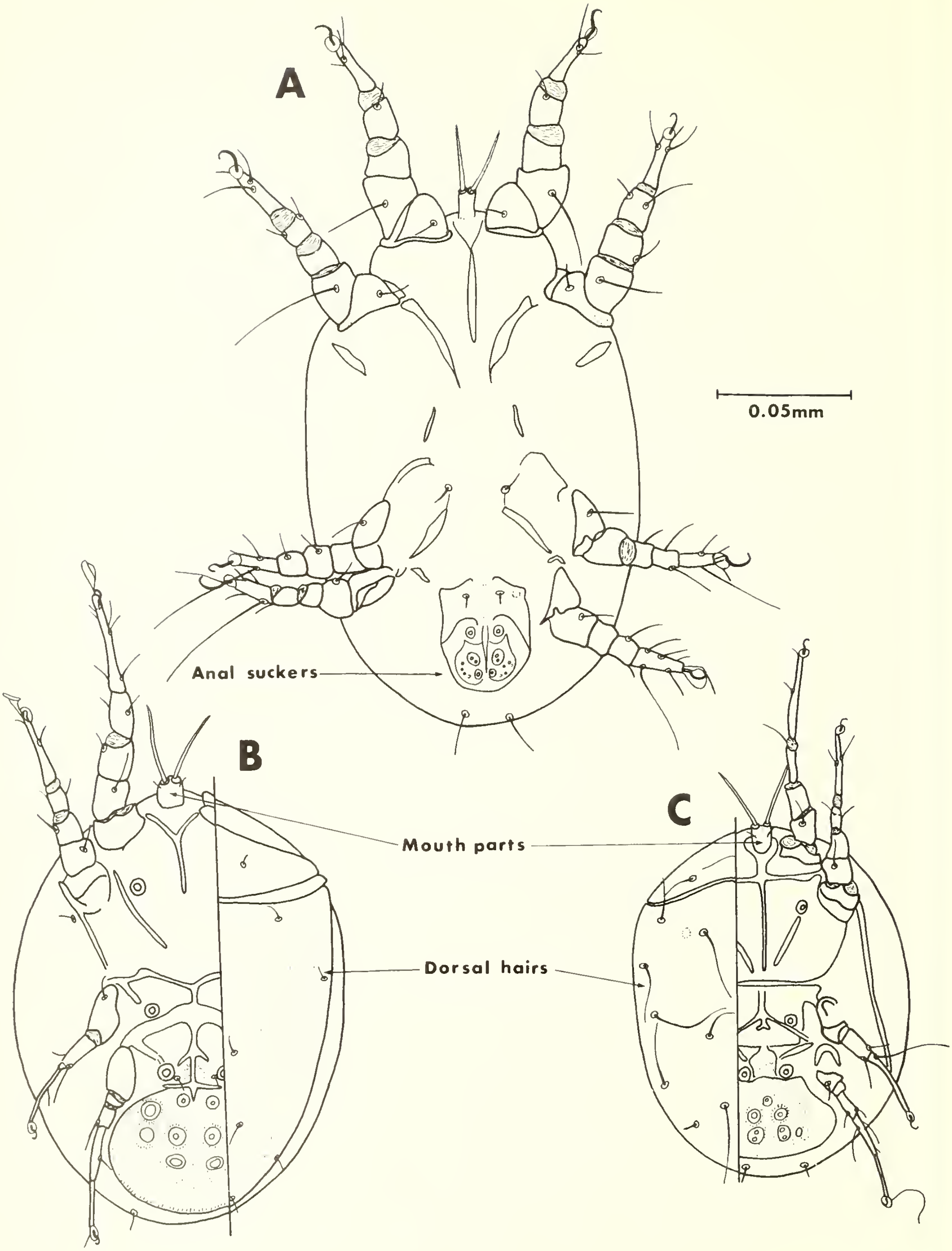

Figure 5.--Ventral aspect of (A) *Histiogaster arborsignis* hypopus, (B) *Anoetus sordida* hypopus, (C) *Anoetus varia* hypopus.

9. Small, slow-moving mites often found under the beetle's wing covers or around the leg bases; mouthparts indistinct; sensory hairs club-shaped; legs short in relation to body (figs. 4b and 6)...Superfamily Tarsonemoidea . . . . 10.

- Fast-moving, orange-colored mite; mouthparts distinct; sensory hairs long and barbed; legs long in relation to body (fig. 4a)...Superfamily Tydeoidea-Family Ereynetidae . . . . *Ereynetoides scutulis*

10. Legs IV without claws and terminating with two whiplike hairs (fig. 6)...Family Tarsonemidae . . . . 11.

- Legs II-IV terminating with two claws; legs I terminate with a single large claw (fig. 4b)...Family Pyemotidae . . . . *Pygmephorus bennetti*

11. Legs II and III with a single claw; claw of leg I short, stout, and straight (fig. 6a) . . . . *Heterotarsonemus lindquisti*

- Legs II and III each with two claws; claw of leg I single, not modified (fig. 6b, c) . . . . 12.

12. Cuticular thickenings anterior to bases of legs III extending laterally beyond bases of legs III; lobe between bases of legs IV not elongated (fig. 6b) . . . . *Tarsonemus krantzi*

- Cuticular thickenings anterior to bases of legs III not extending laterally beyond bases of legs III; lobe between bases of legs IV very elongated and extending behind bases of legs IV (fig. 6c) . . . .*Tarsonemus ips*

13. All legs short and stout; legs III and IV often directed backward; distal segments of legs III and IV short (fig. 5a)...Superfamily Acaroidea - Family Acaridae . . . . . . *Histiogaster arborsignis*

- Legs I and II stouter than legs III and IV; legs III and IV often directed forward and have long, slender distal segments (fig. 5b, c)...Superfamily Anoetoidea - Family Anoetidae . . . . 14.

14. Entire dorsal surface always ornamented; fused mouthparts project well beyond body outline; dorsal hairs short and slender (fig. 5b) . . . . *Anoetus sordida*

- Dorsal ornamentation variable; fused mouthparts do not usually project beyond anterior edge of body; dorsal hairs long and thick (fig. 5c) . . . . *Anoetus varia*

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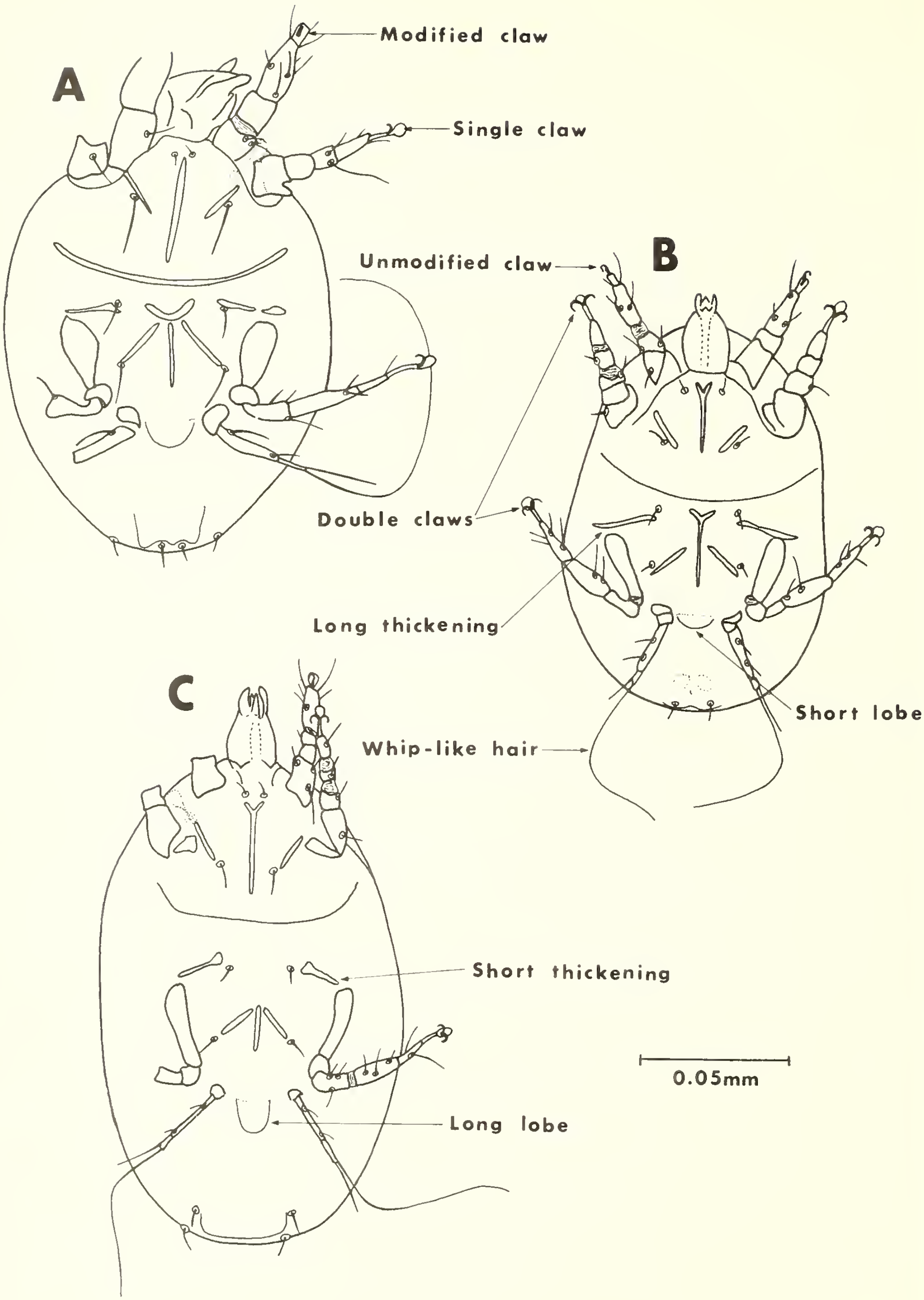

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SO-215

1976

Growth of Planted Yellow-Poplar After Vertical Mulching and Fertilization on Eroded Soils[1]

BY J. B. BAKER AND B. G. BLACKMON

SUMMARY

Fertilization and vertical mulching improved height growth of yellow-poplars planted on eroded soils. A growing demand for hardwood timber accompanied by a diminishing land base has prompted land managers to consider planting hardwoods on marginal sites such as the eroded soils in the Silty Uplands of Arkansas, Louisiana, and Mississippi. Many of these areas were well suited for pine but lack the moisture and nutrients necessary for fast-growing hardwoods. If soil moisture and nutrient content were improved, hardwood management would be feasible on these sites. In two field experiments to improve moisture and nutrient content of eroded Memphis soils, vertical mulching with sawdust plus fertilizer improved height growth by 40 percent on severely eroded soils and by 25 percent on moderately eroded ones. Total height growth during the 5-year study period averaged 12.2 and 14.4 feet for treated trees on severely and moderately eroded sites, respectively, compared to 8.5 and 11.5 feet for untreated controls. Greatest response occurred during the second through fourth years after application. Broadcast fertilization followed by disking also improved height growth, but the response lasted only 2 years. Total height growth of trees ranged from 11.7 feet for controls to 13.3 feet for the fertilizer treatment.

Additional keywords: Liriodendron tulipifera, forest fertilization, Memphis soils, soil erosion.

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PLANTING ON ERODED SITES

A growing demand for hardwood timber, accompanied by a diminishing land base, has prompted land managers to consider planting hardwoods on marginal sites such as the eroded soils in the Silty Uplands of Arkansas, Louisiana, and Mississippi. Many of these areas are well suited for pine but lack the moisture and nutrients necessary for fast-growing hardwoods. During its first decade, for example, yellow-poplar (Liriodendron tulipifera L.), averages only about 1.5 feet in height growth per year, when planted on severely eroded Memphis soils (Typic Hapludalfs) in the Silty Uplands of Mississippi. When planted on noneroded soils of the same series, however, yellow-poplar averages about 5 feet per year during the same growth period. If soil moisture and nutrient content were improved, hardwood management would be feasible on these sites. This note describes two field experiments to improve moisture and nutrient content of eroded Memphis soils.

METHODS

The first experiment was installed in two plantations near Vicksburg, Mississippi, in spring 1967. Noneroded Memphis soils in the area commonly have 8 to 12 inches of topsoil. One of the plantations represented a severely eroded site, as it had 1 inch or less of topsoil; the other site, which had 4 to 5 inches of topsoil, was considered moderately eroded. Both sites had become eroded several years earlier while under agronomic use. At the time of treatment, trees on the severely eroded site were 2 years old and averaged 2.6 feet in height; trees on the moderately eroded site were 3 years old when treated and averaged 8.4 feet in height.

Treatments consisted of a vertical mulch with sawdust, a vertical mulch with sawdust plus fertilizer, and an untreated control. All treatments were replicated four times in a completely random design at each site. Each treatment plot consisted of four trees; there was at least one row of trees between each plot.

The vertical mulch consisted of filling two holes per tree with partially decomposed sawdust. The holes, which were 7 inches in diameter and 20 inches deep, were placed on opposite sides of each tree at a distance of 12 inches. For the fertilizer treatment, 0.6 pounds per tree (equivalent to 1,000 pounds per acre) of 13-13-13 was placed in a horizontal layer at the midpoint of the sawdust column. This provided 130 pounds per acre of N, 57 pounds per acre of P, and 108 pounds per acre of K. There were no holes on the control plots.

During the first year after establishment, both plantations were clean cultivated with a disk harrow; a cross-cultivation technique was used.

Tree heights were measured at the beginning of the study and at the end of each growing season for 5 consecutive years. Diameters (DBH) were measured at the end of the fifth year.

The second study was established near the first one in spring 1969; sample trees were 2 years old and had been clean cultivated during the first year. The experiment tested growth responses after a broadcast application of 1,000 pounds per acre of 13-13-13 fertilizer, which was applied and disked into the soil early in the second growing season. At the time of treatment, the trees averaged 3.1 feet in height. There were four replications installed in a randomized complete block design. Each plot was 100 feet square (0.23 acres) and contained approximately 80 trees. For 28 trees in the interior of each plot, height was measured at the time of

[1] A cooperative study with Greif Bros. Corporation and Anderson-Tully Company.

The authors are Principal Soil Scientists at the Southern Hardwoods Laboratory, which is maintained at Stoneville, Miss., by the Southern Forest Experiment Station, Forest Service--USDA, in cooperation with the Mississippi Agricultural & Forestry Experiment Station and the Southern Hardwood Forest Research Group.

treatment and after the second through the fifth growing seasons; diameters were measured at the end of the third through the fifth seasons.

Differences were tested at the 0.05 level by analyses of variance.

RESULTS AND DISCUSSION

For severely eroded sites, mulching and fertilization significantly improved total height growth of trees during the 5-year study period (experiment 1) (table 1). Total height growth of trees on the poor site ranged from 8.5 feet for the controls to 12.2 feet for the sawdust plus fertilizer treatment. The sawdust mulch alone did not significantly influence growth.

Significant responses to fertilizer occurred on the severely eroded site during the second, third, and fourth years after treatment, when annual height growth increased by 43, 125, and 69 percent over the controls. No growth responses occurred during the first and fifth years. During the first year, the roots had probably not penetrated the sawdust- fertilizer columns sufficiently; by the fifth year, the fertilizer had apparently been depleted, immobilized, or leached. Farmer, Snow, and Curlin (1970) reported that NP fertilization of yellow-poplar on a severely eroded, silty clay loam soil in eastern Tennessee produced significant growth responses during the first 2 years after planting. However, by age 5, only the N effect was significant; trees on the most effective N treatment plots were 80 percent taller than controls.

On the moderately eroded site, mulching plus fertilization appeared to increase height growth by 25 percent, and mulching alone apparently decreased height growth by 29 percent; however the differences were not significant. The only significant finding for moderately eroded sites was increased height growth during the second year after mulching plus fertilization.

A comparison of total height growth by treatment on the two sites indicated that mulching plus fertilizer on the severely

Table 1.--*Annual height growth of yellow-poplar after vertical mulching with sawdust and fertilizer (experiment 1)*

Site and treatment	Annual height growth after treatment [1] 1st year	2nd year	3rd year	4th year	5th year	Total
	Feet					
Severely eroded site						
Control	2.3 a	2.8 a	1.2 a	1.3 a	0.9 a	8.5 a
Sawdust only	1.8 a	2.9 a	1.4 a	1.3 a	1.3 a	8.7 a
Sawdust plus fertilizer	2.1 a	4.0 b	2.7 b	2.2 b	1.2 a	12.2 b
Moderately eroded site						
Control	1.7 a	3.1 a	2.5 a	1.9 a	2.3 a	11.5 a
Sawdust only	1.3 a	2.1 a	1.9 a	1.1 a	1.8 a	8.2 a
Sawdust plus fertilizer	1.8 a	5.0 b	3.7 a	1.3 a	2.6 a	14.4 a

[1] Separate analyses of variance were used for each site-year. Means in the same column and for each site followed by the same letter are not significantly different (0.05 level).

eroded soil produced growth comparable to that of the untreated trees on the moderately eroded site. Thus, 5 years after treatment, the productivity of the poor site was similar to that of the intermediate site.

Mulching and fertilization did not significantly influence diameter growth, although an increase of 25 percent over controls was observed on the severely eroded sites, and a 32 percent increase was recorded on the moderately eroded one.

Because of the early responses to the sawdust plus fertilizer treatment, it was thought that a similar response might be obtained with a simple broadcast application of 13-13-13 fertilizer followed by disking (experiment 2). Fertilization significantly improved height growth for 2 years after treatment (table 2), when total height growth was 11.7 feet for the controls and 13.3 feet for fertilized trees. There was no response to fertilizer during the third or fourth years, but at the end of 4 years, the fertilized trees were 2 feet taller than the controls, though the difference was not significant.

Trees on individual blocks responded differently (table 2). Blocks 1, 2, and 3, which were located on a flat portion of a ridge, were only moderately eroded (4- to 5-inch topsoil depth); block 4 was located on the side slope of the ridge and was severely eroded (topsoil depth of 1 inch or less). Improvements in height growth were greater for trees on the severely eroded block than for those on the three moderately eroded blocks. By the end of the experiment, fertilization had increased block 4 tree heights by 4.5 feet, while tree heights on blocks 1, 2, and 3 were increased by only 0.5 to 1.2 feet. These results are comparable to the findings in experiment 1, where eroded sites showed the best responses to soil improvement. As in the first experiment, fertilization failed to affect diameter growth significantly.

CONCLUSIONS

Both experiments indicated that height growth of yellow-poplar planted on eroded Memphis soils is improved by adding fertilizer. Results were more pronounced on severely eroded than on moderately eroded

Table 2.--*Annual height growth of yellow-poplar after broadcast fertilization (experiment 2)*

Treatment	Block	Annual height growth after treatment[1] 1st year	2nd year	3rd year	4th year	Total
		Feet				
Fertilized	1	5.3	8.9	8.5	7.6	30.3
	2	5.4	7.9	10.4	6.1	29.8
	3	5.8	9.1	9.5	3.8	28.2
	4	4.8	6.2	5.3	3.9	20.2
	Mean	5.3 a	8.0 a	8.4 a	5.4 a	27.1 a
Control	1	5.1	7.5	10.1	6.4	29.1
	2	5.1	7.5	11.0	5.7	29.3
	3	5.4	7.5	10.1	4.2	27.2
	4	4.2	4.8	4.6	2.1	15.7
	Mean	4.9 b	6.8 b	9.0 a	4.6 a	25.3 a

[1] Separate analyses of variance were used for each site-year.
Means in each column followed by the same letter are not significantly different (0.05 level).

sites, although growth responses in both tests were moderate and of brief duration when compared to growth on noneroded sites. After fertilization, productivity of the severely eroded sites was similar to that of moderately eroded ones; however, the treatments did not raise productivity of eroded soils to the high levels typical of noneroded ones.

Responses to fertilization were only temporary but might be enhanced by periodic fertilizer applications during the early plantation development; however, only severely eroded soils should be fertilized.

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SO-216

1976

Botanical Composition of Cattle Diets On a Southern Pine-Bluestem Range

H. A. PEARSON

SUMMARY

The yearly composition of cattle diet averaged 69 percent grasses, 18 percent forbs, and 5 percent browse. The greatest variety in the diet occurred during the winter. Browse and pine needle cast composed more of the diet during winter than in any other season. Grasses made up more than 80 percent of the diet, while forbs averaged 14 percent between May and August.

Additional keywords: grasses, forbs, browse, Brahman crossbreds.

A variety of herbage and browse exists in substantial quantities throughout the southern forest. This paper reports changes in the yearlong diet of cattle on a longleaf pine (*Pinus palustris* Mill.) - bluestem (*Andropogon* spp.) range.

Study Area and Methods

The study was conducted from April 1971 through March 1974 on the Palustris Experimental Forest in central Louisiana in a stand of second-growth longleaf pines about 15 years old. Herbaceous vegetation is predominantly pinehill bluestem (*A. scoparius* var. *divergens* Anderss. ex. Hack.). Other bluestem grasses are prominent, as are the panicums (*Panicum* spp.) and paspalums (*Paspalum* spp.). Principal browse plants include southern waxmyrtle (*Myrica cerifera* L.), oaks (*Quercus* spp.), blackberries (*Rubus* spp.), and blueberries (*Vaccinium* spp.).

Crossbreed Brahman cows grazed the area at a stocking rate of 15 to 20 acres per cow. An Angus bull grazed with the cows from July until October, and calves occupied the range from birth until October. The diet of the cattle was supplemented during the winter with cottonseed cake and hay; salt and steamed bonemeal were provided freely year-round (Pearson and Whitaker 1972). Diet supplements and water were provided in a corral to help gather the cattle from the range.

Herbage production on the study area averaged 614 lbs per acre, and utilization averaged 66 percent (Pearson 1974). Browse ground cover averaged 12 percent, and browse utilization 10 percent.

Diet samples for botanical composition analyses were collected at monthly to bimonthly intervals from two cows with esophageal fistulas. They were allowed to freely graze the forest range for approximately 1 hour or until about a gallon of forage was collected. The samples were preserved in 10 percent formalin.

Composition of the diet was determined from morphological plant characteristics (Galt and Theurer 1968, Galt et al. 1969). Random diet samples were floated in a pan of water over a wire screen. When the sample in the pan was evenly distributed, the wire screen was raised, positioning the particles approximately as they had floated and giving a random distribution of plant fragments. To determine botanical composition, 40 fixed locations (a location is here defined as a microscope field) in each pan were systematically observed under a 10-power binocular microscope. Plant fragments were categorized as grasses, grasslikes (sedges and rushes), forbs, browse (shrubs, vines and trees), green pine needles, pine needle cast, and seeds. Frequency percentages (the number of microscope fields in which the plant category occurred, out of 40 fields) were tabulated for each category. The most common category did not occur in more than 86 percent of the microscope fields, thus fulfilling a condition for converting frequency percentages to density. Frequency percentages were then tabulated for each plant category and converted to relative density, which approximates the percentage of dry weight in the mixture (Sparks and Malechek 1968, Fracker and Brischle 1944).

RESULTS

Yearly botanical composition of the cattle diets averaged 69 percent grasses, less than 0.5 percent grasslike plants, 18 percent forbs, 5 percent browse, 1 percent green pine needles, 6 percent pine needle cast, and 1 percent seeds (table 1). Grasses were generally grazed in all the seasons; the heaviest use occurred in areas burned before the growing season. Use of plants varied, however, according to the season, as the month to month breakdown (beginning in late spring) shows.

During February and early March, hymenopappus (*Hymenopappus artemesiaefolia* DC.) and sumac (*Rhus copallina* L.) were heavily used, while during other periods they were only lightly used or ignored. Longleaf and loblolly pine (*P. taeda* L.) and waxmyrtle, which are not eaten during the growing season, were browsed lightly during February and early March. Browse made up less than 5 percent of the cattle diet from April through November. Bracken fern (*Pteridium aquilium* L. Kuhn var. *pseudocaudatum* (Clute) Heller), a poisonous plant, was grazed lightly in May when young shoots were growing vigorously, and some light use was also noted after plants were dormant. Between May and August, grasses made up more than 80 percent of the diet, and forbs averaged 14 percent.

Table 1.—*Botanical composition of cattle diets collected monthly from 2 esophageally fistulated animals during 1971-74.*

	Botanical composition						
Date	Grasses	Grasslikes	Forbs	Browse	Green pine needles	Pine needle cast	Seeds
	Percent						
Apr 20	70	0	27	1	0	1	1
May 21	80	T[1]	13	3	T	2	1
Jun 27	80	T	18	1	0	1	T
Jul 27	85	T	14	T	0	2	T
Aug 29	85	0	12	T	0	3	T
Sep 28	70	T	21	2	0	4	2
Nov 3	60	0	26	4	0	6	4
Dec 12	53	1	7	22	2	16	T
Jan 27	52	0	21	13	2	12	1
Feb 27	53	T	23	8	1	15	T
Yearly average	69	T	18	5	1	6	1

[1] T = < 0.5 percent.

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Forbs became more prominent in late September and except for December, contributed more than 20 percent of the diet through the next April. Seeds averaged 1 percent of the diet yearlong and reached a high of 4 percent in November. Browse composition exceeded 20 percent during December and remained relatively high through February. Green pine needles were almost absent from the diet from spring until December; from December through February they averaged less than 2 percent. The percentage of pine needle cast consumed increased in December, averaging 14 percent of the diet from December through February; the pine needle cast was probably consumed inadvertently by the cattle while they were trying to eat the mature winter herbage or green basal rosettes of forbs or grasses. By late winter, some forbs, such as hymenopappus, were already growing and being grazed by the cattle.

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Southern Forest Experiment Station **Research Note** SO-217

1976

21-Year Growth and Development of Baldcypress Planted on a Flood-Prone Site

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SUMMARY

Baldcypress is a good species to plant on sites where prolonged flooding is common and few other species can survive. When planted on a site where flooding had repeatedly killed cottonwood plantations, cypress survival at age 21 averaged about 41 percent; average diameter was about 6.1 inches. Some of the cypress was suppressed by other hardwoods such as ash and boxelder. Diameters of the best 10 percent of the cypress trees averaged 11.1 inches at age 21. Thus, mean annual diameter growth of these trees was 0.53--considerably more than the 0.32 inch per year estimated for dominant trees in natural stands during their prime development period.

Additional keywords: *Taxodium distichum*, artificial regeneration, diameter increment.

Baldcypress (*Taxodium distichum* (L.) Rich) heartwood is used extensively in building construction in the South, especially where high decay-resistance is required. Its value as a source of rot-resistant wood has depleted many merchantable stands. Sapwood is not decay resistant. On sites where prolonged flooding is common, baldcypress may be one of the few species capable of surviving. This note describes growth of a 21-year-old cypress plantation in the Mississippi River Delta.

Site.--The plantation was established on the Delta Experimental Forest, in Washington County, Mississippi, in February 1955. The planting area was a difficult Sharkey clay site, which is about 20 percent ridge, 20 percent slope, and the rest flat-slough. There is about a 3-foot difference in elevation from ridge to slough. About 1 to 2 feet of water generally covers the slough in winter. Thus, the area can be considered as five micro-sites--ridge, slope, and three areas of flat-slough.

The site had been cleared and planted to cottonwood (*Populus deltoides* Bartr.) more than 15 years before cypress was installed, but the cottonwoods were immediately killed by flooding. Two more clearings and plantings to cottonwood were also lost to high water, and consequently, heavy vine competition developed. When it became evident that most fast-growing commercial species could not survive on the site, cypress was planted.

Planting and measurements.--A total of 896 1-year-old cypress seedlings were planted at 6 by 10 feet to test regular and deep plantings--with and without top clipping. The trees were cultivated three or four times each year for the first four growing seasons. After the fourth year, annual mowing for the next 6 years was the only cultural treatment. Mowing did not control the vines, so many of the developing trees were bent.

By age 4, there were no significant differences in height or survival (Krinard

1959). Survival was 62 percent; average height was 6.6 feet (range 2.7 to 11 feet). No other measurements were made until age 21 when diameters of all 365 surviving trees (41 percent of the plantings) were measured (figure 1). In planting spots where other species (table 1) had become established in place of cypress, one stem per planting spot was tallied by diameter to determine the basal area of the present stand. For trees 3.0 inches dbh and larger, 38 percent of the planting spots were filled with cypress and 14 percent with other species. For trees less than 3.0 inches dbh only 18 cypress trees per acre were measured; all were in an extremely suppressed position and unlikely to survive. For species other than cypress, no attempt was made to tally trees less than 3 inches dbh or in a suppressed crown position.

Figure 1.—*General view of cypress planting showing 10-foot-within-row spacing and rows 6 feet apart.*

Heights of 30 cypress and seven green ash (*Fraxinus pennsylvanica* Marsh.) were taken to establish height-diameter relationships for these two species. Four cypress, three ash, and three boxelders (*Acer negundo* L.) were cut and measured at 4-foot intervals from 1 foot above the ground to the crown tip to supplement the height-diameter data and to obtain information on total cubic volume outside bark of the main stem.

Volume estimates for cypress, ash, and combined other species, predominantly boxelder but excluding black willow (*Salix nigra* Marsh.) and cottonwood, were obtained from D^2H equations using 1 inch diameter classes and heights from height-diameter curves (figure 2). Although only a small volume sample was obtained, the volume equations developed[1] were comparable to those published for cottonwood (Mohn and Krinard 1971).

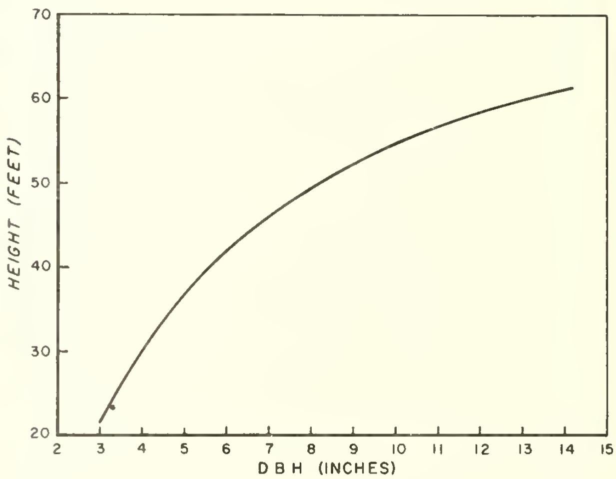

Figure 2.—*Height-diameter relationship of cypress after 21 years, where* $\log H = 1.910840 - 1.736896\,(1/D)$ ($r^2 = 0.89$; $Sy.x = 0.027$).

[1] Cypress: Volume = $0.523 + 0.00183\ D^2H$; $r^2 = 0.99$, Sy.x = 0.40
Ash: Volume = $0.894 + 0.00166\ D^2H$ $r^2 = 0.98$, Sy.x = 0.84;
Boxelder: Volume = $0.320 + 0.00219\ D^2H$; $r^2 = 0.99$, Sy.x = 0.30

Roger Krinard is a Mensurationist and Robert Johnson is Principal Silviculturist at the Southern Hardwoods Laboratory, which is maintained at Stoneville, Mississippi, by the Southern Forest Experiment Station, Forest Service—USDA, in cooperation with the Mississippi Agricultural and Forestry Experiment Station and the Southern Hardwood Forest Research Group.

Average survival and diameter growth of cypress varied by micro-site. Survival after 4 years was 58, 64, 67, 62, and 60 percent, respectively, for trees on ridge, slope, and the three flat-sloughs; after 21 years, survival was 48, 47, 45, 33, and 31 from the most elevated to the lowest site; average survival was 41 percent. Average diameter for all cypress after 21 years from highest to lowest site was 5.5, 7.2, 6.3, 5.9, and 5.8 inches; average diameter was 6.1 inches.

Half of the cypress ≥ 3.0 inches dbh (141 stems per acre) were 6.0 inches dbh or larger, which reflects a total growth rate of about 3 inches every 10 years. The two largest cypress trees were both 14.0 inches dbh; one was 60 feet tall and the other 63 feet. There was no indication of stagnation within the stand, even in spots where survival was high and competition intense. Dominance of individual cypress trees was shown by the wide range in diameters (table 1).

One cottonwood tree and one black willow were the fastest growers in the entire planting area. Both were in the 15-inch diameter class and were 70 to 75 feet tall. The largest ash measured was 10.3 inches dbh and 54 feet tall. Although the largest boxelder was 12.6 inches dbh, it was only 46 feet tall and was of poor form.

When basal area was measured at five random prism points (basal area factor 10) based on all stem sizes, basal area ranged from 70 to 150 square feet per acre and averaged 112 square feet. When planting-spot trees 3.0 inches dbh and larger were considered, basal area of the stand was 95 square feet per acre. Cypress basal area was 72 square feet, ash 7, boxelder 11, and other species 5.

Total volume outside bark per acre in trees ≥3.0 inches dbh was 1,786 cubic feet or 85 cubic feet per acre per year. Cypress volume was 1,299 cubic feet (62 cubic feet per acre per year). Volumes for other species were: green ash, 131 cubic feet; boxelder, 230 cubic feet; sugarberry and persimmon combined, 44 cubic feet; and cottonwood and black willow combined, 82 cubic feet.

Total volume per acre for all species for trees with a 6.0-inch threshold diameter was 1,403 cubic feet (67 cubic feet per

Table 1.—*Trees per acre by species and 1-inch diameter classes*

Dbh classes	Cypress	Ash	Box-elder	a/ Sugar-berry	b/ Per-simmon	Black willow	Cotton-wood	Total
				Stems/acre				
15.0-15.9	--	--	--	--	--	0.8	0.8	1.6
14	1.6	--	--	--	--	--	--	1.6
13	1.6	--	--	--	--	--	--	1.6
12	0.8	--	0.8	--	--	--	--	1.6
11	10.5	--	--	--	--	0.8	--	11.3
10	13.8	0.8	--	0.8	--	--	--	15.4
9	16.2	1.6	1.6	--	--	0.8	--	20.2
8	28.4	2.4	3.2	0.8	--	--	--	34.8
7	29.2	1.6	4.1	--	0.8	--	--	35.7
6	38.9	10.5	15.4	--	0.8	--	--	65.6
5	46.2	4.9	14.6	2.4	1.6	--	--	69.7
4	47.8	5.7	11.3	2.4	--	--	--	67.2
3	42.9	2.4	8.1	0.8	--	--	--	54.2
2	17.0	--	--	--	--	--	--	17.0
1.0-1.9	0.8	--	--	--	--	--	--	0.8
Total	295.7	29.9	59.1	7.2	3.2	2.4	0.8	398.3

a/ *Celtis laevigata* Willd.

b/ *Diospyros virginiana* L.

acre per year); volume of cypress in this diameter class would be 19 percent smaller or 1,051 cubic feet (50 cubic feet per acre per year).

Although there were more than 400 trees per acre at age 21, most of the cypress trees are very limby. The majority of the lower limbs--those 8 to 10 feet up the main bole--were dead but not easily broken off. By comparison, ash, which are naturally pruning, were of much better quality; they were generally limb-free from the ground to a height of 16 feet.

Results reveal that plantation-grown cypress may grow as well as or better than other hardwood species growing in loess soil in small, unthinned plantings for a similar period of time (Broadfoot and Krinard 1961). The top 10 percent or 30 cypress trees per acre in this study ranged from 9.8 to 14.0 inches dbh and averaged 11.1 inches after 21 years. Thus, mean annual diameter growth was 0.53 inch, considerably more than the 0.32 inch per year estimated for dominant trees in natural stands during their prime development period (20 to 28 inches dbh) (Putnam, Furnival, and McKnight 1960).

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SO-218

1976

Poor Aeration Curtails Slash Pine Root Growth and Nutrient Uptake

EUGENE SHOULDERS

SUMMARY

Slash pine may absorb nutrients and water best in spring and early summer because soil moisture, soil aeration, and temperature are apparently optimum at this time.

One-year-old slash pine seedlings maintained at a high oxygen level grew about 1 ½ times as many roots as were produced at a low oxygen level. No other environmental conditions significantly influenced root growth during the 12-day test period. High oxygen level plant roots had long silvery-white tips, which graded gradually to cream, tan, and finally light brown near the base of the root segments. In contrast, new roots of low oxygen level plants were brown or tan to within a few centimeters of their tips.

At 22° C, low oxygen level plants absorbed 21 percent less water, 53 percent less phosphorus, and 54 percent less magnesium at the end than at the beginning of the 12-day observation period. In contrast, high oxygen level plants absorbed 9 percent more water, 61 percent more phosphorus, 22 percent more potassium, and 117 percent more magnesium daily at the end than at the beginning of the 12 days. At the low oxygen level, the 22° C seedlings' calcium absorption increased 152 percent by the second day but declined thereafter. Trends were about the same at 16° C and 28° C, but most differences increased with increasing temperature.

To maintain good growth rates slash pines may require more nutrients in inadequately drained and aerated soils than in well drained soils. Fertilization can possibly substitute for drainage on some sites because poor root aeration may reduce the plant's ability to absorb water and nutrients.

Additional keywords: *Pinus elliottii*, temperature, light intensity, root aeration, solution culture, pine nutrition, absorption of water, phosphorus, potassium, calcium, and magnesium.

Poor Aeration Curtails Slash Pine Root Growth and Nutrient Uptake

Slash pine (*Pinus elliottii* Engelm. var *elliottii*) grows best near ponds and poorest on poorly drained flatwoods, commonly called crawfish flats (Cooper 1957). Poor development and low yields of pines on flat, wet sites have been attributed to inadequate root aeration (McKee and Shoulders 1974), to the death of many fine feeder roots during prolonged exposure to saturated soil (Kramer 1949), to a fluctuating water table in the rooting zone (White and Pritchett 1970), and to phosphorus deficient soil (Bengtson 1968, Pritchett and Smith 1974). Probably all factors contribute. Both bedding (Bethune 1963, McKee and Shoulders 1974) and phosphorus fertilization (Barnes and Ralston 1953, Pritchett and Smith 1972, 1974) have boosted growth of slash pine on crawfish flats. Bengtson (1971) suggested that fertilization could substitute for improved drainage of less severely waterlogged soils because fertilizer stimulates additional growth and rapidly growing pines would remove some of the excess soil moisture by transpiration.

This study focused on the effects of root aeration at three temperatures and two light intensities on slash pine root growth and on the uptake of nutrients. Root growth was curtailed and nutrient uptake was modified by 9 days' exposure of roots to poorly aerated culture solutions.

MATERIALS AND METHODS

One-year-old slash pine seedlings, already acclimated to culture solutions, were observed under carefully regulated conditions to determine the effects of temperature, light intensity, and root aeration on root growth and net uptake of phosphorus, potassium, calcium, and magnesium. Absorption of water was also monitored. Plants were grown for 3 days in well aerated solutions at 22° C with daytime illumination that averaged 4,400 foot candles over the crown surface. Then they were subjected for 9 days to all possible combinations of root aerations, temperatures, and light intensities listed in table 1. A 12-hour photoperiod was used throughout the experiment. Treatments were replicated three times.

Table 1.—*Test environments. Plants were subjected to all possible combinations of these oxygen levels, temperatures, and light intensities for 9 days using a 12 hour photoperiod*

Level	Oxygen in solution: Air saturation	Oxygen in solution: Dissolved oxygen	Temperature	Light intensity (crown average)
	Percent	*- -ppm- -*	^{o}C	*Foot candles*
Low	50	4 to 5 [1]	16	3,000
Intermediate	--	----	22	...
High	90	8 to 9 [1]	28	4,400

[1] In both oxygen levels, dissolved oxygen concentration was higher at low than at high temperature.

Culture solutions were replaced at the end of the second and third days of the pretested period and at 24- or 12-hour intervals thereafter. Ion uptake was reckoned by computing the quantities of individual ions that disappeared from the solution during each study interval. Initial and final root volumes were determined by water displacement.

Additional details on design and conduct of the test are given in a companion article (Shoulders and Ralston 1975).

RESULTS

High oxygen level plants grew 1.43 cm^3 of new roots per seedling, or about 2 ½ times as many as were produced by low oxygen level plants during 12 days in the growth chambers (table 2). No other element of the environment significantly influenced root growth during this period. Much of the growth of low oxygen level plant roots probably occurred during the 3 days that they were in well aerated solutions. This conclusion is supported by the fact that plants which were kept in well aerated culture solutions for 12 days grew about 0.12 cm of new roots per seedling per day.

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Table 2.—*Twelve-day root growth and 9-day uptake of nutrients per seedlings*

Temperature	Oxygen level	Root growth	Net uptake of				
			Water	Phosphorus	Potassium	Calcium	Magnesium
C^o		Cm^3	*ml.*	- - - - - - - - -	*Milligrams*	- - - - - - - - -	
16	Low	0.55	51	.593	- .102	1.327	.261
	High	1.26	69	1.067	4.652	2.017	.527
22	Low	.40	78	.603	-1.021	2.844	.392
	High	1.68	96	1.449	7.788	3.212	.888
28	Low	.82	149	.625	-1.340	5.634	.860
	High	1.35	172	1,536	8.387	3.935	1.017

There were also differences in color between roots of high and low oxygen level plants at the end of the test (figure 1). High oxygen level plant roots had long silvery white tips. Back of these tips color graded gradually to cream, tan, and finally light brown near the base of the root segments that had developed after plants were transferred to culture solutions from soil. In contrast, new roots of low oxygen level plants were brown or tan to within a few centimeters of their tips. Many were entirely devoid of white tips as though their growth had been stopped and suberization had progressed to the root tip. There was no visual evidence, however, that root meristems were actually killed by low oxygen treatment.

Figure 1.—*Typical root systems of slash pine seedlings after exposure for 9 days to low (right) and high (left) levels of dissolved oxygen in culture solutions.*

A companion article described the effect that temperature and oxygen level had on hourly uptake of water and nutrients per unit of root volume during light and dark phases of the diurnal cycle (Shoulders and Ralston 1975). Here I wish to emphasize the effects of oxygen level on amounts of water and nutrients individual seedlings removed from culture solutions at 16, 22, and 28° C and to relate these results to conditions slash pines encounter in the field. Since light intensity had no significant effect on uptake, results for the two intensities have been averaged.

The 22° C seedlings illustrate the effects of oxygen supply on uptake of water and nutrients best because they were kept at a constant temperature for 12 rather than 9 days. Moreover, high and low oxygen level plants assigned to the 22° C temperature differed by only 0.36 cm^3 per seedling (or about 5 percent) in root volume as they entered the growth chambers. At 22° C, the low oxygen level plants absorbed 21 percent less water, 53 percent less phosphorus, and 54 percent less magnesium during the 12th day than they averaged daily during days 1 and 2 in the growth chambers at the high oxygen level. On the 12th day, the low oxygen plants "leaked" about one-third as much potassium to the culture solutions as they had accumulated daily before the low oxygen level was imposed. In contrast to the above trends, 22^{o} C high oxygen level plants absorbed 9 percent more water, 61 percent more phosphorus, 32 percent more potassium, and 177 percent more magnesium daily at the end than at the beginning of the 12 days.

The low oxygen level increased the 22^{o} C seedlings' calcium uptake 152 percent by the second day; however, calcium absorption of these low level plants declined thereafter. By day 12, these plants absorbed only 69 percent more calcium than they had on day 1. Because calcium uptake of 22^{o} C temperature high oxygen seedlings rose 112 percent during the 12-day period, low oxygen level plants each absorbed 0.368 mg less calcium during the final 9 days than high level plants.

During the 9 days, low oxygen level plants at 22^{o} C also absorbed 18 ml less water, 0.846 mg less phosphorus, 8.809 mg less potassium, and 0.496 mg less magnesium each than high oxygen level seedlings. The large difference in net potassium uptake was due in part to the fact that low oxygen level plants surrendered 1.021 mg more of this nutrient to culture solutions than they removed.

Trends were about the same at the two other temperatures, but most differences increased with increasing temperature. Because the high temperature-low oxygen treatment so markedly stimulated calcium uptake initially, 28^{o} C plants absorbed more calcium from low than from high oxygen level solutions during the 9 days.

DISCUSSION AND CONCLUSIONS

In the growth chambers, study seedlings encountered temperatures and root oxygen levels typical of slash pine's natural habitat at different times during the year.

The low temperature approximated the mean January temperature reported for peninsular Florida at the southern limit of typical slash pine's range (Squillace 1966). The high temperature was within 2^{o} C of the mean July temperature throughout the sub-species' commercial range, including Louisiana and east Texas where slash pine is not native.

The low and high solution oxygen contents in table 1 correspond approximately to saturation of water films surrounding roots with atmospheres containing 10 and 19 percent oxygen. The data of Hu and Linnartz (1972) show that soil air in the surface foot of three imperfectly to poorly drained stream terrace and flatwoods soils in southeast Louisiana contained less than 10 percent oxygen for 1 to 3 months in winter and about 20 percent during the rest of the year. Soil air averaged about 20 percent oxygen yearlong in well drained Ruston soil. Soil water collected from water tables within the profiles contained 4 to 8 ppm of dissolved oxygen. Since oxygen diffuses only about 1/10,000 as fast in water as in air, oxygen concentrations at the solution-root interface were probably much lower than those of the soil air or soil water samples. Similar data on soil oxygen are not available for Coastal Plain soils further east, but flatwoods sites of Florida may be saturated with water for prolonged periods in summer because of excess rainfall in that season (McMinn and McNab 1971).

Because of these similarities between test and field conditions, results of the current study indicate that slash pine throughout much of its commercial range may be expected to absorb phosphorus, potassium, calcium, and magnesium faster in spring and early summer than at other seasons. Soil moisture as well as soil aeration and temperature, are apt to be more nearly optimum for rapid uptake then than at other times. To maintain good growth rates, moreover, slash pines may require higher levels of these nutrients in in adequately drained and aerated soils than in well drained soils. The poor growth of unfertilized slash pine plantations on wet savannas in Florida and their proportionally greater response to phosphorus fertilization there than on better drained sites (Pritchett and Smith 1972, 1974) tends to reinforce this interpretation of the results.

Many experiments (e.g., Olsen 1950, 1953, Wallace and Sufi 1963, Leggett and Frere 1971, Shoulders 1972) have shown that ion uptake from weak solutions varies directly with ion concentration. Part of the reason, then, that fertilization can substitute for drainage on some sites (see Bengtson 1971) may be that poor root aeration reduces the plant's ability to absorb water and nutrients and that higher concentrations of nutrients in the soil solution are needed to compensate the plant's loss in efficiency under these conditions.

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Research Note

SO-219

1976

Southern Pine Beetle Survival In Trees Felled By the Cut and Top-Cut and Leave Method

J. D. HODGES AND

R. C. THATCHER

SUMMARY

When the cut & top-cut & leave method was used for control of the southern pine beetle in Central Louisiana, trees were felled into the open or into shade in September, June, July, December, and January. Survival was greatest in September, moderate in July, and relatively low in June, December, and January. The cut and top treatment resulted in lower beetle survival in both the cold and hot seasons. Survival was 17 percent for cut and top, 32 percent for cut and leave, and 35 percent for controls. Survival was apparently related to high inner-bark moisture levels, which were 61 percent for cut and top trees and 51 percent for cut and leave. Total brood survival in trees felled into the open was not significantly different from that in trees felled into shade because many insects on the underside of trees felled into the open survived. Turning the logs so that both surfaces can be exposed to direct sunlight would probably give improved control. Even though these tests indicate that cutting and topping trees into an opening may decrease brood survival, the total population was not eliminated. It is not yet known if enough beetles survive to maintain the population and to spread to other trees. But spread is undoubtedly disrupted by treatment because the beetles must emerge from felled trees and seek new hosts outside the treated area.

Additional keywords: *Dendroctonus frontalis*, *Pinus taeda*, pest control, inner-bark moisture and temperature.

Southern Pine Beetle Survival In Trees Felled By the Cut and Top-Cut and Leave Method

No fully effective, practical, and economical pest management system has been developed for controlling the southern pine beetle (*Dendroctonus frontalis* Zimmerman). Control measures have typically consisted of either cutting infested trees and spraying with pesticide (BHC or lindane in No. 2 fuel oil), salvage removal, or piling and burning of infested material. Many infestations are too small and scattered for practical salvage removal, and concern has been voiced about environmental contamination by chemicals or burning. Consequently, an alternative approach to beetle control, the cut & top-cut & leave method, is being tried in Texas and other states by both public and private timber growers (Anonymous 1975, Ollieu 1969, Williamson 1970). With this method, all infested trees are felled as are all trees within a 40- to 60-foot-wide buffer strip around the active portion of each infestation. Beetles are thought to thrive in moderately dry, cool environments; thus, if felling is done during the hot season (May-October), the insects are theoretically killed by extremely dry inner-bark conditions and high temperatures that result from exposing the felled tree to direct sunlight. During this season, the trees are simply cut and left without topping them so that transpiration of moisture from the trunk to the needles will enhance the very dry, hot conditions in the inner bark. In trees felled during the cool season (November-April) the insects supposedly die because of high inner-bark moisture content. Trees felled during the cool season are therefore topped after cutting to maintain high moisture levels by preventing transpiration. The present paper compares bark beetle survival in standing trees, trees that were cut-and-left, and those that were cut-and-topped.

METHODS

Southern pine beetle infestations of loblolly pines (*Pinus taeda* L.) were studied in the Kisatchie National Forest in 1974-75. Because of an insufficient number of winter infestations, we were unable to determine seasonal differences (summer vs. winter) in treatment effectiveness. Instead we compared data obtained for five plots, representing active infestations selected in June, July, September, and December, 1974, and January 1975. In each plot (month) two trees were left standing (control), and eight were felled. The felled trees were divided into two groups of four trees each. Trees of one group were felled under partial shade or overstory and trees in the other group were felled in an opening to allow maximum exposure to sunlight. To compare cutting treatments on various stages of brood development, each group of felled trees contained two trees that were cut and topped and two trees that were cut and left; one tree in each treatment pair was infested with early brood (egg, young larvae) in the inner bark and one tree with late brood (older larvae, pupae) in the outer bark.

Beetle populations were sampled by removing circular bark disks with a 3/8-inch power drill equipped with a 4½-inch hole saw. Samples were taken from both the exposed and under surfaces of felled trees at three locations along the stems: 6 feet above the lower limit of the infested zone, at the mid-point of infestation, and 6 feet below the upper limit of the infested zone. To determine when brood mortality occurred, bark samples were taken at various stages of insect development. For trees containing mid- to late brood, bark disks were taken immediately after cutting and again just before brood emergence. For trees containing early brood, disks were taken at cutting, at the intermediate stage of development, and just before emergence. Early-stage samples were hand-

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dissected to insure a reliable brood count. Beetle counts from all mid- and late-stage samples were made from radiographs of the bark disks taken with a Faxitron x-ray unit. Duplicate series of late-stage sample disks were taken from all trees for rearing in an insectary and comparison with late-stage x-rays. A survival percentage was determined for each of the three locations on the trees by comparing the number of beetles at final emergence to the maximum number (all stages) found by hand dissection or in x-rays of early samples.

Moisture levels of both inner and outer bark were measured when the trees were felled; during the hot months measurements were repeated at weekly intervals until the broods emerged. Measurements were less frequent during the winter because of slower brood development. Samples were taken with an arch punch near the spot where bark disks were removed for beetle counts and were separated into inner and outer bark at the cork cambium.

Bark temperatures were measured by means of thermocouples and a thermocouple thermometer with a built-in reference junction. For early broods, thermocouples were inserted into inner bark and for late stages into the outer bark. Bark and air temperatures were measured immediately adjacent to areas sampled for beetle counts (two samples at three heights on the infested trunk). Because we wished to compare beetle mortality under shaded versus sunny conditions, we measured bark temperatures only on days when the greatest contrasts occurred between shaded and open conditions--on clear hot days in summer and on clear, and unusually warm or cold days in winter.

Data for brood survival were subjected to analysis of variance after arc sine transformations.

RESULTS AND DISCUSSION

Differences in survival rates for individual sampling dates were highly significant ($P > 0.01$). Survival was greatest in September, moderate in July, and relatively low in June, December, and January (fig. 1). In September, bark temperatures were moderate compared to June and July

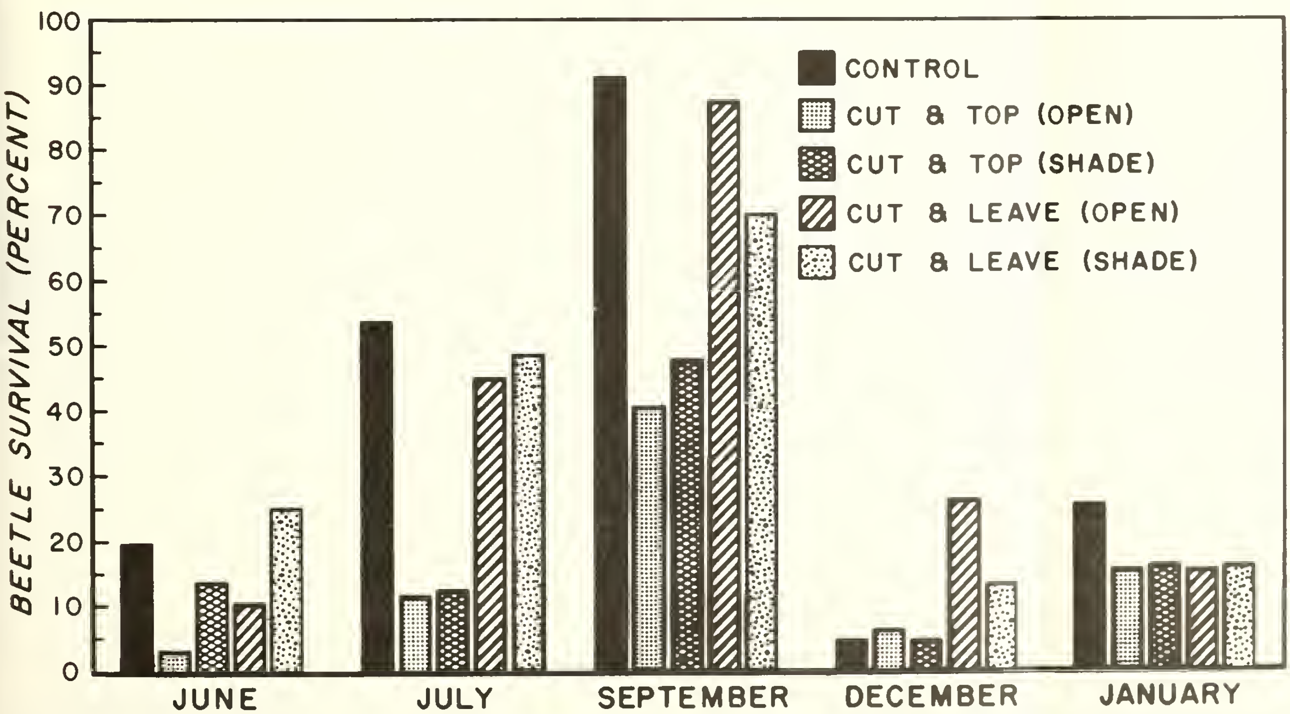

Figure 1.—Survival (percent) of southern pine beetles in Control, Cut & Top, and Cut & Leave Trees felled into the open and into shade.

temperatures, and inner-bark moisture was lower than in December and January (table 1).

Survival was much lower (P=0.05) for cut-and-top trees (17 percent) than for either cut-and-leave (32 percent) or standing trees (35 percent), which did not differ significantly from each other. The survival differences between the two felling treatments appeared related to inner-bark moisture levels (table 2). The average moisture level (wet weight basis) during the time the broods were developing was 61 percent for cut-and-top trees and 51 percent for cut-and-leave trees. In the few cases where survival for cut-and-top trees was as good as that of cut-and-leave trees, moisture levels of both treatments were comparable.

The cut-and-top treatment resulted in lower beetle survival in both the cold and hot season. The extremely hot dry inner-bark conditions that should presumably cause high summer brood mortality in cut-and-leave trees may not occur because of frequent overcast or rainy days. Thus, trees should be topped after felling regardless of season. Beal (1933) found that when felled logs were exposed to direct sunlight, high brood mortality occurred because of high inner-bark temperatures. He reported

Table 1.—Beetle survival, inner-bark temperature and bark moisture levels after tree felling treatments over several months.

Month of felling	Standing Tree (control)		Felled into Shade: Upper-Surface	Felled into Shade: Under-Surface	Felled into Shade: Average		Felled into Sunlight: Upper-Surface	Felled into Sunlight: Under-Surface	Felled into Sunlight: Average	
JUNE										
Survival (percent)	19.6		15.1	24.7	19.9		3.8	9.2	6.5	
Inner-bark temperature (°c)	29.1	(32.3)[a]	33.6	29.2	31.4	(32.6)	54.9	34.1	49.5	(38.0)
Moisture content (percent)[b]	43.2		52.1	52.1	52.1		31.7	49.2	40.4	
JULY										
Survival (percent)	53.5		30.7	28.6	30.7		3.0	61.9	31.5	
Inner-bark temperature (°c)	33.3	(32.8)	34.2	29.7	32.0	(33.0)	51.1	36.4	43.8	(37.0)
Moisture content (percent)	44.0		60.5	54.0	57.2		48.3	53.8	51.0	
SEPTEMBER										
Survival (percent)	91.0		40.3	71.3	57.9		30.5	91.1	58.9	
Inner-bark temperature (°c)	23.3	(24.2)	21.2	19.0	20.1	(22.9)	31.7	22.8	27.2	(27.5)
Moisture content (percent)	48.4		54.0	55.0	54.5		56.2	59.0	57.6	
DECEMBER										
Survival (percent)	4.2		6.5	10.2	8.3		18.0	16.4	17.2	
Inner-bark temperature (°c)	0.1	(3.1)	-1.6	-0.7	-1.2	(0.7)	-2.4	-1.4	-1.9	(-0.5)
Moisture content (percent)	64.6		59.0	54.9	57.0		54.4	61.3	57.8	
JANUARY										
Survival (percent)	25.7		12.8	18.4	17.7		12.9	16.9	15.3	
Inner-bark temperature (°c)	7.6	(7.5)	8.8	5.5	7.2	(8.1)	14.4	8.2	11.3	(8.5)
Moisture content (percent)	63.6		73.2	73.0	73.1		67.7	69.2	68.4	

[a] Air temperature shown in parentheses.

[b] Wet weight.

Table 2.—Inner-bark moisture content and beetle survival in control (C), cut and top (C&T), and cut and leave (C&L) trees.

DATE	Moisture Content (wet weight)			Survival		
	C	C&T	C&L	C	C&T	C&L
			Percent			
JUNE						
Upper surface	[1]43.2	46.8	37.0	[1]19.6	6.4	11.4
Lower surface	—	55.6	45.7	—	7.1	26.1
JULY						
Upper surface	44.0	60.1	48.7	53.5	7.0	29.3
Lower surface	—	58.7	49.1	—	15.9	63.9
SEPTEMBER						
Upper surface	48.4	59.6	50.6	91.0	20.0	59.7
Lower surface	—	59.0	55.1	—	71.2	90.8
DECEMBER						
Upper surface	64.6	62.3	51.0	4.2	3.9	19.1
Lower surface	—	65.3	50.9	—	6.1	19.6
JANUARY						
Upper surface	63.6	69.1	68.4	25.7	12.5	13.3
Lower surface	—	70.2	73.2	--	18.2	17.2

[1] Values for controls (C) are averages taken from two aspects on standing trees.

that almost all of the brood and adults were dead after 1- to 2-hours of exposure to direct sunlight at about 44°C. In the present study, survival was very low for insects collected from the exposed side of felled trees, an apparent result of high temperatures and consequently lower moisture levels (table 1). On sunny days, high bark temperatures prevailed for about 3 hours. Even so, total brood survival in trees felled into the open was not significantly different from that in trees felled into shade because of the relatively high survival of insects on the under side of trees felled into the open. Turning the logs to expose all surfaces to sunlight would probably give better control (Beal 1933). Felling trees away from the stand into an opening would also place infested material away from live trees.

Total beetle survival in felled trees was not significantly affected by stage of insect development at time of felling. However, for trees felled in June and July, most of the mortality (74 percent) occurred before the larvae reached the mid- to late-larval stage; whereas, in December and January almost all mortality occurred between late-larval stage and emergence. In September, greatest mortality in trees cut into an opening occurred by the late-larval stage (76 percent), but for trees felled into a stand, only 15 percent of the total mortality had occurred by that stage. Although bark averaged 0.2 inch thicker at the basal end of the infested trunk than at the upper end, we could detect no interaction between bark thickness and beetle survival--even for felled trees exposed to full sunlight.

The cut-and-top technique should logically prevent spot growth or proliferation by decreasing survival of developing broods in felled trees or by disrupting the normal spread of infestation into newly attacked, nearby trees by surviving beetles. The present work indicates that cutting and topping into an opening may decrease brood survival, especially if the entire log is exposed to direct sunlight. However, the total population is not eliminated, as was also demonstrated by Ollieu (1969). It is not yet known if enough beetles survive to pose a serious threat to surrounding forests. However, spread is undoubtedly disrupted since the beetles are emerging from felled trees, and there are no attractive trees nearby for them to attack.

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Research Note

SO-220

1976

Survival and Growth of Cottonwood Clones After Angle Planting and Base Angle Treatments

W. K. RANDALL AND H. E. KENNEDY

SUMMARY

Presently, commercial cottonwood plantations in the lower Mississippi Valley are established using vertically planted, unrooted cuttings with a flat (90°) base. Neither survival nor first-year growth of a group of six Stoneville clones was improved by angle planting or cutting base angles diagonally. For one clone, survival was significantly better when base angle was 45°.

Additional keywords: *Populus deltoides*, artificial regeneration, planting techniques, root development.

Survival and growth of eastern cottonwood (*Populus deltoides* Bartr.) cuttings are influenced by clone and environment (Randall and Mohn 1969, Mohn and others 1970), preplanting preparation, and planting technique (dePhilippis 1963, Peterson and Phipps 1976). Presently commercial cottonwood plantations in the Lower Mississippi Valley are established using vertically planted, unrooted cuttings with a flat base. When stem cuttings are planted vertically, they develop a horizontal root system, many of whose primordia grow at right angles to the stem periphery and are initiated in the wound cambium zone of the callus (Komissarov 1964). Thus, planting cuttings at an angle should encourage roots to grow downward. Warren-Wren (1973) suggests that willow cuttings should have a sloping cut at each end to expose a larger surface for callus development.

Our objective was to determine how planting angle and the angle of base cut affect survival, first-year growth, and root development of six cottonwood clones. Specifically, we compared cuttings planted vertically with flat and diagonal bases to cuttings planted at a 45° angle with flat and diagonal bases.

METHODS

Cuttings were planted in mid-February at Huntington Point, 15 miles north of Greenville, Mississippi. The area was typical of those where cottonwood is commercially planted in the Lower Mississippi Valley. The soil was Commerce silt-loam, classified as excellent for cottonwood growth; site index was 120 feet at age 30.

Cuttings from six cottonwood clones were evaluated. Five of the clones (Stoneville 66, 67, 74, 92, and 109) had been previously released by the Southern Hardwoods Laboratory for commercial use (Mohn and others 1970). The sixth (Stoneville 124) has a low survival rate and only average first-year growth, but its growth after the first year is the best of the six clones. All cuttings were 18 inches long and had a top diameter of ½ inch. Cuttings were planted either vertically (standard method) or at an angle of 45° to the soil surface. The base angle on some cuttings was 90° (standard method); the basal angle on others was either 45° or 30° measured from the longitudinal axis of the cuttings. The slant faced downward when cuttings with a diagonal base were planted at an angle.

Planting layout was a split-split-plot design with three blocks. Main plots were clones, split plots were planting angle, and split-split plots consisting of 10 cuttings each were angle of basal cut. Spacing between rows of clones was 42 inches, and spacing between cuttings in the rows was 12 inches. Survival was recorded on June 1, 1975, and height was measured on September 11, 1975. When the plants were dug up on September 22, 1975, position and number of roots were recorded.

Differences in survival and height were tested by analysis of variance (0.05 level of significance).

RESULTS AND DISCUSSION

Neither survival nor first-year growth were improved by deviating from the standard planting procedures (vertical planting, 90° base angle). The treatments did not increase number of roots per cutting but did influence their distribution. Cuttings planted at a 45° angle grew twice as many roots (3.5) on the bottom and sides as they did on the top (1.8) (fig. 1). Therefore, angle planting might enable roots of freshly planted cuttings to reach subsurface moisture quicker and thus avoid stress under dry conditions. Angle planting may also encourage the development of a more wind-firm tree.

Heights of clones ranged from 7.3 to 8.8 feet. There were no differences in height growth among the five clones released for commercial use, but after the first year all five of them were significantly taller than clone 124, a difference that confirms the known growth patterns. Analysis of individual clones, however, revealed a significant interaction of clone x base angle. For Stoneville 124, best survival was attained

Figure 1.—*Downward root growth from angle planted cottonwood cuttings. Note that more roots occurred on sides and bottom than on upper surfaces.*

when base angle of cuttings was 45° (table 1). This interaction suggests that refined planting techniques might be possible for difficult-to-root clones and for unusual planting conditions.

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Table 1.--*Survival by clone, planting angle, and angle of base.*

Angle of base	Clone number					
	66	67	74	92	109	124
	- - - - *Percent* - - - -					
	Vertical Planting					
90^o	97	90	63	97	77	70
45^o	100	83	77	93	97	[1]87
30^o	100	83	53	80	87	60
Mean	99	86	64	90	87	72
	Angle Planting					
90^o	100	97	80	87	77	60
45^o	100	83	77	90	73	[1]83
30^o	100	83	83	93	90	57
Mean	100	88	80	90	80	67

[1] For clone 124, significantly (0.05 level) better survival was attained when base angle was 45^o.

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SO-221

1977

Impact of Tip Moth Injury on Growth and Yield of 16-Year-Old Loblolly and Shortleaf Pine

H. L. WILLISTON AND S. J. BARRAS

SUMMARY

For the first six growing seasons, 47 loblolly and shortleaf pine plots throughout the South were treated to protect them against tip moth (at first with DDT and later with a granular phorate). Treatments provided good protection, and in the early years treated trees appeared to outgrow untreated trees. But by age 16 there were no substantial differences in height or diameter except at one location. Overall, treatment increased the loblolly yield 3.9 cords per acre and the shortleaf yield 0.4 cord per acre. At current stumpage prices, such an increase in yield would not provide enough economic gain to justify treatment.

Additional keywords: Pinus taeda, P. echinata, forest management, pesticide use.

Attacks by the pine tip moth Rhyacionia spp. kill the growing tips of young loblolly (Pinus taeda L.) and shortleaf (P. echinata Mill.) pine. But how serious is the economic impact on the trees' long-term growth and yield? Beal (1967) reported that in the Midsouth loblolly and shortleaf plantation trees protected from tip moths significantly outgrew attacked trees at some locations during the first 6 years after planting. We examined these same plantations 9 years later to determine if the early growth advantage of protected trees continued and to see if the increase in volume justified the expense of treatment.

METHODS

In 1959-1960, four plots were planted at each of eight locations: Brewton, Alabama; Gulfport, Mississippi; Harrison, Arkansas; Many, Louisiana; Marianna, Florida; Nacogdoches, Texas; Oxford, Mississippi; and Sewanee, Tennessee. At Crossett, Arkansas, six plots were planted, and at Alexandria, Louisiana, nine plots were planted. Each plot was divided into two subplots. One was planted with shortleaf and the other with loblolly pine, except that at Alexandria no shortleaf was planted. Furthermore, at Marianna half the area was prepared by chopping and half by rootraking, thus nullifying the opportunity for replication of treatments.

At most locations half the plots were repeatedly treated with insecticide to prevent tip moth attack, and half were left unprotected. However, at Alexandria three plots were treated once at the beginning of each growing season, three were treated

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at monthly intervals, and three were left untreated as a check.

In 1959, a 5-percent water emulsion of DDT was sprayed on the study trees several times during the early part of the growing season. During the second and third growing seasons, a 2-percent water emulsion of DDT was applied at about monthly intervals. Research in 1959-1961 indicated that systemic insecticides offered promise in eliminating the critical timing involved with the use of DDT and other contact insecticides (Treece and Mathyssee 1959, Barras et al. 1967). Therefore, in the fourth, fifth, and sixth growing seasons, 10 grams of 10-percent granular phorate were sprinkled on the soil around each tree in early spring. (Neither pesticide is now acceptable, but Cygon, Di-Syston, and Guthion are registered for use.[1]) These treatments prevented tip moth damage.

Each subplot was planted with 81 trees at 7- by 9-foot spacing. The inner 25 trees were the measurement trees. For the first 5 or 6 years, they were examined at the end of each growing season to determine height growth and tip moth infestation.

Because the main terminals are the most important, attacks on them were used to classify severity of infestation:

Percent of main terminals infested	Severity of attack
1-10	very light
11-40	light
41-70	medium
71-100	heavy

The number of larvae in each terminal was recorded at the end of the growing season. Single attack was defined as one or two insects per tip, multiple as more than two. Trees were examined at the end of the growing season because it was impractical to do so after each generation of moths. There can be as many as five generations a year along the Gulf Coast.

At the end of the 15th growing season in the field, the d.b.h. of each tree was measured with a diameter tape, and its height was determined with a clinometer or hypsometer. Local volume tables were developed giving cubic volumes inside bark to a 3-inch top d.i.b. for all trees 3.6 inches in d.b.h. and larger. Plot volumes (ft^3) were converted to a per acre basis by multiplying by 27.7. These were in turn converted to cords by dividing by 75.

Differences in cubic volumes per acre and average heights were tested for significance at the 90-percent level of confidence by analyses of variance. Data from the Many, Louisiana, plots were not included in the analyses because the treated plots had only been sprayed the first year; nor were data from the Alexandria plots included because there were no shortleaf plots in this installation.

RESULTS AND DISCUSSION

By age 16, tip moth attack had produced a substantial height loss only at Marianna, Florida, where treated trees averaged 9 to 15 feet taller than controls (table 1). At all other locations, height growth during the 9 to 10 years after pesticide treatments ceased was virtually the same for treated and untreated trees.

Average tree diameters differed by only 0 to 0.5 inch at all locations except Marianna, where treated trees averaged up to 1.3 inches bigger than controls (table 2). Apparently, diameter growth was influenced as much by stocking differences as by tip moth attack. Furthermore, the high site quality of many installations (a number had site indexes above 100 feet at age 50 for loblolly) assured good diameter growth regardless of treatment.

These findings agree with those of Warren and others (1975a, p. 23 and 1975b, p. 26):

> Data collected through the 13th year indicate that although trees that are protected from tip moth and competing vegetation show superior early growth, the rate of growth subsequently becomes equal in treated and untreated trees, though initial advan-

[1]Mention of trade names if for identification only and does not imply endorsement by the U.S. Department of Agriculture.

Table 1.— *Degree of tip moth attack after 5 or 6 growing seasons in the field and its effect on tree height after 15 growing seasons.*

Location	Severity of attack on untreated trees	Type of attack	Tree height at age 16		
			Treated	Untreated	Difference
			- - - - - -	*Feet*	- - - - - -
<u>Loblolly pine - 6th year</u>					
Crossett, AR	Heavy	Multiple	39	39	0
Oxford, MS	Medium	Multiple	52	47	5
<u>Loblolly pine - 5th year</u>					
Alexandria, LA	Medium	Multiple	47	44	3
Brewton, AL	Medium	Single	44	45	-1
Gulfport, MS	Very Light	Single	46	46	0
Harrison, AR	Very Light	Single	36	35	1
Marianna, FL[1]	Medium	Single	36	21	15
Marianna, FL[2]	Medium	Single	26	16	10
Nacogdoches, TX	Medium	Multiple	51	48	3
Sewanee, TN	Very Light	Single	45	45	0
<u>Shortleaf pine - 6th year</u>					
Crossett, AR	Heavy	Multiple	35	33	2
Oxford, MS	Medium	Multiple	40	39	1
<u>Shortleaf pine - 5th year</u>					
Brewton, AL	Medium	Single	45	45	0
Gulfport, MS	Very Light	Single	44	44	0
Harrison, AR	Very Light	Single	28	29	-1
Marianna, FL[1]	Medium	Single	27	18	9
Marianna, FL[2]	Medium	Single	17	15	2
Nacogdoches, TX	Medium	Multiple	45	41	4
Sewanee, TN	Very Light	Single	39	39	0

[1] Site prepared by chopping.
[2] Site prepared by rootraking.

tages in height and diameter remain to some extent. Whether this initial growth advantage represents significant economic gains is not clear....

Tree measurements made in October, 1975, following completion of the 16th growing season, indicate that earlier differences detected between trees in the treated and untreated plots are no longer so obvious.

In the present study, mean height averaged over all plots was 42.6 feet for treated loblolly and 38.0 feet for controls. Means for shortleaf were 36.6 feet for treated trees and 34.9 feet for controls. In each species, the difference in height was significant.

Plot volume averaged 2,130 ft^3 for treated loblolly and 1,837 ft^3 for untreated loblolly, 1,472 ft^3 for treated shortleaf and

Table 2.—*Effect of tip moth control on d.b.h., basal area, and cubic volume after 15 growing seasons in the field.*

	Trees surviving		D.B.H.		Basal Area		Cubic volume		
	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Difference
	- - - No./acre - - -		- - - Inches - - -		- - - Ft^2/acre - - -		- - - - - Cords/acre - - - - -		
Loblolly pine									
Alexandria, LA	646	674	6.5	6.4	148	151	32.5	29.7	+ 2.8
Alexandria, LA[1]	665	674	6.4	6.4	147	151	31.7	29.7	+ 2.0
Brewton, AL	498	651	6.0	5.9	98	123	21.5	26.2	- 4.7
Crossett, AR	629	646	6.6	6.4	150	145	23.2	22.5	+ .7
Gulfport, MS	498	554	7.2	6.9	143	145	31.5	32.9	- 1.4
Harrison, AR	586	576	6.9	6.6	152	125	23.2	17.9	+ 5.3
Many, LA	596	526	6.9	7.2	157	148	38.6	37.0	+ 1.6
Marianna, FL[2]	581	609	5.4	3.6	92	43	11.1	2.0	+ 9.1
Marianna, FL[3]	637	581	4.2	2.9	61	27	5.0	0.7	+ 4.3
Nacogdoches, TX	512	434	7.1	6.8	144	108	36.7	24.7	+10.0
Oxford, MS	595	595	7.5	7.2	183	169	49.7	37.9	+11.8
Sewanee, TN	512	526	7.8	7.5	169	161	36.1	34.8	+ 1.3
Shortleaf pine									
Brewton, AL	568	665	6.0	6.2	111	140	20.6	28.4	- 7.8
Crossett, AR	489	517	6.1	5.7	98	92	15.5	13.4	+ 2.1
Gulfport, MS	568	609	6.8	6.6	145	146	31.9	30.1	+ 1.8
Harrison, AR	491	525	5.4	5.4	78	77	10.0	9.4	+ 0.6
Many, LA	610	568	6.3	5.8	130	103	28.6	20.5	+ 8.1
Marianna, FL[2]	665	665	4.8	3.9	83	56	7.8	4.1	+ 3.7
Marianna, FL[3]	637	471	3.0	3.0	32	24	1.0	0.8	+ 0.2
Nacogdoches, TX	610	664	6.6	6.9	144	174	34.8	34.7	+ 0.1
Oxford, MS	692	678	6.2	6.3	145	148	27.5	25.7	+ 1.8
Sewanee, TN	458	430	5.9	5.4	88	56	16.3	12.3	+ 4.0

[1] Treated only once a year.
[2] Site prepared by chopping.
[3] Site prepared by rootraking.

1,440 ft^3 for untreated shortleaf. The difference between treatments was significant for loblolly but not for shortleaf. Overall, treatment increased the loblolly yield 3.9 cords per acre and the shortleaf yield 0.4 cord per acre.

The economic implications of tip moth damage in most plantations appear to be minimal. Loblolly pulpwood stumpage in Louisiana is now worth $6.55 per cord. Treatment has increased our loblolly stumpage return, if clearcut at age 16, by $25.54 per acre (volume increase of 3.9 cords per acre x $6.55 per cord). If we discount this increase back 15 years at 6 or 8 percent, we find that our break-even investment in tip moth control during the first growing season in the field would be $10.65 at 6 percent or $8.05 at 8 percent per acre to pay for 5 or 6 years of protection. Although treatment cost records were not kept, it is reasonable to assume that we could not do the work for $8.05 to $10.65 per acre. Possibly differences in yield would have been greater had treatment been continued longer; nevertheless, we believe the chemical treatments did not pay off.

To effectively control tip moth damage at a reasonable price, we need a controlled-release systemic pesticide that remains active for several years. Lacking such a chemical, we must rely on continued refinement of silvicultural techniques and genetic selection for tip moth resistance. The periodicity of tip moth infestations and its causes also need further study. In the Lower Coastal Plain where tip moths are a problem, slash pine can be planted in place of loblolly.

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Southern Forest Experiment Station

Research Note

SO-222

1977

First-Year Growth and Survival Of Long Cottonwood Cuttings

W. K. RANDALL AND R. M. KRINARD

SUMMARY

When five Stoneville cottonwood clones were grown in a nursery for one season, lifted with about a foot of root, and planted in 3-foot deep holes, they averaged 9.6 feet in height growth and 92 percent survival after 1 year in the field. Planted height averaged 8.3 feet. The same clonal material planted without roots averaged only 36 percent survival.

These results do not imply that the standard method of planting 20-inch unrooted cuttings in the lower Mississippi River Valley should be changed. But where the aim is to grow large sawtimber and veneer trees at wide spacings (16 by 16 to 24 by 24 feet) or to alleviate deer damage without expensive fencing, or where early season cultivation may prove difficult, planting 1-year-old rooted cuttings 3 feet deep provides an excellent, although more expensive, alternative.

Additional keywords: *Populus deltoides*, planting techniques, artificial regeneration.

Wide initial spacings in cottonwood *(Populus deltoides* Bartr.*)* plantations permit large crown development and rapid diameter growth, thus shortening rotation age for sawlogs and veneer and eliminating the need for small pulpwood thinnings. However, wide spacings (16 by 16 to 24 by 24 feet) require at least 90 percent survival of planted material to insure a future stand and full site utilization. The common practice of planting 20-inch-long unrooted cottonwood cuttings does not insure such survival. However, long cuttings—grown one season in a nursery, lifted with about a foot of the belowground material attached to the stem, and planted in 3-foot deep holes—may provide the high survival needed. Furthermore, tall cuttings are visible during early cultivations when weed competition is heavy, probably require less intensive site preparation than standard cuttings, and need no fencing for deer protection. Obvious disadvantages to long, rooted cuttings are increased nursery and planting costs. This study compared first-year survival and growth of five Stoneville cottonwood clones when planted as four types of long cuttings.

METHODS

Five Stoneville clones were tested: 66, 67, 74, 238, and 240. The first three have been released for commercial use. Cutting treatments were (1) roots, no branches; (2) roots, with branches; (3) no roots, no branches; (4) no roots, with branches. Roots were about a foot long. Where roots were not included, stems were cut at ground level in the nursery. For treatments 1 and 3, branches were pruned before planting. All material had one growing season in the nursery.

The planting was established at 20- by 20-foot spacing on cleared ground at Hooker's Ridge, Warren County, Mississippi. Soil was Commerce silt-loam, considered excellent for cottonwood. Planting stock was lifted one day and planted the next in 3-foot deep holes 6

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inches in diameter made with a tractor-mounted auger. After a cutting was put in a hole, the loose soil was shoveled back in and tamped. Some settling occurred, which necessitated additional fill.

Planting was during the first week of February, and planted height of all trees was tallied. After the first growing season in the field, height and diameter of surviving trees were recorded.

A split-plot statistical design with 10 replications was used for height and height growth analyses. Plots were clones, and subplots consisted of one cutting of each treatment. For survival, a two-way analysis of variance was used with data transformed (arcsin $\sqrt{\text{percentage}}$).

RESULTS

At time of planting, the above-ground height of cuttings ranged from 5.0 to 10.7 feet and averaged 7.6 feet. Clonal differences were statistically significant: the mean for all treatments ranged from 7.1 feet for clone 240 to 8.3 feet for clone 238. Mean planted height of all rooted cuttings (8.3 feet) was significantly greater than that of all unrooted cuttings (7.0 feet).

Survival after the first growing season was significantly better for cuttings planted with roots (92 percent) than for those planted without roots (36 percent) (table 1). Clones 66 and 67 were the only two clones exhibiting greater than 40 percent survival of unrooted cuttings. Branches had no effect on survival of rooted cuttings. Unrooted cuttings without branches survived better than those with branches (46 vs. 26 percent).

Because of the poor survival of unrooted cuttings, analysis of height after one growing season was limited to rooted cuttings. During the first year, height growth was significantly lower for clone 74 (8.8 feet) than for the other clones (9.5 to 10.2 feet) (table 2). By the end of the growing season, mean total height ranged from 16.6 feet for clone 74 to 19.1 feet for clone 238, which was significantly taller than all other clones except 67. Clones ranked the same for total heights as for planted heights.

A significant first-year height growth-clone-treatment interaction was obtained, but in no case was there a difference between rooted stock with or without branches within the same clone. The interaction accounted for 42 percent of the total variation in height growth; clonal differences accounted for only 21 percent of the total variation.

First-year diameters of cuttings planted with roots ranged from 2.1 inches for clone 74-branched to 2.8 inches for clone 240-branched. Maximum diameter of rooted cuttings was 3.0 inches, although an unrooted cutting of clone 240 grew to 3.1 inches.

Table 1.—*First-year survival of long cottonwood cuttings planted with or without roots and with or without branches*

Clone	With roots		Without roots	
	Without branches	With branches	Without branches	With branches
No.	———	———*Percent*———		
66	90	90	70	20
67	100	90	60	40
74	90	90	40	10
238	90	100	40	20
240	80	100	20	40
Mean	90a[1]	94a	46 b	26 c

[1]Means with same letter were not significantly different at the 0.05 level by Duncan's new multiple range test.

DISCUSSION

This study indicates increased survival when roots are included on long cuttings, but rooted cuttings may not be necessary with different site-moisture conditions. On wet sites or areas subjected to prolonged flooding, rooted stock is superior to unrooted cuttings (Maisenhelder and McKnight 1968). Phares and White (1972) have shown that deep-planted, large cottonwood seedlings survived better than either 18- or 30-inch unrooted cuttings. Herpka (1974) found no differences in growth by age 11 years when comparing 2-year-old Euramerican hybrids planted with or without roots, but Euramerican clones generally have higher rootability than *P. deltoides* clones.

Some benefits of deep planting were demonstrated by Simon (1965), who found that roots developed vigorously at great depths and that root growth continued throughout the winter where soil temperature was 10°C. Additionally, deep-planted poplars did not shed their leaves during dry summers; thus, they made excellent second-season growth. Kaszkurewicz (1975) emphasized that survival and growth of cotton-

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Table 2 —*First-year height growth and total height of long cottonwood rooted cuttings planted with or without branches*

Clone	Height growth			Total height		
	Without branches	With branches	Mean	Without branches	With branches	Mean
No.	———	———	———	*Feet*	———	———
66	10 1	9 2	9 6a	18 0	17 4	17 7 bc
67	9 5	9 5	9 5a	18 3	18 6	18 4ab
74	8 4	9 1	8.8 b	17 1	16 2	16 6 d
238	10 1	10 3	10 2a	18 7	19 4	19 1a
240	9 2	10 2	9 7a	17 0	18 0	17 5 c
Mean	9 5a[1]	9 7a		17 8a	17 9a	

[1]Means with the same letter were not significantly different at the 0 05 level by Duncan s new multiple range test

wood can be improved when long cuttings are deep-planted, then mulched and bedded.

Presence or absence of branches did not affect survival or height growth of rooted cuttings. Branches reduced the survival of unrooted cuttings, but this reduction is unimportant considering the generally low survival of unrooted stock. In contrast to our observations, Marcel (1973) found that removal of *Populus 'robusta'* branches at time of planting improved first-year height and diameter growth. Admittedly, the true effect of branches is hard to discern because in a 1-year-old nursery only border row trees have numerous and large branches and such trees were not included in our study.

The large clone X treatment interaction suggests the opportunity for testing specific clone-treatment combinations to achieve additional growth. However, this difference was not large.

Although good survival was obtained with long, rooted cuttings, mean first-year height growth of about 9 to 10 feet was less than that expected from standard cuttings on good sites. A 30-tree sample of an adjacent planting of standard 20-inch, unrooted cuttings at a closer spacing averaged 12.1 feet in height and 1.1 inches in diameter after the first year.

These results do not imply that the planting method now used in the lower Mississippi River Valley should be changed. They do, however, indicate that for specific situations where the aim is to grow large sawtimber and veneer trees rapidly by starting with wide initial spacings or to alleviate deer damage without expensive fencing, or where early season cultivation may prove difficult, planting 1-year-old rooted cuttings 3 feet deep provides an excellent alternative.

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* U.S. GOVERNMENT PRINTING OFFICE 1977-774-003

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SO-223

1977

Timber, Browse, and Herbage on Selected Loblolly-Shortleaf Pine-Hardwood Forest Stands

GALE L. WOLTERS, ALTON MARTIN, JR., AND WARREN P. CLARY

SUMMARY

A thorough vegetation inventory was made on loblolly-shortleaf pine-hardwood stands scheduled by forest industry for clearcutting, site preparation, and planting to pine in north central Louisiana and southern Arkansas. Overstory timber, on the average, contained about equal proportions of softwood and hardwood basal area. Browse plants ranged from 5,500 to over 10,000 per acre, with about 60 to 70 percent desirable for deer. Herbage production averaged 180 pounds per acre on silty soil, but less than 75 pounds per acre on loamy, gravelly and clayey soils. Of the 177 plant species encountered, none were listed as endangered or threatened.

Additional keywords: Overstory, herbage, browse, botanical composition, soils.

Present and projected demands for timber, forage, and other forest resources have increased the need for balanced management programs on commercial forest lands. One concern is site preparation. While it improves timber production, how does it affect other forest values such as browse and herbage?

The objective of this study was to inventory overstory and understory vegetation on loblolly-shortleaf pine-hardwood stands prior to clearcutting and site preparation. These inventories will provide benchmarks to evaluate ecological changes in woody and herbaceous plants during the years following site preparation and planting to pine. With five important soil groups covered, the study areas are generally representative of areas requiring site preparation in the South.

STUDY AREAS AND METHODS

This study, part of a cooperative effort between Timber Management and Range Management Research Units at Alexandria, La., was conducted on forest industry lands in the West Gulf Coastal Plain in Louisiana and Arkansas. Ownerships included Boise Southern Company, Continental Forest Industries, Georgia-Pacific Corporation, International Paper Company, Olinkraft Inc., T. L. James and Company, and Crown-Zellerbach Corporation.

Representatives of the previously mentioned companies, Louisiana Forestry Commission, Soil Conservation Service, Kisatchie National Forest, and Timber and Range Management Research Work Units agreed upon site requirements which would permit application of research findings to the West Gulf Coastal Plains. Five soil groups were selected for study based on textural classification of the B horizon. These are silty, loamy, gravelly, slowly permeable clayey, and very slowly permeable clayey, characterized by Henry, Ruston, Kirvin, Sawyer, and Boswell series, respectively. Textures of A horizons of all soils were generally sandy to silty loams. The Soil Conservation Service assisted in soils identification.

Sampling areas were selected in loblolly-shortleaf pine-hardwood stands scheduled for clearcutting, site preparation, and planting to pine. Each area had more than 500 hardwood stems with over 20 square feet of basal area per acre. Past management consisted primarily of periodic logging and protection from fire. Because logging had removed the highest grade timber, the residual stands did not permit efficient land management. Low-grade hard-

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woods were abundant on all stands and occasionally were dominant. No pines were present on the silty soil, which had developed on a very flat loessial terrace that is poorly drained.

Twenty-nine 0.5- to 4-acre areas were inventoried with 3 to 9 replications per soil group. All tree species 1-inch dbh (diameter at breast height) and larger were considered overstory. Trees in the overstory were measured and counted by species in each of four 0.025-acre circular plots on each sampling area. Merchantable trees on a few areas were cut before inventory; on these areas, basal area and species composition were reconstructed from residual stumps.

Vines and other woody stems less than 1-inch dbh were considered browse because most produce foliage within 5 feet of the soil surface. Browse density (vines and woody stems) was measured and browse crown diameter (excluding vines) was estimated by species in each of four 0.01-acre circular plots on each sampling area.

Herbage production and botanical composition were sampled in 20 plots 9.6 sq. ft. in size on each sampling area. Production (ovendry weight) was determined by weight-estimate (Pechanec and Pickford 1937) and composition of yield was estimated by species.

Data were tested by analysis of variance and mean differences were compared by Tukey's test at the $P<0.05$ level (Steel and Torrie 1960).

RESULTS AND DISCUSSION

Overstory

Density.—Overstory density averaged 645 one-inch dbh or greater woody stems per acre (table 1), with no significant differences found among soil groups. Loblolly pine was the most abundant species, averaging 100 to 200 stems per acre on all soils except silty, where pines were not present. Southern red oak also was common and had relatively uniform distribution on all soils. Shortleaf pine, white oak, post oak and hickory occasionally exhibited subdominant roles. Red maple and sweetgum were the most abundant species on silty soil, with an average of 150 and 120 stems per acre, respectively. Other species were generally not abundant on any soil.

Approximately 70 percent of the stems on all soils were less than 5 inches dbh, but most foliage had grown beyond the reach of deer.

Table 1.—*Average density and basal area of trees on all soils*

Species	Density (Stems/acre)[1]	Basal Area (ft^2/acre)
Loblolly pine	132	29.9
Southern red oak	83	13.0
Sweetgum	72	2.7
Post oak	60	5.8
Red maple	55	1.0
Shortleaf pine	36	5.4
White oak	36	4.2
Hickory	32	1.9
Blackgum	28	0.6
Flowering dogwood	24	0.6
Winged elm	23	0.7
Water oak	15	2.7
Blackjack oak	12	1.9
Cherry	8	.3
Eastern hophornbeam	7	.2
American holly	5	.1
Sassafras	4	.1
Common persimmon	4	1
White ash	2	.1
American elm	2	.1
Hackberry	1	.1
Cherrybark oak	1	.1
American beech	1	.1
Others	2	.0
Total	645	71.7

[1]Includes stems 1-inch dbh and larger.

Basal Area.—Basal area averaged 72 sq. ft. per acre (table 1). Again, total basal area and species basal area differences were nonsignificant among soil groups.

Loblolly and shortleaf pine combined produced 1/2 to 2/3 of the total basal area on all soils except silty, where pines were absent. On silty soil, southern red, white, water and post oaks produced about 90 percent of the total basal areas. Southern red oak and post oak were subdominants on other soils, with hickory, sweetgum, and blackjack oak ranking secondary in importance. Species of lesser importance produced one square foot or less of basal area.

Browse

Density.—Total density of browse species diminished from just over 10,200 stems per acre on the gravelly soil to slightly less than 5,500 on the slowly permeable clayey soil, but differences were nonsignificant. Trees, shrubs, and vines contributed about equal shares to total browse density across all soils (table 2).

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Table 2.—*Average browse density and crown cover on all soils*

Species	Preference by deer[2]	Density (stems/acre)[3]	Crown cover (ft²/acre)
Trees[1]			
Southern red oak	L	494	941
Red maple	M	338a	730a
Sweetgum	L	324	718
Blackgum	M	220	352
Flowering dogwood	M	215	360
Pines	L	175	144
Hickory	L	173	245
White oak	M	101	89
Water oak	M	67	102
Other oaks	L	216	478
Elms	M	91a	99a
Common persimmon	L	72a	150
Cherry	L	70	104
Sassafras	H	58	58
Fringetree	M	21	20
Eastern hophornbeam	L	17	58
White ash	H	13	21
American hornbeam	L	10	13
American holly	L	5	5
Eastern redcedar	L	5b	4b
Red mulberry	M	4	3
American beech	L	1	1
Black locust	L	1	1
Total trees		2691	4696
Shrubs			
Tree sparkleberry	L	529	1091
American beautyberry	M	492	1423
Hawthorn	M	245	588
Witch-hazel	L	98	218
Shining sumac	L	269	426b
Elliott blueberry	L	258	240
Rusty blackhaw	M	66	47
St. John's-wort	H	58	46
Southern waxmyrtle	L	44	90
Possumhaw	M	43	36
Red buckeye	L	36	33b
Arrowwood	M	30	79
Bigleaf snowbell	M	27	64
Devils-walkingstick	L	21	47
New Jersey-tea	M	20	16
Carolina buckthorn	L	9	8
Common sweetleaf	M	7	21
Eastern baccharis	L	6b	5b
Yaupon	H	4	7
Pawpaw	M	2	1
Piedmont azalea	M	2	5
Total shrubs		2266	4491
Vines			
Greenbrier	H	849a	—
Poison-ivy	M	742	—
Grape	M	431	—
Blackberry	H	278	—
Carolina jessamine	H	277	—
Virginia creeper	M	127	—
Alabama supplejack	H	58	—
Trumpet-creeper	L	38	—
Crossvine	M	7	—
Japanese honeysuckle	H	6	—
Total vines		2813	—
Total browse		7770	9187

[1]Trees less than 1-inch dbh were classified as browse.
[2]High (H), medium (M), and low (L) preference rating for deer are generally in agreement with Goodrum and Reid (1958), Lay (1967), Halls and Ripley (1961), and Ripley and McClure (1963).
[3]Species followed by the letter "a" differed significantly among soils and had highest values on silty soils. Species followed by "b" had highest values on gravelly soils.

Red maple, sweetgum, blackgum, and oaks were the most abundant tree species qualifying as browse based on stem diameter. Three browse-sized tree species occurred in significantly higher densities on silty soils as opposed to the other soils — red maple (958 vs. 184), elms (267 vs. 47), and common persimmon (208 vs. 38). Eastern redcedar was most abundant on the more droughty gravelly soil.

The most common shrubs were tree sparkleberry, American beautyberry, Elliott blueberry, hawthorn, and shining sumac. Eastern baccharis was more abundant on the gravelly soil than on other soils.

Vines collectively were an important component of total browse density. Poison-ivy was the most common on all soils except silty, where greenbrier predominated. Greenbrier density was significantly greater on silty soil (1,775) than on other soils (617).

Preference value of browse is highly important to the deer carrying capacity of the site. According to preference ratings established for many of the browse species on southern forest (Goodrum and Reid 1958; Lay 1967; Ripley and McClure 1963; Halls and Ripley 1961), soils in the present study produced 3,300 to 6,000 stems per acre of medium and high preference deer browse. Thus, 60 to 70 percent of the stems were in the medium or high preference categories.

Crown Cover.—Total browse crown cover ranged from 6,000 sq. ft. per acre on very slowly permeable clayey soil to over 13,500 sq. ft. on loamy soil, but differences were not significant.

The proportion of total crown cover contributed by trees and shrubs was approximately equal when averaged across all soils (table 2); however, the crown cover contributed by the two groups varied widely from soil to soil. Trees < 1 inch dbh furnished over 75 percent of the total browse crown cover on silty soil, but less than 30 percent on loamy soil.

Some differences in crown cover are attributed to soils. For example, red maple and winged elm had significantly more crown cover on silty than on any other soil. The only other tree species influenced by soil was Eastern redcedar. Other species fluctuated widely, such as red oak which varied from around 200 sq. ft. per acre on very slowly permeable clayey soil to over 2,500 sq. ft. per acre on gravelly soil, but differences were not significant. Overstory tree density also may have influenced browse crown cover to some extent, but regressions were nonsignificant.

Of the major crown cover producers, tree sparkleberry was the only shrub species that exhibited any degree of uniformity among soils. Shining sumac, red buckeye, and Eastern baccharis were the only shrubs significantly influenced by soil group.

Species with medium and high preference ratings for deer produced over 7,700 sq. ft. of crown cover per acre on loamy soil but only about 2,000 sq. ft. of clayey soils.

Herbage

Total herbage varied significantly, with silty soils producing an average of 180 pounds per acre as compared to 48 pounds on the other soils. Grasses alone produced about 60 to 75 percent of the total herbage on all soils, with grasslikes producing up to 18 percent (table 3). Legumes produced 2 to 8 percent of the total

Table 3.—*Average herbage production on all soils*

Species	Production (lb/acre)
Grasses	
Longleaf uniola	18.4
Low panicums	10.8a[1]
Spike uniola	8.1a
Crabgrass	3.7
Broomsedge bluestem	3.3a
Little bluestem	2.2
Roundseed paspalum	1.6
Big bluestem	1.3
Redtop panicum	.5
Barnyard grass	.3
Brownseed paspalum	.3
Common carpetgrass	.2
Others	.6
Total grasses	51.3
Grasslikes	
Sedges	6.4a
Rushes	.2
Total grasslikes	6.6
Legumes	
Tickclover	1.6
Downy milk pea	.5
Yellow woodsorrel	.4
Partridge pea	.2a
Butterfly pea	.2
Pencilflower	.2
Other legumes	.4
Total legumes	3.5
Other forbs	
Dwarf St. John's-wort	4.6
Stinking pluchea	.9a
Eupatorium	.8
Flowering spurge	.6
Fragrant goldenrod	.4a
Low ruellia	.4
Hairy elephantfoot	.4
Aster	.4a
Bracken fern	.3
Copperleaf	.3
Roughstem rosinweed	.3
Poor-joe	.2
Grassleaf goldaster	.2
Cudweed	.2
Sunflower	.2
Partridge berry	.2
Maryland meadowbeauty	.2
Nettleleaf noseburn	.2
Beebalm horsemint	.2
Other forbs	1.6
Total forbs	12.6
Total herbage	74.0a

[1]Species followed by the letter "a" differed significantly among soils and had highest values on silty soils.

herbage. Other forbs produced 10 to about 20 percent of the herbage.

All soils contained an abundance of species, but many species were uncommon. For example, about 85 species produced less than 0.5 pound per acre, and 50 species produced less than 0.1 pound per acre.

Of the 102 species of herbaceous plants identified, longleaf uniola and spike uniola combined were the largest herbage producers on all soils. These two cool-season grasses are not only shade-tolerant, but they produce more under shade than in full sunlight (Wolters 1974). Low panicums, also considered somewhat shade tolerant, were major herbage producers on all soils. Low panicums, spike uniola, and broomsedge bluestem produced significantly more herbage on silty soil than on other soil groups.

Tickclover was the most productive legume, but it yielded only 1 to 3 pounds per acre. Dwarf St. John's-wort was the highest producing forb, reaching 23 pounds per acre on the silty soil.

Herbaceous species that were significantly influenced by soil group produced the most on silty soils. This may be due to an inherent production capability of the silty soil and the moisture relations of the site, although the absence of pines in the overstory may also have influenced herbage production.

Of the 177 plant species encountered, none were listed as endangered or threatened (Smithsonian Institution 1975).

CONCLUSIONS

Few significant differences occurred in botanical composition among the soils investigated. The most obvious differences occurred on the silty loessial terrace soils that appear to be poorly drained. Here pines were absent and some browse-size trees suggestive of a moist site (red maple, for example) had significant greater densities. Overall, an approximately similar botanical composition can be expected to occur on the soils studied except that the silty soil will show a greater proportion of hardwoods and will likely have greater herbage yields.

The variable management histories experienced by such poorly stocked cutover stands confounds the accurate prediction of botanical composition from soils alone. This is likely to be the case on much of the South's timbered lands subjected to periodic harvest.

However, the mean values found should be broadly representative of much of the vegetation present on West Gulf Coastal Plains timber stands currently being clearcut, site prepared, and planted. This information provides a base for comparing overall forest values after site preparation and regeneration to pine.

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APPENDIX

Appendix Table 4.—*Scientific and common names of trees, shrubs, and vines that occurred on five soil groups in north central Louisiana and south central Arkansas*

Scientific Name	*Common Name*	*Scientific Name*	*Common Name*
Acer rubrum L.	red maple	Lonicera japonica Thunb.	Japanese honeysuckle
Aesculus pavia L.	red buckeye	Morus rubra L.	red mulberry
Anisostichus capreolata (L.) Bureau	crossvine	Myrica cerifera L.	southern waxmyrtle
Aralia spinosa L	devils-walkingstick	Nyssa sylvatica Marsh.	blackgum
Asiminia triloba (L.) Dunal	pawpaw	Ostrya virginiana (Mill.) K. Koch	eastern hophornbeam
Baccharis halimifolia L	eastern baccharis	Pinus echinata Mill.	shortleaf pine
Berchemia scandens (Hill) K. Koch	Alabama supplejack	Pinus taeda L.	loblolly pine
Callicarpa americana L.	American beautyberry	Prunus spp.	cherry
Campsis radicans (L.) Seem.	trumpetcreeper	Quercus alba L.	white oak
Carpinus caroliniana Walt.	American hornbeam	Quercus facata Michx.	southern red oak
Carya spp.	hickory	Quercus falcata var. pagodaefolia Ell.	cherrybark oak
Carya tomentosa (Lam.) Nutt.	mockernut hickory	Quercus marilandica Muenchh.	blackjack oak
Carya cordiformis (Wang) K. Koch	bitternut hickory	Quercus muehlenbergii Engelm.	chinkapin oak
Ceanothus americanus L.	New Jersey-tea	Quercus nigra L	water oak
Celtis laevigata Willd	hackberry	Quercus stellata Wang	post oak
Chionanthus virginicus L.	fringetree	Rhamnus caroliniana Walt.	Carolina buckthorn
Cornus florida L.	flowering dogwood	Rhododendron canescens (Michx.) Sweet	Piedmont azalea
Crataegus spp.	hawthorn	Rhus copallina L.	shining sumac
Crataegus marshallii Eggl.	parsley haw	Rhus radicans L.	poison-ivy
Crataegus opaca Hook. & Arn.	mayhaw	Robinia pseudo-acacia L	black locust
Crataegus pyracanthoides Beadle	pyracantha haw	Rubus spp.	blackberry
Crataegus spathulata Michx.	littlehip haw	Rubus floridus Tratt.	blackberry
Diospyros virginiana L.	common persimmon	Rubus trivialis Michx.	dewberry
Fagus grandifolia Ehrh.	American beech	Sassafras albidum (Nutt.) Nees	sassafras
Fraxinus americana L.	white ash	Smilax spp.	greenbrier
Gelsemium sempervirens (L.) Ait. f.	Carolina jessamine	Smilax bona-nox L	saw greenbrier
Hamamelis virginiana L.	witch-hazel	Smilax glauca Walt	cat greenbrier
Hypericum spp.	St. John's-wort	Smilax laurifolia L.	laurel greenbrier
Hypericum hypericoides (L.) Crantz	St. Andrew's cross	Smilax rotundifolia L.	common greenbrier
Hypericum stans (Michx.) P. Adams & Robson	St. Peter's-wort	Styrax grandifolia Ait.	bigleaf snowbell
Ilex decidua Walt	possumhaw	Symplocos tinctoria (L.) L'Her.	common sweetleaf
Ilex opaca Ait.	American holly	Ulmus alata Michx.	winged elm
Ilex vomitoria Ait.	yaupon	Ulmus americana L	American elm
Juniperus virginiana L.	eastern redcedar	Vaccinium arboreum Marsh.	tree sparkleberry
Liquidambar styraciflua L.	sweetgum	Vaccinium elliottii Chapm.	Elliott blueberry
		Viburnum dentatum L.	arrowwood
		Virburnum rufidulum Raf	rusty blackhaw
		Vitis spp.	grape
		Vitis aestivalis Michx	summer grape
		Vitis rotundifolia Michx.	muscadine grape

Appendix Table 5.—*Scientific and common names of herbaceous plants that occurred on five soil groups in north central Louisiana and south central Arkansas*

Scientific Name	*Common Name*
Acalypha gracilens Gray	copperleaf
Amaranthus retroflexus L.	redroot amaranth
Ambrosia artemisiifolia L.	common ragweed
Andropogon gerardii Vitm.	big bluestem
Andropogon glomeratus (Walt.) BSP.	bushy bluestem
Andropogon scoparius Michx.	little bluestem
Andropogon tener (Nees) Kunth	slender bluestem
Andropogon virginicus L.	broomsedge bluestem
Aristida spp.	threeawn
Arnica spp.	leopards-bane
Asclepias tuberosa L.	butterfly milkweed
Asclepias variegata L.	white milkweed
Aster spp.	aster
Axonopus affinis Chase	common carpetgrass
Baptisia nuttalliana Small	Nuttall wildindigo
Boltonia diffusa Ell.	smallhead boltonia
Carex spp.	sedge
Cassia fasciculata Michx.	partridge pea
Centrosema virginianum (L.) Benth.	butterfly pea
Crotalaria sagittalis L.	arrow crotalaria
Croton capitatus Michx.	wooly croton
Cynodon dactylon (L.) Pers.	Bermudagrass
Desmodium spp.	tickclover
Digitaria spp.	crabgrass
Diodia teres Walt.	poor-joe
Dioscorea villosa L.	Atlantic yam
Echinochloa crusgalli (L.) Beauv.	barnyard grass
Echinocytis lobata (Michx.) T. & G.	wild cucumber
Elephantopus tomentosus L.	hairy elephantfoot
Eragrostis spectabilis (Pursh) Steud.	purple lovegrass
Erigeron canadensis L.	horseweed
Erigeron strigosus Muhl. ex Willd.	prairie fleabane
Eryngium prostratum Nutt.	creeping eryngo
Eryngium yuccifolium Michx.	button snakeroot
Eupatorium spp.	eupatorium
Euphorbia corollata L.	flowering spurge
Eustylis purpurea (Herb.) Engelm. & Gray	purple pleatleaf
Galactia volubilis (L.) BSP.	downy milkpea
Galium pilosum Ait.	hairy bedstraw
Gnaphalium spathulatum (Lam.) Ahles	cudweed
Gratiola pilosa Michx.	shaggy hedgehyssop
Helianthus spp.	sunflower
Heterotheca graminifolia (Michx.) Shinners	grassleaf goldaster
Hieracium gronovii L.	Gronovius hawkweed
Hypericum mutilum L.	dwarf St. John's-wort
Juncus spp. L.	rush
Lactuca spp.	wild lettuce
Lechea villosa Ell.	hairy pinweed
Lespedeza spp.	lespedeza
Liatris aspera Michx.	rough gayfeather
Liatris elegans (Walt.) Michx.	pinkscale gayfeather
Liatris pycnostachya Michx.	Kansas gayfeather
Linum virginianum L.	woodland flax
Lobelia spicata Lam.	palespike lobelia
Mitchella repens L.	partridge berry
Monarda fistulosa L.	beebalm horsemint
Muhlenbergia expansa (DC.) Trin.	cutover muhly
Oenothera pilosella Raf.	evening primrose
Oxalis stricta L.	yellow woodsorrel
Panicum spp.	low panicums
Panicum agrostoides Spreng.	redtop panicum
Panicum rhizomatum (Hitchc. & Chase) Fern.	spreading panicum
Paspalum ciliatifolium L.	fringeleaf paspalum
Paspalum circulare (Nash) Fern.	roundseed paspalum
Paspalum dilatatum Poir.	dallisgrass
Paspalum floridanum Michx.	Florida paspalum
Paspalum plicatulum Michx.	brownseed paspalum
Paspalum urvillei Steud.	vaseygrass
Passiflora lutea L.	yellow passionflower
Phytolacca americana L.	pokeweed
Plantago aristata Michx.	bottlebush plaintain
Pluchea foetida (L.) DC.	stinking pluchea
Podophyllum peltatum L.	common mayapple
Polygonum punctatum Ell.	dotted smartweed
Polypremum procumbens L.	juniperleaf
Pteridium aquilinum (L.) Kuhn var. pseudocaudatum (Clute) Heller	bracken fern
Pycnarnhemum tenuifolium Schrad.	slender mountainmint
Pyrrhopappus carolinianus (Walt.) DC.	false dandelion
Rhexia mariana L.	Maryland meadow-beauty
Rhynchosia difformis (Ell.) DC.	hairy rhynchosia
Rhynchosia reniformis DC.	dollarleaf rhynchosia
Rudbeckia grandiflora (Sweet) DC.	rough coneflower
Rudbeckia hirta L.	blackeyed susan
Ruellia humilis Nutt.	low ruellia
Sanicula canadensis L.	Canada sanicle
Schrankia uncinata Willd.	Catclaw sensitivebrier
Scutellaria integrifolia L.	rough skullcap
Silphium asperrimum Hook.	roughstem rosinweed
Solanum carolinense L.	carolina horsenettle
Solidago nitida T. & G.	shiny goldenrod
Solidago odora Ait.	fragrant goldenrod
Solidago rugosa Ait. var. celtidifolia (Small) Fern.	wrinkled goldenrod
Stipa avenacea L.	blackseed needlegrass
Stylosanthes biflora (L.) BSP.	pencilflower
Tephrosia virginiana (L.) Pers.	Virginia tephrosia
Tradescantia hirsuticaulis Small	spiderwort
Tragia urticifolia Michx.	nettleleaf noseburn
Uniola laxa (L.) BSP.	spike uniola
Uniola sessiliflora Poir.	longleaf uniola
Verbena brasiliensis Velloso	blue verbena
Vernonia angustifolia Michx.	pinebarren ironweed
Viola spp.	violet

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Research Note

SO-224

1977

Planting Depth and Source Affect Survival of Planted Green Ash Cuttings

HARVEY E. KENNEDY, JR.

SUMMARY

Horizontally and vertically planted cuttings from 1-0 nursery-grown green ash seedlings sprouted and grew well during the first growing season. Cuttings from 1- and 2-year-old sprouts and older material did not perform satisfactorily. Planted seedlings survived and grew well. Cuttings should be 10 to 15 inches long made from 1-0 seedlings and planted horizontally in slits 1 to 2 inches deep or planted vertically with 2 to 3 inches of cutting left above ground. If there is danger of standing water for long periods, seedlings rather than cuttings should be used.

Additional keywords: *Fraxinus pennsylvanica*, artifical regeneration, layering, vegetative propagation.

Green ash (*Fraxinus pennsylvanica* Marsh.) wood finds a ready market, growth rate in plantations appears satisfactory, and the trees do well on wet sites. This paper reports results of horizontal and vertical planting of green ash cuttings, which grew well in earlier studies (Kennedy 1972, 1974), and compares survival and growth of cuttings and seedlings. Planting cuttings horizontally and vertically can be easily mechanized and might be an excellent way of reducing the cost of establishing plantations.

METHODS

The study was installed on the Delta Experimental Forest (DEF) and Huntington Point, Mississippi, on recently cleared forest land, in the winter of 1973-74. Soil type on the DEF is Sharkey clay and at Huntington Point is Commerce silt loam.

Cuttings were made from material of four sources:

(1) One-year-old nursery-grown seedlings.
(2) One-year-old sprouts.
(3) Two-year-old sprouts.
(4) Older material (3- to 15-year-old understory trees up to 1 inch in diameter).

Cuttings from seedlings were made starting at the rootcollar up to a top that was a minimum of one-eighth inch in diameter. Cuttings did not include any of the seedling root system.

Horizontally planted cuttings were inserted by hand in slits either 1 or 3 inches deep. Cutting lengths were 6, 10, and 14 inches, giving a total of 24 treatment combinations (two depths X three lengths X four sources). Vertically planted cuttings (15 inches long) from each source were tested as were planted seedlings.

Four blocks, approximately 20 by 280 feet, were planted at each location. Three blocks were used for measurements and the fourth for excavating cuttings to study root and shoot development. Rows were 20 feet long with 10 cuttings planted equidistant in each row. Spacing between rows was 10 feet to allow disking in one direction. Plots were kept weed-free.

A randomized block design with three replications of each treatment combination was used at each site. Because of extremely low survival, treatments involving 1- and 2-year-old sprouts and older material were dropped from the statistical analysis. After one growing season, survival percentages, diameters at rootcollar, and heights of cuttings made from 1-0 seedlings planted horizontally and vertically, and seedlings were analyzed for differences at the 0.05 level. Differences among treatments were determined using Duncan's new multiple range test.

RESULTS AND DISCUSSION

Cuttings from 1-0 seedlings horizontally and vertically planted performed satisfactorily at both sites except 6-inch cuttings planted 3 inches deep at Huntington Point and all cuttings planted 3 inches deep on the DEF (table 1). On the DEF, the poor survival at 3 inches could have been caused by wetter than normal soils. Survival of seedlings was good at both locations.

At both locations seedlings were significantly larger than sprouts from cuttings after 1 year in the field (table 1). However, seedlings were about 2 feet tall when planted, so their actual growth the first year is comparable to that of the sprouts. Seedlings also had significantly larger diameters than sprouts but, again, the advantage is offset by the fact that seedlings were 1 year old when planted.

Performance was unsatisfactory in all treatments where cuttings from 1- and 2-year-old sprouts and from older material were used. After one growing season, survival ranged from 0 to 33 percent on the DEF and 0 to 53 percent at Huntington Point. Many of the cuttings sprouted but died during the growing season. When cuttings were dug up in the extra block most showed no sign of roots; sprouts of cuttings from 1-0 seedlings developed good root systems.

CONCLUSIONS

If green ash cuttings are planted, they should be made from 1-0 nursery-grown seedlings. Horizontal planting of 10- to 14-inch cuttings in slits 1 to 2 inches deep, or vertical planting of 15-inch cuttings should give satisfactory results. But, vertical planting may be easier than horizontal. Using cuttings from 1-0 seedlings has both advantages and disadvantages over planting seedlings themselves. Planting cuttings mechanically might be cheaper than planting seedlings mechanically because the machinery would be less complicated and less expensive. However, where there is danger of standing water for long periods, seedlings would probably be better than cuttings.

Table 1 —*Survival, heights, and diameters at groundline of cuttings taken from 1-0 seedlings and of planted seedlings*[1]

Planting depth	Cutting length	Survival	Diameter	Height
		Percent	*Inch*	*Feet*
		Delta Experimental Forest		
1	6	83 bc	47ab	2 0ab
1	10	86 bc	53 b	2 1ab
1	14	100 c	47ab	2 1ab
3	6	37a	50ab	2 5 b
3	10	53ab	47ab	2 1ab
3	14	56abc	43a	1 6a
Vertical	15	90 bc	47ab	1 9ab
Seedling		97 bc	73 c	3 1 c
		Huntington Point		
1	6	77 bc	67ab	3 0a
1	10	100 c	77 bc	3 4a
1	14	83 bc	77 bc	3 6a
3	6	37a	67ab	2 9a
3	10	73 b	70abc	3 1a
3	14	83 bc	80 c	3 6a
Vertical	15	97 bc	60a	3 2a
Seedling		100 c	97 d	4 3 b

[1]Treatments followed by the same letter are not significantly different at the 05 level

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Research Note

SO-225

1977

Ground-Water Levels and Soil Characteristics in a Forested Typic Glossaqualf

PETER L. LORIO, JR.

SUMMARY

The presence of impermeable layers can affect the development of a soil and its water regime. In a forested Typic Glossaqualf in southwest Louisiana, moisture, density, and piezometer measurements revealed an impermeable layer of soil between about 1.8 and 2.8 m below the surface. A high proportion of very fine sand and development of platy structure appeared related to a low proportion of drainable pores in the layer. Glossic characteristics were well developed in the B horizon and were associated with an intermittent perched water table but disappeared as moisture content became more uniform at greater depths. An auger hole that extended through the impermeable layer indicated, during dry periods, the pressure variations of a deep water source rather than a continuous water table.

Additional keywords: Water, regime, texture, density.

In an earlier study of the soil water regime under loblolly pine (*Pinus taeda* L.) on a wet site in southwest Louisiana, impermeable layers were not evident in the soil profile (Lorio and Hodges 1971). The presence of such layers in or immediately below the solum can affect the interpretation of the development of a soil and affect the soil's current water regime. The present study was conducted to clarify the nature of the water regime in relation to characteristics of a forested Typic Glossaqualf.

METHODS

The study was done in the West Bay Game Management Area in Allen Parish, Louisiana, in a natural stand of loblolly pine that was about 44 years old. Elevation in 34.50 m above mean sea level. Climate is humid with an average annual rainfall of about 151 cm.

Soils in the study area were formed on the fluviatile Montgomery terrace, a stream deposit associated with a former Mississippi River course (Holland et al., 1952). The predominant soil is classified as Guyton silt loam, a member of the fine-silty, mixed, thermic family of Typic Glossaqualfs. Soils on the numerous mounds are somewhat more sandy and less clayey in the upper solum, and apparently have developed under less moist conditions than those on flats. The Messer series (Typic Glossudalf, coarse-silty, mixed, thermic) is representative of these soils. Although both soils are classified as Alfisols, chemical analyses indicated that soils in this area may be marginal to the Ultisols (Lorio and Hodges 1971).

An intermound site (Guyton series) was selected for this study. The profile description is for moist soil conditions.[1]

Horizon	Depth, cm	Description
A1	0-5	Dark grayish brown (10YR 4/2) silt loam; few fine faint grayish brown mottles; weak fine granular stucture; friable; many fine and medium roots; common fine and medium pores; common fine soft black specks; strongly acid (pH 5.5); clear wavy boundary.
A21g	5-30	Light brownish gray (10YR 6/2) silt loam; many (35%) medium distinct brownish yellow (10YR 6/6) mottles; weak fine subangular blocky

[1]Profile description by Mr. Arville Touchet, State Soil Scientist, Soil Conservation Service.

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Horizon	Depth, cm	Description
		structure; friable; common fine, medium and coarse roots; common fine and medium pores; few medium krotovinas; many fine and few medium brown concretions; very strongly acid (pH 4.9); gradual wavy boundary.
A22g	30- 74	Light brownish gray (10YR 6/2) silt loam; common medium distinct yellowish brown (10YR 5/6) mottles; weak medium subangular blocky structure; friable; few fine roots; many fine and medium pores lined with clear silt; few medium brown concretions; tongues 5 to 15 cm wide extending through B21tg horizon; very strongly acid (pH 4.9); abrupt irregular boundary.
B21tg	74-117	Gray (10YR 6/1) silty clay loam; common medium distinct yellowish brown (10YR 5/6) mottles; compound moderate coarse prismatic and moderate medium subangular blocky structure; firm; few fine and medium roots between prisms; common fine pores inside of peds; few fine pores through face of peds; thick continuous clay films on surface of peds; few medium brown concretions; (30 to 40% of the mass is A22g tongues); very strongly acid (pH 4.9); gradual wavy boundary.
B22tg	117-158	Gray (10YR 6/1) silty clay loam; common coarse yellowish brown (10YR 5/8) and strong brown (7.5YR 5/8) mottles; compound moderate coarse prismatic and moderate medium subangular blocky structure; few fine and medium roots between prisms; common fine pores inside of peds; few fine pores through face of peds; thick continuous clay films on surface of peds; few medium silt loam pockets and thin patchy silt coats in vertical cracks; few medium brown concretions; strongly acid (pH 5.2); gradual wavy boundary.
B3g	158-183	Gray (10YR 6/1) silty clay loam; common medium distinct yellowish brown (10YR 5/4) mottles; compound moderate coarse platy and moderate medium subangular blocky structure; few fine and medium roots in cracks; few fine pores; thin patchy clay films on surface of peds; few medium brown concretions; strongly acid (pH 5.4).

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Piezometer tubes (5.08 cm inside diameter thin-walled electrical conduit) were installed on a 0.04 ha plot previously used for auger-hole and neutron-probe measurements. The tubes were 2 m apart and their lower ends were 0.75, 0.90, 1.20, 1.35, 1.65, 2.15, and 2.70 m below the surface of the soil. A cavity 10.2 cm long and 4.9 cm in diameter was augured below the bottom end of each tube. In anisotropic soils piezometers measure essentially horizontal hydraulic conductivity and can be used at almost any depth below a water table (Reeve and Kirkham 1951). Installation techniques and methods of measuring saturated hydraulic conductivity were those developed by Luthin and Kirkham (1949) and Reeve and Kirkham (1951) and described by Boersma (1965).

Depth to free water was measured weekly from January 1972 through December 1973 with the piezometers and with an auger hole. The auger hole extended to 4.4 m and was lined with perforated 5-cm diameter aluminum tubing. In both years, ground-water levels from January through June provided the best conditions for evaluating the nature of the water regime, and results presented are for those months.

Two access tubes (4.8 cm inside diameter) were installed to permit soil moisture readings to 4.2 m; three additional tubes allowed measurements to 1.4 m. A Kaiser probe (Model VMP 487)[2] adapted to a Troxler portable scaler-ratemeter (Model 1651) was used to measure moisture. Two 4.0 cm inside diameter tubes allowed access for density measurements that were made with a Troxler Model 505 density gauge and a Model 200B scaler-ratemeter. Moisture measurements were made from January through June 1972 and at the time of density measurements in June 1974. Density measurements were adjusted to dry density by subtracting the water component of total density indicated by the moisture gauge.

Soil samples from access tubes were collected at 15-cm increments for particle-size distribution analysis by the hydrometer method (Day 1965). Rainfall on the site was measured with a recording gauge. Average semiannual precipitation (1931-1971) was calculated from data of the official weather station at Elizabeth, Louisiana, 4 miles from the study site.

[2]Mention of trade names is solely to identify material used and does not imply endorsement by the U.S. Department of Agriculture.

RESULTS AND DISCUSSION

The average January through June rainfall for Elizabeth from 1931-1971 was 78.2 cm. The January through June rainfall in 1972, the first year of the study, was 65.7 cm; rainfall in the first 6 months of 1973 was 101.5 cm.

Saturated hydraulic conductivity varied from moderately slow to very slow, based on O'Neal's classification (1952). At 0.75 m, saturated hydraulic conductivity was 23×10^{-5} cm sec^{-1}; at .90 m, 2.6×10^{-6} cm sec^{-1}; at 1.20 m, 2.3×10^{-6} cm sec^{-1}; at 1.35 m, 5×10^{-6} cm sec^{-1}. Conductivities could not be measured at 1.65, 2.15, and 2.70 m because very little water entered the piezometer cavity at 1.65 m and none entered at the lower levels.

Water levels in the .75 m piezometer from January to June of both years closely paralleled those in the auger hole; levels in the deeper piezometers indicated the very low hydraulic conductivity of the soil at those depths (fig. 1). In 1973, after a year of equilibration, the water levels in the .90 m piezometer more closely approximated auger-hole fluctuations than in 1972.

By January 1974, no water had entered the two deepest piezometers. When the 2.15 m piezometer was lowered to 2.85 m and the cavity extended to 3.95 m and the cavity below the 2.70 m tube was extended to 4.15 m, water slowly entered both piezometers. By April it rose to 2.0 m and by June to 1.8 m, indicating that water was under pressure below an impermeable layer.

Changes in soil density with depth were nearly the inverse of changes in soil moisture (fig. 2). The density and moisture measurements indicated a nearly impermeable zone between 1.8 and 2.8 m that varied little in moisture content. Soil moisture above the impermeable layer varied greatly, with especially large fluctua-

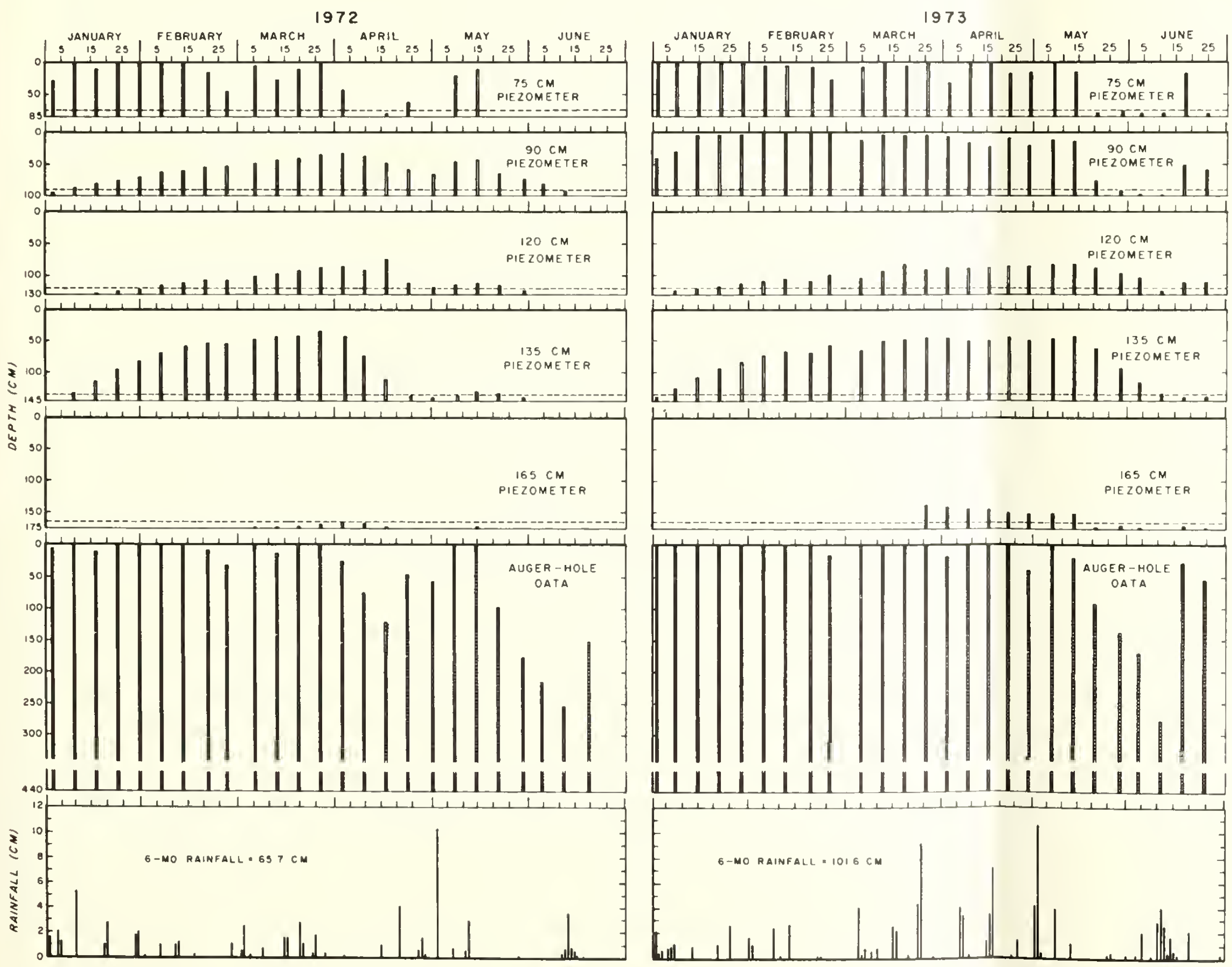

Figure 1.—*Daily rainfall and depth to free water measured in auger hole and in piezometers (January through June 1972 and 1973).*

tions in and above the B21 tg (74-117 cm). Such conditions are considered necessary for the development of tongues. As noted in the profile description, tongues of A22g disappeared in the B3tg horizon (158-183 cm) where moisture conditions are less variable. Below 3.0 m, the soil was apparently saturated or near saturation at all times.

Analyses of soil texture revealed the presence of the clay bulge characteristically associated with Btg horizons. No dramatic textural changes occurred in the apparently impermeable zone — clay was nearly constant (26-30 percent) and sand varied from about 25 percent near the top to about 40 percent near the bottom of the zone (fig. 3). Silt decreased from about 50 percent at the top to about 30 percent at the bottom. Very fine (50 to 100μ) and fine (100 to 250μ) particles comprised most of the sand fraction; very fine sand averaged 76 percent and ranged from 73 to 84 percent in the impermeable zone.

Because density was greatest at the top of the impermeable zone and tended to decrease with depth, it alone probably is not responsible for the low hydraulic conductivity of the layer. The abundance of very fine sand, the platy structure in the B3tg horizon, and the high density may combine to produce a high proportion of undrainable pores.

The water regime described is at least partly the result of the impermeable zone that exists below the developed soil. Tonguing, evidence that the argillic horizon, has been partly destroyed (Soil Survey Staff 1975), is highly developed. This characteristic feature of Glossaqualfs may be viewed both as a factor affecting current water regime and direction of soil development, and as a product of soil degradation processes. In this case water depletion and accretion patterns and tree rooting are profoundly affected by the tongues that occupy 30 to 40 percent of the soil mass in the B21tg. However, assuming that water movement is an important factor in tongue development in these soils, the constant moisture below the B horizon probably is limiting deeper development of glossic characteristics.

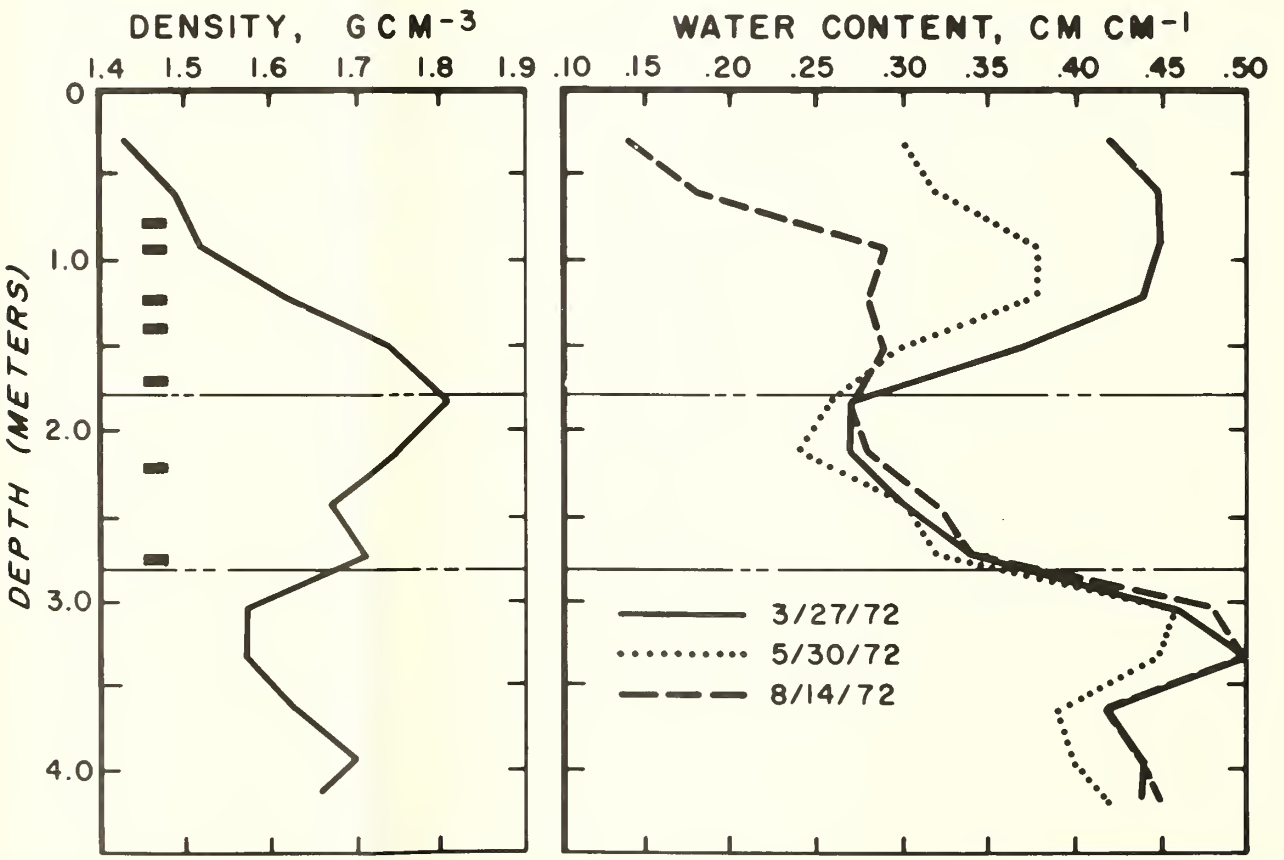

Figure 2.—*Dry density profile and soil moisture profiles representative of typical wet, intermediate, and dry conditions in the study area. The lines at 1.8 and 2.8 m indicate the impermeable zone. Depth of piezometer cavities are indicated along the left side of the figure.*

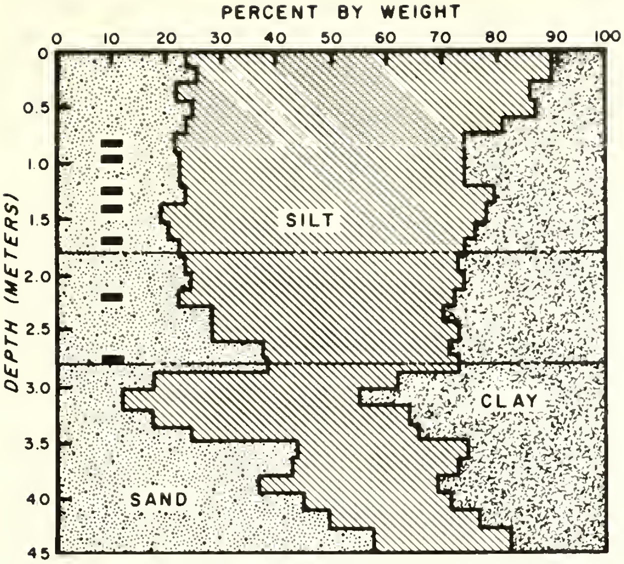

Figure 3.—*Particle-size distribution by 15-cm depth increments.*

ACKNOWLEDGEMENT: I thank the Southwestern Improvement Company for the use of its land and the Kirby Lumber Corporation for cooperation during the study.

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Research Note

SO-226

1977

Strobili and Conelet Losses In Four Species Of Southern Pines

B. F. McLEMORE

SUMMARY

In a central Louisiana seed orchard, 27,677 female strobili were tagged on selected clones of 4 pine species (loblolly, slash, shortleaf, and longleaf) over 4 years. Only 41 percent developed into cones. Losses were tallied by date and, when possible, by cause.

For loblolly, differences in losses were significant between years but not among clones. For slash there were significant differences both among clones and between years. Shortleaf showed no significant differences among clones or between years, but there were consistently higher losses for both shortleaf and longleaf than for loblolly and slash.

Insects were the largest single identifiable cause of mortality. Losses were greatest in early spring. Damage from birds, mechanical breakage, or weather was minimal. The only weather that caused any large loss was a hailstorm that caused a 20-percent loss of shortleaf conelets and strobili in 1974. If losses in the missing, unknown, and aborted stage-1 categories are included with known insect depredations, over 98 percent of all losses can be attributed to insects.

Additional keywords: cone insects, *Pinus palustris, Pinus taeda, pinus elliottii, Pinus echinata.*

THE PROBLEM

The loss of female strobili, conelets, and cones[1] from southern pines is an important problem for seed orchard managers charged with producing genetically improved seed. This study was initiated in 1971 to learn what agents are responsible for the losses, when the losses occur, and how losses differ among species.

METHODS

Grated trees, established at 15 x 30 foot spacing, in the Stuart Seed Orchard near Pollock, La., were used in the study. The trees were 6 years old in 1971. Loblolly (*Pinus taeda* L.) and slash (*P. elliottii* Engelm. var. *elliottii*) trees were about 20 feet tall, and shortleaf (*P. echinata* Mill.) and longleaf trees (*P. palustris* Mill.) were 10 to 15 feet tall. Loblolly trees had been producing female strobili for 2 or 3 years, but the slash had produced few strobili. Shortleaf and longleaf did not produce sufficient strobili for inclusion in the study until 1973. The orchard consisted of 50 clones each of Texas and Louisiana loblolly, Louisiana slash, Texas and Louisiana shortleaf, and Texas and Louisiana longleaf.

All female strobili were counted and observed on two loblolly trees from each of 10 clones that were high, medium, and low producers of female strobili in January 1971. A tally of all female strobili was repeated on the same trees in 1972. In 1973, however, strobili were tagged on only one tree in each clone because of increased production and inclusion of other species.

Only three slash clones had enough strobili for study purposes in 1971, and all female strobili on two ramets of each clone were tagged in early February. In January 1972 and 1973, two ramets from each of seven additional clones were added to the study.

In March 1973 and 1974, all female strobili on a single tree from each of 10 Texas shortleaf clones were counted and tagged.

All strobili were tagged on two trees from each of 10 Texas longleaf clones in March 1973, and repeated on the same trees in late February 1974.

[1] In this paper, female strobilus applies to the reproductive bud from the time it becomes visible until pollination. Conelet refers to this structure from pollination until it starts enlarging in the second year; thereafter, the term cone is used.

Observations of strobili and conelet mortality were made from January 1971 until October 1975. All female strobili were tagged and counted each year. For all species each year, inspections were made at 1- to 3-week intervals during spring and early summer, and every 1 to 3 months during the rest of the year. Conelets were picked as they died and examined in detail to determine cause of death. Losses were tallied by date and, when possible, by cause.[2] In some instances death could be attributed to a specific insect because of the type of damage done or presence of the insect. Many times, however, strobili suffered feeding damage or punctures that could not be attributed to a specific insect. In these cases, losses were tallied as "caused by unknown insects." Cones were harvested and counted in the fall of each year. Healthy and some insect-damaged strobili and conelets were picked from trees not in the study for microscopic examination from 1971-75.

RESULTS

Of 27,677 strobili tagged over the 4 years, only 11,303 (41 percent) developed into apparently sound cones. Losses varied widely among species and years. Losses in 1973-74 were significantly higher for loblolly, slash, and longleaf than for any other year in which observations were made.

Insects were a major cause of mortality. Species identified in the orchard that are known predators (Ebel, et al., 1975) were thrips *(Gnophothrips fuscus),* tip moth *(Rhyacionia frustrana),* looper *(Nepytia semiclusaria),* May beetles (*Phyllophaga* spp.), coneworms (*Dioryctria* spp.), cone borers (*Eucosma* spp.), midges (family Cecidomyiidae), seedworms (*Laspeyresia* spp.), and seedbugs (*Leptoglossus corculus* and *Tetyra bipunctata*). Microscopic examination of healthy conelets also revealed the presence of large numbers of mites in many instances, of which the most prevalent were Tyediids and some Tarsonemus.

Losses were usually greatest in early spring, immediately before, during, and shortly after pollination (fig. 1). Typically, at that time, strobili became discolored at their distal end, usually died within 2 or 3 days, and were promptly shed.

[2] Assistance in identification of insects was obtained from D. R. Kucera and N. A. Overgaard of the Southeastern Area of State and Private Forestry.

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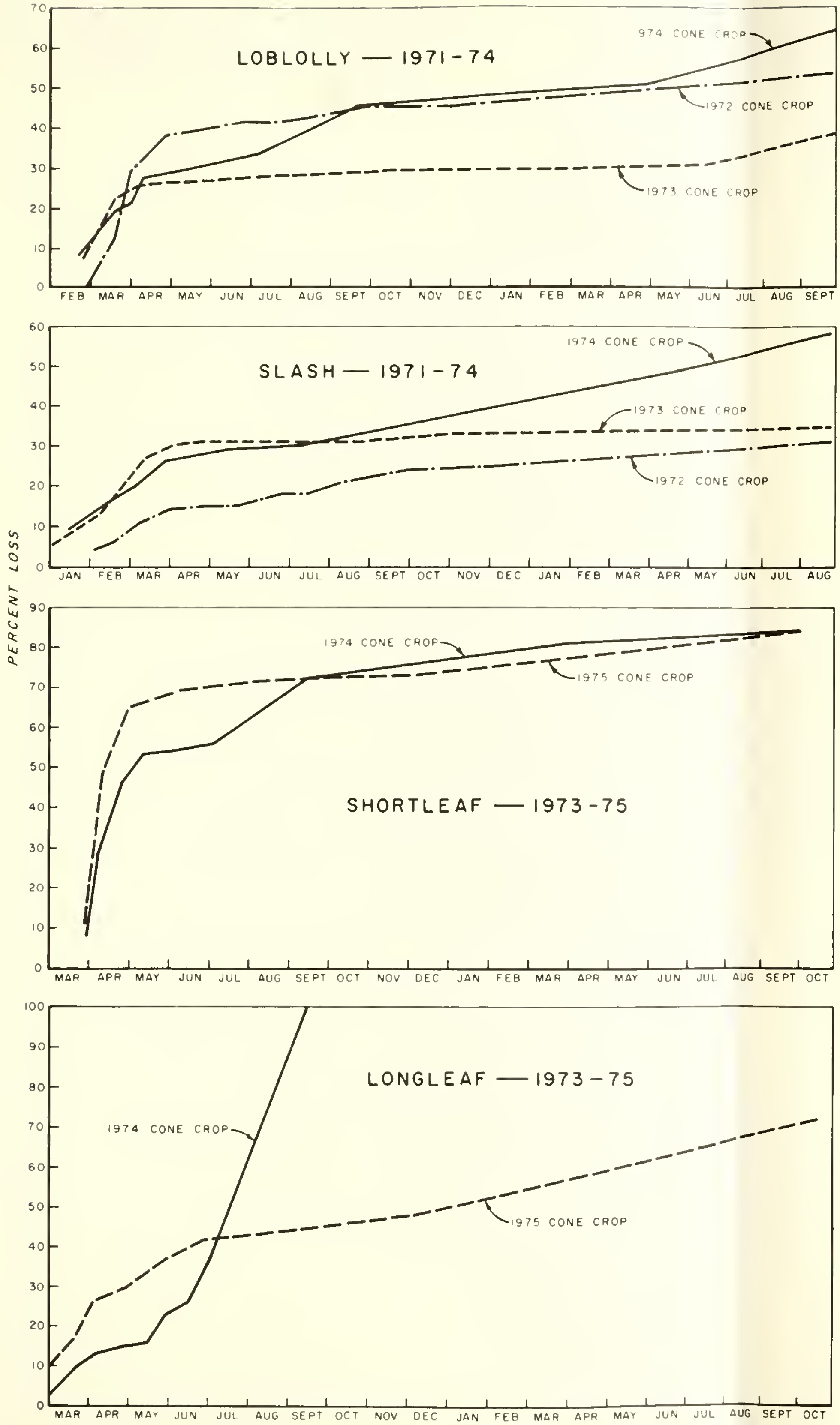

Figure 1.—*Losses of loblolly, slash, shortleaf, and longleaf strobili and conelets by month.*

Figure 2.—*Puncture mark on scale of loblolly strobilus. White dots are pollen grains.*

When larvae were not present, it was not always possible to ascertain which insect was responsible. Microscopic examination often showed puncture marks in the scales of living strobili (fig. 2), but marks were not detectable after strobili had withered and died.

Loblolly

Insects were the most common cause of death, with known mortality rates of at least 30 percent. Estimates of mortality attributed to insects are conservative since strobili and conelets were picked from trees and brought into the laboratory for microscopic examination as soon as they died. The conelets often contained larvae that may have killed other strobili had they remained on the trees. Mortality in the "presumed insects" category ranged from 12 to 30 percent. In such cases, it was impossible to determine the predator, since it was not present, but tip moths, *Dioryctria,* loopers, and midges were suspects.

Stage-1 buds are often no larger than the point of a pencil and are difficult to see, so the 2-percent loss for loblolly in 1971 tallied as aborted stage-1 is probably low. Not as many were tagged in 1971 as in subsequent years, because of inexperience. Losses of 9 percent in 1972 and 13 percent in 1973 were recorded.

Destruction of conelets by birds perching on young, succulent leaders bearing female strobili was negligible (table 1). Other mechanical losses resulted from branches breaking during mowing or inspection.

No consistent pattern in conelet mortality existed among the 10 loblolly clones, that is, individual clones did not have high losses or low losses in consecutive years, and regression analyses did not indicate correlations between years. An analysis of variance showed no significant differences among clones, although differences between years were significant.

Slash

Losses of slash strobili and conelets ranged from 31 percent in 1971-72 to 59 percent in 1973-74 (table 1). Percentages in 1971-72 would have been higher, because although stage-1 abortions occurred, they were not tallied. Insects were a major cause of losses. *Dioryctria* was the most destructive of the known insect predators. As with loblolly, however, unidentified insects caused the greatest losses.

There was a tendency for losses to be greater from some slash clones than from others. When clonal data from 1972-73 were compared with 1973-74 data, the r value of 0.649 was significant. An analysis of variance showed significant differences among clones and between years.

Shortleaf

Shortleaf strobili and conelet mortality averaged 84 percent for two successive crops, 1973-74 and 1974-75 (table 1). Missing conelets and unidentified insects accounted for most losses. Of the known insects, *Dioryctria* and *Phyllophaga* were the most damaging and together caused a loss of 4 percent in 1973-74 and 20 percent in 1974-75. The only significant losses attributed to agents other than insects were caused by a hail storm in April 1974. Twenty percent of the shortleaf strobili were lost when hail broke leaders bearing strobili.

Losses did not differ significantly among clones or between years but were significantly higher than for loblolly and slash.

Longleaf

The highest percentage loss (>99 percent) for all species occurred with longleaf in 1973. In that year, only one conelet remained in September of the 1,027 female strobili tagged 7 months earlier.

Table 1.—*Losses of strobili and conelets by species and year*

Cause of loss	Loblolly 1971-72	Loblolly 1972-73	Loblolly 1973-74	Slash 1971-72	Slash 1972-73	Slash 1973-74	Shortleaf 1973-74	Shortleaf 1974-75	Longleaf 1973-74	Longleaf 1974-75
	Percent									
Aborted stage-1	2	9	13	- -	8	14	8	5	5	5
Dioryetria	3	10	20	- -	2	20	3	9	7	33
Phyllophaga	- -[1]	1	2	- -	- -	- -	< 1	11	- -	1
Tip moth	- -	- -	- -	- -	- -	- -	3	1	- -	- -
Presumed insects	30	12	16	15	16	9	39	18	57	16
Unknown	9	< 1	- -	4	2	- -	- -	- -	11	- -
Missing	8	5	12	9	6	15	28	19	19	10
Mechanical breakage	< 1	< 1	< 1	3	< 1	< 1	1	1	< 1	1
Birds	< 1	< 1	< 1	- -	< 1	< 1	< 1	< 1	< 1	- -
Hail	- -	- -	- -	- -	- -	- -	- -	20	- -	6
Total	53	38	64	31	35	59	84	84	> 99	72
(No. strobili observed)	1,876	8,240	5,787	209	1,621	2,330	2,083	4,170	1,029	334

[1] Dash (-) indicates no data rather than 0.

Longleaf conelet losses in 1973 were greatest in July and August, but in 1974 most losses occurred in the spring, as was found with the other species. *Dioryctria* was the primary predator in both years. Again, substantial losses occurred in the unknown, missing, and "presumed insect" categories.

Hail killed 6 percent of the longleaf strobili in 1974. Aborted strobili accounted for 5 percent of the losses in both years.

DISCUSSION

Although it is not certain, most losses in the missing, unknown, and aborted stage-1 categories were probably caused by insects. If these losses are included with known insect depredations, over 98 percent of the losses incurred can be attributed to insects. DeBarr and Ebel (1974), DeBarr and Barber (1975), and Ebel and Yates (1974) have previously recorded high losses of conelets caused by insects. In view of the major role insects appear to have in conelet losses, periodicity of cone crops may be related to cycles of insect populations.

In earlier years of seed orchard management, weather was often blamed for losses of female strobili and conelets. Although freezes and extended periods of dry or wet weather can be responsible for losses, hail was the only weather condition that caused losses in this study. In 1971, slash strobili withstood a temperature of −6° C shortly after pollination without harm, and receptive loblolly strobili were unharmed by a temperature of −4° C.

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Southern Forest Experiment Station

Research Note

SO-227

1977

Forest Fire Occurrence in Southern Counties, 1966-1975

M. L. DOOLITTLE

SUMMARY

'orest fire occurrence data for individual pro- ε tion units generally are unavailable outside 'ticular state organizations. Number of fires, 'a protected and fire occurrence rate (fires ·· 1,000,000 acres) from 1966 to 1975, are ›sented in tables for the 993 counties under ›tection in 13 southern states. These data are ›mpared with data for the preceeding decade ›56-1965). A map shows the geographical tribution of fire occurrence rates as very low, v, moderate, high or very high.

REGIONAL PERSPECTIVE

Although all thirteen states in the Southern ·gion maintain fire occurrence records for lividual protection units, the data are not adily available to individuals and organiza- ns outside each state. The Southern Forest periment Station's Forest Fire Prevention ·search Work Unit at Starkville, Mississippi, llected and summarized fire occurrence data · the 1956-1965 period.[1] Though general, the ormation was valuable in gaining a regional rspective on fire occurrence and in selecting eas for intensive field studies.

This note updates the information for the previous decade. The same basic data are presented: average annual number of fires, average area protected, and fire occurrence rate (FOR).[2] These data are shown for each of the thirteen states (table 1). The FOR's for the 1956-1965 period are given for comparison.

To further facilitate comparison between the two periods, the 1966-1975 FOR's were placed in the same five categories that were employed for the 1956-1965 data:

Very low	=	0-132
Low	=	133-206
Moderate	=	207-282
High	=	283-407
Very high	=	408+

Table 2 shows the distribution to the five FOR categories of the protection units in each state. Data for both decades are presented.

Tables 3 through 15 show the number of fires, acres protected, and FOR for individual protection units in each state. Where possible, the 1956-1965 FOR is shown, also. Geographical distribution of FOR is depicted in figure 1.

[1] . L. Doolittle, Forest Fire Occurrence in the South, 1956- ›65. U. S. Forest Service Research Note SO-97, 16 pgs., ›69.

[2] $FOR = \frac{\text{Number of fires}}{\text{Acres protected}} \times 1,000,000$

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Table 1.--Mean annual fire occurrence data by state and for the region, 1966-1975.

State	No. Fires	Acres Protected	F.O.R.	F.O 1956
Alabama	6,752	22,581,450	299	311
Arkansas[1/]	2,768	15,268,200	181	187
Florida[1/]	7,892	21,701,802	364	336
Georgia	9,741	25,017,650	389	337
Kentucky	2,090	10,909,578	192	296
Louisiana	5,958	12,257,480	486	527
Mississippi	5,700	18,010,300	317	456
North Carolina	4,048	17,785,199	228	195
Oklahoma[2/]	886	4,405,499	201	230
South Carolina	4,730	12,049,000	393	348
Tennessee	3,130	12,575,290	249	304
Texas	1,570	17,562,208	89	179
Virginia	1,632	14,350,562	114	126
Region	56,897	204,474,218	278	298

1/ Only 9 years of data available

2/ Only 6 years of data available

Doolittle is Research Forester, Forest Tree Seed Laboratory, Forest Service—USDA, Southern Forest Experiment Stat
maintained at Starkville, Miss., in cooperation with Mississippi State University.

le 2.--Number and percent of protection units in each occurrence rate category by state, 1956-65 and 1966-75.

tes and cades	Occurrence Rate Categories										
	Very Low		Low		Moderate		High		Very High		Total
	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.
bama											
956-65	11	16	10	15	17	25	10	15	19	28	67
966-75	12	18	11	16	14	21	10	15	20	30	67
ansas[1/]											
956-65	5	22	9	39	4	17	5	22	0	0	23
966-75	30	40	25	33	14	19	5	7	1	1	75
rida[1/]											
956-65	7	13	8	15	10	19	16	30	14	23	53
966-75	4	7	8	13	13	21	11	18	25	41	61
rgia											
956-65	6	5	15	12	25	20	37	30	42	34	125
966-75	4	3	20	13	24	15	45	28	66	42	159
tucky											
956-65	6	9	16	23	22	32	18	26	7	10	69
966-75	63	52	31	26	11	9	12	10	3	2	120
isiana											
956-65	4	10	12	29	6	15	6	15	13	32	41
966-75	12	29	11	26	4	10	2	5	13	31	42
sissippi											
956-65	3	4	14	19	11	15	12	16	34	46	74
966-75	23	29	14	18	9	11	11	14	22	28	79
th Carolina											
956-65	37	40	28	30	9	10	13	14	5	5	92
966-75	18	19	32	34	18	19	16	17	10	11	94
ahoma[2/]											
956-65	1	17	2	33	2	33	1	17	0	0	6
966-75	4	31	3	23	2	16	3	23	1	8	13
th Carolina											
956-65	2	4	13	28	7	15	10	22	14	30	46
966-75	4	9	9	20	6	13	11	24	16	35	46

Table 2.--cont'd.

States and Decades	Occurrence Rate Categories									
	Very Low		Low		Moderate		High		Very High	
	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
Tennessee										
1956-65	6	8	10	14	22	30	26	35	10	14
1966-75	11	12	34	37	20	22	19	21	8	9
Texas										
1956-65	16	41	6	15	10	26	3	8	4	10
1966-75	36	75	10	21	2	4	0	0	0	0
Virginia										
1956-65	64	67	18	19	8	8	3	3	2	2
1966-75	62	64	24	25	4	4	4	4	3	3
Region										
1956-65	168	21	161	20	153	19	160	20	162	20
1966-75	283	29	232	23	141	14	149	15	188	19

1/ Only 9 years of data available

2/ Only 6 years of data available

Table 3.--Alabama

County	10-year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Autauga	58	270,179	215	269
Baldwin	494	789,247	626	585
Barbour	59	407,483	145	190
Bibb	58	290,309	200	249
Blount	113	271,657	416	418
Bullock	64	271,971	235	242
Butler	122	391,340	312	246
Calhoun	88	202,976	434	433
Chambers	53	271,616	195	149
Cherokee	67	255,408	262	334
Chilton	132	316,312	417	497
Choctaw	73	516,435	141	162
Clarke	39	708,897	55	62
Clay	77	262,348	294	224
Cleburne	127	248,879	510	496
Coffee	80	248,718	322	251
Colbert	38	239,022	159	222
Conecuh	128	425,097	301	229
Coosa	94	373,247	252	263
Covington	177	422,260	419	327
Crenshaw	68	263,932	258	166
Cullman	121	296,104	409	306
Dale	45	185,436	243	255
Dallas	42	395,208	106	126
De Kalb	69	275,066	251	261
Elmore	75	281,760	266	266
Escambia	219	461,696	474	499
Etowah	137	220,028	623	578
Fayette	66	325,466	203	194
Franklin	90	297,043	303	356
Geneva	82	191,658	428	472
Greene	35	301,505	116	125
Hale	21	265,381	79	92
Henry	56	223,086	251	261
Houston	66	159,346	414	445

Table 3.--Alabama (cont'd.)

County	10-year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Jackson	49	458,539	107	164
Jefferson	308	502,447	613	948
Lamar	75	309,471	242	205
Lauderdale	25	205,002	122	308
Lawrence	37	153,328	241	201
Lee	59	293,535	201	293
Limestone	31	128,598	241	104
Lowndes	26	306,070	85	99
Macon	78	261,436	298	410
Madison	29	191,692	151	205
Marengo	40	449,162	89	124
Marion	107	375,144	285	304
Marshall	107	179,441	596	611
Mobile	509	594,764	856	629
Monroe	85	534,768	159	120
Montgomery	30	280,938	107	242
Morgan	101	171,182	590	417
Perry	18	311,562	58	111
Pickens	59	442,271	133	222
Pike	63	272,233	231	324
Randolph	80	281,940	284	272
Russell	113	269,048	420	482
St. Clair	177	324,782	545	554
Shelby	189	414,506	456	468
Sumter	28	427,681	65	78
Talladega	207	287,282	721	545
Tallapoosa	128	388,259	330	291
Tuscaloosa	144	705,146	204	277
Walker	222	414,050	536	646
Washington	215	619,972	347	203
Wilcox	22	447,765	49	68
Winston	62	253,321	245	217

Table 4.--Arkansas

County	9-Year Averages, 1967-1975[1]			F.O.R. 1956-65[1]
	No. Fires	Acres Protected	F.O.R.	
Arkansas	7	135,100	52	
Ashley	92	406,900	226	
Baxter	46	172,900	266	
Benton	48	209,600	229	
Boone	24	190,100	126	
Bradley	39	354,000	110	
Calhoun	96	348,000	276	
Carroll	48	236,400	203	
Chicot	0	75,600	0	
Clark	37	413,100	90	
Clay	4	54,000	74	
Cleburne	53	237,600	223	
Cleveland	49	319,000	154	
Columbia	68	379,300	179	
Conway	22	127,400	173	
Craighead	7	45,500	154	
Crawford	17	126,000	135	
Crittenden	0	24,200	0	
Cross	6	49,500	121	
Dallas	76	372,600	204	
Desha	0	122,800	0	
Drew	77	378,300	204	
Faulkner	30	145,300	206	
Franklin	15	106,600	141	
Fulton	63	245,500	257	
Garland	27	218,200	124	
Grant	113	346,800	326	
Greene	7	52,900	132	
Hempstead	49	279,500	175	
Hot Springs	107	288,200	371	
Howard	37	244,600	151	
Independence	63	243,600	259	
Izard	49	240,000	204	
Jackson	6	65,000	92	
Jefferson	66	174,900	377	

Table 4.--Arkansas (cont'd.)

County	9-Year Averages, 1967-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Johnson	12	124,500	96	
Lafayette	57	212,800	268	
Lawrence	21	100,300	209	
Lee	10	78,000	128	
Lincoln	18	142,500	126	
Little River	34	187,800	181	
Logan	21	158,500	132	
Lonoke	4	91,800	44	
Madison	37	302,200	122	
Marion	44	259,700	169	
Miller	76	208,100	365	
Mississippi	0	20,400	0	
Monroe	20	128,300	156	
Montgomery	3	109,200	27	
Nevada	44	292,800	150	
Newton	28	275,600	102	
Ouachita	88	374,400	235	
Perry	26	177,400	147	
Phillips	13	64,000	203	
Pike	21	310,000	68	
Poinsett	3	61,100	49	
Polk	38	255,500	149	
Pope	23	153,000	150	
Prairie	9	126,700	71	
Pulaski	56	223,900	250	
Randolph	39	179,600	217	
Saline	64	319,500	200	
Scott	18	98,300	183	
Searcy	36	279,400	129	
Sebastian	30	87,800	342	
Sevier	31	260,200	119	
Sharp	65	255,300	255	
Stone	52	263,400	197	
St. Francis	28	55,400	505	
Union	114	571,500	199	

Table 4.--Arkansas (cont'd.)

County	9-Year Averages, 1967-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Van Buren	29	271,200	107	
Washington	38	299,800	127	
White	43	207,500	207	
Woodruff	4	77,400	52	
Yell	13	174,400	75	

1/ Data not available for counties prior to 1967.

Table 5.--Florida

County	9-Year Averages, 1966-68; 1970-75[1]			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Alachua	190	384,443	494	347
Baker	157	279,545	562	305
Bay	132	434,577	304	266
Bradford	137	146,432	936	677
Broward[2]	75	526,829	142	NA
Calhoun	48	320,004	150	183
Charlotte	161	370,006	435	379
Citrus[3]	197	287,314	686	NA
Clay	196	326,614	600	437
Collier	199	942,713	211	344
Columbia	125	302,368	413	307
Dade	171	409,249	418	7
Dixie	136	404,500	336	293
Duval	362	439,843	823	814
Escambia	200	334,840	597	672
Flagler	55	288,824	190	126
Franklin	41	312,388	131	91
Gadsden	79	244,788	323	383
Gilchrist	34	153,969	221	191
Glades	38	337,443	113	88
Gulf	69	340,081	203	123
Hamilton	57	268,828	212	188
Hendry	30	364,601	82	204
Hernando	135	268,224	503	343
Highlands	152	404,519	376	117
Hillsborough	344	528,698	651	560
Holmes	99	229,070	432	342
Indian River	112	187,896	596	420
Jackson	103	374,741	275	190
Jefferson	55	281,491	195	155
Lafayette	31	299,173	104	NA
Lake	180	377,044	477	326
Lee	201	440,130	457	435
Leon	86	236,675	363	333
Levy	141	576,098	245	209

Table 5.--Florida (cont'd.)

County	9-Year Averages, 1966-68; 1970-75			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Liberty	34	243,222	140	126
Madison	67	325,558	206	188
Manatee	71	340,279	209	212
Marion	230	616,360	373	268
Nassau	119	389,321	306	265
Okalossa	99	321,941	308	277
Okeechobee	69	298,289	231	NA
Orange	222	434,136	511	491
Osceola 2/	120	695,999	172	NA
Palm Beach 3/	169	597,635	283	NA
Pinellas	143	134,816	1061	1084
Polk	435	739,515	588	NA
Putnam	114	428,323	266	292
St. Johns	172	338,106	509	391
St. Lucie	94	203,620	462	NA
Santa Rosa	249	528,848	471	597
Sarasota	61	272,952	223	361
Seminole	137	140,720	974	887
Sumter	88	254,413	346	305
Suwannee	86	251,214	342	221
Taylor	158	619,445	255	193
Union	30	127,715	235	207
Volusia	283	631,352	448	420
Wakulla	49	118,630	413	381
Walton	141	504,001	280	251
Washington	73	325,678	224	208

1/ Data for counties not available for 1969.

2/ Came under protection in 1970.

3/ Came under protection in 1968.

Table 6.--Georgia

County	10-Year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Appling	92	247,510	372	301
Atkinson[1/]	60	171,943	349	314
Bacon	64	129,070	496	393
Baker	60	175,060	343	NA
Baldwin	72	190,140	379	240
Banks[1/]	33	117,529	281	369
Barrow[1/]	36	66,857	538	298
Bartow	135	206,220	655	448
Ben Hill	47	113,610	414	359
Berrien	84	209,590	401	295
Bibb	126	166,750	756	594
Bleckley	35	75,650	463	371
Brantley	88	254,250	346	178
Brooks	62	189,680	327	210
Bryan	88	135,490	649	360
Bulloch	127	257,490	493	381
Burke	117	319,440	366	501
Butts	42	123,390	340	489
Calhoun	28	122,990	228	396
Camden	80	343,370	233	173
Candler	45	96,160	468	530
Carroll	154	239,340	643	666
Catoosa	47	64,140	733	525
Charlton	77	330,450	233	156
Chatham	99	152,980	647	600
Chattahoochee	11	37,140	296	261
Chattooga	95	148,500	640	444
Cherokee	143	229,600	623	463
Clarke	39	66,790	584	354
Clay[1/]	12	85,814	140	175
Clayton	71	80,720	814	1081
Clinch	123	520,200	236	NA
Cobb	78	148,780	524	1035
Coffee	105	294,100	357	314
Colquitt	100	161,970	617	498

Table 6.--Georgia (cont'd.)

County	10-Year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Columbia	59	144,610	408	230
Cook	55	87,120	631	423
Coweta	67	223,980	299	374
Crawford	50	237,840	210	225
Crisp	61	110,680	551	413
Dade	102	85,960	1187	694
Dawson	42	104,390	402	196
Decatur	112	253,270	442	329
DeKalb	51	93,640	545	1082
Dodge	75	223,780	335	370
Dooly 1/	37	102,629	361	413
Dougherty	37	111,550	332	267
Douglas 1/	74	100,671	735	761
Early	50	178,160	281	219
Echols	59	256,240	230	88
Effingham	126	259,340	486	280
Elbert	64	189,070	338	231
Emanuel	142	314,950	451	475
Evans	31	64,010	484	386
Fannin	46	156,430	294	345
Fayette 1/	43	93,043	462	1081
Floyd	115	224,810	512	671
Forsyth	61	116,350	524	450
Franklin	28	112,980	248	231
Fulton	126	183,900	685	707
Gilmer	36	229,710	157	138
Glascock	36	120,640	298	NA
Glynn	96	196,460	489	588
Gordon	60	137,630	436	346
Grady 2/	57	172,733	330	214
Greene	35	228,930	153	103
Gwinnett	131	199,490	657	583
Habersham	42	146,590	287	168
Hall	121	214,310	565	369
Hancock 1/	43	273,457	157	240

County	10-Year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Haralson	150	197,920	758	672
Harris	75	251,770	298	281
Hart[1/]	16	69,386	231	231
Heard	43	186,080	231	259
Henry[1/]	57	140,886	405	489
Houston	47	170,930	275	305
Irwin	43	139,000	309	230
Jackson	63	159,430	395	298
Jasper	32	224,560	142	220
Jeff Davis	94	230,880	407	336
Jefferson[1/]	46	203,971	226	286
Jenkins	73	147,220	496	608
Johnson	77	210,580	366	NA
Jones[1/]	30	187,071	160	220
Lamar	63	184,650	341	633
Lanier[1/]	73	86,514	844	NA
Laurens	131	321,610	407	266
Lee	52	114,240	455	425
Liberty	224	224,310	999	822
Lincoln	22	89,360	246	169
Long[1/]	81	212,329	381	287
Lowndes	150	225,810	664	338
Lumpkin	32	118,080	271	196
McDuffie	32	142,650	224	182
McIntosh	176	203,760	864	NA
Macon	41	187,240	219	228
Madison[1/]	52	107,600	483	231
Marion	47	191,810	245	203
Meriwether	66	249,260	265	250
Miller	43	106,400	404	405
Mitchell[1/]	65	143,943	452	514
Monroe	72	223,414	322	212
Montgomery	82	179,410	457	314
Morgan	36	196,080	184	234
Murray	49	132,040	371	261

Table 6.--Georgia (cont'd.)

County	10-Year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Muscogee	20	57,040	351	1203
Newton	70	137,800	508	647
Oconee 1/	17	75,371	226	354
Oglethorpe	35	219,660	159	88
Paulding	93	173,360	536	506
Peach 1/	29	45,743	634	NA
Pickens 2/	132	126,233	1046	542
Pierce	69	149,130	463	341
Pike 1/	28	99,300	282	509
Polk 1/	102	153,271	665	532
Pulaski 1/	19	93,229	204	305
Putnam	30	156,390	192	133
Quitman 3/	27	161,589	167	NA
Rabun	14	77,730	180	122
Randolph	29	217,770	133	209
Richmond	84	108,880	771	524
Rockdale 1/	30	58,071	517	647
Schley 1/	12	74,129	162	NA
Screven	87	257,790	337	338
Seminole 1/	27	79,600	339	340
Spalding 1/	36	83,371	432	509
Stephens 1/	32	60,429	530	288
Stewart 4/	29	259,412	112	100
Sumter	59	169,830	347	460
Talbot	41	224,480	183	173
Taliaferro 1/	21	110,371	190	103
Tattnall	56	220,420	254	233
Taylor 1/	69	206,614	334	186
Telfair 1/	106	214,914	493	336
Terrell 1/	25	105,200	238	209
Thomas	102	207,020	493	302
Tift	47	93,900	501	398
Toombs	96	146,160	657	555
Towns 1/	9	40,786	221	NA
Treutlen 1/	60	90,143	666	376

Table 6.--Georgia (cont'd.)

County	10-Year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Troup[2/]	64	217,100	295	290
Turner[5/]	67	97,425	688	398
Twiggs	90	279,100	322	331
Union[1/]	16	78,543	204	NA
Upson[1/]	56	181,786	308	361
Walker	73	202,170	361	411
Walton[1/]	50	130,886	382	234
Ware	147	352,100	417	295
Warren[1/]	17	132,757	128	182
Washington[1/]	51	316,971	161	224
Wayne	104	354,050	294	231
Webster[1/]	16	94,543	169	100
Wheeler[1/]	59	153,129	385	314
White[1/]	6	98,229	61	168
Whitfield	62	107,020	579	551
Wilcox	76	162,630	467	488
Wilkes	29	229,430	126	67
Wilkinson[1/]	47	257,771	182	149
Worth	83	189,150	439	403

1/ Data unavailable for 1966-68 because of county combinations.

2/ Data unavailable for 1968 because of combinations.

3/ Came under protection in 1967.

4/ Data unavailable for 1967 because of combinations.

5/ Data unavailable for 1966 and 1967 because of combinations.

Table 7.--Kentucky

County	10-Year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Adair	10	104,900	95	182
Allen	3	83,500	36	NA
Anderson	2	34,000	59	NA
Ballard	4	46,270	86	NA
Barren	2	40,884	41	NA
Bath	3	41,861	72	165
Bell	38	179,169	212	324
Boone	1	44,283	23	NA
Bourbon	0	5,100	0	NA
Boyd	18	57,100	315	392
Boyle	5	25,098	199	NA
Bracken	0	39,300	0	NA
Breathitt	77	266,825	289	333
Breckinridge	18	158,600	113	169
Bullitt	14	74,000	189	237
Butler	17	134,900	126	150
Caldwell	10	78,735	127	219
Calloway	15	76,262	197	259
Campbell	1	23,700	42	NA
Carlisle	2	42,400	47	NA
Carroll	1	26,019	38	NA
Carter	76	179,820	423	430
Casey	24	152,700	157	298
Christian	16	123,300	130	208
Clark	2	12,000	167	NA
Clay	59	207,889	284	399
Clinton	6	52,700	114	200
Crittenden	10	87,200	115	254
Cumberland	27	115,700	233	259
Daviess	6	70,000	86	NA
Edmonson	17	80,840	240	NA
Elliott	23	113,450	203	269
Estill	25	120,704	207	213
Fayette	0	5,500	0	NA
Fleming	5	60,100	83	115

Table 7.--Kentucky (cont'd.)

County	10-Year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Floyd	93	180,406	516	690
Franklin	4	44,285	90	NA
Fulton	2	32,300	62	NA
Gallatin	2	19,500	103	NA
Garrard	3	23,800	126	NA
Grant	2	38,282	52	NA
Graves	15	80,200	187	290
Grayson	17	121,077	140	NA
Green	9	59,700	151	NA
Greenup	40	154,567	259	342
Hancock	5	56,300	89	214
Hardin	20	112,049	178	341
Harlan	55	255,043	216	292
Harrison	1	33,400	30	NA
Hart	16	111,800	143	250
Henderson	2	60,578	33	NA
Henry	2	43,800	46	NA
Hickman	3	37,882	79	NA
Hopkins	22	165,600	133	343
Jackson	17	108,465	157	134
Jefferson	2	33,400	60	NA
Jessamine	0	12,100	0	NA
Johnson	52	136,700	380	548
Kenton	2	27,668	72	NA
Knott	75	195,000	385	375
Knox	59	177,578	332	451
Larue	10	55,300	181	NA
Laurel	21	137,910	152	142
Lawrence	49	221,900	221	288
Lee	37	102,239	362	266
Leslie	44	195,613	225	441
Letcher	63	181,600	347	376
Lewis	24	225,900	106	141
Lincoln	15	58,200	258	NA
Livingston	7	73,278	96	259

Table 7.--Kentucky (cont'd.)

County	10-Year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Logan	7	109,300	64	101
Lyon	9	77,347	116	240
McCracken	6	37,219	161	258
McCreary	15	86,678	173	251
McLean	3	45,400	66	276
Madison	8	43,842	182	NA
Magoffin	57	159,400	358	398
Marion	11	82,200	134	NA
Marshall	8	63,620	126	235
Martin	48	128,400	374	625
Mason	0	18,500	0	NA
Meade	11	78,500	140	244
Menifee	7	78,042	90	100
Mercer	1	17,497	57	NA
Metcalfe	5	87,500	57	161
Monroe	15	98,397	152	239
Montgomery	6	18,500	324	NA
Morgan	43	164,198	262	313
Muhlenberg	23	139,970	164	331
Nelson	4	115,757	35	69
Nicholas	0	23,800	0	NA
Ohio	22	194,800	113	166
Oldham	1	22,000	45	NA
Owen	4	80,416	50	NA
Owsley	30	91,588	328	377
Pendleton	1	49,830	20	NA
Perry	126	185,474	609	679
Pike	93	427,552	218	275
Powell	12	68,254	176	224
Pulaski	17	183,635	93	184
Robertson	0	16,190	0	NA
Rockcastle	25	128,081	195	241
Rowan	16	90,739	176	177
Russell	8	60,300	133	340
Scott	2	25,400	79	NA

Table 7.--Kentucky (cont'd.)

County	10-Year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Shelby	1	31,300	32	NA
Simpson	0	23,200	0	NA
Spencer	0	24,500	0	NA
Taylor	12	65,200	184	202
Todd	5	61,098	82	43
Trigg	12	135,640	88	140
Trimble	1	34,300	29	NA
Union	2	43,225	46	NA
Warren	15	90,200	166	NA
Washington	1	46,789	21	NA
Wayne	13	166,925	78	112
Webster	13	66,227	196	NA
Whitley	37	194,134	191	176
Wolfe	13	92,108	141	203
Woodford	1	8,600	116	NA

Table 8.--Louisiana

County	10-Year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Allen	540	367,080	1471	1621
Avoyelles	7	131,600	53	900
Beauregard	671	661,000	1015	956
Bienville	62	437,000	142	216
Bossier	92	398,000	231	297
Caddo	157	353,000	445	552
Calcasieu	148	244,000	607	722
Caldwell	54	305,000	177	146
Catahoula	48	100,000	480	325
Claiborne	51	366,000	139	264
Concordia	4	314,000	13	55
DeSoto	39	428,000	91	223
E. Baton Rogue	9	55,000	164	222
E. Carroll[1/]	1	109,000	9	52
E. Feliciana	36	161,000	224	219
Evangeline	165	220,000	750	1715
Franklin	8	144,000	56	151
Grant	42	221,000	190	189
Jackson	27	335,000	81	166
Jefferson Davis	3	20,000	150	325
LaSalle	98	374,000	262	322
Lincoln	31	218,000	142	280
Livingston	559	358,000	1561	2454
Madison	3	245,000	12	51
Morehouse	28	125,000	224	321
Natchitoches	87	484,000	180	204
Ouachita	44	301,000	146	204
Rapides	280	520,000	538	531
Red River	26	174,000	149	171
Richland[1/]	11	149,000	74	192
Sabine	176	530,000	332	200
St. Helena	495	203,000	2438	1749
St. Tammany	750	405,000	1852	1469
Tangipahoa	468	346,000	1353	1073
Tensas	5	230,000	22	45

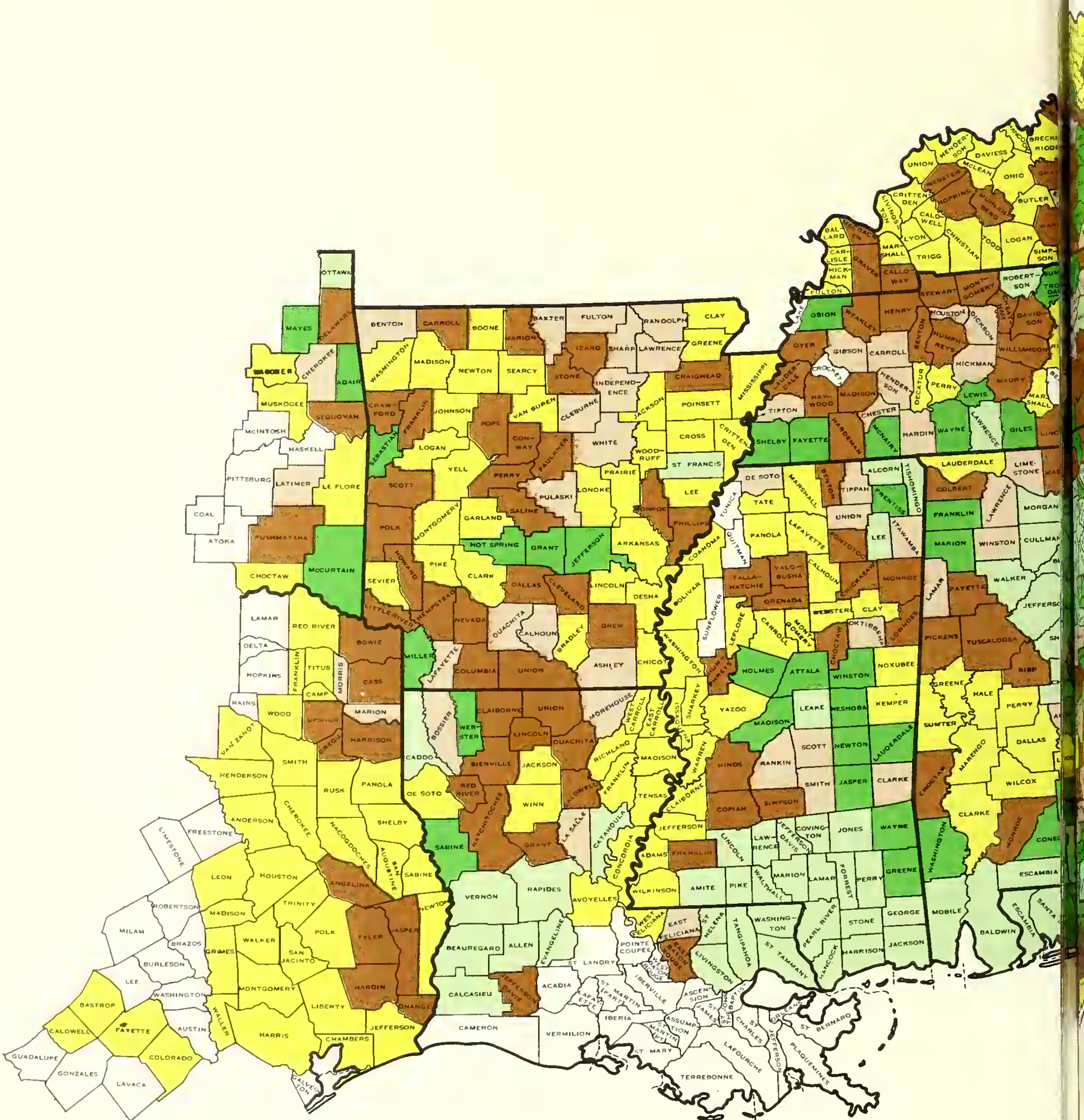
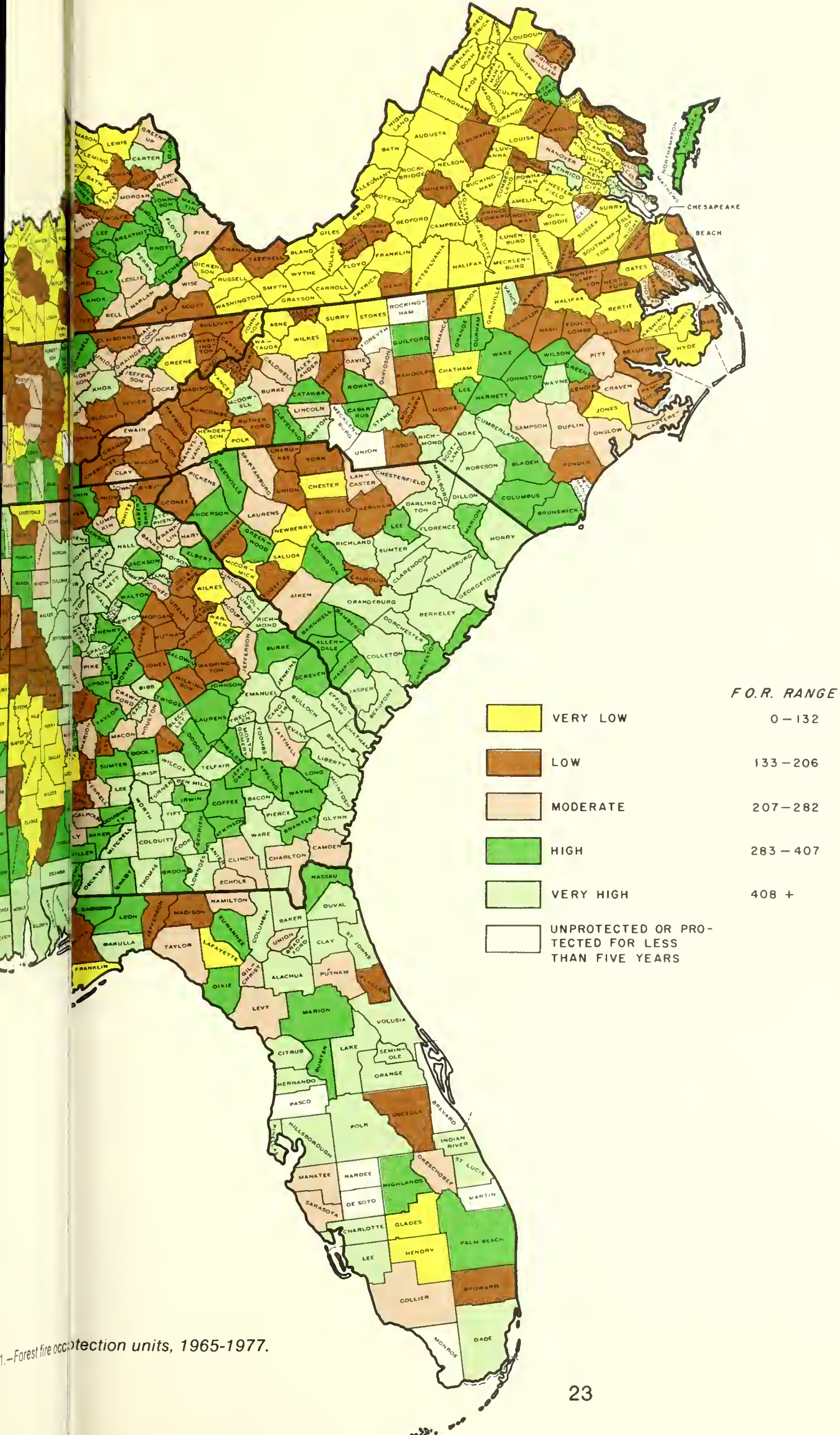


Figure 1.—*Forest fire occ*



1.—Forest fire occ tection units, 1965-1977.

Table 8.--Louisiana (cont'd.)

County	10-Year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Union	68	490,000	139	164
Vernon	319	568,000	562	536
Washington	201	281,000	715	489
Webster	87	286,000	304	388
W. Carroll	2	68,000	29	166
W. Feliciana	10	179,000	56	NA
Winn	52	457,000	114	197

1/ Data not available for 1972-1975.

Table 9.--Mississippi

County	10-Year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Adams	6	142,000	42	232
Alcorn	129	160,600	803	975
Amite	147	330,200	445	558
Attala	128	354,100	361	576
Benton	22	155,200	142	192
Bolivar	4	135,600	29	NA
Calhoun	25	258,400	97	169
Carroll	39	300,900	130	253
Chickasaw	38	215,900	144	234
Choctaw	39	209,200	186	263
Claiborne	8	232,800	34	74
Clarke	92	366,200	251	321
Clay	20	158,600	126	166
Coahoma[1/]	2	78,125	26	NA
Copiah	67	381,700	176	152
Covington	83	191,900	433	779
DeSoto	21	95,800	219	443
Forrest	171	170,800	1001	1651
Franklin	34	229,100	148	NA
George	140	238,000	588	944
Greene	133	382,500	348	453
Grenada	30	161,500	186	286
Hancock	286	247,200	1157	800
Harrison	396	219,600	1803	1738
Hinds	42	216,000	194	271
Holmes	87	282,100	308	529
Humphreys	10	65,600	152	590
Issaquena	6	167,600	36	95
Itawamba	66	266,000	248	318
Jackson	161	355,300	453	669
Jasper	94	332,000	283	424
Jefferson	15	254,400	59	162
Jefferson Davis	108	168,300	642	910
Jones	131	296,200	442	769
Kemper	48	392,100	122	175

Table 9.--Mississippi (cont'd.)

County	10-Year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Lafayette	31	272,000	114	209
Lamar	221	262,900	841	1639
Lauderdale	106	285,900	371	468
Lawrence	104	210,000	495	857
Leake	151	260,400	580	852
Lee	56	130,400	429	503
Leflore	7	132,000	53	169
Lincoln	198	280,700	705	810
Lowndes	33	160,100	206	283
Madison	44	139,900	315	687
Marion	108	253,000	427	694
Marshall	28	271,600	103	196
Monroe	47	277,400	169	237
Montgomery	21	198,700	106	182
Neshoba	81	240,700	337	574
Newton	89	258,000	345	479
Noxubee	16	279,500	57	NA
Oktibbeha	32	138,000	232	276
Panola	18	208,800	86	144
Pearl River	219	400,300	547	675
Perry	88	155,000	568	1077
Pike	109	171,600	635	705
Pontotoc	41	215,400	190	351
Prentiss	54	185,800	291	369
Rankin	83	348,100	238	313
Scott	60	221,300	271	295
Sharkey	6	51,300	117	236
Simpson	53	272,200	195	395
Smith	68	264,600	257	360
Stone	93	194,700	478	532
Tallahatchie	28	202,400	138	170
Tate	19	157,600	121	181
Tippah	53	199,000	266	332
Tishomingo	101	223,900	451	420
Union	35	166,200	211	259

Table 9.--Mississippi (cont'd.)

County	10-Year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Walthall	54	121,500	444	494
Warren	12	284,200	42	50
Washington	6	67,300	89	300
Wayne	109	368,700	296	481
Webster	24	202,700	118	178
Wilkinson	27	328,200	82	NA
Winston	91	248,000	367	424
Yalobusha	26	192,800	135	277
Yazoo	30	311,600	96	203

1/ Came under protection in 1968.

Table 10.--North Carolina

County	10-Year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Alamance	27	128,900	209	172
Alexander	23	98,800	233	169
Alleghany	10	66,100	151	110
Anson	39	240,600	162	130
Ashe	18	149,500	120	54
Avery	17	105,200	162	184
Beaufort	69	354,200	195	127
Bertie	35	321,010	109	64
Bladen	133	457,800	291	292
Brunswick	139	461,200	301	298
Buncombe	54	262,400	206	178
Burke	45	201,000	224	175
Cabarrus	35	99,800	351	81
Caldwell	42	178,400	235	133
Camden	16	103,210	155	102
Carteret	41	173,300	237	170
Caswell	29	184,000	158	121
Catawba	36	123,000	293	160
Chatham	41	343,600	119	115
Cherokee	35	174,200	201	214
Chowan	17	68,600	248	125
Clay	12	55,800	215	151
Cleveland	42	127,500	329	181
Columbus	152	422,100	360	354
Craven	69	291,900	236	170
Cumberland	156	222,900	700	779
Dare	37	181,400	204	65
Davidson	39	178,000	219	189
Davie	17	74,900	227	NA
Duplin	71	339,000	209	216
Durham	38	113,300	335	505
Edgecombe	33	160,500	206	180
Franklin	37	185,000	200	134
Gaston	59	122,600	481	407
Gates	12	162,800	74	74

Table 10.--North Carolina (cont'd.)

County	10-Year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Graham	10	65,600	152	241
Granville	19	225,500	84	87
Greene	26	82,400	316	297
Guilford	61	191,800	318	265
Halifax	28	273,000	103	147
Harnett	76	244,000	311	291
Haywood	25	140,700	178	182
Henderson	13	143,400	91	69
Hertford	21	149,400	141	131
Hoke	88	91,700	960	644
Hyde	14	257,500	54	53
Iredell	27	157,100	172	107
Jackson	36	224,300	160	120
Johnston	67	216,400	310	267
Jones	19	197,400	96	97
Lee	38	111,000	342	206
Lenoir	21	139,000	151	153
Lincoln	26	94,100	276	344
McDowell	95	166,000	572	178
Macon	21	132,700	158	115
Madison	28	170,400	164	124
Martin	27	200,900	134	93
Mitchell	16	95,300	168	195
Montgomery	34	233,800	145	114
Moore	67	366,800	183	77
Nash	34	180,000	189	237
Northampton	28	206,800	135	133
Onslow	70	295,900	237	311
Orange	44	154,500	285	295
Pamlico	28	143,300	195	157
Pasquotank	21	81,800	257	144
Pender	81	466,100	174	186
Perquimans	16	101,200	158	90
Person	20	155,400	129	NA
Pitt	54	216,400	250	225

Table 10.--North Carolina (cont'd.)

County	10-Year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Polk	9	110,900	81	94
Randolph	41	306,900	134	117
Richmond	122	220,900	552	283
Robeson	158	318,100	497	666
Rowan	53	138,400	383	166
Rutherford	36	255,700	141	80
Sampson	97	395,100	246	246
Scotland	84	102,800	817	398
Stanly	53	111,200	477	206
Stokes	15	183,000	82	68
Surry	18	193,500	93	63
Swain	15	68,500	219	123
Transylvania	27	128,900	209	162
Tyrrell	9	221,000	41	31
Vance	38	89,300	426	546
Wake	93	317,700	293	334
Warren	28	192,800	145	101
Washington	12	148,700	81	72
Watauga	10	120,700	83	93
Wayne	66	157,330	420	340
Wilkes	34	366,300	93	69
Wilson	33	113,300	291	278
Yadkin	16	99,200	161	150
Yancey	14	121,400	115	105

Table 11.--Oklahoma

County	6-Year Averages, 1970-1975[1]			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Adair	88	281,547	313	NA
Cherokee	92	380,480	242	NA
Choctaw	5	94,950	53	NA
Delaware	64	338,147	189	NA
Latimer	89	416,707	214	NA
LeFlore	53	662,147	80	NA
McCurtain	276	949,987	291	NA
Mayes	28	88,587	316	NA
Muskogee	1	34,863	29	NA
Ottawa	6	7,919	758	NA
Pushmataha	128	819,607	156	NA
Sequoyah	56	326,080	172	NA
Wagoner	0	4,480	0	NA

[1] Data for counties not available prior to 1970.

Table 12.--South Carolina

County	10-Year Averages, 1966-1975[1/]			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Abbeville	32	194,361	165	143
Aiken	128	477,331	268	324
Allendale	61	190,786	320	268
Anderson	63	211,031	299	303
Bamberg	56	154,407	363	344
Barnwell	65	161,433	403	584
Beaufort	77	170,405	452	283
Berkeley	314	404,049	777	616
Calhoun	24	131,757	182	173
Charleston	84	264,643	317	482
Cherokee	28	149,092	188	178
Chester	28	262,651	107	139
Chesterfield	101	359,570	281	183
Clarendon	202	225,189	897	796
Colleton	216	500,875	431	312
Darlington	110	177,189	621	503
Dillon	75	146,786	511	460
Dorchester	123	282,250	436	332
Edgefield	28	196,105	143	165
Fairfield	55	375,414	146	118
Florence	295	291,549	1012	717
Georgetown	180	389,793	462	283
Greenville	81	286,608	283	509
Greenwood	58	175,510	330	174
Hampton	114	283,378	402	266
Horry	268	494,462	542	358
Jasper	194	277,557	699	358
Kershaw	80	419,876	191	195
Lancaster	53	230,775	230	205
Laurens	65	276,837	235	216
Lee	45	117,215	384	502
Lexington	117	302,394	387	241
Marion	76	228,579	332	200
Marlboro	110	174,497	630	646
McCormick	19	143,541	132	150

Table 12.--South Carolina (cont'd.)

County	10-Year Averages, 1966-1975[1/]			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Newberry	24	232,222	103	105
Oconee	42	233,784	180	201
Orangeburg	207	377,160	549	740
Pickens	48	217,575	221	258
Richland	174	311,022	559	524
Saluda	16	182,185	88	136
Spartanburg	53	242,131	219	281
Sumter	148	231,546	639	652
Union	29	206,601	140	207
Williamsburg	317	410,339	773	512
York	49	277,440	177	336

[1/] All entries are for the period July 1, 1965 to June 30, 1975.

Table 13.--Tennessee

County	10-Year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Anderson	28	134,780	208	334
Benton	31	165,700	187	199
Bledsoe	83	193,800	428	343
Blount	18	114,980	157	241
Bradley	16	127,400	126	235
Campbell	65	222,680	292	308
Cannon	28	91,800	305	395
Carroll	32	152,150	210	300
Carter	13	73,600	177	238
Cheatham	23	121,100	190	234
Chester	22	94,950	232	209
Claiborne	28	168,740	166	156
Clay	16	102,900	155	308
Cocke	28	122,020	229	268
Coffee	28	139,100	201	374
Cumberland	54	353,700	153	123
Davidson	23	120,000	192	325
Decatur	18	142,450	126	132
DeKalb 1/	23	88,200	261	NA
Dickson	46	188,800	244	257
Dyer	15	80,450	186	NA
Fayette	44	111,000	396	392
Fentress	46	252,000	183	293
Franklin	70	198,000	354	333
Gibson	16	63,350	253	NA
Giles	52	163,200	319	525
Grainger	25	99,040	252	216
Greene	7	100,100	70	92
Grundy	97	193,500	501	551
Hamblen 2/	8	25,200	317	NA
Hamilton	147	209,200	703	1065
Hancock	21	86,600	242	NA
Hardeman	28	211,300	133	202
Hardin	54	224,400	241	285
Hawkins	40	161,820	247	175

Table 13.--Tennessee (cont'd.)

County	10-Year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Haywood	17	84,050	202	280
Henderson	35	164,750	212	274
Henry	24	132,650	181	261
Hickman	66	285,000	232	381
Houston	23	101,500	227	203
Humphreys	46	237,500	194	260
Jackson	27	133,100	203	541
Jefferson	15	59,220	253	NA
Johnson	4	82,760	48	66
Knox	46	106,200	433	262
Lauderdale 2/	18	95,214	189	NA
Lawrence	82	190,500	430	443
Lewis	52	152,900	340	355
Lincoln	26	142,800	182	NA
Loudon	11	53,240	207	94
McMinn	30	120,660	249	176
McNairy	66	195,700	337	394
Macon 3/	33	86,100	383	NA
Madison	21	111,600	188	376
Marion	157	252,000	623	623
Marshall 3/	8	87,000	92	NA
Maury	26	143,000	182	434
Meigs	13	70,280	185	157
Monroe	42	208,800	201	242
Montgomery	24	132,300	181	251
Moore	8	41,600	192	298
Morgan	90	294,840	305	297
Obion	28	77,350	362	NA
Overton	24	177,800	135	285
Perry	17	216,600	78	107
Pickett	9	71,500	126	NA
Polk	50	128,860	388	670
Putnam	21	148,500	141	153
Rhea	49	141,200	347	417
Roane	36	138,160	261	398

Table 13.--Tennessee (cont'd.)

County	10-Year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Robertson[2/]	33	73,200	451	NA
Rutherford	9	137,800	65	NA
Scott	60	307,700	195	231
Sequatchie	53	142,900	371	350
Sevier	27	159,620	169	269
Shelby	31	83,900	369	256
Smith	32	78,300	409	NA
Stewart	42	218,800	192	223
Sullivan	14	70,500	199	168
Sumner	31	102,400	303	416
Tipton	15	56,500	265	341
Trousdale[4/]	7	23,800	294	NA
Unicoi	6	43,860	137	256
Union	22	85,440	257	295
Van Buren	42	135,000	311	233
Warren	12	109,200	110	151
Washington[2/]	6	45,100	133	NA
Wayne	108	361,600	299	319
Weakley	12	79,450	151	307
White	15	126,200	119	210
Williamson	30	158,200	190	380
Wilson	15	128,700	117	NA

1/ Came under protection in 1968.

2/ Came under protection in 1969.

3/ Came under protection in 1967.

4/ Came under protection in 1970.

Table 14.--Texas

County	10-Year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Anderson	33	500,100	66	139
Angelina	76	511,400	149	221
Bastrop[1/]	24	434,400	55	NA
Bowie	77	577,900	133	229
Caldwell	3	95,100	32	NA
Camp	16	121,600	132	467
Cass	115	608,000	189	407
Chambers	1	37,100	27	NA
Cherokee	36	670,700	54	165
Colorado	3	271,800	11	NA
Fayette	9	254,029	35	NA
Franklin	3	101,830	29	118
Gregg	29	180,800	160	230
Grimes	6	172,500	35	46
Hardin	99	572,800	173	380
Harris	5	70,000	71	80
Harrison	80	570,900	140	506
Henderson[2/]	14	253,691	55	NA
Houston	27	720,950	37	82
Jasper	87	600,400	145	279
Jefferson	2	61,400	33	94
Lee[1/]	4	199,230	20	NA
Leon[2/]	1	345,544	3	NA
Liberty	30	532,528	56	115
Madison	0	113,284	0	10
Marion	50	240,000	208	412
Montgomery	73	693,800	105	250
Morris	22	95,306	231	438
Nacogdoches	31	597,100	52	105
Newton	53	602,200	88	161
Orange	34	203,677	167	280
Panola	37	563,200	66	134
Polk	61	700,200	87	136
Red River	21	478,856	44	105
Rusk	73	601,300	121	269

Table 14.--Texas (cont'd.)

County	10-Year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Sabine	24	354,600	68	195
San Augustine	23	352,600	65	112
San Jacinto	27	396,200	68	110
Shelby	29	524,100	55	117
Smith	44	532,842	83	266
Titus	5	207,139	24	130
Trinity	24	450,600	53	109
Tyler	83	587,500	141	230
Upshur	51	375,100	136	329
Van Zandt	5	102,405	49	NA
Walker	19	503,000	38	69
Waller	2	64,200	31	26
Wood	20	311,366	64	216

1/ Came under protection in 1970.

2/ Came under protection in 1971.

Table 15.--Virginia

County	10-Year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Accomack	36	103,860	347	326
Albemarle	38	268,440	142	171
Alleghany	11	121,315	91	82
Amelia	10	169,300	59	65
Amherst	25	166,410	150	183
Appomattox	12	158,890	76	98
Augusta	11	146,900	75	66
Bath	5	146,760	34	33
Bedford	16	297,640	54	105
Bland	5	142,928	35	44
Botetourt	16	194,450	82	87
Brunswick	24	277,840	86	113
Buchanan	39	281,260	139	173
Buckingham	20	282,010	71	67
Campbell	29	226,040	128	99
Caroline	34	210,160	162	129
Carroll	13	167,430	78	84
Charles City	9	86,840	104	137
Charlotte	15	203,200	74	75
Chesapeake	15	135,810	110	NA
Chesterfield	28	220,590	127	189
Clarke	0	33,020	0	14
Craig	3	63,800	47	50
Culpeper	12	110,670	108	90
Cumberland	15	127,400	118	89
Dickenson	20	169,340	118	132
Dinwiddie	26	237,390	110	148
Essex	11	100,910	109	124
Fairfax	15	106,410	141	207
Fauquier	17	171,130	99	126
Floyd	8	127,470	63	67
Fluvanna	12	122,410	98	86
Franklin	23	298,290	77	108
Frederick	7	145,710	48	30
Giles	11	117,310	94	94

Table 15.--Virginia (cont'd.)

County	10-Year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Gloucester	26	98,170	265	259
Goochland	25	128,870	194	131
Grayson	5	146,050	34	51
Greene	8	49,300	162	118
Greensville	19	138,220	137	175
Halifax	37	330,590	112	96
Hanover	42	202,440	207	197
Henrico	79	86,810	910	1779
Henry	26	171,480	152	172
Highland	3	142,920	21	23
Isle of Wight	15	118,930	126	185
James City	28	68,670	408	269
King and Queen	11	157,890	70	49
King George	9	78,170	115	95
King William	5	129,440	39	25
Lancaster	7	47,310	148	103
Lee	26	150,180	173	193
Loudoun	7	99,100	71	92
Louisa	19	232,080	82	65
Lunenburg	18	202,670	89	71
Madison	7	91,440	77	65
Mathews	11	29,680	371	270
Mecklenburg	20	220,860	91	109
Middlesex	8	53,980	148	114
Montgomery	20	141,450	141	150
Nansemond	28	164,940	170	169
Nelson	23	215,330	107	118
New Kent	13	107,950	120	94
Northhampton	10	32,760	305	418
Northumberland	11	77,250	142	129
Nottoway	21	118,680	177	143
Orange	13	131,830	99	91
Page	8	68,700	116	150
Patrick	12	227,640	53	104
Pittsylvania	26	397,070	65	58

Table 15.--Virginia (cont'd.)

County	10-Year Averages, 1966-1975			F.O.R. 1956-65
	No. Fires	Acres Protected	F.O.R.	
Powhatan	8	124,460	64	45
Prince Edward	24	154,300	156	158
Prince George	18	124,040	145	235
Prince William	21	87,060	241	196
Pulaski	8	91,410	88	154
Rappahannock	4	65,790	61	90
Richmond	8	80,400	100	75
Roanoke	18	113,430	159	244
Rockbridge	8	188,860	42	56
Rockingham	9	143,600	63	35
Russell	13	157,060	83	114
Scott	28	184,840	151	97
Shenandoah	2	110,630	18	18
Smyth	8	113,690	70	102
Southampton	12	255,770	47	71
Spotsylvania	37	195,510	189	122
Stafford	31	101,910	304	240
Surry	6	135,600	44	67
Sussex	17	247,900	69	79
Tazewell	29	193,270	150	240
Virginia Beach	8	47,230	169	NA
Warren	1	65,500	15	56
Washington	13	163,620	79	87
Westmoreland	14	87,990	159	107
Wise	39	181,840	214	231
Wythe	7	104,410	67	51
York	14	32,420	432	347

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Research Note

SO-228

1977

Spring Burn Aids Longleaf Pine Seedling Height Growth

WILLIAM R. MAPLE

SUMMARY

Prescribed burning in midspring may stimulate height growth of longleaf pine seedlings. Seedlings were planted on sandy and clayey sites that were prescribed burned 2 years later. Treatments were cool, moderate, and hot burns and an unburned control. The hot, May burn significantly increased height growth of seedlings on the sandy site. The number of seedlings with 50 percent or more brown-spot infection was reduced on both sites after the fires, and the hot and moderate burns were better than the cool burn.

Additional keywords: *Pinus palustris* Mill., brown-spot needle blight, *Scirrhia acicola*, planting.

Spring burns may stimulate height growth by longleaf pine (*Pinus palustris* Mill.) seedlings on some sites, a possibility suggested by follow-up observations on a burning study reported earlier (Croker 1975). The study was established on the Escambia Experimental Forest in southwest Alabama to determine the effect of hot, moderate, and cool prescribed fires on survival of grass-stage longleaf pine seedlings. Two years after burning, an inspection of the plots revealed that many seedlings were beginning height growth where fires had been set. The effects of the fires on height growth of seedlings and on brown-spot infection are reported here.

METHODS

Six blocks of plots were established for this study. Three were on a sandy soil characterized by loamy sand to a depth of 5 feet or more, and classified as Alaga soil series. The other three were on a heavier soil, classified as Dothan soil series, with loamy sand or sandy loam surface soils underlain by a sandy clay loam subsoil at 12 to 14 inches.

Each block was a rectangular clearing in longleaf pine stands of sawtimber size. These clearings, about 2 chains wide and 6 chains long, were oriented in a north-south direction. Each block was divided into four 0.2 acre plots extending from wall to wall across the clearing. Three intensities of fire and an unburned check were randomly assigned among plots in each block. Four transects, each 3 feet apart, extended perpendicularly from the east-facing timber wall on each plot. Ten Grade one, 1-0 longleaf seedlings were planted at 6-foot intervals along each transect.

Burning treatments were applied in 1973, the second year after planting. Weather at the time of setting the fires is shown in table 1. Although the burning treatments were designated as cool, moderate, and hot, the intensity of these fires was modified by lighter rough and higher fuel moisture and relative humidity than would normally be expected with these classifications.

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Table 1.—*Weather conditions when burns were made.*

Item	Cool	Moderate	Hot
Date	1-11-73	1-15-73	5-10-73
Time	12 noon-1:30 p.m.	10:00 a.m.-1:00 p.m.	1:00 p.m.-3:35 p.m.
Last previous rain			
Date	1-11-73 (before the burn)	1-12-73	5-08-73
Amount, inch	0.12	0.02	0.50
Humidity, percent	55	65-32	40-35
Temperature, °F	48	55	85
Sky	Cloudy	Clear	Clear
Wind			
Mph	2-5	0-7	Light
Direction	NE	NW	Variable

Height of surviving seedlings was measured to the nearest 0.1 foot in January 1975, 2 years after burning (4 years from planting). Longleaf pine seedlings with 50 percent or more of the needles infected with brown-spot disease (*Scirrhia acicola* (Dearn.) Siggers) were also tallied at that time. Treatment effects on seedling height and brown-spot infection were evaluated by analysis of variance.

RESULTS AND DISCUSSION

Contrary to expectations, the spring burn did not significantly reduce seedling survival (Croker 1975). Seedlings on sandy sites burned in May were significantly taller two years after burning than those in any other soil-burn treatment combination (table 2). Also, a higher proportion of the seedling stand was in active height growth. Grelen (1975) reported that after 12 years of study, longleaf pines periodically burned in May were significantly taller than seedlings on unburned areas and taller than those burned in March or July. Why a spring burn should stimulate longleaf seedling height growth is not known. Further research and testing are needed to find reasons for this response and the conditions under which it occurs.

Two years after burning, the percentage of seedlings with half or more of their foliage destroyed by brown-spot was significantly greater on the unburned plots (28%) than on the burned. Cool-burned plots had significantly more seedlings with high brown-spot (16%) than plots receiving the other burning treatments. Only five percent of the seedlings on plots burned with moderate fires in winter and hot fires in spring had half or more of their needles destroyed by the disease. Soil type had no effect on these brown-spot infection levels.

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Table 2.—*Average height of longleaf pine seedlings and percent in active height growth 2 years after burning (5 years from seed).*

Fire treatment	Seedling Total Height: Sandy Soil	Seedling Total Height: Clay Soil	Seedlings in Height Growth [1]: Sandy Soil	Seedlings in Height Growth [1]: Clay Soil
	Feet		*Percent*	
Control	.29	.23	20	16
Cool	.32	.18	26	10
Moderate	.30	.21	19	19
Hot	.56	.24	38	15
Average	.37	.21	26	15

[1] Seedlings 0.5 foot or more in height to base of the terminal bud.

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Southern Forest Experiment Station

Research Note

SO-229

1977

Cottonwood Response To Nitrogen Related To Plantation Age and Site

B. G. BLACKMON

SUMMARY

When applied at plantation age 4, 336 kg N/ha increased diameter growth of cottonwood on Sharkey clay by 33 percent over unfertilized controls. Fertilizing at ages 2 and 3 resulted in no response, nor was there any benefit from applying nitrogen fertilizer to cottonwood on Commerce silt loam. On both sites, foliar N levels were increased by fertilization regardless of plantation age.

Additional keywords: Fertilization, *Populus deltoides* Bartr., growth, foliar N, rooting depth.

PROBLEM

Nitrogen deficiency can be a serious problem on medium-textured old-field soils in the Mississippi River floodplain (Blackmon and Broadfoot 1969, Blackmon and White 1972). Large responses to fertilization are now being measured on Commerce soils, when much of their indigenous soil nitrogen has been depleted.

The present study was installed primarily to determine if applying high rates of nitrogen would improve the growth of eastern cottonwood (*Populus deltoides* Bartr.) on a recently sheared Commerce silt loam and on an old-field Sharkey clay. The study also allowed an investigation of the relationship between plantation age and responses to nitrogen.

METHODS

Plantations were established in 1967, 1968, and 1969 on Commerce silt loam (Aeric Fluvaquent) which recently had been sheared of timber and on Sharkey clay (Vertic Haplaquept) which previously had been in agriculture. Both soils developed from Mississippi River alluvium. Plantings originally were made at about 3 X 3-meter spacing. In the fall of 1970, every other row was removed, leaving a spacing of 3 X 6 meters.

Average tree heights and diameters at the time of fertilization were as follows:

Age	Sharkey clay		Commerce silt loam	
	Height (m)	DBH (cm)	Height (m)	DBH (cm)
2	3.3	2.8	6.3	7.4
3	5.3	5.6	11.8	10.7
4	6.8	7.9	13.6	12.4

Ammonium nitrate fertilizer at 0, 336, and 672 kilograms of nitrogen per hectare was broadcast onto the soil surface in April 1971. The study areas, including controls, were disked immediately following treatment and maintained free of herbaceous vegetation by disking during the first season after treatment. The study was replicated two times on each site in a split-plot experimental design. Plantation age constituted major plots, and rates of N, subplots. Each subplot contained 15 trees and occupied 0.024 hectare.

DBH and total heights were measured at the end of the 1971 growing season. Foliage samples were taken from the mid-crown position in August of 1971, dried at 70° C, ground, and analyzed for N by the macro-Kjeldahl procedure.

DBH and height growth and foliar N were studied by analysis of variance and Duncan's new multiple range test at the 0.05 level of probability. The study was designed, installed, and recorded in English measure, but the results are reported here in metric equivalents.

RESULTS AND DISCUSSION

Nitrogen fertilizer significantly influenced diameter growth of 4-year-old trees on the Sharkey clay soil (fig. 1). Trees treated with 336 and 672 kg of N/ha grew 24 mm and 21 mm respectively, compared to 18 mm for the control. However, the 672-kg treatment was not significantly different from the control. When done at ages 2 and 3, fertilization had no significant influence on growth. Even though the trees treated at age 4 with 336 kg of N/ha were 65% taller than the controls, height growth differences were not significantly different. Neither height nor diameter responded to fertilization on the Commerce silt loam soil.

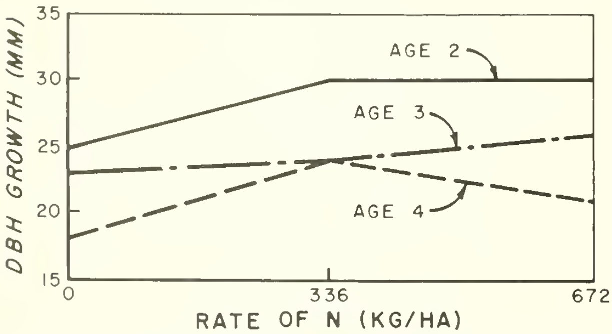

Figure 1.—*Effect of nitrogen fertilization on dbh growth of eastern cottonwood on Sharkey clay (applied at ages 2, 3, and 4).*

The actual growth responses for cottonwood on Sharkey clay were very small — 33% more dbh growth than the unfertilized controls. However, these results do indicate an important relationship between stand age and response to added nutrients. No response to treatment at age 2 and 3 probably indicates that the young trees' root systems lacked sufficient development to take advantage of the added nitrogen. Also, at these ages competition among trees was not significant, and the nitrogen demands were apparently met by indigenous soil nitrogen. But a slight response to N fertilization occurred in the 4-year-old plantation after the trees developed larger root systems and the trees began to compete for nutrients. Similar trends have been reported for irrigation responses (Rawitz, Karschon, and Mitrani 1966).

Both Sharkey clay and Commerce silt loam soils generally contain levels of soil nitrogen adequate for good cottonwood growth. However, because of poor physical conditions in Sharkey, most of the roots are confined to the upper 20 cm (Baker and Blackmon--In press). Root development is restricted and the trees are not able to extract sufficient soil nitrogen. Since rooting is usually deeper in Commerce, a greater soil volume is exploited. Thus the tree is able to meet its needs for nitrogen, and fertilization usually is not required.

On both sites fertilization significantly increased foliar N concentrations (table 1). On the clay soil fertilizer increased foliar N from 1.7% to 2.1%. On the silt loam site, foliar N was increased from 2.0% to 2.4%. Foliar N was not related to stand age on either site, nor was there a difference between the 336- and 672-kg rates.

Earlier results have shown the critical foliar N level to be about 2% for cottonwood (White and Carter 1970, Blackmon and White 1972).

B. G. Blackmon is Principal Soil Scientist at the Southern Hardwoods Laboratory, which is maintained at Stoneville, Miss., by the Southern Forest Experiment Station, Forest Service—USDA, in cooperation with the Mississippi Agricultural and Forestry Experiment Station and the Southern Hardwood Forest Research Group.

Table 1.—*Effect of nitrogen fertilization on foliar N levels in cottonwood (averaged over all three ages)*

Rate of nitrogen	Foliar nitrogen: Sharkey clay	Foliar nitrogen: Commerce silt loam
-kg/ha-	------------*percent*------------	
0	1.7a [1]	2.0a
336	2.1 b	2.4 b
672	2.1 b	2.4 b

[1]Means followed by the same letter are not significantly different by Duncan's new multiple range test (.05 level).

In the present study a growth response occurred on the clay site when foliar N levels (averaged over all ages) were increased from 1.7% to slightly above 2%. In the 4-year-old stand — the one in which the growth response was observed — control trees averaged only 1.5% foliar N. On the silt loam soil, foliar N was increased; however, N in the controls was at 2.0%, which apparently was not a deficiency level since no response occurred.

CONCLUSIONS

Even though the growth response was small, this study indicates that response to broadcast applications of N fertilizer is not likely to occur in widely spaced plantations until the site becomes fully occupied and competition for nutrients is established. Such a delayed response appeared to occur at age 4 on the Sharkey clay soil in this experiment.

The study also indicates that cottonwood growing on recently sheared, highly productive soils such as Commerce silt loam is not likely to respond even to high rates of N.

Finally, this study supports the thesis that a foliar N level of less than 2% represents a deficiency level for eastern cottonwood.

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U.S. GOVERNMENT PRINTING OFFICE 1977 774-960

Southern Forest Experiment Station

Research Note

SO-230

1977

Fertilization To Accelerate Loblolly Pine Foliage Growth For Erosion Control

PAUL D. DUFFY

SUMMARY

On the southern Coastal Plain, loblolly pine (*Pinus taeda* L.) can be used to help control erosion because it produces abundant soil-protecting litter. The species requires several years to produce enough litter for adequate soil protection, but on loamy soils fertilization can reduce the time by a year or more.

When five fertilizer combinations were tested, one application of N at 150 lb/acre together with P at 33 lb/acre, and K at 62 lb/acre was best. Seedlings fertilized with this combination produced 1.6 times the foliage weight of unfertilized seedlings through the first 2 years without decreased survival. Additions of N up to 300 lb/acre in several small applications may further stimulate foliage growth.

Additional keywords: Nitrogen, ureaform, phosphorus, potassium, ammonium nitrate, litter, *Pinus taeda* L.

INTRODUCTION

Loblolly pine (*Pinus taeda* L.) is considered the most satisfactory tree species for erosion control on most upper Coastal Plain sites because it produces abundant soil-protecting litter (McClurkin 1967, Ursic 1963). Several years, however, are necessary for loblolly to produce enough litter to control erosion. Fertilization to increase the amount of foliage per seedling and shorten the time required to obtain enough litter for site protection was studied in field tests in northern Mississippi, and results are presented here.

METHODS

After preliminary pot tests were used to determine the best combinations and methods of application of nitrogen (N), phosphorus (P), and potassium (K), four fertilizer combinations and one untreated control were tested in two trials with field-planted year-old loblolly pine.

The treatments tested were:

1. $N_{50}P_{33}K_{62}$ in one application with N as ammonium nitrate.
2. $N_{150}P_{33}K_{62}$ in one application with N as ammonium nitrate.
3. $N_{300}P_{87}K_{62}$ in 10 small applications at 10-day intervals with N as ammonium nitrate.
4. $N_{300}P_{87}K_{62}$ in one application with N as ureaform.

Subscripts denote the application of the elements in lb/acre. Multiple small applications equaling a total of $N_{300}P_{87}K_{62}$ were tested because pot tests showed this combination improves growth but reduces survival unless applied in small increments over several weeks. Ureaform was tried to determine if its slow release of N would produce a response similar to that of several small applications of ammonium nitrate. Potassium was applied as muriate of potash and P as normal superphosphate. Fertilizers were broadcast and worked into the soil surface with fire rakes and hoes 6 weeks after planting.

In both tests, two eroded but naturally revegetated sites near ridgetops were cleared of vegetation, litter, and of A_1 horizon to simulate bare, eroded, relatively dry soils. For each test, one site had a sandy surface soil (upper 9 inches), and the other had a loamy surface soil. At each site, 15 plots, each 10 x 15 feet, were planted with 50 seedlings. The 1.5- x 2.0-foot spacing on the plots provided enough seedlings to evaluate growth and survival on a small area with almost completely uniform soil. Each of the four fertilizer treatments and an unfertilized control were randomly assigned to three plots per site. Soil on the sandy site in test I was the Troup series (loamy, siliceous, thermic, Grossarenic Paleudult); on the loamy site, the soil was a Mayben (fine, mixed, thermic, Ultic Hapludalf). In test II, the soil on the sandy site was Smithdale (fine-loamy, siliceous, thermic, Typic Paleudult) and the soil on the loamy site was a Tippah (fine-silty, mixed, thermic, Aquic Paleudalf). Particle size distribution was:

	Test I			Test II		
Site	Sand	Silt	Clay	Sand	Silt	Clay
	Percent			*Percent*		
Loamy	30	44	26	23	50	27
Sandy	80	14	6	59	34	7

In test I, all current-year foliage on randomly selected seedlings was clipped, dried, and weighed after each of three consecutive growing seasons. Test II observations were limited to two consecutive growing seasons since, on many plots, clipping and mortality left too few seedlings for third-year sampling. In each test only current-year foliage was used for measurements because, as was shown in the pot tests, needles grew only in their first year. Number of fascicles were counted after the first season in test I. In both tests, height growth of the seedlings was measured at 2-week intervals throughout each growing season. Variation caused by site, fertilization, and site-fertilization interaction was tested at the 0.05 probability level. Rainfall was measured in a recording gage located on the Experimental Forest about a mile from all plots.

RESULTS AND DISCUSSION

Test I seedlings planted on loamy soils and fertilized with $N_{150}P_{33}K_{62}$ produced 1.6 times the foliage weight of unfertilized seedlings through their first 2 years (table 1) because, as the counts showed, the fertilized seedlings produced more fascicles, at least in the first year. The pot tests also showed that fertilization increases number of needles per seedling and needle length. Seedlings receiving $N_{50}P_{33}K_{62}$ produced no more foliage weight than the unfertilized seedlings. Because of their second-year response when multiple ammonium nitrate applications were used, seedlings receiving $N_{300}P_{87}K_{62}$ on the loamy site yielded even more foliage weight than those receiving $N_{150}P_{33}K_{62}$. Third-year response to $N_{300}P_{87}K_{62}$ in both ammonium nitrate and ureaform applications also seemed to exceed response to $N_{150}P_{87}K_{62}$, but clipping in the first 2 years limited third-year observations to few trees, and results were not statistically tested. Perhaps ureaform released N unusually slowly on these rather poor soils and did not supply N in amounts supplied by ammonium nitrate until the third year. Height growth response to fertilization was similar to the response in foliage growth (table 1).

In test I, seedlings on the sandy site responded to fertilization, but the low level was as effective as the other levels. Periodic height growth and rainfall measurements within the growing season suggested that soil moisture availability probably limited response to fertilizer on the sandy site. In their first year, test I seedlings on the two sites grew in height at similar rates through early June as rainfall replenished soil moisture. On the loamy site seedlings continued growing at the same rate into September. However, growth on the sandy site slowed greatly in June, a dry month, and although it increased in late July and August with above normal rainfall, growth for the year was significantly less than on the loamy site. Available moisture also influenced response the second year. On the loamy site, growth, which was rapid and greatest on fertilized plots, continued into August although June, July, and August rainfall was below normal. On the sandy site growth was rapid through June and was greatest on fertilized plots, but it practically ceased for the year on all plots by early July.

Seedlings on the loamy site of test II responded to fertilization, but total foliage weights were less than in test I (table 1). Weight differences seemed related to differences in rainfall and soil moisture availability, particularly during the first year. In both tests, first-year rainfall was above normal through April and May, and height growth of seedlings on the loamy sites was about the same. Though June rainfall in the first year of each test was below normal, test I seedlings continued growing at a constant rate into September because July-August rainfall was above normal. In test

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Table 1.—*Total pine foliage production and height growth during 2 years following planting.*

Site	Fertilization[1]	Foliage weight[2]		Height growth[2]	
		Test I	Test II	Test I	Test II
		Ounce/seedling		------- *Feet* -------	
Loamy	$N_0P_0K_0$	4.30_c	1.59_b	3.37_b	1.55_c
	$N_{50}P_{33}K_{62}$	4.34_c	2.36_b	3.24_b	1.69_c
	$N_{150}P_{33}K_{62}$	6.88_b	3.00_{ab}	4.15_a	2.28_{ab}
	$N_{300}P_{87}K_{62}$ 10 small applications	8.11_a	4.20_a	4.28_a	2.54_a
	$N_{300}P_{87}K_{62}$ with urea-form	6.60_b	2.47_b	4.19_a	1.95_{bc}
Sandy	$N_0P_0K_0$	1.20_e	0.46_c	1.45_d	0.73_d
	$N_{50}P_{33}K_{62}$	1.76_d	$.46_c$	1.81_c	$.88_d$
	$N_{150}P_{33}K_{62}$	1.87_d	$.56_c$	1.73_c	$.84_d$
	$N_{300}P_{87}K_{62}$ 10 small applications	1.55_{de}	$.71_c$	1.69_c	1.02_d
	$N_{300}P_{87}K_{62}$ with urea-form	1.83_d	$.60_c$	1.80_c	$.77_d$

[1]Subscripts denote elemental N, P, and K in lb/acre.
[2]Mean weights or height growth in the same column with different subscripts differ significantly.

II, summer growth was much slower as rainfall continued below normal through July and August.

No statistical differences existed between foliage weights of fertilized and unfertilized seedlings on the sandy site in test II. First-year height growth of the seedlings indicated that there was a response while moisture was available, but growth nearly ceased by late June, so seedlings did not fully use the fertilizers.

Fertilization did not reduce survival in either test I or test II; survival, like growth, appeared related to first-year rainfall. Test I first-year and second-year survival ranged from 93 to 96 percent for the fertilized treatments on the loamy soil and was 97 percent for the control; on sandy soil, survival ranged from 86 to 92 percent for the fertilizer treatments and was 94 percent for the control. In test II, survival ranged from 72 to 82 percent for the fertilizer treatments on loamy soil and was 83 percent for the control. On sandy sites, survival was 68 to 83 percent for the fertilizer treatments and was 78 percent for the control. Survival on fertilized plots might have been substantially reduced if large amounts of competing vegetation had been present and responded to fertilization (McClurkin 1958 and 1961). However, on sites where such vegetation is present, fertilization to increase foliage production would not be needed since the competing vegetation already would protect the site.

CONCLUSIONS

The time needed by loblolly pines to cover eroding sites with protective litter may be reduced by a year, perhaps more, by accelerating foliage production with fertilization. A plantation with a 6- x 6-foot spacing on a loamy soil receiving near-normal rainfall and moderate fertilization ($N_{150}P_{33}K_{62}$) should produce about 510 pounds of foliage per acre in the first 2 years. An unfertilized plantation would produce only about 315 pounds, and would require 3, perhaps 4, years to produce as much foliage as the fertilized plantation would in 2 years. This greater amount of foliage on fertilized plants also intercepts more rainfall and reduces impact on the soil. Response to fertilization can be expected when moisture is available for a large part of the growing season, but may not occur if soil moisture is limited. Fertilization of loblolly pine appears useful where accelerated formation of permanent cover is needed to protect unattractive eroding soils or on any site yielding large amounts of sediment that is filling ditches, channels, or ponds that require costly cleaning or rebuilding.

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Research Note

SO-231

1977

Fertilizer and Mulch Improves Yellow-Poplar Growth on Exposed Hartsells Subsoils

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SUMMARY

Fertilizing and mulching of eroded Hartsells soil increased height and diameter of yellow-poplars. To see if chemical infertility of exposed Hartsells subsoils limits yellow-poplar growth and to test fertilizer and mulch as remedial agents, seedlings were planted on undisturbed soil, soil with the topsoil removed, and soil with the topsoil removed but mulched with leaf litter. After one growing season, 9 of the 18 plots were fertilized.

Topsoil removal with no remedial treatment reduced growth through four growing seasons. Mulching did not improve growth the first year but did in subsequent years. The first year after application, fertilizer greatly increased growth; thereafter growth on fertilized plots was about the same as growth on unfertilized mulched and undisturbed plots. Fertilizer with mulch provided no added growth. Mineral deficiencies and rapid drying apparently limit growth on exposed subsoils, but physical structure does not.

Additional Keywords: *Liriodendron tulipifera*, forest fertilization, erosion.

PLANTING ON ERODED SITES

Abundant rainfall and decay of forest vegetation have formed nutrient-rich topsoils in the Cumberland Plateau of Tennessee, but on thousands of acres, the topsoil has eroded. When the rich topsoil is removed — as it often is by farming, logging, construction of forest roads and trails, and site preparations exposing mineral soil — the loss of nutrients limits tree growth. And once a site loses its topsoil, it continues to erode and loses moisture rapidly, making it suitable for only "poor site" trees like upland oak and Virginia pine. Yellow-poplar, which needs moist, fertile soil, grows slowly on exposed subsoils (Loftus 1971).

The objectives of this study were to determine the extent that infertility of exposed Hartsells subsoils limits yellow-poplar growth, and to test fertilization and mulching treatments for trees in eroded areas.

METHODS

A typical Cumberland Plateau hollow near Sewanee, Tennessee was chosen for study. Soils are Hartsells, an extensive Typic Hapludult. The area was cleared of a mixed oak stand, all other vegetation was removed, and stumps were treated to prevent sprouting. Plots were arranged in a randomized block design in six blocks containing one 12 x 12 foot plot of each of three initial treatments.

Treatments were: (1) undisturbed (2) organic and A horizons removed (3) organic and A horizons removed and a litter layer returned. The topsoil was removed with a shovel. The litter layer in the third treatment was raked up and spread again by hand after the topsoil had been removed. In the spring of 1970, nine yellow-poplar seedlings graded 1-0 with roots and tops clipped uniformly were planted in each plot at a 4 x 4 foot spacing.

At the end of the first growing season (fall, 1970) height and root-collar diameter of all seedlings were measured. Four seedlings per plot were excavated, oven dried, and weighed. Two tons per acre of dolomitic limestone were hoed into the surface of 9 of the 18 plots. In the spring of 1971, fertilized plots received 150 lbs N/acre as NH_4NO_3 and 100 lbs P/acre as triple super phosphate topdressed.

Tree heights and root-collar diameters were measured each succeeding fall for three seasons. After the last measurement, one seedling per plot was excavated, oven dried, and weighed. The results were evaluated by analysis of variance supplemented by Tukey's ω procedure.

RESULTS AND DISCUSSION

During the first growing season, growth was significantly depressed by removal of topsoil (table 1). Leaf mulch added to the subsoil did not increase growth the first year. During the second through the fourth years, however, seedling growth on unfertilized mulched plots equalled that on the undisturbed control plots (table 2). Seedlings on exposed subsoil that was not mulched or fertilized grew slowly throughout the experiment (fig. 1). Mulching apparently improves the intake of water, protects the soil from drying, and may speed mineralization of nutrients.

Table 1. — First year response of planted yellow-poplar to topsoil removal with and without mulching.[1]

	Undisturbed	Exposed B	Mulched B
Height growth (cm)	27.5 a[2]	16.9 b	19.2 b
Root collar diameter (mm)	9.8 a	8.2 b	8.2 b
Top dry weight (gms)	6.4 a	4.1 b	3.9 b
Root dry weight (gms)	9.6 a	7.4 ab	6.0 b

[1] Each entry for height growth and root collar diameter is the average of 54 seedlings and each entry for top and root dry weight is the average of 24 seedlings.

[2] Means in each line followed by the same letter are not significantly different at the .05 level of probability.

In the first year after fertilization, fertilized trees increased significantly in height and diameter (table 2). In the following years, fertilized seedlings grew at about the same rate as those on unfertilized mulched and undisturbed plots. Fertilizer and mulch each helped seedlings overcome the growth depression caused by topsoil removal, but mulching combined with fertilizer produced little additional growth. Fertilized plots quickly built up a light natural mulch created by weed growth in the year of fertilization.

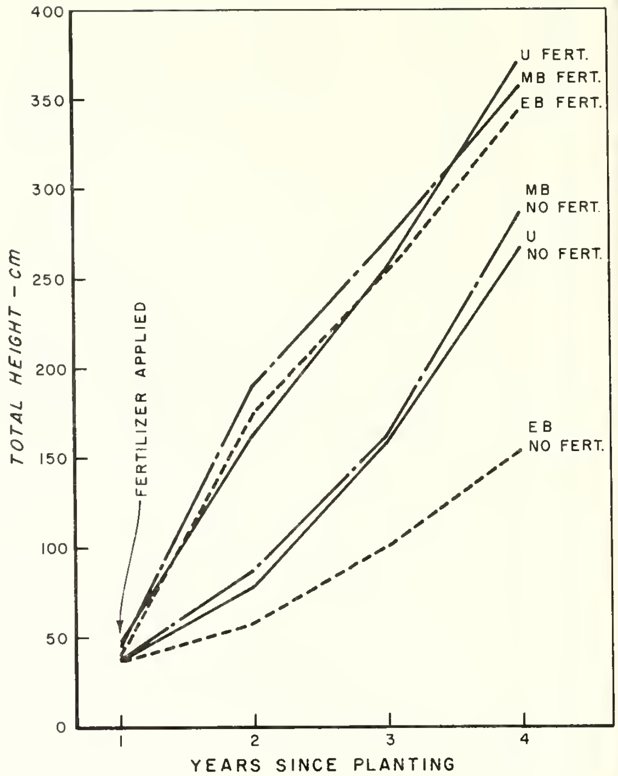

Figure 1.—*Total height of yellow-poplar on fertilized and unfertilized plots that were undisturbed (U), had B horizon exposed (EB), or had B horizon exposed and were mulched (MB).*

At the end of the experiment, root weight was significantly increased by fertilization (table 2). Root weight was depressed by removal of topsoil, but not significantly so.

The experiment indicates that the chemical infertility of Hartsells subsoil severely limits yellow-poplar growth on exposed subsoil. Because improving the nutrient or moisture levels of the exposed subsoil makes growth equal to or greater than that found where the topsoil is still present, physical properties of the subsoil are apparently not the reason for poor growth. Where loss of topsoil has been extensive enough to warrant treatment, ease of application and promotion of growth and litter accumulation make fertilization a valuable aid to establishment and early growth of yellow-poplar.

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Table 2. — Yellow-poplar height growth, root-collar diameter growth, and root weight on fertilized and unfertilized soil that was undisturbed (U), had B horizon exposed (EB) or had B horizon exposed and was mulched (MB). Times shown indicate time since fertilizer application.[1]

	No Fertilizer			Fertilizer		
	U	EB	MB	U	EB	MB
Height growth yr. 1 (cm)	42 a[2]	22 a	49 a	116 b	135 b	153 b
Height growth yr. 2 (cm)	79 b	42 a	72 b	92 b	76 b	79 b
Height growth yr. 3 (cm)	111 b	47 a	124 b	118 b	92 b	90 b
Diam. growth yr. 1 (mm)	4.6 a	4.0 a	6.4 ab	13.4 bc	18.4 c	17.0 c
Diam. growth yr. 2 (mm)	11.8 bc	5.8 a	9.6 ab	15.9 c	12.2 bc	14.2 bc
Diam. growth yr. 3 (mm)	10.6 bc	5.7 a	9.5 bc	11.7 c	8.6 ab	10.1 bc
Root weight yr. 3 (gms)	424 abc	125 a	278 ab	986 d	608 bcd	718 cd

[1] Each figure is the average of 15 seedlings except for root weight which is the average of 3 seedlings.

[2] Means in each line followed by the same letter are not significantly different at the .05 level of probability.

SO-232

Southern Forest Experiment Station

Research Note

1978

Herbage Yield Related To Basal Area and Rainfall In A Thinned Longleaf Plantation

HAROLD E. GRELEN AND RICHARD E. LOHREY

SUMMARY

Herbage yields averaged 1,295, 1,024, and 865 lb/acre/yr in longleaf pine stands thinned to 60, 80, and 100 ft^2 of basal area/acre. Yields were also related to May-September rainfall.

Additional keywords: *Pinus palustris* Mill.

Herbage Yield and Stand Density

Managers of grazed pine stands need to know how herbage yield is related to stand density. Previous research has shown that yields decrease when stand density increases (Gaines and others 1954; Halls and Schuster 1965; Jameson 1967). Little is known, however, of the fluctuations in herbage production resulting from frequent thinnings and variations in annual rainfall.

In this study, herbage production was measured annually from age 30 through 40 years in a longleaf pine (*Pinus palustris* Mill.) plantation near Alexandria, Louisiana. This paper reports the relationship of herbage yield to stand basal area, density, and rainfall for that 11-year period. Grelen and Enghardt (1973) reported early herbage production in this stand. Timber production was reported to age 30 years by Derr and Enghardt (1969) and to age 35 by Lohrey (1974).

THE PLANTATION

The 40-acre longleaf pine plantation was established in 1935 on a moderately well-drained silty loam soil with a site index of 78 for longleaf pine at age 50. The stand is part of a study to determine how pine growth is related to initial planting spacing (about 4, 5, 6, and 13 feet), stand density after thinning (60, 80, and 100 ft^2/acre basal area), and height of pruning (17 feet, two-thirds tree height, total height, and none).

The plantation contains four square blocks with sixteen 0.62-acre plots each. Four randomly selected plots per block were planted at each spacing. In the three close spacings, stands were thinned to 60, 80, or 100 ft^2/ac. Thinnings began at age 20 years and were repeated at 5-year intervals. Stands that had not reached their assigned density were not cut until the next scheduled thinning. Some of the 80- and 100-ft^2/ac. plots did not reach their assigned densities until age 35. Only one plot had not reached its prescribed basal area by age 40.

The fourth thinning left a maximum of 100 crop trees per acre at age 20 years with no later cuttings. Some small trees later grew to merchantable size but were not cut. Crop trees had been pruned to 17 feet at age 16 years.

Plots in the wide 13-foot spacing treatment were not thinned because stand densities were low. In these wide spacings, four pruning treatments were compared. Crop trees were pruned at age 16 years to heights of 17 feet, two-thirds tree height, total height, or left unpruned. Many pruned trees in this wide spacing were heavily damaged by an ice storm shortly after the treatments were installed. Consequently, data for pruned plots in the wide spacing were not used in this study. Data for pruned plots in the three narrow spacings and unpruned plots in the 13-ft. spacing were used to provide data at densities below 60 ft^2/ac.

The plantation was control burned every third year through age 15; since then prescribed fires have been applied at 5-year intervals, 1 year before thinnings. Cattle grazed the plantation until herbage measurements began in 1964.

Tree basal area and herbage yield were measured on all plots of the 4-, 5-, and 6-ft spacings and on the unpruned check plots in the 13-ft spacing. Measurements were restricted to a 0.1-acre plot in the center of each 0.62-acre treatment plot. Beginning at age 20, all trees within this plot were measured, and basal area per acre was determined at 5-year intervals. Herbage production was measured annually from age 30 to 40 years on a grid of twelve 2.4-ft^2 quadrats within the measurement plot. Rainfall was measured by a recording guage in an open area about 100 yards from the northeast corner of the plantation.

RESULTS

Heavy grazing of the plantation before the herbage study began apparently reduced herbage growth the first years of the study (fig. 1). For this reason, herbage yields for plantation ages 30 through 32 years were not included in stand density/herbage yield/rainfall correlations. Annual yields from ages 33 to 40 years averaged 1,295, 1,024, and 865 lb/acre for basal area treatments of 60, 80, and 100 ft^2/acre.

Botanical composition was also apparently influenced by the heavy grazing. Pinehill bluestem (*Andropogon scoparius* var. *divergens* Anderss. ex Hack.), which generally makes up 50 to 60 percent of the herbage on longleaf-slash pine bluestem range, comprised only 29 percent by weight of the herbage at age 30. By age 35, pinehill bluestem made up 51 percent of the herbage, and at age 40, 52 percent. Slender bluestem (*A. tener* Nees, Kunth), which is usually the second most abundant grass and comprises about 30 percent of the herbage on cutover range, was reduced by shading or root competition to 3 percent of the herbage at age 35, and to 1 percent at age 40. Other major components of the herbage at age 40 were the panicum grasses (*Panicum* spp.) and forbs, averaging 16 percent and 14 percent, respectively, of the herbage weight. Other bluestem species averaged less than 5 percent.

Herbage yields among the three close spacings did not differ significantly at any time during the study. Stems per acre and height to live crown were related to herbage yield, but neither, alone or in combination with basal area, improved the equation enough to justify their

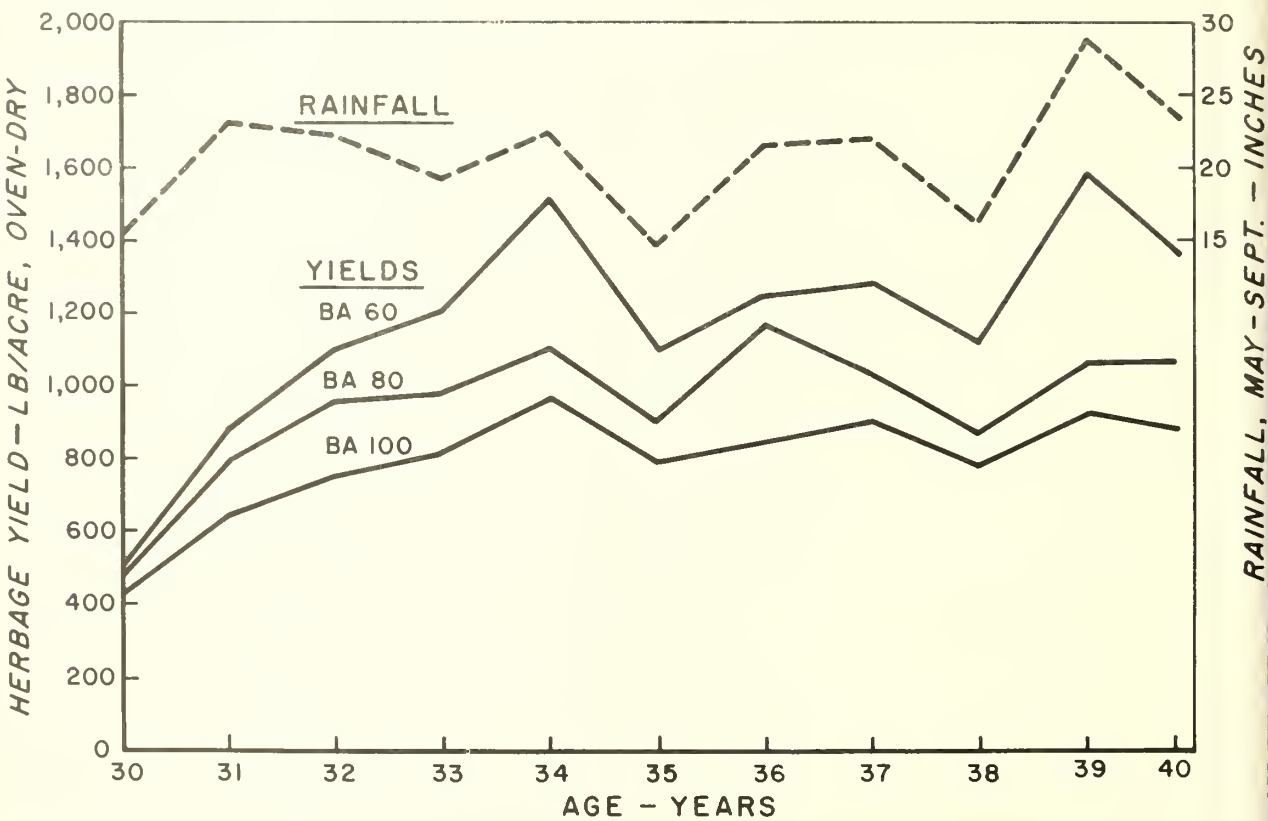

Figure 1.—*Annual herbage yields and summer rainfall in a longleaf pine plantation.*

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use as predictors of herbage yield.

Linear regressions relating herbage yield to basal area per acre at ages 35 and 40 were not significantly different from each other in either slope or level. Data from 35 and 40 years were combined to calculate the following equation relating herbage yield to basal area:

$$Y = 1{,}670 - 6.80(X)$$

where Y = predicted oven-dry herbage yield (lbs./acre/year)

X = pine basal area stocking (ft^2/acre)

This equation explained 20 percent of the total variation in herbage yield, and the standard error was 264 lbs/acre/year. It predicts yields of 1,262, 1,126, and 990 lbs/acre for basal areas of 60, 80, and 100 ft^2/acre (fig. 2).

Because herbage yields varied markedly from year to year, we examined the correlation between average annual yield and rainfall. Rainfall during several periods, as well as total annual rainfall, was used in correlation tests, but only the periods below were significantly related to herbage yield:

Rainfall period	Correlation coefficient
May through September	0.89
April through September	.84
April through August	.72

Herbage yield predictions were much closer to observed yields when May to September rainfall was added as an independent variable. Herbage yield on plots with low basal area density responded more to differences in precipitation than did yield on plots with high densities.

Several linear and curvilinear models involving thinning treatment and May-September rainfall were screened to determine their relationships to herbage yield. Equations for all models were plotted. The most logical model, determined by visual inspection of the curves, resulted in the equation:

$$Y = 10^{[3\ 1865 \quad 00432753\,(X_1) \cdot 0084653\,(X_2)]}$$

where:

Y = predicted oven-dry herbage yield (lbs/acre/yr)

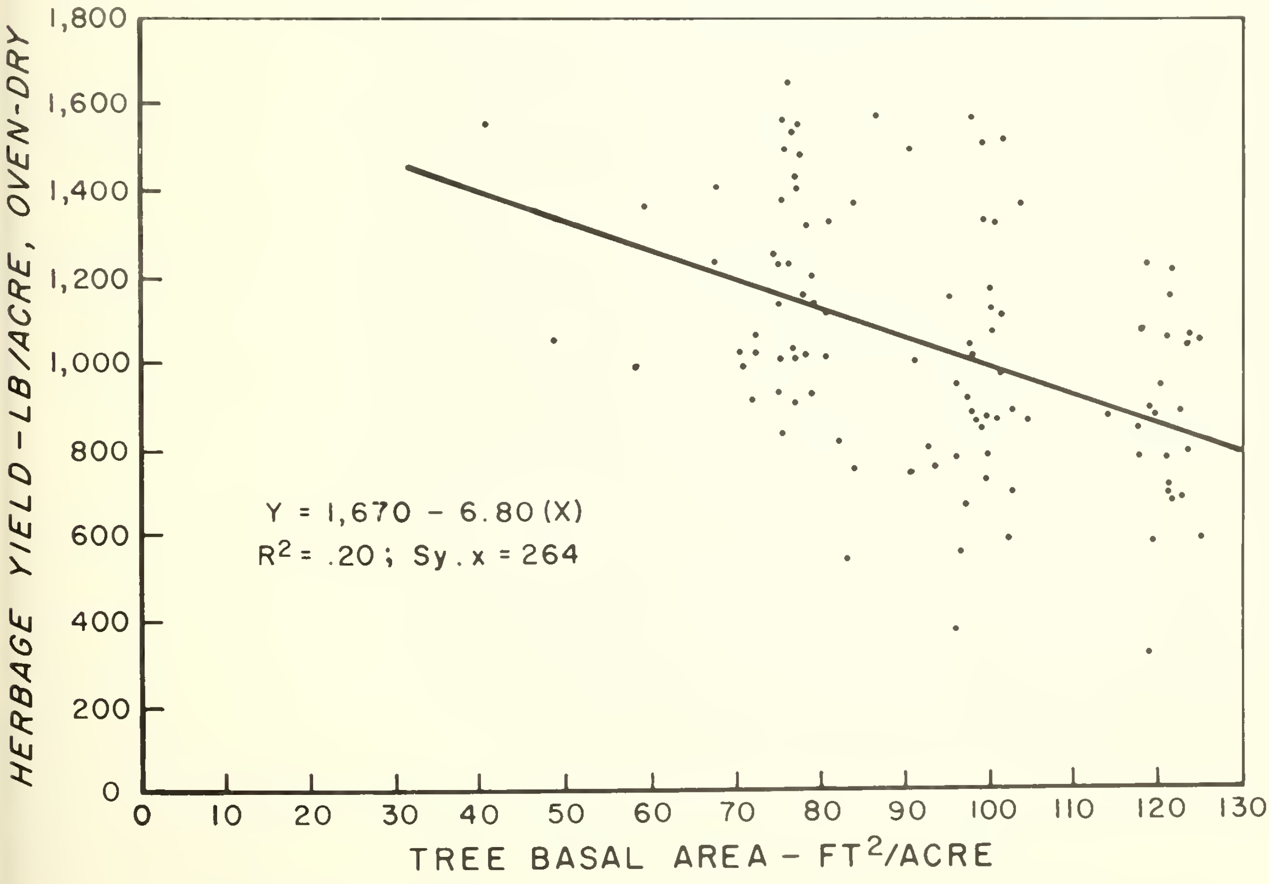

Figure 2.—*Relationship of herbage yield (Y) to tree basal area (X) at ages 35 and 40 years in a longleaf pine plantation.*

X_1 = pine basal area treatment (ft^2/acre)
X_2 = May-September rainfall (inches)

This equation gave estimates within 10 percent of the actual yield for all but two observations. The average deviation was less than 5 percent. Table 1 contains solutions for this equation for the three basal areas maintained by thinning in this study and the range of May-September rainfall that occurred during the 11 years reported here.

Table 1.—*Predicted herbage yields at selected levels of pine basal area and May-September rainfall, based on equation (2)*

Basal area	May-September rainfall (inches)			
	15	20	25	30
	Herbage yield (lb/acre)			
60	*1132*	*1248*	*1376*	*1517*
80	*927*	*1022*	*1127*	*1243*
100	*772*	*837*	*923*	*1018*

Pearson (1975) found that for moderately grazed range about 100 pounds of oven-dry herbage is required per cow-day to allow for consumption, trampling, weathering, wildlife use, and the ungrazed forage residue. Thus, based on the average annual yields from age 33 to age 40, grazing capacities would be about 28, 35, and 42 acres/cow/yr, for 60, 80, and 100 ba. On an animal-unit month basis, the conversion factors would be 2.3, 2.9, and 3.5 acres/aum, respectively.

The yield equations presented here should be useful to land managers planning multiple-use of similar longleaf pine forests in the South. The accuracy of yield estimates will improve as more is learned about the complex relationships among yield, environment, and stand management.

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U.S. GOVERNMENT PRINTING OFFICE: —1978—772-011

Southern Forest Experiment Station **Research Note** SO-233

1978

Antiserum Preparation For Immunodiffusion In Southern Pine Beetle Predation Studies

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SUMMARY

An anti-adult southern pine beetle serum was produced by subcutaneous injection of rabbits with southern pine beetle (SPB) adult antigen. Initial tests demonstrated the ability of the anti-adult SPB serum to detect adult SPB antigen in the body of the adult predator, *Thanasimus dubius* (F.). Cross reactivity was found between the anti-adult serum and extracts of immature stages of *Dendroctonus frontalis* Zimmerman, adult *D. terebrans* (Olivier), *Ips grandicollis* (Eichhoff), and *I. calligraphus* (Germar).

Adult southern pine beetle protein can be detected in a whole predator extract at least 28 hours after feeding.

Additional keywords: *Dendroctonus frontalis, Thanasimus dubius,* Agar gel double diffusion, precipitin test, predation.

STUDY OF PREDATORS

Through most of its life cycle the southern pine beetle (SPB), *Dendroctonus frontalis* Zimmermann, is a cryptic insect. Except for the adult stage, SPB life cycle stages are hidden beneath the bark of the host tree. A sizeable SPB insect-associate complex exists (Moser and others 1971), but direct measurements of successful attack by SPB natural enemies have not been possible. Accepted methods of estimating insect predation are indirect (Berryman 1967). Identification of biological roles of insect associates of the SPB and related bark beetles has been limited to small-scale, time-consuming rearings and to laboratory or field observations. Work has concentrated mainly on adult stages of those predators easy to obtain, rear, or maintain in the laboratory (Thatcher and Pickard 1966, Berryman 1967, Amman 1970, 1972, Moore 1972, Nagel and Fitzgerald 1975). Few adult insect associates have been studied in a way that provides information regarding their direct impact on the SPB population (Thatcher and Pickard 1966).

Precipitin reactions provide a means for determining the biological roles of predatory insects and mites by indicating their food preferences (West 1950, Dempster 1960, Dasgupta and Cunliffe 1970). These reactions also provide a means for measuring the minimum number of prey consumed (Dempster 1960, Kiritani and Dempster 1973).

This study concerns preparation of an anti-adult southern pine beetle serum, determination of sensitivity and selectivity of the antiserum, and development of a laboratory feeding test for SPB predators.

MATERIALS AND METHODS

Antigen preparation

Newly emerged SPB adults were collected in an emergence box and refrigerated collector similar to that of Browne (1972). Beetles were starved for 24 h, screened, and hand sorted to remove debris. They were washed with distilled water, dried on paper towelling, and crushed in equal volumes of 0.85 percent NaCl in a mortar with a pestle. To inhibit melanization, a few drops of 0.001 M KCN were added to the resulting mixture (Dempster 1960), which was then stored at 4°C in 30-ml portions for 24 h. Gross beetle fragments were removed by filtration through glass wool and cheesecloth. When filtering was completed, the glass wool was compressed to extract the liquid, which was then centrifuged at 23,500 *g* for 30 min. at 4°C, and filtered sequentially through Gelman Metrica™[1/] 5.0, 1.2, 0.8, 0.45, and 0.20 um pore filters. Before the liquid was sterilized with the 0.20 um filter, a sample of supernatant was taken for protein determination (Lowry and others 1951). The antigen contained 2.8 mg/ml of protein. Seventy mg of protein antigen was placed in each presterilized bottle and lyophilized before shipment to the Center for Disease Control (CDC) for immunization of rabbits.

Immunization of Rabbits

At the CDC the adult SPB antigen in each bottle was reconstituted with 5 ml of sterile distilled water to produce a stock antigen, which was further diluted with water to prepare an antigen containing 1 mg of SPB protein per kg of animal weight. Freund's incomplete adjuvant was added in equal volumes to the aqueous SPB antigen and emulsified as described by White and others, (1975). Three New Zealand white rabbits, ranging in weight from 3.8 to 5.0 kg, were immunized by footpad-subcutaneous injection (Chappell and others 1976) with enough adult SPB antigen to constitute 1 mg/kg of gross body weight (GBW). The dose of adjuvant-antigen was divided between the 2 front footpads. Ten ml of preimmunization blood was collected from the central artery of an ear of each rabbit. On the 32nd day after the initial injection, all rabbits were given booster footpad injections of 1 mg/kg GBW SPB antigen without adjuvant.

On days 11, 18, 25, 32, 39 and 46 after the initial injection of antigen, samples of blood were collected for antisera titer determinations. Sera were stored at -20°C.

We determined antiserum titers by reacting twofold dilutions (1/10, 1/20, 1/40,...1/5120) of SPB antigen stock with undiluted anti-adult SPB serum by agar gel double diffusion, using the glass slide method described by Chamberlain and Sudia (1967). The adult SPB antigen was diluted with 0.85 percent NaCl. The greatest dilution of adult SPB antigen producing a distinct precipitin line with undiluted anti-adult SPB serum was considered the titer of the antiserum.

Laboratory Testing

Individual adult *Ips grandicollis* (Eichhoff, adult *I. avulsus* (Eichhoff), adult platypodid, and SPB larva, pupa, teneral adult *I. calligraphus*, (Germar), *Dendroctonus terebrans* (Olivier), adult, and a day-old adult were crushed in 0.25 ml of 0.85 percent NaCl. The resulting suspensions were tested by agar gel double diffusion with undiluted anti-adult SPB serum.

Thanasimus dubius (F.) adults were collected in a bucket trap (Moser and Browne in press) baited with Frontalure® and hung in an active SPB infestation. *T. dubius* were stored separately in gelatin capsules until they arrived at the laboratory, where each was held in a 6.0 cm plastic Petri dish and presented with 1 or more adult SPB. Those seizing and feeding on the SPB adults were manipulated into gelatin capsules where feeding was completed. Those not feeding were held either in plastic Petri dishes or in gelatin capsules for 18-24 hours and were assumed to be starved.

Ten starved and 10 laboratory-fed *T. dubius* adults were crushed individually on a small piece of filter paper and given code numbers. Each smear was suspended overnight in 0.5 ml of 0.85 percent NaCl at 4°C. Coded aliquots of the undiluted predator suspensions were tested by agar gel double diffusion with undiluted rabbit anti-adult SPB serum.

Nineteen adult *T. dubius* were fed various numbers of SPB adults; 8 fed on 1 SPB each, 8 fed on 2 SPB each, and 3 were left overnight to feed at will. Specimens of *T. dubius* were killed and crushed on filter paper after feeding was complete. All were held over P_2O_5 at room temperature (Dempster 1960) until extracted in 0.25 ml of 0.85 percent NaCl at 4°C. An additional 20 *T. dubius* were starved to death at room temperature, then individually crushed and extracted in 0.25 ml of 0.85 percent NaCl at 4°C. These uncoded, undiluted, predator suspensions were tested in separate groups by agar gel double diffusion with undiluted anti-adult SPB serum.

Because 15 ul of predator extract might not contain enough antigen to produce a positive test, we used a concentrated predator extract to determine duration of SPB protein in the predator.

T. dubius adults, collected from baited bucket traps, were held with an excess of SPB adults for 24-48 hours in gallon plastic containers to assure removal of any other prey material from their

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digestive systems. Each *T. dubius* adult was placed in a 6.0 cm plastic petri dish and presented with 1 or more adult SPB. Those seizing and feeding on the adult SPB were manipulated into gelatin capsules. These *T. dubius* were held without feeding for 0 to 36 hours and were killed by freezing at 4-hour intervals. They were extracted as previously described and a 15 ul portion of each 0.25 ml extract was tested against undiluted homologous anti-adult SPB serum by agar gel double diffusion. The remaining 235 ul were concentrated by lyophilization, reconstituted in 15 ul of distilled, demineralized H_2O and tested as previously described.

RESULTS AND DISCUSSION

Titers for the rabbit-produced, anti-adult SPB sera reached 1/80 on day 18, and all 3 rabbit antisera reached titers of 1/160 on days 25 and 32. Downe and West (1954) indicate that acceptable results in detecting prey in a predator can be obtained with titers as low as 1/100. Although anti-SPB sera from all 3 rabbits were used in the experiments described above, the results with antiserum from rabbit No. 3 were the most consistent and are presented in table 1.

The anti-adult SPB serum is not genus specific. We obtained positive reactions to extracts of adult *I. calligraphus,* adult *I. grandicollis,* SPB larva, pupa, teneral adult, day-old adult, and adult *D. terebrans.* Downe and West (1964) and Boreham[2] found that antisera made from adult antigen of insects with paurometabolous development are sensitive to antigen from at least the older nymphal instars. Downe and West (1964) hypothesize that adult hemolymph may contain nymphal antigens and discrete adult antigens. Our results indicate that the same may be true of insects that exhibit holometabolous development.

Table 1 shows the increase in sensitivity of the anti-adult SPB serum to its homologous antigen as time passes. With day-46 anti-adult SPB serum, all 10 of the *T. dubius* adults that fed on adult SPB produced positive precipitin reactions. Seven of the 10 predators starved from 18-24 hours after feeding produced negative precipitin tests. There were 3 positive tests, #2,7, and 14. These may be the result of the more sensitive antisera reacting to small amounts of the SPB protein in the 15 ul samples from the

Table 1 — *Precipitin reactions to individual predator extracts.*

T. dubius number	Fed on SPB	Days antiserum collected after initial immunization: 11	18	25	32	39	46
1	No	−	−	−	−	−	−
2	No	−	−	−	+	+	+
3	Yes	−	+	+	+	+	+
4	Yes	+	+	+	+	+	+
5	Yes	−	+	+	+	+	+
6	No	−	−	−	−	−	−
7	No	−	−	−	−	−	+
8	Yes	−	+	−	+	+	+
9	Yes	+	+	+	+	+	+
10	No	−	−	−	−	−	−
11	Yes	−	+	+	+	+	+
12	No	−	−	−	−	−	−
13	Yes	−	+	−	+	+	+
14	No	−	−	−	+	+	+
15	No	−	−	−	−	−	−
16	Yes	+	+	+	+	+	+
17	No	−	−	−	−	−	−
18	Yes	+	+	+	+	+	+
19	Yes	−	−	−	−	+	+
20	No	−	−	−	−	−	−

T. dubius adults that retained incompletely digested SPB material in their gut from eating adult SPB captured in the bucket trap with them. Greenstone finds that some spiders stop digesting when starved and retain detectable prey for a week.[3]

Positive reactions in tests 2 and 14 first occur with day-32 antiserum, and only with day-46 antiserum for test 7. An explanation for the delayed positive test is that, since each visible precipitin line is the result of more than one antigen-antibody system (Crowle 1973), not enough of the particular antibody required for a visible precipitin line was produced until at least days 32 or 46.

In another experiment, 19 *T. dubius* adults that had fed on either 1 or 2 SPB adults, or had fed overnight, gave positive precipitin tests in every case. When extracts of the 20 *T. dubius* adults that were starved to death were tested, no precipitin tests were positive. Control agar gel double diffusion tests with undiluted SPB antigen against homologous anti-adult SPB serum were positive in every case.

Table 2 shows the effect of time on starvation and the use of dilute and concentrated predator extractions in the agar gel double diffusion test. The number of positive tests decreases rapidly when 15 ul of predator extract are used until

[1] Use of trade names is solely for the purpose of identification and does not constitute endorsement by the U.S. Department of Agriculture or U.S. Department of Health, Education and Welfare.

[2] Dr. P. F. L. Boreham, Imperial College Field Station, Silwood Park, Ascot, Berks. SL57PY, personal communication.

[3] Dr. Matthew Greenstone, University of California, Irvine 92717, personal communication.

Table 2. — *Effect of starvation and use of partial and whole predator extracts on the agar gel double diffusion test.*

Hours Post-Feeding	No. of *T. dubius*	% Positive Tests: 15 ul extract	% Positive Tests: Concentrated Extract (235 ul)
0	12	96.6	100
4	14	85.7	100
8	12	83.3	100
12	7	57.1	100
16	7	0	100
20	15	0	100
28	10	—	100
36	8	—	75

there are no positive tests for 16 and 20 hours. Using the concentrated predator extracts, we achieved 100 percent positive tests through 28 hours after feeding. The tests were arbitrarily terminated at 36 hours when less than 100 percent results were achieved. Probably *T. dubius* adults in the field would not be without food this long (Thatcher and Pickard 1966). Negative findings for 7 of the 10 starved *T. dubius* adults in the previous experiment (table 1) are more likely the result of using a portion of the predator extract (15 ul) rather than the whole insect concentrate.

Use of a whole insect concentrate and a broad spectrum antiserum produced positive results in the controlled laboratory feeding study (table 2). Research is in progress to increase test sensitivity and produce a species specific anti-adult SPB serum.

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ACKNOWLEDGEMENT – The authors thank Mr. Edwin George, CDC, for technical assistance with this research.

SO-234

Southern Forest Experiment Station

Research Note

1978

May Burns Stimulate Growth of Longleaf Pine Seedlings

HAROLD E. GRELEN

SUMMARY

Annual and biennial fires applied around May 1 are more beneficial to the growth of young longleaf pines than March 1 fires. Four years of testing on a poorly drained silt loam soil in central Louisiana showed that more grass-stage seedlings survived, began height growth, and grew taller on plots burned in May than on March-burned plots. A biennial May burn was best for survival and initial height growth of grass-stage seedlings. Annual May fires favored growth of older seedlings and were more effective in the control of brown-spot needle blight.

Additional keywords: *Pinus palustris, scirrhia aricola.*

PRESCRIBED BURNING OF LONGLEAF

Fire has long been recognized as important in the silviculture of longleaf pine, (*Pinus palustris* Mill.) (Greene 1931, Pessin 1944). Burning apparently maintains vigor in seedlings by destroying foliage infected by brown-spot needle blight [*Scirrhia acicola* (Dearn.) Siggers] and by reducing competition. Despite indications that light summer fires result in superior height growth of longleaf seedlings (Bruce 1951), most prescribed burning is done in winter or late fall to reduce the risk of wildfire. But late winter or early spring burning has been recommended for proper management of pine forest range because it leaves forage for winter grazing and destroys the old growth about the time new growth begins (Duvall and Whitaker 1964). An earlier study (Grelen 1975) of the effects of March, May, and July fires on herbage yield and botanical composition established that May burned plots of longleaf pine showed best growth. Four-year results in a new study comparing the effects of May and March burns on longleaf seedling growth are reported here.

PROCEDURES

The study was installed in March 1973 in an 80-acre ungrazed unit of the Palustris Experimental Forest on the Kisatchie National Forest about 30 miles south of Alexandria, Louisiana. The soil is a poorly drained Acadia silt loam with abundant wax myrtle (*Myrica cerifera* L.) and sprouts of blackjack oak (*Quercus marilandica* Muenchh.), sweetgum (*Liquidambar styraciflua* L.), black tupelo (*Nyssa sylvatica* Marsh.), and other moist-site hardwoods. Scattered loblolly pines (*P. taeda* L.) of various ages were deadened by girdling when the study was begun. Longleaf pine was direct-seeded in 1968 and in 1970 survival averaged over 3000 seedlings per acre. Most of the 1968 seedlings were in the grass stage when this study began. Many older and some younger natural seedlings were also present. The unit was last burned and grazed in 1970. By 1973 there was a 3-year accumulation of herbaceous litter, primarily pinehill bluestem (*Andropogon scoparius* var. *divergens* Anderss. ex. Hack.) which provided abundant fuel for first-year burning treatments.

Three replications of the following treatments were randomly assigned to a block of fifteen ¼-acre square plots: unburned control, annual March 1 burn, biennial March 1 burn, annual May 1 burn, and biennial May 1 burn. All fires were set within 4 days of the target dates. Plots were burned with headfires except when hazardous burning conditions made backfires necessary. Although no fuel or climatological data were recorded on the study site, temperature, rainfall, and humidity records were kept at a weather station less than a mile away. Fires were applied no later than 9 days after a rain on days when the maximum temperature did not exceed 82 degrees. Lowest relative humidity recorded on a burning day was 28 percent on

March 1, 1977, but burning was completed before the minimum was reached. Generally, humidity was above 50 percent during the burns. When winds were high or fuel extremely dry, plots were not burned because of the danger to adjacent plots.

In each ¼-acre plot, 25 grass-stage longleaf pine seedlings that had not yet formed a terminal bud were selected and marked by wire pins with numbered aluminum tags. Five older seedlings, which had already begun height growth but were less than one foot in height when the study began, were similarly selected and marked. Treatment fires began March 1 or May 1, 1973, and have been repeated annually or biennially as scheduled. Each autumn after the 1973 growing season, seedlings were inspected for survival, height to tip of bud (or presence or absence of pointed bud in grass-stage seedlings), and degree of brown-spot needle blight infection. After 1976 treatments, annually burned plots had been burned four times. Biennially burned plots received the second treatment in 1975.

RESULTS AND DISCUSSION

The most obvious result of burning was the control of hardwoods. Some unburned plots were almost impenetrable by the end of the fourth year because of the hardwoods (fig. 1). Compared with unburned plots burned plots were significantly[1] higher in percentage of surviving seedlings beginning height growth, total height growth of both size classes of seedlings, and seedlings with less than 50 percent brown spot infection. Such benefits of burning are well known and have been thoroughly documented (Bruce and Bickford 1950, Siggers 1932, Wakeley and Muntz 1947). Although most of the reported burning was done in the dormant season, the following results indicate that burning in May is even more beneficial.

Grass-stage seedlings

At the end of the first growing season after initial treatment, over 90 percent of all tagged grass-stage seedlings were still alive, and fewer than 1 percent of the surviving grass-stage seedlings in any treatment had begun height growth. By the end of the second season, survival remained above 90 percent on May-burned and control plots but dropped to 80 and 88 percent on annual and biennial March burns (fig. 2). One percent of the seedlings on unburned control plots were in height growth, compared with 3 to 5 percent for March-burned plots and 7 to 14 percent for May-burned plots (fig. 3).

By the end of the fourth season, survival had dropped to 56 percent on annual March burns and 75 percent on biennial March burns but remained about 80 percent on May-burned plots. Survival on control plots averaged 76 percent (fig. 2). Sixty-five percent of the surviving grass-stage seedlings on plots burned May 1 were in height growth, and March-burned plots averaged 58 percent. The difference between March- and May-burn survival percentages was not significant. An average of only 25 percent of the seedlings on control plots were in height growth, which was significantly lower than on any of the burned plots (fig. 3). At the end of the fourth season, the actual number of seedlings in height growth on the May-burned plots was significantly higher than on the March-burned or control plots.

At the end of the second season, seedlings in height growth were found only on the plots burned every second May. Average height of seedlings exceeded that of other treatments by about 4 inches. By the end of the fourth season, seedlings on the plots burned biennially in May averaged 20 inches tall, significantly taller than seedlings in other treatments (fig. 4).

When measurements were made at the end of the fourth growing season, annually burned plots had significantly fewer seedlings with 50 percent or more brown-spot needle blight than either biennially burned treatment plots or the control. The annual May burn was little different from the annual March burn, but the plots burned every other May contained significantly fewer diseased seedlings than the ones burned every other March.

Older Seedlings

Since only five older seedlings were examined on each treatment plot, survival percentages may be unreliable. Highest survival after four seasons was recorded on annually burned plots, with 93 percent (14 of 15 trees) surviving on plots burned each May and 80 percent (12 of 15 trees) on those burned each March. Survival on biennially burned plots and on the control averaged about 50 percent. Superior survival on annually burned plots may be

[1]Significance was determined at the 95 percent level of probability.

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Figure 1.—*Top photograph shows an unburned control plot. Note that only the cap of the man in the center of the picture is visible. Bottom photo of plot burned four successive years shows excellent scrub oak control, herbage production, and longleaf pine height growth.*

attributable to better control of brown spot and to the prevention of fuel build-up.

Height of surviving seedlings after four seasons was significantly greater on May-burned plots than on March-burned or control plots. The annual May-burned plots, in addition to having the highest survival, also had the tallest trees, averaging 67 inches tall from an initial height of less than 6 inches (fig. 5).

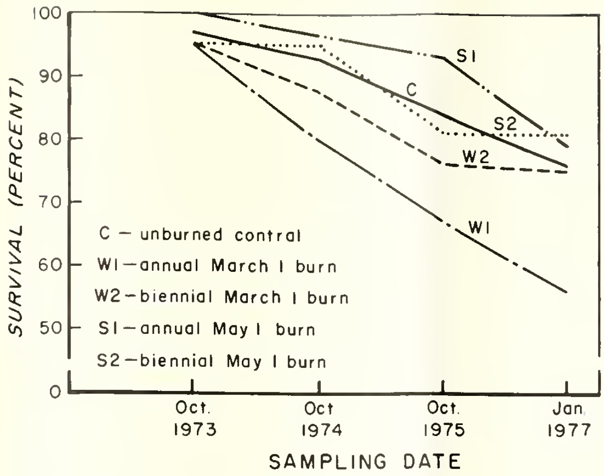

Figure 2.—*Survival of grass-stage seedlings.*

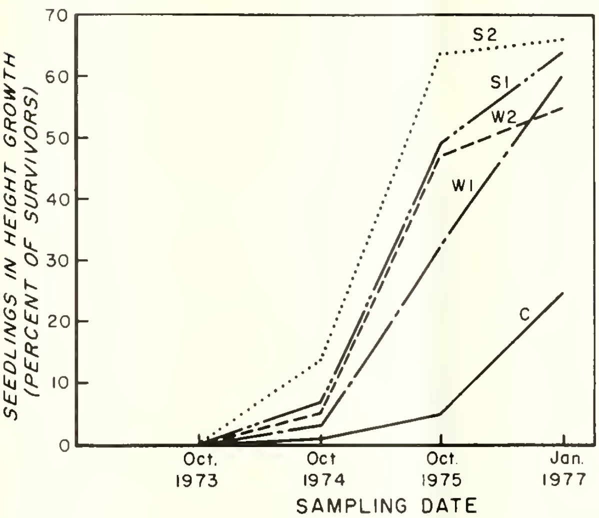

Figure 3.—*Percentage of surviving grass-stage seedlings in height growth.*

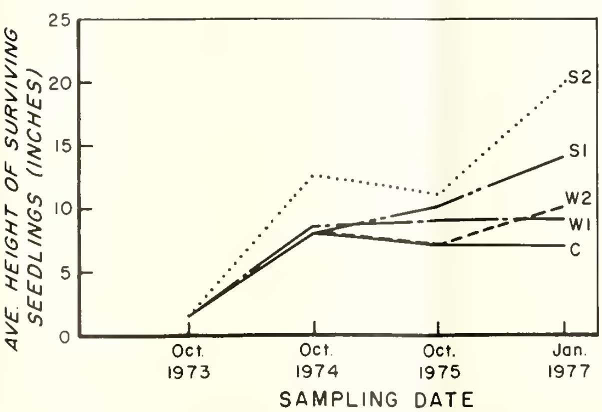

Figure 4.—*Cumulative height of surviving grass-stage seedlings.*

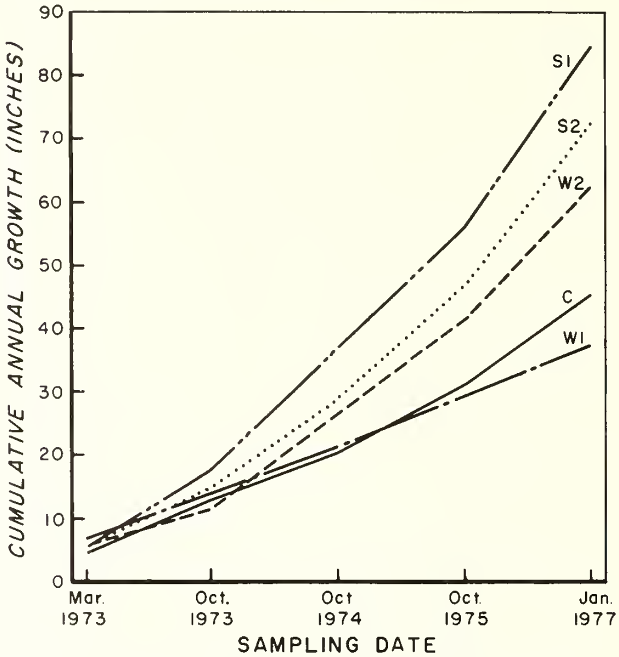

Figure 5.—*Development of older seedlings already in height growth.*

CONCLUSIONS

Results of this study confirm previous observations and measurements on the responses of longleaf pines to seasonal burning (Grelen 1975). Benefits of May burning may be related to the eradication both of brown-spot needle blight and of woody and herbaceous competition at a critical growth period. Another factor may be the timing of the fire in relation to the development of longleaf pine buds and twigs. About March 1 the twig or "candle," is elongating and bare except for a coat of white hair, and is vulnerable to flame and heat. By May 1, needles are developing on the candle, forming an insulating barrier that may prevent heat damage to terminal growth (fig. 6).

May burning is harmful to ground- or low-nesting birds and other small wildlife species. Thus, the purpose of this paper is not so much to recommend May burning as to report its beneficial effects on young longleaf pine seedlings. Since comparable results have been obtained on both well-drained and poorly drained sites, response of longleaf pine seedlings to burning on or about May 1 seems predictable throughout the range of the species. Recent tests on sandy soils in southwest Alabama corroborate these findings but also indicate that longleaf pine seedlings on clay soils do not respond favorably to a single mid-May burn (Maple 1977). Additional research may be necessary to fit May burning into multiple-use management of longleaf pine, particularly in regard to wildlife management.

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Figure 6.—*Longleaf pine seedling ignites during a May burn. Developing needles provide partial protection from the fire.*

Southern Forest Experiment Station

Research Note

SO-235

1978

Performance of Species-Reciprocal Hybrids Between Slash and Shortleaf Pines

O. O. WELLS

SUMMARY

Hybrids between shortleaf and slash pine were made by controlled pollination with each species used alternatively as the female parent. Hybrids with shortleaf as the female parent survived planting better than those with slash as the female parent. In all other respects—height, d.b.h., and resistance to diseases and insects—the species used as female parent did not affect resulting progeny.

Additional keywords: *Cronartium fusiforme*, interspecific hybridization.

TESTING OF HYBRIDS

On forest sites where risk of fusiform rust (*Cronartium fusiforme* Hedgc. & Hunt ex Cumm.) infection is high, southern pine hybrids may be an alternative to susceptible loblolly (*Pinus taeda* L.) and slash pines (*P. elliottii* var. *elliottii* Engelm.). A recent study has shown the hybrid between shortleaf (*P. echinata* Mill.) and slash pine to be rust resistant and well adapted to certain Upper Coastal Plain and Piedmont sites in Georgia and Alabama (Wells and others 1978). If hybrids are to be planted commercially, they must be efficiently mass-produced and therefore more information about artificial pollination techniques is desirable.

This report describes an experiment designed to test effects of using slash pine and shortleaf pine alternatively as the female parent for the production of hybrids. The main objective was to test the assumption that maternal effects would not be of practical importance in the hybrid. A secondary objective was to test how geographic seed source of the shortleaf parent affected the performance of the hybrid.

MATERIALS AND METHODS

Parent trees in this experiment are slash pines of northern Florida origin growing on the Harrison Experimental Forest in southern Mississippi, and shortleaf pines of various provenance growing in the A. J. Hodges Experimental Area near Many, Louisiana. The slash pines originated from a commercial seed collection and the shortleaf pines from seed collections made for the Southwide Pine Seed Source Study (Wakeley 1961). Pollen from 21 of the slash pines was composited and used on from two to six trees of each of six provenances of shortleaf pine in 1960. Pollen was collected from the shortleaf pines in 1960, stored, and applied to the slash pines in 1961. Sausage-casing isolation bags were used, and standard controlled pollination methods were applied.

Hybrid seed, seed from local shortleaf, and seed from the same slash pines that provided pollen for the study were sown in the spring of 1963 at the Harrison Experimental Forest nursery. Hybrid seed from the slash and shortleaf mother trees were grown in adjacent 90-

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foot-long seedbeds. The area had been used as a pine nursery for many years and was uniform. In addition, both beds received similar culture before sowing and during the growing season. Seedlings were planted in February 1964 on the Harrison Experimental Forest. The site was cutover longleaf (*P. palustris* Mill.) land with infertile, sandy soil; plantation spacing was 8 x 10 feet. A randomized complete block design was used with 10 blocks of five-tree plots and 14 "treatments."

Heights were measured at time of planting, and trees were remeasured and scored for height, survival, and insect and disease attack annually for the first 3 years and at the end of the 5th and 10th years in the field. Diameter at breast height was measured after 10 years. Competition between row plots was becoming severe after 10 years, so the test was ended. Tip moth (*Rhyacionia frustrana* [Comst.]) and fusiform rust were the only serious pests during the 10-year period. Plot means were calculated and used as the units of analysis, and data expressed as percent were transformed to arc sine $\sqrt{\text{proportion}}$.

RESULTS AND DISCUSSION

Immediately after germination, the slash x shortleaf hybrids grew much faster than those with shortleaf as the female parent. This initial growth advantage gradually decreased until the two groups of hybrids in the adjacent seedbeds were about the same size by the end of the growing season. The sample removed for planting showed hybrids with slash as the female parent were about one-tenth of a foot taller. This performance is probably explained by the differences in seed size between the two groups. Slash pine seeds are about three and one-half times as large as shortleaf pine seeds (U.S. Forest Service 1974), and their larger food reserves promote fast early growth.

Differences due to geographic origin of the shortleaf parents were very small in the seedbed. The parent species provided the only discontinuities in the appearance of the seedbeds as slash was taller and shortleaf shorter than the hybrids. Hybrids in both beds took on a typical slash "bronzy" color by midwinter. With one exception (PA), the hybrids did not survive planting or the period between establishment and age 10 as well as either shortleaf or slash pine (table 1). Between 2 and 10 years after planting, about 17 percent of the hybrids died, but only 5 percent each of shortleaf and slash pines died.

The hybrids made with shortleaf as the female parent survived planting better than those made with slash as the female parent. The tendency was statistically significant but inexplicable. As previously noted, the two groups of hybrids did develop in the nursery at different rates and perhaps this put them into slightly different physiological states at lifting time and affected their ability to survive planting.

The hybrid is usually made with shortleaf as the female parent because slash flowers 2-3 months earlier in the spring, thus making possible the use of slash pollen that has been stored for only 2-3 months. Also, the later flowering of shortleaf minimizes the chances of losing female flowers to late freezes. Shortleaf also flowers more profusely than slash. The survival differences found in the present study constitute one more reason for using shortleaf as the female parent.

The survival differences were the only consistent species-reciprocal effect in the study. In all other traits at whatever age—height, d.b.h., and attack by rust, tip moth, scale insects, needlecast, and rodents—the means of the two groups of progeny did not differ. In fact, the three economically important traits measured at 10 years (height, d.b.h., and rust infection) were virtually identical for the two groups (table 1). Hybrids varied considerably in species-reciprocal effect among individual sources of shortleaf, but the variation did not consistently favor either species as the male or female parent. Experimental error was undoubtedly higher in the comparisons of individual hybrids than for the means of all six. Most notable in this regard, the poor survival of hybrids made with northern Mississippi shortleaf as male parent probably biased to some extent the species-reciprocal effect in other traits for that particular hybrid.

Geographic origin of the shortleaf parent provided no recognizable pattern for differences in survival, height, d.b.h., and rust infection. Hybrids made with shortleaf from northwestern Georgia and southeastern Arkansas ranked high in 10-year height and d.b.h. Hybrids made with shortleaf from these same areas also grew well in plantings in another test in northern Alabama and central Louisiana (Wells and others 1978). In the present experiment, slash ranked high in height and d.b.h., and shortleaf ranked below average. Apparently geographic origin, though it has affected growth rate in provenance tests of shortleaf pine (Wells and Wakeley 1970), is not important when choosing shortleaf pine parents for hybrids to be used in the southern

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Table 1.—*Performance of species-reciprocal hybrids between slash and shortleaf pines and parent species when grown in southern Mississippi. Geographic source of the shortleaf parent is designated by compass quadrant (SE =southeast, etc.) and Post Office abbreviations.*

Geographic source of shortleaf parent	Shortleaf (♀) x slash (♂) Survival —Year— 2	10	Height (At 10 years)	D.b.h. (At 10 years)	Rust (At 10 years)	Slash (♀) x shortleaf (♂) Survival —Year— 2	10	Height (At 10 years)	D.b.h. (At 10 years)	Rust (At 10 years)
	Percent		*Ft*	*In*	*Percent*	*Percent*		*Ft*	*In*	*Percent*
NW GA	76	70	28.0	5.2	5	68	60	24.8	4.1	8
SW AR	68	44	25.8	4.4	0	74	62	22.7	4.1	4
SE AR	70	60	25.6	4.3	3	58	44	28.5	5.3	0
PA	94	72	23.7	4.3	2	82	62	24.5	4.6	10
N MS	66	48	22.1	4.1	19	14	8	27.5	4.6	0
N AR	78	54	20.8	3.8	13	48	30	19.6	3.5	20
Mean of hybrids	75	58	24.3	4.4	7	57	44	24.6	4.4	7
Slash	90	82	29.4	4.8	36					
Shortleaf	80	78	23.7	4.4	2					

Coastal Plain and Piedmont. So if the shortleaf x slash hybrid is to be used within the range of fusiform rust, its principal area of potential use, outstanding individual shortleaf trees can be used as parents regardless of geographic origin. Farther north, nearer the northern extremities of the shortleaf range, geographic source becomes an important factor in choosing shortleaf parents for the shortleaf x slash hybrid (Wells and others 1978). Geographic source of parents is also important for the pitch pine (*P. rigida* Mill.) x loblolly pine hybrid when it is to be planted in the northeastern United States (Little and Trew 1977).

Thirty-six percent of the slash pines had either a branch or stem infection at 10 years, but only 2 percent of the shortleaf pines were infected. The hybrid most resembled the shortleaf parent in this respect with 7 percent average infection. Clearly, the hybrids possess a very potent form of resistance, a trait that should make them particularly valuable in a breeding program for rust resistance.

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Acknowledgment: The experiment was designed by P. C. Wakeley, now retired, Southern Forest Experiment Station.

U.S. GOVERNMENT PRINTING OFFICE:—1978-772-032

Southern Forest Experiment Station

Research Note

SO-236

1978

Canker Production By Strains Of *Botryodiplodia Theobromae* In Cephalosporium-Wilted Sycamore

R. LEWIS, JR., AND E. P. VAN ARSDEL

SUMMARY

Two strains of *Botryodiplodia theobromae* were isolated from cankered sycamore trees; one was virulent and the other was less virulent. The less virulent strain colonized all sycamores inoculated with it but, in most cases, did not induce cankers unless the sycamores were wilting from *Cephalosporium diospyri* infections. The virulent strain of *B. theobromae* induced cankers in both wilting and non-wilting sycamores but it induced cankers more rapidly in the wilting trees. Cephalosporium wilt can make sycamores more vulnerable to Botryodiplodia cankers.

Additional keywords: *Diplodia theobromae, Platanus occidentalis*.

THE PROBLEM

Wilting sycamores (*Platanus occidentalis* L.) with cankers and dieback were observed throughout east Texas during the summers of 1973-1976. The wilt, caused by *Cephalosporium diospyri* Crandall, had been observed by Van Arsdel (1970) and Bush (1973) but they did not associate cankers with it. The cankers, caused by *Botryodiplodia theobromae*, were observed on wilting sycamores in more than 90 percent of the cases (Lewis and Van Arsdel 1975) and were believed to be stimulated by *Cephalosporium* wilt. This study measured the effects of Cephalosporium wilt on canker production by *B. theobromae* in sycamore.

METHODS

Two-year-old nursery-grown sycamores were field planted near College Station, Texas. Trees were 2-3 feet (0.6-0.9 m) tall when inoculated. The inocula consisted of mycelium from a 2-week-old potato dextrose agar (PDA) culture of *C. diospyri* and from PDA cultures of the virulent and less virulent strains of *B. theobromae*, all isolated originally from wilted and cankered sycamores. The less virulent strain of *B. theobromae* seldom produced cankers in artificially inoculated sycamores; the virulent strain almost always produced cankers (Lewis and Van Arsdel 1975).

Canker production by the two strains of *B. theobromae* in sycamores that were inoculated with *C. diospyri* was compared with canker production in sycamores that were not inoculated with *C. diospyri*. Fifteen sycamore trees were inoculated 1-2 inches (2.5-5 cm) above the soil line with *C. diospyri* by surface sterilizing stems with 70 percent ethanol, cutting into the xylem, and placing PDA with mycelium onto the wounded surfaces. Inoculated wounds were covered with masking tape. After the sycamores inoculated with *C. diospyri* developed wilt symptoms (5 weeks after inoculation), five of them were inoculated with the virulent strain of *B. theobromae*, five were inoculated with the less virulent strain, and five controls received PDA only. Fifteen healthy sycamores that had not been inoculated with *C. diospyri* were also inoculated with *B. theobromae*: five were inoculated with the virulent strain, five with the less virulent strain, and five controls received PDA only. The main stem of each sycamore was inoculated in three separate places with *B. theobromae* to yield 15 inoculations for each strain of the fungus. Each inoculation experiment was triplicated to yield 15 trees and 45 inoculation points for each strain of *B. theobromae*.

RESULTS AND DISCUSSION

The less virulent strain of *B. theobromae* induced cankers in only 3 percent of the inoculation points on sycamores not infected with *C. diospyri* but in 80 percent of the inoculation points on *C. diospyri*-infected sycamores. All cankers appeared within 15 days after inoculation. Canker length varied from 17 to 80 mm but averaged 26 mm in sycamores inoculated with both *C. diospyri* and the less virulent strain of *B. theobromae;* however, canker length averaged only 12 mm in sycamores inoculated with *B. theobromae* alone. The less virulent strain of *B. theobromae* was reisolated consistently from above and below inoculation points on canker-free sycamores that had been inoculated with it.

The virulent strain of *B. theobromae* induced cankers in 90 percent of the inoculation points on sycamores not infected with *C. diospyri* and in 100 percent of the inoculation points on *C. diospyri*-infected sycamores. Cankers were not observed on the controls, but wilt symptoms were observed in all trees inoculated with *C. diospyri.*

Cephalosporium wilt stimulated canker production by the less virulent strain of *B. theobromae* but had little effect on canker production by the virulent strain. Cephalosporium-wilted sycamores were killed, often within one growing season, after becoming naturally infected with *B. theobromae* early in the growing season. We never observed unwilted sycamores that were killed by Botryodiplodia cankers and dieback and seldom observed cankers on them.

Ross (1971) isolated two strains of *Diplodia theobromae* (=*B. theobromae*) from sycamore cankers. One strain produced cankers on artificially inoculated sycamore trees, but the other strain did not produce cankers even though it was re-isolated from the trees. The less virulent strain of *B. theobromae* used in our study was also re-isolated from canker-free trees. Therefore, the canker-producing ability of strains of *B. theobromae* in sycamore is not entirely due to their ability to colonize sycamore tissues. Host vigor at the time of infection appears to be a factor in determining whether strains of *B. theobromae* can induce cankers in sycamore. Trees that are stressed by Cephalosporium wilt are very vulnerable to *B. theobromae* infections and canker production.

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Southern Forest Experiment Station

Research Note

SO-237

1978

Planted Loblolly and Slash Pine Response To Bedding and Flat Disking on a Poorly Drained Site —An Update

Michael D. Cain

SUMMARY

Early gains in loblolly and slash pine height growth achieved by bedding an imperfectly drained Beauregard-Caddo silt loam diminished somewhat by age 15. After age 8 there were no increases in growth response to site treatment for either species. For loblolly, yields on flat-disked and bedded plots were about 6 cords (500 ft^3) per acre greater than controls. Much of the difference is attributed to better first-year survival on mechanically treated plots. For slash, yield differences among treatments were small and relatively unimportant.

Additional keywords: Mound disking, bedding, flat disking, site modification, *Pinus taeda, Pinus elliottii.*

SITE PREPARATION

Southern pines planted on imperfectly drained soils in the western Gulf Coastal Plain often have poor survival rates and growth unless there is some degree of site improvement prior to planting. Soils on wet sites in this region are often saturated for long periods in winter but dry in summer. Bedding or mound disking usually improves the drainage characteristics of such sites. Seedlings are elevated 5 to 8 inches above the saturated zone in soil that is more adequately aerated.

This study is one of a series established in southwest Louisiana to test growth response of planted loblolly (*Pinus taeda* L.) and slash (*P. elliottii* var. *elliottii* Engelm.) pine on sites that were prepared mechanically before planting. Soils on the sites are classified as Beauregard-Caddo silt loams. Results should apply to similar soils in the western Gulf Coastal Plain.

The following data summarize results through age 15. Earlier results were reported by Mann and Derr (1970) and Derr and Mann (1977).

METHODS

Soils on slopes are Beauregard silt loam and soils in lower flats are Caddo silt loam. Relief is level to slightly sloping, with a few natural pimple mounds present on the study area. The Caddo soil has slow surface and internal drainage; the Beauregard has medium drainage throughout.

The site was originally covered with longleaf pine and had not been cultivated. At study installation, cover species included *Andropogon* spp. and scattered post oak (*Quercus stellata* Wang.), blackjack oak (*Q. marilandica* Muench.), and southern bayberry (*Myrica cerifera* L.). The area was burned to eliminate grass rough and woody vegetation was removed.

Treatments were: control, flat disking, and bedding (mound disking). Controls received no treatment except burning of grass rough to facilitate planting. Flat-disked plots were completely tilled with an offset disk to eliminate grass competition. Plots were disked in November to December 1960 and July 1961. Bedded plots were flat disked, then mounded by double disking with a bedding harrow in September 1961. Mounds were spaced 8 feet apart and averaged 20 inches in height (from furrow to crest) before settling (fig. 1). At age 15 beds were intact and averaged 10 inches in height (fig. 2).

All seedlings were from the Louisiana Forestry Commission nursery at Columbia. They were hand planted in February 1962 at a 6- x 8-foot spacing.

Although gross plots measure 108 x 144 feet, the center 100 planting spots comprise the measurement subplot of 60 x 80 feet. Plots are separated by 50-foot untreated and unplanted strips on four sides that facilitated equipment moving during site preparation. Treatments were replicated four times in a randomized complete block design.

Total heights of surviving pines were measured annually through age 10 and again at ages 13 and 15. Diameters were taken at the same frequency beginning at age 5. Incidence of fusiform rust (*Cronartium fusiforme* Hedgc. & Hunt ex. Cumm.) has been recorded periodically, and was last observed at age 15.

Plots were selectively thinned at age 13 during September and October, leaving an average of 345 trees per acre. Number of stems per acre for individual plots ranged from 335 to 354 after thinning. Thinning helped to equalize stocking among and within treatments, reduce incidence of fusiform bole cankers, and insure more precise height measurements. Thinning caused no apparent damage to the residual stand; no trucks or heavy equipment were allowed within the plots.

Total cubic-foot volume (o.b.) was calculated by prediction equations at ages 13 and 15 (Hasness and Lenhart 1972; Moehring and others 1973).

Figure 1.—*Bedded plot in October 1961, 10 days after treatment.*

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Figure 2.—*Bedded plot in June 1977, 15 years after treatment.*

Growth differences among treatments were tested for significance by analysis of variance at the 0.05 level.

RESULTS

Survival

First-year survival of loblolly pine was 16 percentage points higher on bedded plots than on controls; flat disking improved survival by 14 percentage points (table 1). At age 13, mortality on loblolly control plots was twice as great as on bedded plots, but these differences had developed by the end of the first year. For slash pine, differences in survival among treatments have been small and unimportant.

Table 1.—*Mean survival by species and treatment at three ages*

Site treatment	Loblolly pine			Slash pine		
	Age					
	1	6	13	1	6	13
	Percent					
Control	74	73	72	87	86	76
Flat disked	88	87	81	82	81	74
Bedded	90	89	87	89	89	76
Mean	84	83	80	86	85	75

Survival by species differed by only 2 percentage points at the end of the first year. By age 13, loblolly survival excelled by 5 percentage points because more slash pines were lost to fusiform rust infection.

Mound disking was completed 5 months before February planting, allowing beds to stabilize, which no doubt contributed to the exceptional pine survival for that treatment. Flat disking has also improved pine survival in some studies, most likely because of reduced grass competition.

Height Growth

For loblolly, all trees and the 100 tallest per acre were significantly taller on flat-disked plots than on controls at age 15 (table 2). Heights of all trees on bedded plots did not differ significantly from controls. From age 2, bedded plots consistently produced taller pines than controls, but height difference declined from a 2.7-foot advantage at age 8 to a 2-foot advantage at age 15. The 100 tallest trees per acre on both flat-disked and bedded plots were significantly taller than the 100 tallest controls, with differences ranging from 2.2 to 2.9 feet.

For slash, there were no significant height differences among treatments even though pines on bedded plots have consistently averaged about 2 feet taller than those on controls throughout the study.

Periodic annual height growth has been excellent for both species and has averaged over 3 feet per year. Peak annual height growth occurred between ages 6 and 8, averaging 5.15 feet for loblolly and 4.13 feet for slash (fig. 3).

Loblolly height growth excelled on bedded plots from ages 2 through 8; thereafter, growth has been less than or equal to that for other treatments. Similarly, slash pine height growth was best on bedded plots through age 8, but has subsequently ranked last.

Slash pines outgrew loblolly through age 4 but lagged behind between ages 4 and 10. Since age 10, slash pine has again held a slight height-growth advantage. However, at age 15, loblolly was significantly taller than slash.

Diameter Growth

Diameter differences among treatments at age 15 were not significant for either species (table 2). Throughout the study, diameters have generally followed the same pattern as heights among treatments. From ages 5 through 8, pines of both species had largest diameters on bedded plots. Bedding was also the superior treatment for slash pine at age 10. From age 10 through 15, bedding no longer ranked first (fig. 4 and 5). For both species, periodic annual

Table 2.—*Average tree size at age 15*[1]

Site treatment	Average total height				Average dbh all trees[3]	
	All trees[2]		100 tallest per acre			
	Loblolly	Slash	Loblolly	Slash	Loblolly	Slash
	Feet				*Inches*	
Control	50.6a	48.7a	53.8a	52.4a	7.49a	7.16a
Flat disked	53.4 b	48.6a	56.7 b	52.2a	7.38a	7.07a
Bedded	52.6ab	50.4a	56.0 b	54.0a	7.18a	7.08a
Mean	52.2	49.2	55.5	52.9	7.35	7.10

[1] Within-column means not followed by the same letter are significantly different.
[2] Includes only those trees not damaged by ice in January 1977.
[3] All surviving trees.

diameter growth from age 6 has been less on bedded plots than for other treatments.

Volume Production

At age 15 total production for loblolly was greatest on bedded and flat-disked plots and surpassed controls by about 500 cubic feet per acre (table 3). Difference in yields between bedded and flat-disked plots was not significant. Volume differences among treatments were not significant for slash. On a per-tree basis, volume production among treatments varied by less than 1 cubic foot for both species and differences were not significant.

Although volume growth of residual trees (after thinning) from age 13 to 15 ranked last on bedded plots, growth differences among treatments were not significant. Volume of surviving trees at age 15 averaged well over 2,000

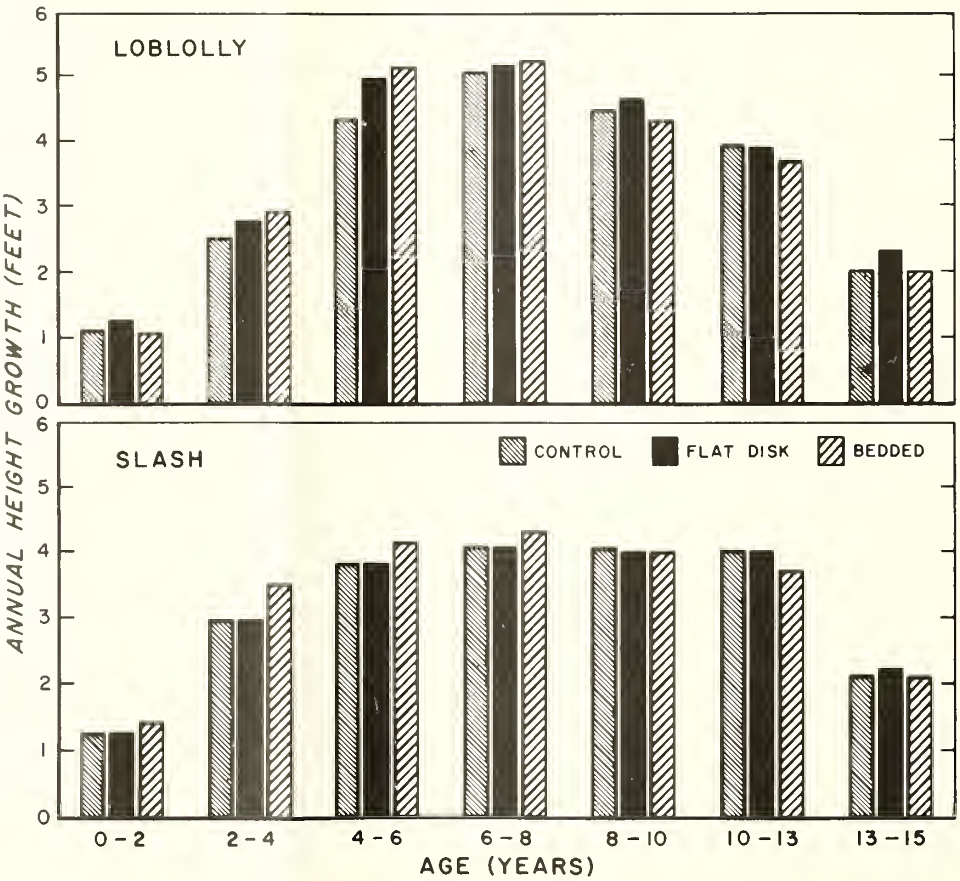

Figure 3.—*Periodic annual height growth of all trees by site treatment.*

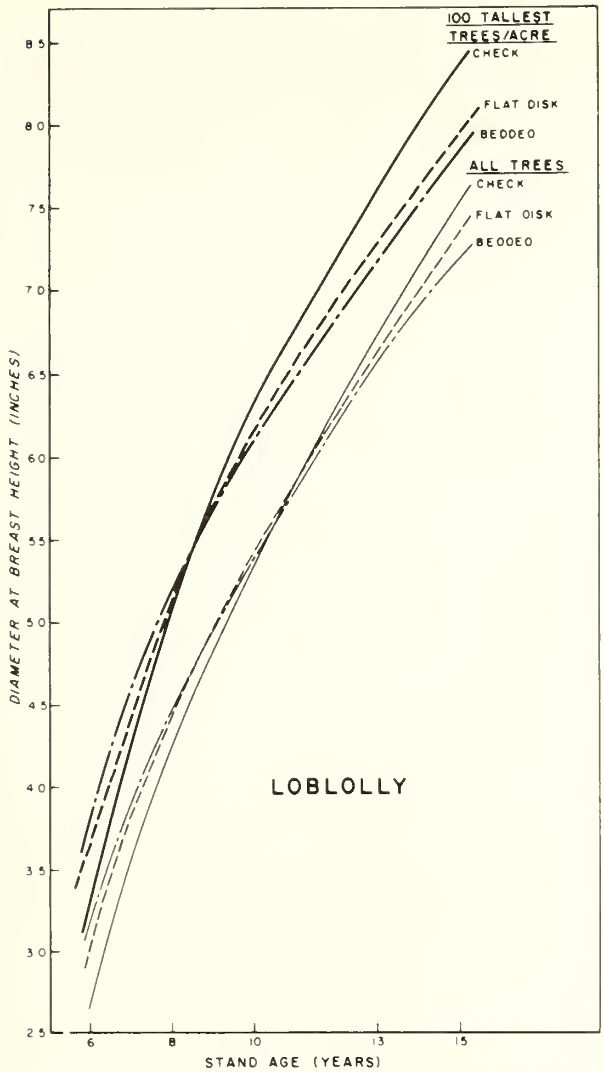

Figure 4.—*Average diameters by site treatment at selected ages, 6 to 15 years.*

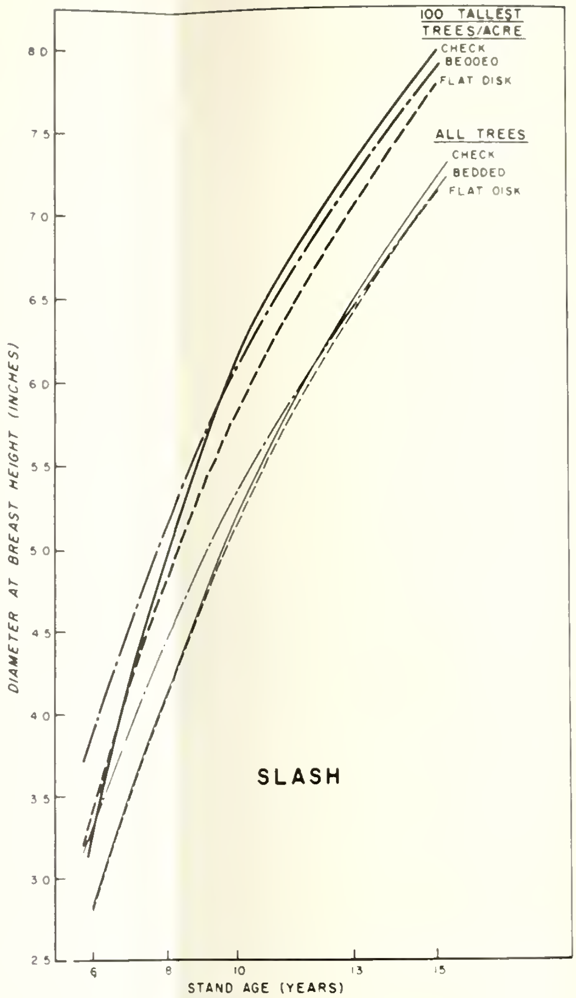

Figure 5.—*Average diameters by site treatment at selected ages, 6 to 15 years.*

cubic feet per acre. For both species volumes on bedded plots lagged behind other treatments by more than 100 cubic feet (about 1 cord) per acre, but differences were not significant.

Fusiform Rust Infection

At age 8, 44 percent of the slash pines were diseased; infection of loblolly was modest, averaging 9 percent (table 4). Thinning reduced the proportion of stem-infected pines 4 percentage points for loblolly and 7 percentage points for slash, but the disease is still a serious problem for the slash pines. Site treatments did not significantly influence the incidence of trunk infections for either species.

DISCUSSION

Both species excelled in height and diameter growth on bedded plots for the first 6 to 8 years. Thereafter, periodic annual growth response (height and dbh) on bedded plots has generally fallen behind control and flat-disked plots, but differences have been relatively small. Early height gains achieved by bedding were maintained through age 15. Early response to that treatment is attributed to improved soil moisture and aeration.

Improved growth response on both control and flat-disked plots after age 8 may have been caused by improvement of soil moisture conditions on the site from drying out. With crown closure, pines probably act as pumps to substantially reduce saturated soil conditions through transpiration. In contrast, bedding on relatively flat sites can impound water, especially during winter, which may suppress root development between bedded rows. Lack of inter-bed root systems may therefore inhibit a tree's ability to absorb enough moisture to sustain growth during dry summers. These effects

Table 3.—*Average volume production by species and site treatment*

Species and treatment	Volume			
	Total per acre[1]	Per tree[2]	Growth per tree[3]	Residual per acre[4]
	Cubic feet (o.b.)			
Loblolly				
Control	3,707a [5]	5.28a	1.70a	2,589a
Flat disked	4,122 b	5.08a	1.78a	2,520a
Bedded	4,209 b	4.77a	1.52a	2,405a
Mean	4,013	5.04	1.67	2,505
Slash				
Control	3,687a	4.99a	1.75a	2,460a
Flat disked	3,566a	4.89a	1.78a	2,422a
Bedded	3,684a	5.07a	1.68a	2,313a
Mean	3,646	4.98	1.74	2,398

[1] 13th-year cut volume plus 15th-year standing volume of all surviving trees.
[2] Based on the 13th-year cut volume plus 15th-year standing volume of trees not damaged by ice in January 1977.
[3] From age 13 to 15, based on the same number of trees.
[4] All surviving trees at age 15.
[5] Within-column means followed by the same letter are not significantly different.

Table 4.—*Proportion of living trees with fusiform rust bole cankers at ages 8 and 15, by treatment*

Treatment	Loblolly		Slash	
	Age 8	Age 15	Age 8	Age 15
	Percent			
Control	9.0	4.6	42.6	28.6
Flat disked	7.9	5.4	39.2	37.9
Bedded	10.6	6.6	49.8	44.2
Mean	9.2	5.5	43.9	36.9

may be more critical after trees reach the sapling stage.

Bedding increased total loblolly volume production over controls by about 6 cords per acre after 15 years, but on a per-tree basis the difference among treatments was less than 1 cubic foot. Flat disking was as effective as bedding for increasing loblolly volume growth. Much of the difference in total production among loblolly treatments was probably due to higher survival on bedded and flat-disked plots.

Although slash pines have averaged consistently taller on bedded plots, volume production at age 15 was practically the same for all treatments. It appears that the soil modification treatments gave marginal economic benefits at best, especially for slash pine.

Derr and Mann (1977) reported that gains in pine growth on six bedding studies in southwest Louisiana were modest and inconsistent. They found that loblolly did not respond as well as slash to bedding treatments, especially on the poorest sites. Their largest recorded response to bedding was 2.6 feet in height growth by age 5 for slash pine on a poor site with a Caddo silt loam soil. The site tested in this study has proved to be excellent for pine growth. Since Beauregard silt loam is usually capable of supporting pine without mechanical modification, it may be that the gains in height and volume that were achieved by bedding and flat disking in this study occurred on the Caddo silt loam.

As a general rule, landowners should bed only those sites where the water table is at or near the surface for several consecutive weeks (Derr and Mann 1977). Also, beds should be oriented perpendicular to land contour to facilitate natural surface drainage.

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SO-238

Southern Forest Experiment Station

Research Note

1978

Seed Treatment with Systemic Fungicides for the Control of Fusiform Rust in Loblolly Pine

JOHN G. MEXAL AND GLENN A. SNOW

SUMMARY

A new systemic fungicide, Bayleton, may economically control fusiform rust in southern pine nurseries. Stratified seeds of loblolly pine (*Pinus taeda* L.) were imbibed with Bayleton and two other systemic fungicides, and the seedlings were inoculated at three stages of emergence with spores of *Cronartium quercuum* (Berk.) Miyabe ex Shirai f. sp. *fusiforme*. Bayleton was the only effective fungicide. Soaking seed at a concentration of 800 mg/L did not inhibit seed germination and afforded significant protection against the disease.

Additional keywords: Bayleton, *Cronartium quercuum*.

CONTROLLING RUST IN NURSERIES

Fusiform rust caused by *Cronartium quercuum* (Berk.) Miyabe ex Shirai f. sp. *fusiforme* (Burdsall and Snow 1977) is a serious disease of pines in southern nurseries. Current control methods consist of frequent applications of the contact fungicide, ferric dimethyldithiocarbamate (ferbam) (Foster and Henry 1956). Despite as many as 30 spray applications during the 90-day infection season, infection levels of 15 to 20 percent are not uncommon (Rowan 1972). Many infections occur during the first few days after seed germination, the most difficult time to protect the germinating seedlings adequately. One reason is that they are rapidly elongating and new growth is not protected by previously applied contact fungicides. Also, repeatedly moving tractors carrying spray equipment through the nursery during spring rains can cause considerable mud damage to seedlings.

Several systemic fungicides have been used experimentally to control fusiform rust with some success. However, control was accomplished by spraying the foliage or by soil drenching (Hare and Snow 1976, Rowan 1972, 1977). Seed coating has been attempted but with little success (Rowan 1972); unless the fungicide is washed off the seed coat before seedling emergence so that it can be taken up by the roots, it is unlikely that this method could be effective. The objective of our trial was to permeate stratified pine seed with systemic fungicides, a method that has not been investigated before. Our aim was to: (a) determine the effect of systemic fungicides on loblolly pine seed germination, and (b) determine if seed permeation affords protection against rust during the early phases of seedling emergence.

Biswas and others 1972, permeated stratified loblolly pine seed with plant growth regulators, which improved germination. Effective control of other diseases through seed permeation has been proven for dry seed only (Maude and Kyle 1970, Tao and others 1974).

MATERIALS AND METHODS

The fungicides tested were 2-iodobenzanilide (Benodanil), 1-(4-chlorophenoxy)-3, 3-dimethyl-1-1-(1H-1,2,4-triazol-1-yl)-2-butanone (Bayleton), and Thiadiazole Compound (NA_{43410}).

To determine the best concentration of fungicides to use in solutions, seeds were germinated after treatment with three levels of the chemicals (table 1). Seeds from the flatwoods seed zone in Mississippi that were known to be susceptible to rust were stratified for 30 days, soaked in aqueous solutions of a fungicide for 24 hours, and surface dried. They were then germinated in the laboratory on moist cellulose wadding at room temperature. Each treatment consisted of three replicates of 100 seeds each, and germination was monitored daily for 2 weeks. A seed was counted as germinated when the radical protruded 2 mm from the coat.

After the germination trial seeds from the same source were soaked in the highest concentration of each fungicide that did not inhibit the rate of germination. These treatments were: (1) Benodanil (80 mg/L), (2) NA_{43410} (300 mg/L), and (3) Bayleton (800 mg/L). These concentrations and a control (no fungicide) were used in the inoculation trial.

Seedlings representing three stages of development were inoculated with rust spores 18 days after the seed treatment (fig. 1). Each treatment X size combination consisted of 24 seedlings and was replicated three times, which constituted a randomized complete block design. Inoculum was prepared from a mixture of aeciospores collected near Laurel, Mississippi, and Bogalusa, Louisiana. Each plant received 18 ± 3 basidiospores/mm² using the pine inoculation method described by Snow and Kais (1972). Percent infection was determined 12 months after sowing.

RESULTS

The concentrations of the fungicides used in the germination test did not significantly influence total germination, but speed of germination (as indicated by percent germination 5 days after sowing) was significantly affected (table 1). However, no difference existed in rate of germination between concentrations of the fungicides used in the inoculation trial and the control.

Neither Benodanil nor NA_{43410} was effective in controlling rust; treated seedlings averaged 78 and 84 percent infection, respectively (table 2). However, Benodanil and NA_{43410}

Table 1.—*Percentage germination of loblolly pine seed infused with various systemic fungicides.*

Chemical	Concentration	Germination Test (%)[1] By Day 5	Total
	mg/L		
Benodanil	30	23.0 d[2]	80 a
	80	13.7 abc	79 a
	200	6.3 a	79 a
NA_{43410}	30	13.7 abc	80 a
	300	14.0 bc	81 a
	3000	10.7 ab	71 a
Bayleton	50	18.0 bcd	76 a
	200	14.0 bc	82 a
	800	13.3 abc	77 a
Control	—	19.0 cd	77 a

[1] Germination percentage of seed used in rust inoculation trial.

[2] Percentages in a column followed by the same letter are not significantly different ($\alpha = 0.05$).

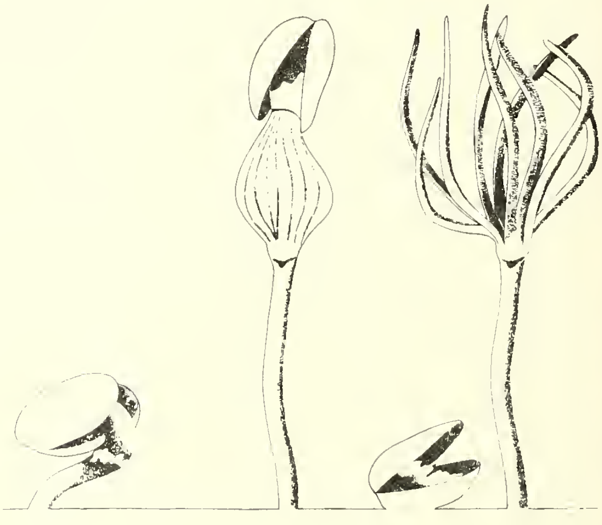

Figure 1.—*Stages of seedling development at time of rust inoculation.*

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Table 2.—*The effect of seed treatment with systemic fungicides on seedling infection 12 months after inoculation with rust spores.*

Chemical	Concentration	Seedlings with rust galls > 5 mm[1] (%)			Seedlings with galls or lesions (%)		
		Small	Medium	Large	Small	Medium	Large
	(mg/L)						
Benodanil	80	88 a[2]	67 a	67 a	89 a	71 a	71 a
NA_{43410}	300	88 a	75 a	87 a	88 a	76 a	90 a
Bayleton	800	14 b	22 b	21 b	14 b	22 b	22 b
Control	—	93 a	63 a	77 a	96 a	66 a	83 a

[1] Rust galls >5 mm long were considered active.

[2] Values followed by the same letter are not significantly different ($\alpha = 0.05$) according to Duncan's multiple range test.

(Rowan, personal communication) have been effective as systemic fungicides in pine seedlings; thus, these chemicals may not have permeated the seeds in our test.

Bayleton was significantly more effective than any other treatment. When the three size classes of seedlings were averaged, only 18% of those treated with this chemical had active galls (that is, galls greater than 5 mm long) after 12 months (table 2). The protection afforded by Bayleton appeared to diminish as seedlings developed, but the increase in infection with increasing seedling size was not significant ($\alpha = .05$). This probably occurred because the fungicide was diluted or degraded as the seedlings developed.

DISCUSSION

About 500 ha of nursery space are devoted to the production of pine seedings in the South, and more than $100,000 is spent annually on the control of fusiform rust. Often control is poor, especially during seedling emergence when most infections occur. Treating seeds with Bayleton may afford better early spring protection than current methods, at a considerable savings. It is difficult to extrapolate these results to a field response, but Snow and others (1977), indicated that high spore densities, such as used in this study, result in maximum rust infections. Densities this high rarely occur in nature. We are testing this fungicide further in nursery trials, both as a seed treatment and as a foliar spray.

Acknowledgments

The authors thank Wyandotte Corporation for supplying Benodanil, Chemagro for Bayleton, and North American Chemical Company and Dr. S. J. Rowan, USFS, for Thiadiazole Compound.

Note: This paper reports the results of research involving fungicides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of fungicides must be registered by appropriate State and/or Federal agencies before they can be recommended.

Mention of a trademark or proprietary product does not imply a recommendation of the product by the USDA to the exclusion of other products that may also be suitable.

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U.S. GOVERNMENT PRINTING OFFICE: 773-383

SO-239

Southern Forest Experiment Station

Research Note

1978

Size and Age of Tree Affect White Oak Stump Sprouting

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SUMMARY

Eighty overtopped white oaks were felled in winter of 1976-1977, and overtopping hardwoods were removed from 40 of the stumps. During the next growing season, 62 of the stumps produced a total of 1086 sprouts. The removal of the overtopping hardwoods had little effect on whether or not a stump sprouted or on numbers or height of the sprouts. Trees over 60 years of age or over 8 inches in d.b.h. produced few or no sprouts. The tallest sprout on each stump averaged 2.5 feet. Almost all sprouts grew from below the ground line on the stump.

Additional keyword: *Quercus alba.*

EARLY WHITE OAK STUMP SPROUTING

In the upland hardwood region, millions of white oak trees are overtopped by competing hardwoods. During forestry activities, these white oaks and the trees that overtop them are often felled, releasing the stumps from competition. Whether these stumps sprout or do not sprout greatly affects the early value of the land for wildlife and later for timber. Ivan Sander (1976) reported that stump sprouts are the most rapidly growing part of a new oak stand and that the number of sprouts can be projected by the size distribution of the trees being cut. In this experiment, we examined the effects of release, age, and size on early sprouting of white oak stumps.

METHODS

Eighty vigorous and well-formed white oak trees—overtopped for all or at least the last part of their lives—were selected for study. These trees were felled near the ground line with no notch in the stump. Forty of the stumps were then released by cutting one or more overtopping hardwoods. In August of the first growing season after cutting, each stump was checked for early sprouting. Data recorded included tree age, number of sprouts per stump, height of tallest sprout, and the location of the sprout on the stump.

RESULTS

Sixty-two of the eighty stumps produced sprouts. The number of sprouts ranged from 0 to 115 per stump and averaged about 13. The height of the tallest sprout on each stump ranged from a few inches to over 4 feet and averaged 2.5 feet. The release from overtopping trees had no apparent effect on either the number or height of stump sprouts (table 1). While it is likely that the released sprouts will perform better in the long run, the shaded sprouts could provide a quick source of browse for wildlife.

Of the 16 sample trees over 8 inches d.b.h., only 3 sprouted and only 1 had more than 10 sprouts (table 1). The trees smaller than 8 inches d.b.h. showed great variation in numbers

Table 1.—*Number of white oak sprouts per released or unreleased stump in relation to size of tree.*

Tree Size	Released		Unreleased	
	Sample Trees	Sprouts	Sample Trees	Sprouts
Inches d.b.h.	No.	Avg. No.	No.	Avg. No.
1.6 — 1.9	3 (3)[1]	6	2 (2)[1]	14
2.0 — 3.9	9 (9)	12	7 (6)	14
4.0 — 5.9	12 (11)	16	11 (11)	15
6.0 — 7.9	9 (8)	22	11 (9)	21
8.0 +	7 (1)	1	9 (2)	2
Average Sprouts Per Stump		11		14

[1]Number in parentheses indicates stumps sprouting in that category.

of stump sprouts. The wide variation among smaller trees spoiled attempts to associate tree size and number of sprouts by regression analysis. Wendel (1975) found somewhat similar sprouting patterns for white oak stumps from even-aged trees that were free-to-grow. But he found that free-to-grow trees up to 17 inches dbh would produce stump sprouts. Thus, at smaller sizes than free-to-grow trees overtopped white oak apparently loses the ability to produce stump sprouts.

Regressions of age on sprouting pattern were very weak. The actual data, however, suggest that age is important (table 2). Maximum sprouting came from stumps of trees about age 40, with a gradual decline to age 60. Beyond age 60, only 1 of 10 trees produced stump sprouts, and it had only four.

Age or size of the mother tree apparently has little effect on the height growth of stump sprouts. Many of the sprouts from trees of different ages and sizes were over 3 feet tall.

The location of the sprouts on the stump is of particular importance because sprouts originating above the ground line are generally of poor form and short lived. In this experiment, 936 of 1086 sprouts originated below the ground line. On 2 stumps all sprouts originated above the ground, but on 38 stumps all sprouts originated below ground. Apparently, no way exists to predict which stumps will have sprouts originating above ground.

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Table 2.—*Number of white oak sprouts per released or unreleased stump in relation to age of tree.*

Age	Released		Unreleased	
	Sample Trees	Sprouts	Sample Trees	Sprouts
Years	No.	Avg. No.	No.	Avg. No.
30 — 39	12 (12)[1]	15	14 (13)[1]	15
40 — 49	13 (11)	14	14 (13)	10
50 — 59	11 (8)	12	6 (4)	31
60 +	4 (1)	1	6 (0)	0
Average Sprouts Per Stump		11		14

[1]Number in parentheses indicates stumps sprouting in that category.

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U.S. GOVERNMENT PRINTING OFFICE. 1978 773-231

Southern Forest Experiment Station

Research Note

SO-240

1978

Progeny Testing Longleaf Pine At Two Locations

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SUMMARY

Means for brown-spot infection and 3- and 8-year height growth were determined in progeny testing of 540 parents in two Gulfport, Mississippi, plantings and an Alexandria, Louisiana, planting, and of 60 of the parents at a subsequent Alexandria planting. To estimate growth at ages 5 and 8, both degree of brown-spot infection and height growth at age 2 were necessary independent variables, but for growth at age 8, 3rd-year height growth alone was sufficient. Families selected for rapid growth and brown-spot resistance in one location may not be the ones selected in another. Likewise, those selected in a brown-spot free area differed from those selected in an area where brown spot was prevalent. Implications for future breeding and seed orchard development are discussed.

Additional keywords: *Pinus palustris*, genotype x environment interaction, survival, growth, brown-spot needle blight.

IMPROVING BREEDING PROCEDURES

Longleaf pine (*Pinus palustris* Mill.) is recognized as a species with good wood, form, and growth potential. Natural regeneration techniques have been developed, and new plantations are being established. Through the use of genetically improved seed, increased planting success and production seem promising. In this study we determine what effect variation in infection by brown spot [*Scirrhia acicola* (Dearn.) Siggers] has relative to that of early height growth in predicting later growth, examine family x environment effects, and recommend genotypes for advanced generation breeding programs.

METHODS AND MATERIALS

Four open-pollinated progeny tests of the same natural growth parents were established—three in 1963 and one in 1969. The 1969 test was a retest of some parents included in the 1963 tests.

The 1963 tests included progeny from 540 parents selected from Louisiana, Mississippi, Alabama, Georgia, and Florida (Snyder and Derr 1972). Of these, 417 were from a Louisiana area known to have been severely infected with brown spot. One progeny test was established near Alexandria, Louisiana, and two near Gulfport, Mississippi. Each was laid out in a randomized, complete block design with 10 replications of single tree plots.

At Alexandria, trees were spaced 3 feet apart in furrows placed every 8 feet. Numerous infected volunteer seedlings between rows provided brown-spot inoculum. The two sites at Gulfport were disked a year before planting. At one site, disease spreader trees were established every 3 feet in rows 12 feet apart. A year later, test seedlings were planted in the same rows between each two disease spreader trees. At the other Gulfport site, test seedlings were planted at the same spacing but without disease spreader trees, and brown spot was controlled by spraying with Bordeaux mixture in May, June, and September. After three seasons in the field, the proportion of current needle tissue lost to brown spot in the three 1965 tests was estimated as a percentage of total needle tissue. Heights of all trees were measured at age 3 and those of some trees at age 8.

To test the goodness-of-fit for the family x location effects in the sprayed versus unsprayed plots at Gulfport, we used a chi-square procedure. Values corresponding to probabilities of less than 0.05 were considered significant. To determine the importance of early growth and brown-spot incidence as predictors of later growth (Draper and Smith 1966), we used stepwise regressions on individual trees.

To follow-up the 1963 brown-spot test, we established a fourth test at Alexandria in 1969, using newly collected seed from 60 parents randomly selected from the original 540. Added to these as resistant, wind-pollinated controls were two Alexandria families, Abe and 1.1E, that displayed good early growth in previous tests (Derr 1963). A susceptible Alexandria family, PR, was also included. (Abe x W) x W was entered to determine the effects of backcrossing. Spring-sown seedlings were lifted in the fall, transplanted to 1-quart milk cartons, and planted in the spring.

The 1969 test site was open and devoid of natural seedlings, but brown-spot infection was heavy in an adjacent longleaf plantation. The area was burned, then furrowed with a fireplow. Seedlings were planted in the furrow at 6 x 6 foot spacing in a randomized, complete block design with four replications of 10-tree row plots. At age 2, the proportion of current needle tissue lost to brown spot was estimated as it was for the 1963 tests. At ages 2 and 5, the heights of all trees were measured. In summary, the four experiments were: 1963 brown-spot test at Alexandria, 1963 brown-spot test at Gulfport, 1963 sprayed test at Gulfport, and the 1969 brown-spot follow-up test at Alexandria.

RESULTS

Early prediction

Brown-spot infection and 3- and 8-year height means for the four experiments are given in table 1. For each of 202 random individuals in the 1963 brown-spot test at Gulfport and 154 in the one at Alexandria, individual and family means for 3-year-old height and brown-spot damage were entered into stepwise regressions to determine their contributions to the 8-year height variation. Numbers of trees chosen were proportional to survivals at the two locations. With only 3-year individual growth included, R^2 values were 0.52 and 0.46 for Gulfport and Alexandria, respectively. Inclusion of any combination of the other three traits did not change the R^2 values by more than 0.01. Thus, for practical purposes, selections at age 3 could be based solely on an individual's height—additional variables explain little of the 8-year height variation.

The 1969 test was used to relate 2nd-year growth and brown spot to 5th-year growth. When considered together variation in height and brown spot at age 2 explained 71 percent of the variation in 5-year heights. With only 2-year heights or only brown spot in the equation, $R^2 =$ 0.36. This correlation indicates that, unlike the test above, the predictive index requires both 2-year height and brown-spot resistance. Thus, the use of brown-spot damage as a selection criterion in these tests depended on age of trees at time of selection.

Roguing a progeny test may be necessary before trees are mature, particularly if the test is to be converted into a seedling orchard. The breeder should be aware that selection criteria may change with time. Roguing for brown-spot susceptibility could start in the greenhouse as early as 6 months of age, and badly diseased families could be eliminated from subsequent expensive field tests (Kais 1975). A similar

Table 1.—*Mean brown spot and height*

Test	Brown spot[1]	Early height[2]	Later height[3]
	Percent	*Inches*	*Feet*
1963 brown-spot test at Alexandria, La.	55	3.0	16.5
1963 brown-spot test at Gulfport, Ms.	71	6.4	19.1
1963 sprayed test at Gulfport, Ms.	0	23.6	23.2
1969 brown-spot test at Alexandria, La.	49	5.3	7.2

[1] Percentage of needle tissue killed at age 3 (1963 tests) or age 2 (1969 test).
[2] Heights at 3 years (1963 tests) or 2 years (1969 test).
[3] Heights at 8 years (1963 tests) or 5 years (1969 test).

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roguing for brown-spot susceptibility could be performed after one season in the field.

Since only a few families began height growth during the 2nd year, there was only minimal opportunity for brown spot to have an impact on height growth. Consequently, at age 2 both brown spot and height were needed in a predictive index. By age 3, height growth alone becomes a satisfactory predictor of 8-year growth since damage from brown spot is almost completely translated into decreased height growth.

Comparison of family performances in two tests at one location

Results of the two brown-spot tests at Alexandria show that a single preliminary selection test is not necessarily the best solution. The correlation between family means for age 3 heights in the 1963 test with age 5 heights of the 1969 test was 0.31. If the best 30 percent were selected on the basis of age 3 heights, the 1969 average of the selected trees would be 7.6 feet versus an average of 6.7 feet for the worst 30 percent. Four families, or two-thirds of the best six 1969 performers would have been isolated. To illustrate the types of relationships found, we contrasted mean heights of families performing best and worst in 1969 with their 1963 performance (table 2). Wind-pollinated families of Abe, 1.1E, and PR, which had been tested in former Alexandria tests but not represented in the 1963 tests, performed as expected in the 1969 test. Also as expected, the growth potential of Abe was reduced by the backcrossing effects of wind pollination in the progeny of (Abe x W) x W.

Table 2.—*Mean heights of fastest and slowest growing families in the 1969 brown-spot test at Alexandria compared to their mean heights in the 1963 brown-spot test*

Family	1963 test 3-year ht.	1969 test 5-year ht.
	Inches	*Feet*
Fast growing		
168	13.5	10.4
306	2.1	10.4
98	5.6	9.4
163	3.4	9.3
216	2.0	9.2
61	6.0	9.1
1.1E	—	8.6
Abe x W	—	7.9
Slow growing		
(Abe x W) x W	—	5.4
301	2.2	5.4
433	2.0	5.2
145	1.9	5.2
396	1.6	5.2
395	1.6	4.6
202	3.4	3.6
PR	—	2.6
General Mean	*3.0*	*7.2*

The lack of high correlation between the 1963 and the 1969 tests is not too surprising. The test material was from a different seed year and perhaps had some different pollen parents. The earlier test was planted in a more severe brown-spot infection year (55 versus 40 percent). Yearly variation in weather may have influenced establishment. Thus, it seems appropriate to use results from several progeny tests where they are available.

Comparison of family performances at two locations

Although 3-year data from the 540 trees of the 1963 study showed a significant family x location interaction, earlier speculation was that the best families for breeding could be selected from combined data. The following results, however, suggest the need to conduct progeny tests in the area where the seed is to be used.

Using 3rd-year data of the 1963 test, we ranked the top 5 percent of the 540 families adapted to Gulfport and, similarly, the top 5 percent adapted to Alexandria. The 17 families selected only for Gulfport were, on the average, in the 42nd percentile in the 1963 Alexandria test (table 3). The 22 families selected only for Alexandria were in the 40th percentile in the 1963 Gulfport test. The 1969 Alexandria test generally supports the 1963 rankings at Alexandria and supports the suggestion that single location results such as those at Alexandria may not be adequate for selection for broad geographic areas.

If we limit families selected to those in the upper 10 percent in the two 1963 brown-spot plantings, eight families (1.5 percent) appear to be generally adapted (last columns, table 3). Several more are included on the basis of the 1969 test. The scarcity of generally adapted types indicates the need for supplementing them with a breeding procedure using more specifically adapted types. Using generally adapted types would permit interchange of material over large sections of the range, but to obtain gains equal to those for specifically adapted types, the selection and testing program necessarily would have to be large. We believe that breeding the best specifically adapted 5 percent and the best generally adapted 10 percent is realistic. Control pollinations are in progress, and progeny tests will reveal which of

Table 3.—*Percentile rankings in three brown-spot tests of heights for families adapted to Gulfport, Alexandria, and both locations*

Family	Adapted to Gulfport Only			Family	Adapted to Alexandria Only			Family	Adapted to Both Locations		
	Gulfport 1963	Alex 1963	Alex 1969		Gulfport 1963	Alex 1963	Alex 1969		Gulfport 1963	Alex 1963	Alex 1969
142	1	28	—	101	81	1	—	168	1	1	1
301	1	57	86	190	77	1	—	435	1	4	—
366	1	30	—	199	23	1	—	446	4	1	—
119	2	50	22	449	22	1	—	216	1	—	5
198	2	63	—	20	28	1	79	239	2	6	—
215	2	53	64	313	50	2	—	269	8	2	—
360	2	32	—	519	47	2	—	258	1	10	—
77	3	21	21	525	15	2	—	163	3	20	2
267	3	53	—	15	78	3	—	65	1	20	6
296	3	48	—	78	29	3	—	471	4	11	—
108	4	22	—	140	22	3	—	194	8	9	—
118	4	42	—	386	26	3	—	230	7	2	26
290	4	39	58	464	44	3	—	214	7	12	20
302	4	31	—	503	72	3	—	62	3	33	10
75	5	43	—	113	47	4	—				
241	5	76	—	123	19	4	—				
429	5	20	38	390	48	4	—				
				538	14	4	—				
				71	28	4	—				
				61	54	5	14				
				265	38	5	—				
				451	23	5	—				
				Abe	—	—	12				
				1.1E	—	—	16				
Average Percentile	*3*	*42*	—		*40*	*3*	—		*4*	*10*	*10*

those tested have sufficiently high breeding values for inclusion in second generation orchards. Meanwhile, parents that have so far produced good progeny will be available shortly for inclusion in first generation orchards.

Comparison of family performance with and without the presence of brown spot

Poor correspondence between family height growth in diseased and disease-free tests has been reported (Snyder and Derr 1972). This finding is now supported by the 8-year growth in the two Gulfport tests—one with and one without brown-spot control. Of the 540 parents, only 12 percent originated east of Louisiana. Yet, after 8 years in plots where brown spot was controlled, eight of the 25 tallest families (32 percent) were from the eastern source. That is, in sprayed plots, eastern sources were three times as effective in providing good performers. In the adjacent infected plots, none of the top 25 was of eastern origin—a significant difference according to chi-square tests. This suggests that selecting trees from western origins (west of Florida panhandle where there are greater selection pressures for resistance to brown spot) would not be efficient for eastern areas where brown spot is not severe. If this is confirmed by tests now in progress, still greater emphasis will have to be placed on geographic areas for selection and progeny testing if the improvement programs are to be most effective.

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U. S. GOVERNMENT PRINTING OFFICE 1978 773-232

Southern Forest Experiment Station

Research Note

SO-241

1978

Genetic Gains Through Testing and Crossing Longleaf Pine Plus Trees

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SUMMARY

A progeny test of 226 superior tree selections from nine geographic sources across the South confirmed earlier results that showed the Gulf Coast source superior in survival and growth. Family variation within a region was large and provided additional genetic gain. Control-pollinated tests of elite x elite trees yielded even more gains. Progeny of the elite x elite crosses had higher survival, less brown-spot infection, and greater wood volume than progeny from crosses involving only one or no elite parent.

Additional keywords: *Pinus palustris*, geographic variation, progeny test, survival, growth, brown-spot needle blight.

IMPROVING BREEDING PROCEDURES

Good form, natural pruning, and high quality wood favor longleaf pine (*Pinus palustris* Mill.) for use as poles and lumber in the South. Yet because of low planting survival, susceptibility to brown-spot needle blight [*Scirrhia acicola* (Dearn.) Siggers], and slow early growth, it has not been widely planted. Tree improvement offers an opportunity for overcoming these negative traits. In studies reported here, objectives were to show geographic seed source trends, family variation for each of nine geographic areas, and gains realized at ages 12 and 13 through control-pollination among elite parents.

METHODS AND MATERIALS

We established three randomized complete block studies. Test A was a progeny test of 226 superior tree selections divided among nine geographic sources across the South (Derr 1971). Included as a control were the wind-pollinated progeny of an elite parent, "Abe" (Derr 1963). In 1969, 1-year-old potted trees were planted in plowed furrows on a fertile, well-drained, sandy loam soil near Alexandria, Louisiana. Four replications of 10 seedlings per row-plot were planted at 6 ft x 8 ft spacing. Data collected or calculated were:

- Age 2 — Height and percentage of needle tissue killed by brown spot
- Age 5 — Height
- Age 8 — Height; diameter; percentage of surviving trees, trees with fusiform rust, trees with crooks, or trees with forks.

Percentage figures were transformed by an arc sine procedure for analyses of variance. For 8-year growth, average volume per tree and volume per plot were computed.

In test B, 18 random parents were wind-pollinated and control-pollinated by Abe. The Abe x wind family was included as a control. Potted seedlings from the 37 families were transplanted to plowed furrows in the spring of 1965. The study is located at Alexandria, Louisiana, and consists of three replications of 20-tree row-plots. Data were collected at age 2 from all families for height, survival, and percentage of brown-spot infection. At age 12, we remeasured height, diameter, and survival for the two random x Abe families that were tallest at age 2, Abe x wind, and random tree 3 x wind (an average random control). The two tallest random parents probably have above average genotypes. Mean volume per tree and volume per plot were computed.

In test C, we compared families derived by crossing Abe with two elite trees (including reciprocals), Abe x wind, and four random trees x wind. For comparison we grouped crosses with their reciprocal crosses and also the four random x wind crosses. These and other intermediate crosses were included in earlier analyses (Derr and Melder 1970). The test was established in 1964 at Alexandria, Louisiana, with four replications of 25-tree plots. At age 3, data were collected from all families for percentage of brown-spot infection, survival, and height. Height, diameter, and survival data were collected at age 13 from the elite x elite crosses, Abe x wind, and a representative random control (4-1 x wind). Average volume per tree and volume per plot were computed.

RESULTS AND DISCUSSION

Test A—Geographic seed source effects

After 8 years, progeny from plus trees of the south Alabama source had the largest volume per tree and volume per plot among all sources (table 1). The source means were significantly different. This confirmed results from the Southwide Pine Seed Source Study, which used randomly selected trees and showed that the Gulf Coast source excelled over most of the commercial range of longleaf (Wells and Wakeley 1970). For current reforestation and tree improvement programs in Louisiana, the Gulf Coast source should be emphasized. In this experiment the south Alabama source had 58 percent survival (vs. 29 percent for the Louisiana source) and had 157 percent more volume per plot than did the Louisiana source. On the basis of volume per plot, we should not use Texas, North Carolina, or Louisiana seed in Louisiana unless we can find better clones from these sources. The downward trend of the relative height growth of northern Alabama trees between 5 and 8 years also cautions against use of this source in Louisiana.

The South Carolina source had unexpectedly good growth. Its origin is much farther north than the three other best performing sources and is over 350 miles northeast from the recommended central Gulf Coast seed collection area. Although we would be cautious in recommending trees from the South Carolina source for planting in Louisiana, the growth potential looks good. The South Carolina source deserves additional testing, particularly in areas across the northern part of the longleaf range.

Variation in brown-spot infection contributed most to 8-year volume per plot variation among seed sources. However, additional variation was accounted for by including 2-year height growth. The prediction that provided best fit for 8-year volume was the 2-year percentage of foliage free of infection x the 2-year height growth ($R^2 = 0.91$). The high correlation is further evidence of the efficiency of early testing and selection before seed orchard establishment.

Although 2-year height growth differences were significant, the range was narrow (0.36 to 0.49 ft) and not well correlated with later height data. By age 5, family height growth differences were well expressed and correlated with 8-year

Table 1.—*Progeny performance by source of seed in test of 226 National Forest clones (Test A)*

Source	No. of Fam.	2-year Brown Spot	2-year Height	5-year Height	8-year Survival	8-year Rust	8-year Height	8-year Diameter	8-year Avg. volume/ tree	8-year Avg. volume/ plot	8-year Range volume/ plot
		Percent	*Feet*	*Feet*	*Percent*	*Percent*	*Feet*	*Inches*	*Feet*^{3}	*Feet*^{3}	
South Alabama	22	18	0.42	6.67	58	9	19.9	2.86	0.415	2.52	.71 — 4.39
South Carolina	37	21	0.44	6.31	56	5	19.2	2.87	0.402	2.29	.58 — 4.48
Mississippi	22	25	0.45	6.01	56	6	19.0	2.71	0.371	2.11	.65 — 3.64
Florida	25	20	0.46	6.66	49	8	20.0	2.89	0.415	2.05	.74 — 4.11
North Alabama	33	21	0.41	5.93	57	9	18.2	2.74	0.349	2.02	.73 — 3.66
Texas	42	32	0.49	5.15	39	5	18.8	2.75	0.374	1.51	.09 — 3.45
North Carolina	13	33	0.36	4.07	32	6	17.4	2.70	0.334	1.14	.52 — 2.00
Louisiana	32	38	0.40	3.73	29	6	18.0	2.60	0.320	0.98	.18 — 2.09
Mean		26	0.43	5.60	47	6	18.9	2.77	0.376	1.83	
Significance[1]		S	S	S	S	NS	S	S	S	S	

[1]S — significant at 0.01 level; NS = not significant

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heights (r = 0.87). Height trends from age 5 to age 8 must be evaluated in conjunction with survival differences. At first, the fastest growing sources tend to survive best. As crowding begins, trees in the slower growing and less dense sources begin to catch up because they have more growing room. In this test, crowding was occurring so the study was ended.

Crook and forking is not usually a problem in longleaf pine. Mean frequency of trees crooked or forked ranged from 0 to 4 percent. Because the frequency of crook within and among sources was so low, no statistical analyses were made.

Variation and selection of families within sources

Because growth of the best families within sources is often of more interest to breeders than that of source averages for all families, we looked at the heights for the top 12 percent of the families in each source. Surprisingly, mean heights for the top 12 percent of the families from the south Alabama, South Carolina, Mississippi, Florida, and Texas sources all converged at 21.1 ± 0.1 ft. The trees are closely spaced (6 x 8 ft), and height convergence is probably caused by crowding. Under these spacing conditions, geographic source height differences are not easily differentiated by using only the tallest families.

Volume of wood per unit area is probably the most useful family selection trait. Among families with the highest wood volume per unit area, those with the highest fusiform rust or crook ratings should be avoided. In this progeny test, which is being converted to a breeding arboretum, the 70 best families out of 226 were saved. At age 8, the 70 selected families averaged 2.92 ft^3 in volume per plot, or 60 percent more than the 1.83 ft^3 average for all families. Within each 10-tree plot of each selected family, only the best tree was saved. This within-family selection will provide additional gains.

Although volume selection at age 8 may seem early enough in the life of the plantation for some, we believe that even earlier selection has some merit. We were reasonably successful in estimating 8-year volume from 2-year height and 2-year brown-spot infection. Correlation between observed and estimated values was r = 0.69. This is considered good, since we are going from a few inches tall at age 2 to 20-30 feet at age 8. Certainly by age 3 or 4, when the trees are out of the grass stage, the correlation would be even higher. Initial screening or selection at this age seems appropriate for making initial parent tree selections or for roguing a seedling seed orchard.

The 70 families were selected without regard for geographic seed source effects. The number of families selected per geographic source therefore depended upon average source performance and total number of families per source in the test. The number and percentage of families selected from each source were: SC-17 (40 percent), MS-15 (41 percent), S. AL-12 (54 percent), N. AL-10 (30 percent), FL-8 (32 percent), TX-7 (17 percent), LA-1 (3 percent), NC-0 (0 percent).[1]

This progeny test has provided satisfactory brown-spot evaluation for all families. In using these data from a single planting we assume little genotype x environment interaction for brown spot. The test will also serve for roguing on the basis of growth in the nearby Kisatchie clonal seed orchard. However, only clones from the Kisatchie Forest and Texas are included in the orchard, and their overall performance in the progeny test was poor. For greater genetic gain for this region, faster growing eastern clones should be included in the Kisatchie seed orchard.

The test information is also satisfactory for moderately roguing clones to be planted in other areas where brown spot is serious. However, for seed orchards in areas that are unlike the test region, especially North Carolina and north Alabama, this progeny test should not be used. Trees selected for adaptation to one area are not necessarily those adapted to another (Snyder and Bey 1978). In the future, orchards should include selections from the most promising geographic sources in addition to the local source. Orchards should be rogued on the basis of progeny tests in the area where the seed is to be used. Progeny testing for brown-spot resistance and early growth is necessary for rapid advancement in tree improvement programs.

Tests B and C—Crossing among the elite

Material similar to the elite clones in Test A were intercrossed (table 3). Results at age 12 to 13 indicate that much additional gain can be made by intercrossing elite parents. Progeny of crosses involving elite parents generally survived much better than progeny from crosses involving only one or no elite parent. The poor survival of wind-pollinated (random) material is perhaps the most surprising and important result of all. Only progeny from the elite x elite

[1] Data similar to those for south Alabama for all 226 families for brown spot, fusiform rust, survival, 5-year height, and 8-year volume (table 2) are available from the authors.

Table 2.—*The ranks of families from the Conecuh N.F., Alabama (Test A) ranked by volume per plot*

Forest and clone ID	2-year brown spot	5-year height	8-year rust	8-year survival	8-year vol/tree	8-year vol/plot
	Percent	*Feet*	*Percent*	*Percent*	*Feet³*	*Feet³*
12 AL CON 68 23	9	9.04	3	30	0.551	4.391
20 AL CON 100 31	8	8.92	3	72	0.504	3.821
22 AL CON 165 41	11	8.90	9	80	0.485	3.802
2 AL CON 18 19	18	7.17	27	60	0.542	3.511
4 AL CON 36 14	12	7.74	3	71	0.455	3.184
6 AL CON 47 8	14	7.32	15	70	0.439	2.938
17 AL CON 92 6	14	7.31	3	65	0.421	2.890
15 AL CON 75 3	22	7.24	18	63	0.449	2.772
10 AL CON 61 10	10	7.31	11	65	0.414	2.713
11 AL CON 65 12	15	7.76	4	55	0.490	2.623
3 AL CON 35 13	20	6.38	18	60	0.447	2.597
5 AL CON 40 16	20	7.46	6	65	0.395	2.566
19 AL CON 98 30	16	6.42	15	60	0.381	2.278
21 AL CON 138 18	19	6.81	15	52	0.410	2.222
18 AL CON 96 28	20	6.75	9	52	0.391	2.218
16 AL CON 80 4	16	6.25	10	62	0.347	2.189
14 AL CON 72 25	26	5.72	4	47	0.390	2.019
13 AL CON 71 24	15	4.93	3	52	0.305	1.775
7 AL CON 50 9	21	5.31	15	50	0.331	1.690
9 AL CON 58 21	26	4.41	0	40	0.351	1.450
8 AL CON 55 20	21	4.63	0	38	0.246	1.027
1 AL CON 4 2	39	2.88	13	15	0.386	0.714
Means for:						
Conecuh N.F., Ala.	18	6.67	9	58	0.415	2.518
Region	26	5.60	6	47	0.376	1.830
Control (Abe)	22	6.40	0	56	0.483	2.510

crosses had acceptable survival (35 to 86 percent). Survival in the random x wind and even Abe x wind progeny was very poor (0 to 18 percent). It is hardly surprising that planting run-of-the-mill longleaf seedlings has been discouraging to many foresters.

Families derived from crossing elite x elite parents also were taller, had better brown-spot resistance, greater volume per tree, and five or more times greater volume per plot than random material. In Test C, progeny in the best cross (1-2 x Abe) averaged about 3 feet per year in height growth and one-half inch per year in diameter growth. The general superiority in height growth at age 12 to 13 for crosses between elite parents can be attributed in part to their coming out of the grass stage earlier and in part to their brown-spot resistance. Many trees from the elite parents were out of the grass stage by age 3. In most cases, brown-spot incidence in progeny of elite parents was one-third to one-half that of random material.

The high correlation between early brown spot readings and 8-year volume in this study and evidence from other studies suggest that for first generation orchards, the use of short-term, open-pollinated progeny tests that are completed before grafting might be more efficient than the traditional pine seed orchard approach (Schoenike and Williams 1975). Rather than using rigorous individual tree selection standards, we recommend that a larger number of less intensively selected parent trees be tested. As shown in this study, even with intensive phenotypic selection, many trees with low breeding value are included. Rather than grafting parents into an orchard at time of selection, we recommend waiting until the breeding value is estimated from open-pollinated progeny tests. Then the elite can be grafted into an orchard, or the progeny test itself can be heavily rogued to make a seedling seed orchard.

If the latter approach is adopted, trees can be closely spaced to accommodate early roguing (Snyder and Derr 1972, Rockwood and Kok 1977). Whatever approach is used, tree improvement specialists need to recognize and use geographic variation to obtain maximum improvement for the species.

Table 3.—*Open- and controlled-pollination results for random and elite parents in progeny tests B and C*

Type of Pollination	Brown Spot *percent*	Survival *percent*	Ht *inches*	Survival *percent*	Ht *feet*	D.B.H. *inches*	Vol/tree *feet*^{3}	Vol/plot *feet*^{3}
Test B	Age 2			Age 12				
Random (19Y) x Elite Abe	41	98	24	47	29	6.0	2.19	20.6
Random (9R) x Elite Abe	37	95	23	35	32	6.0	2.39	16.7
Abe x Wind	62	93	11	12	26	5.5	1.60	3.8
Random (1Y) x Wind (control)	75	87	5	0	0	0	0	0
18 random trees x Abe	52	92	16	—	—	—	—	—
18 random trees x wind	74	90	5	—	—	—	—	—
Significance[1]	S	NS	S	S	NA	NA	NA	NA
Test C	Age 3			Age 13				
Elite 1-2 x Elite Abe	19[2]	99	28[2]	86	38	6.2	3.30	71.0
Elite 1-3 x Elite Abe	22	100	25	85	34	5.7	2.36	50.0
Elite Abe x Wind	42	94	21	58	35	5.6	2.44	35.6
Random 4-1 x wind	65	99	6	18	31	5.2	2.18	10.0
4 random trees x wind	65	96	8	—	—	—	—	—
Significance[1]	S	NS	S	S	S	NS	S	S

[1] S — signficant at .05 level; NS — not-significant; NA — not applicable because there were no surviving controls
[2] Data from Derr and Melder 1970.

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☆ U.S. GOVERNMENT PRINTING OFFICE. 1978–773-233

SO-242

Southern Forest Experiment Station

Research Note

1978

Wood Performance in Doorways of Single-Family Houses

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SUMMARY

Front doors and door frames in 175 new houses with slab-on-ground foundations were examined for moisture and decay problems in three Mississippi counties that border the Gulf of Mexico during summer 1973. Defects were often the result of building techniques of particular developers. No special problem was detected that would cause frames or doors to have excessively high moisture contents. The lengths of roof overhang in front of the doorway generally did not significantly affect the moisture content of wood at the base of either the door or the door casing.

INTRODUCTION

Since wood is the most commonly used material in exterior doorways of homes, it is important to determine construction factors that will extend the service life of the doorways. Most of all, techniques that minimize moisture content in the wood should be used.

METHODS

Front doors and door frames of 175 houses were examined in the three Mississippi counties that border the Gulf of Mexico (Hancock, Harrison, and Jackson Counties). Most of the houses were built between 1968 and 1972 (some before 1960) under the U.S. Department of Housing and Urban Development's (HUD) program that is commonly referred to as "235." All were managed by either the USDA Farmer's Home Administration (FmHA) or by HUD. Houses were randomly selected from HUD and FmHA lists and were visited in order of their selection during summer 1973.

For each doorway the type of door (panel or flush) was recorded. Panel doors consist of filler panels of wood framed by stiles (solid vertical members) and rails (solid cross members). The upper panels may be of glass. Flush doors consist of thin plywood faces applied to a framework of wood with a wood block or particle board core (Anderson 1970). In exterior applications flush doors should be of the solid-core type. The distance to the edge of the roof directly in front of the door was measured, and the distance to the edge of the roof nearest the front door was measured (fig. 1). The direction perpendicular to the front door when closed was determined with a compass. Moisture content at the (A) top of the exterior casing, (B) exterior base of the jamb, (C) exterior bottom of the door itself, and (D) base of the interior casing, was measured to the nearest percent with a Delmhorst moisture meter (fig. 2). We also noted the condition of the wood: presence of splitting veneer, fungal discoloration, or decay detectable by probing with a knife. The presence or absence of weather-stripping between door and frame and condition of sealants about the exterior frame were recorded.

Doors were divided into four groups by direction faced. An analysis of covariance, with distance to the edge of the overhang as covariate, was made to determine if the directions doors faced affected their moisture content. Moisture contents at the locations around the door were regressed against the distance

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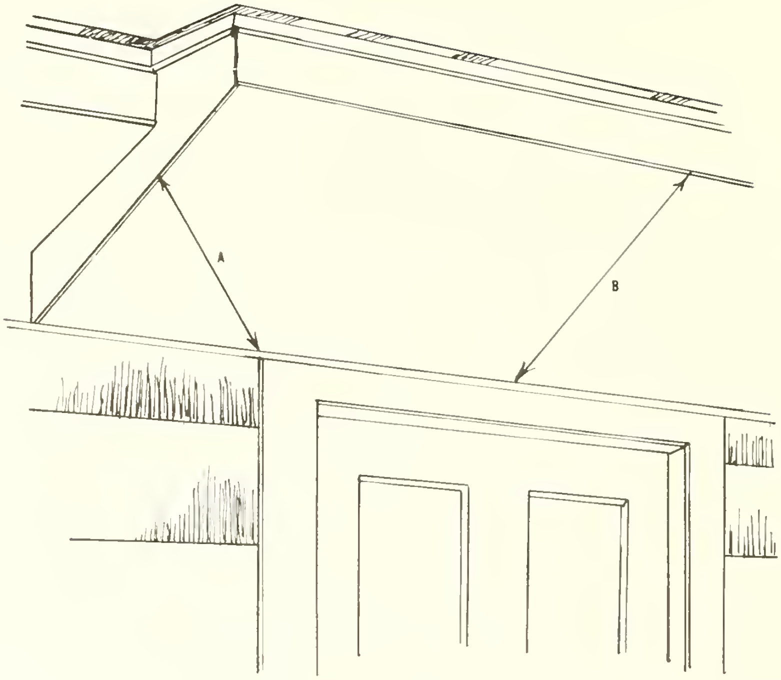
Figure 1.—*Measurement of overhang at doorways: A, Overhang distance to nearest edge from doorway; B, Overhang distance to edge directly in front of the doorway. In some instances A and B are the same.*



to the edge of the roof in front of the door and against the minimum distance to the edge of the overhang for each group of doors and all doors combined. A second degree polynomial was suggested by the assumption that at some point increasing the overhang offers no additional protection.

One hundred fifty-five of the houses were in subdivisions where the developers could be identified. The nine developers were labeled A through I, and their houses were then grouped and compared for frequency of defects in the front doorways.

RESULTS

More than anything else, defects in doors and frames were related to developer (α .0004). Two developers for which a total of 39 houses were examined had front doorways entirely free of defects (table 1).

The average distance to the edge of the roof directly before the doorways was 57 inches. The average minimum distance to edge of roof overhang above the doorways was 49 inches. Regression analyses of the relationships between distance to edge of roof overhang and wood moisture content never explained more than 5 percent of the variation in observed wood moisture contents.

We could not determine the quality of flush doors nor whether the frames or doors had been treated with a preservative. Informal contacts with building suppliers in the three counties suggested that preservative-treated frames were seldom used in these houses.

Frames

The average wood moisture content of the frames was 11 percent (Standard deviation = 1.84) at the top of the exterior casing, 13 percent (sd. = 6.04) at the

Table 1.—*Percent of houses with a defect in doorway.*

Developer	A	B	C	D	E	F	G	H	I
No. houses examined	24	39	15	12	9	10	13	17	16
Percent of houses with defect	0	5	0	17	56	10	8	12	25

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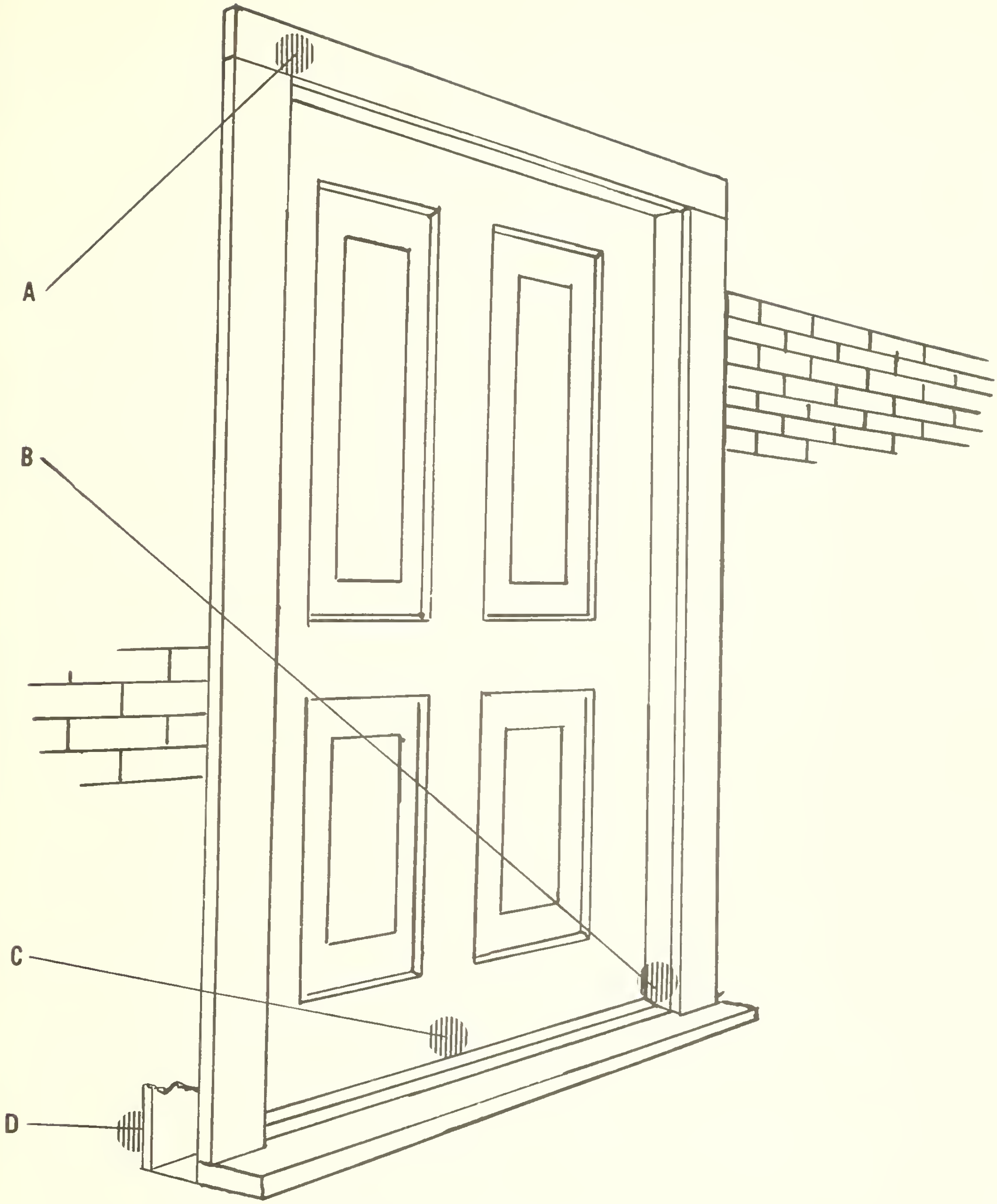

Figure 2.—*Moisture content measurements in doorway area; A, Top of the exterior casing; B. Exterior base of the jamb; C, Exterior bottom of the door; D, Base of the interior casing.*

exterior base of the jamb, and 15 percent (sd. = 7.58) at the base of the interior casing. The consistency of wood moisture contents at the top of the exterior casing is the result of the protection the roof overhang affords to this part of the doorway. Moisture content at the top of the exterior casing was never above 30 percent, but in nine houses, either the exterior base of the jambs or the interior casing had moisture contents above 30 percent (30 to 95 percent), a level beyond which decay occurs in untreated wood. In no case was a moisture content of above 30 percent caused by a specific rainfall. The fact that moisture content in the base of the frames varied considerably indicates that this area is often wet. Construction that retards drying has more influence on moisture content at the base than at the top of frames.

The moisture content of above 30 percent in some door frames could not be attributed to a particular construction detail. All frames with high moisture content had no caulking between the jamb and the exterior step, but so did many others. Some frames with high moisture content had weather stripping, others did not. Two door frames with high moisture contents were sheltered by roof overhangs extending more than 4 feet which suggests that even large overhangs may not protect frames from getting wet. In one doorway, a reverse grade on the exterior step caused water to accumulate against the threshold and door jamb, and it is possible that the situation occurred in other cases. Visible decay was found in the base of five frames and never in a door. Wood soft to a knife was found in 12 frames and in one door.

Houses usually faced one of the four cardinal directions, received little shelter from trees, and were built on nearly flat sites. No dangerously high moisture content was associated with doorway aspect and the difference in average moisture contents among frames facing different directions was very small. Still, statistical analysis indicated that direction affected moisture content of the exterior frame: α = .080 for top of exterior casing and α = .110 for base of exterior casing.

Doors

Thirty-three of the doorways had exterior, wood-panel screen doors; all of these doors were free of moisture-related defects. The moisture content at their bases averaged 12 percent (sd. = 3.33) which indicates that if the doors were wet by rains they apparently dried readily.

Thirty-two doors were of the panel type. All were free of moisture-related defects, and the moisture content at their bases averaged 12 percent (sd. = 1.91).

Thirty-seven of 189 flush doors (20 percent) had defects. Twenty-nine flush doors had veneer splitting at the base on the outside, and seven were discolored by fungi. Of the 189 flush doors, only one was sufficiently decayed that wood was soft to a knife probe. Defects were not associated with house age.

A statistical difference in moisture content existed for exterior base of door by direction faced (α = .001). Average moisture contents for bases of doors was: north, 15 percent; south, 14 percent; east, 12 percent; and west, 13 percent. Veneer splitting was less frequent on north-facing doors than on doors facing other directions; α = .05 as computed by chi-square tests. Five of the 13 doors with splitting veneer (38 percent) occured in a single development. These doors represented 56 percent of the houses that we examined in that development.

DISCUSSION

The fact that defects were most strongly related to developer suggests that doorways can be adequately constructed without greatly increasing the cost. Similar associations between developer and practices that affected performance of other wood products used in construction have been reported previously (DeGroot and Popham 1975).

Moisture associated failures in doors usually were physical failures (veneer splitting) rather than biological (fungal decay or insect attack). Frames, however, are exposed to decay. All but one instance of moisture content sufficient to support decay occurred in frames.

Observations of these houses suggest that three bands of exposure to prevailing rains can be delineated. The upper part of the doorway, which is as long as the roof overhang, is almost completely sheltered from rain. The middle band, which extends from lower margin of upper band to twice the length of overhang is subject to infrequent storm driven rains. The lower part of the wall is frequently wet by rain. This corresponds with Griffin's (1959) findings that a 36-inch overhang did not completely protect the entire wall from rain and a 24-inch overhang would not protect the average-height window sill or part of the lower sash unit from all rains.

Lateral absorption of water along the length of both frame and door is slight. Endgrained surfaces at the bases of both door and frame receive maximum exposure to rain, rain splash, and to water draining down the exterior surface. If water is not quickly drained off the threshold the interior casing can be wet. If these surfaces are not protected with a water repellent, rapid absorption and slow drying sustain high wood moisture content.

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Southern Forest Experiment Station

Research Note

SO-243

1978

Fertilization Increases Growth of Thinned and Nonthinned Upland Oak Stands in the Boston Mountains of Arkansas

D. L. GRANEY AND P. E. POPE

SUMMARY

Thinning and fertilization tests with pole-sized red oaks (northern red oak *Quercus rubra* L. and black oak *Q. velutina* Lam.) and white oak (*Q. alba* L.) were begun in the Boston Mountains of Arkansas in the spring of 1975. Fertilizer treatments of either (1) no fertilization, (2) 200 lbs N + 45 lbs P per acre, or (3) 400 lbs N + 45 lbs P per acre were applied to 288 red and white oaks that had received thinning or nonthinning treatments. Two-year diameter growth response for thinned red oaks increased by 52 percent for the 200-lb treatment and by 97 percent for the 400-lb treatment. Increases for nonthinned red oaks averaged 40 and 58 percent for the 200- and 400-lb treatments.

Diameter growth for thinned white oaks increased by 95 percent for the 200-lb treatment and by 86 percent for the 400-lb treatment. Increases for nonthinned white oaks averaged 48 and 74 percent for the 200- and 400-lb treatments. Thinning did not significantly increase response to fertilization for either red or white oaks.

HELPING ACCELERATE GROWTH OF HARDWOOD STANDS

Over 200,000 acres of forest land in the Boston Mountains of Arkansas support overstocked, even-aged, pole-sized stands of oaks and associated species. Although many stands are on medium to good sites (height of 60 to 70 ft at 50 years), diameter growth averages only about 1 inch in 10 years. A lack of outlets for small diameter hardwoods has prevented intermediate cutting in these stands. But, because demands for sawtimber are increasing and inventories of large hardwood poletimber and immature sawtimber are small, some land managers have begun non commercial thinning programs to accelerate growth in the slow-growing hardwood stands. Fertilization may further stimulate growth of crop trees. Positive growth responses of oaks and other upland hardwoods to fertilization have been demonstrated (Mitchell and Chandler 1939, Farmer and others 1970, Ward and Bowersox 1970, Karnig 1972, Watt 1974). Generally, the greatest response of hardwoods has been associated with nitrogen (N) and to a lesser degree phosphorus (P) when applied with N.

PROCEDURES

Study Area

The Boston Mountains are the highest and southernmost member of the Ozark Plateaus physiographic province (fig. 1). They form a band 30 to 40 miles wide and 200 miles long from north central Arkansas westward into eastern Oklahoma. Elevations range from about 900 ft in the valley bottoms to 2500 ft at the highest point. The plateau is sharply dissected, and most ridges and spurs are flat to

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gently rolling and generally less than one-half mile wide. Mountain slopes consist of an alternating series of steep simple slopes and gently sloping benches.

Rocks in the area are sedimentary and predominantly of Pennsylvanian age; they consist of alternate horizontal beds of shales and resistant sandstones.

Annual precipitation averages 46 to 48 inches in the 2.2 million acre portion within Arkansas. March, April, and May are the wettest months. Extended summer dry periods are common, and autumn is usually dry. The frostfree period is normally 180 to 200 days long.

Three study areas were selected from overstocked stands on mountain benches that range from 2 to 3 chains wide and are typified by deep, well-drained soils of the Nella or Leesburg series (Typic Paleudults). These soils were formed from sandstone and shale colluvium and are among the most productive upland soils in the mountains.

Sample Trees

In each study area, 48 red oak and 48 white oak trees were selected for the thinning and fertilizer treatments. The trees from each species were arranged into 16 sets of 3 trees each. Individual members of each three-tree set were uniform in diameter, crown size, and height, and were located on essentially the same site conditions. Consecutive three-tree sets were randomly assigned the thin or nonthin treatments, and three fertilizer treatments were randomly assigned each three-tree thinned or nonthinned set. Thus, 144 red oaks and 144 white oaks at three locations were used to determine the effects of thinning and fertilization on diameter growth.

Tree Measurements

For each sample tree, diameter at breast height (d.b.h.) was measured to the nearest 0.01 inch. The diameter measurement point was identified by a painted band on each tree. Increment cores were

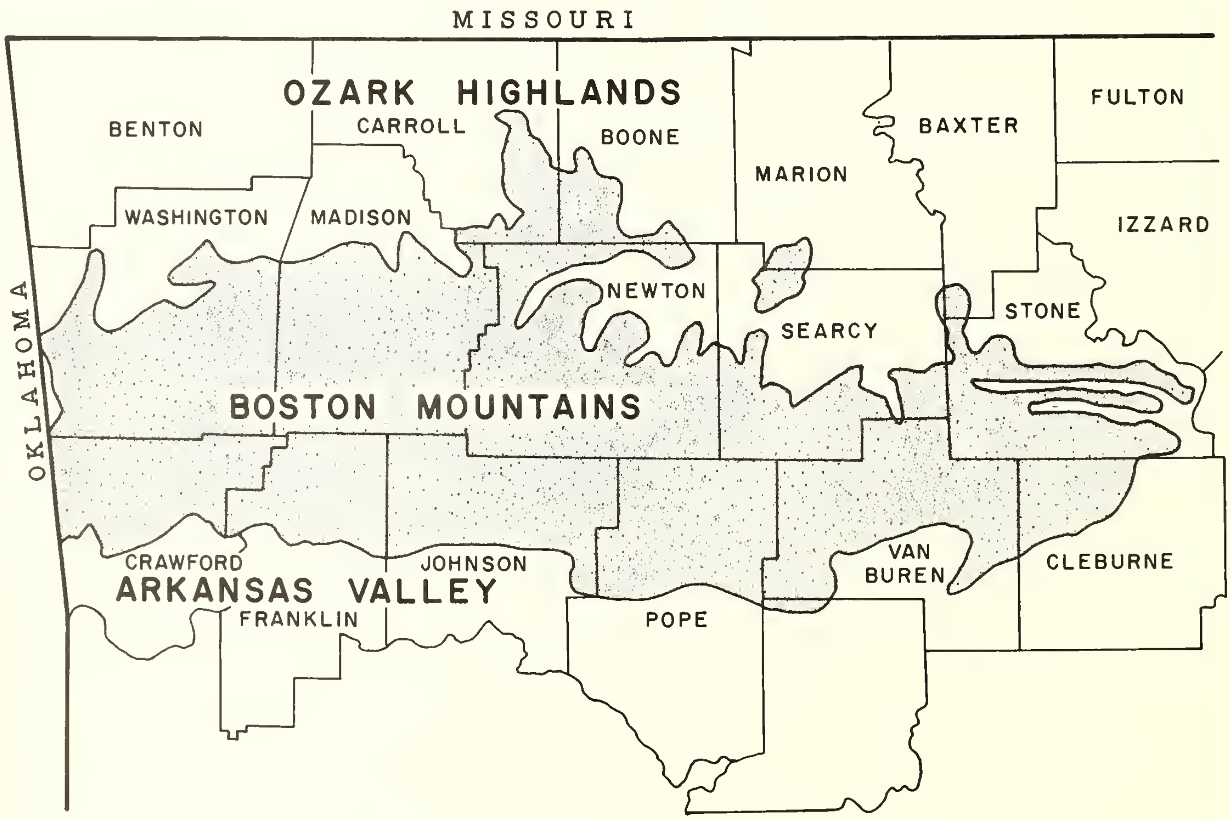

Figure 1.—*The Boston Mountains in Arkansas.*

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extracted from the north, east, south, and west sides of each tree and were used to determine tree age and to obtain a measure of past growth, which served as a covariate in the data analysis. After extraction, cores for each tree were sealed in plastic soda straws. For each core, a binocular microscope was used to measure annual radial growth to the nearest 0.01 inch. Total height was also recorded for each sample tree.

Thinning Treatments

Basal area near each sample tree was determined with a prism. From this initial value, the basal area was reduced by removing two major competitors and several smaller trees until an area of about 70 ft^2 per acre was attained. Thinning treatments were completed in March 1975. Average stand and tree characteristics for red and white oak thinned and nonthinned treatments are shown in table 1.

Table 1.—*Average stand and tree characteristics for red and white oak plots.*

Treatment	Age	Site index	Initial diameter	Basal area
	(years)	*(feet)*	*(inches)*	*(ft^2/acre)*
		RED OAKS		
Thinned	50	62	8.18	68
Nonthinned	50	62	8.48	120
		WHITE OAK		
Thinned	52	59	8.26	66
Nonthinned	52	59	7.89	123

Fertilizer treatments

Fertilizers used were ammonium nitrate (34-0-0) and diammonium phosphate (18-46-0). Fertilizer treatments were: (i) no fertilizer (control), (ii) 200 lbs N + 45 lbs P per acre (200 lb treatment), (iii) 400 lbs N + 45 lbs P per acre (400 lb treatment). Fertilizers were surface broadcast on a 0.01 acre circular plot surrounding each tree. Fertilizer was applied in late April 1975 about 1 week after trees leafed out.

RESULTS AND DISCUSSION

Response to Thinning

After two growing seasons neither the red oaks nor white oak had responded to thinning (table 2). Diameter growth of thinned and nonthinned white oak control trees averaged about 0.12 inch per year for the 1975-76 growing seasons. Nonthinned red oak controls averaged 0.13 inch per year while thinned trees averaged about 0.12 inch. But, as indicated in figure 2, the nonthinned trees had indicated a slightly higher growth rate before thinning.

Response to Fertilization

Fertilization significantly increased growth of both red and white oaks (table 2). Mean annual diameter growth for red oak was 0.18 and 0.23 inch for the thinned 200- and 400-lb treatments, 52 and 97 percent increases over growth of controls. Response of red oak nonthinned trees was not as dramatic but averaged 40 and 58 percent greater than the controls for the 200- and 400-lb treatments.

Our results for fertilized and thinned red oaks compare favorably with the initial response of red oaks to fertilization in New York (Mitchell and Chandler 1939, Karnig 1972), but are greater than responses of black oak in the Missouri Ozarks (Watt 1974) and red oaks in West Virginia (Auchmoody and Smith 1977) and the Tennessee Valley (Farmer and others 1970). Response for fertilized but nonthinned red oak trees was fairly close to that found by Farmer and others (1970) for red oaks in the Tennessee Valley.

The significant growth response of red oaks to increasing levels of nitrogen was essentially linear over the range of 0 to 400 lbs per acre. Watt (1974), working with thinned black oak in the Missouri Ozarks, also reported a linear diameter growth response to increasing levels of N fertilization up to 900 lbs per acre.

Diameter growth of thinned white oaks was not significantly different for the 200- and 400-lb treatments but was 95 and 86 percent greater than growth of nonfertilized trees. Response for thinned white oaks was greater than responses to fertilization reported elsewhere (Mitchell and Chandler 1939, Farmer and others 1970, Ward and Bowersox 1970). Mean annual diameter growth for nonthinned white oaks was 48 percent greater than controls for the 200-lb treatment and 74 percent greater for the

Table 2.—*Mean annual diameter growth response to fertilization for thinned and nonthinned red and white oaks.*

Fertilizer treatment	Thinned		Nonthinned	
	Growth	Response[1]	Growth	Response[1]
	(inches)	*(%)*	*(inches)*	*(%)*
		RED OAKS		
Control	.118	—	.129	—
200 lb	.180	52	.180	40
400 lb	.233	97	.204	58
		WHITE OAK		
Control	.117	—	.119	—
200 lb.	.228	95	.176	48
400 lb.	.218	86	.207	74

[1]Percent increase over control.

400-lb treatment. Response of nonthinned white oak was similar to that of white oak in the Tennessee Valley (Farmer and others 1970).

Unlike red oaks, white oak did not respond significantly to increasing levels of N. Ward and Bowersox (1970) reported no significant increases in white oak diameter growth between N applications of 60 and 180 lbs per acre but did observe an increase in 5-year gross volume growth between lower and higher N levels when N was combined with lime.

In the Boston Mountains of Arkansas, differences between red oaks and white oak in response to fertilization are probably due to inherent differences in site requirements. A recent site quality investigation for upland oaks in the Boston Mountains (Graney 1977) found that red oaks were highly sensitive to changes in site and soil characteristics. White oak, however, had similar site indices over a wide range of site and soil conditions. Although response for both red and white oaks to fertilization indicates that N (and possibly P) limits growth in this area, requirements for white oak are apparently satisfied with lower levels of fertilization than are those of red oaks.

Before thinning and fertilization, patterns of both red and white oak diameter growth (after the wet growing seasons of 1967 and 1968) reflected increasing crown and root competition in the overstocked stands (figs. 2 and 3). With few exceptions, crowns of sample trees were small and by remeasurement in 1976 had not begun to expand much. Red oak diameter growth declined from a maximum of about 0.22 inch in 1968 to about 0.12 inch in 1974 (fig. 2). White oak diameter growth declined from a high of about 0.18 inch in 1968 to about 0.11 inch before thinning and fertilization (fig. 3). The slight increase in control diameter growth for red oaks and white oak in the 1975-76 growing seasons probably reflected the wet 1975 growing season.

Among fertilized red and white oaks, thinned trees had slightly higher diameter growth rates than nonthinned trees, but differences were not significant. Our results are only for 2 years, and effects of thinning on fertilized trees may become more apparent in later remeasurements.

Two-year results of this study indicate that growth of pole-sized red and white oaks in overstocked stands can be significantly increased by fertilization. Studies in other areas have indicated the maximum response of upland oaks to fertilization occurs within the first 3 years and then declines over a period of years. We will continue to monitor diameter growth in this study for a minimum of 5 years or until no further response is observed.

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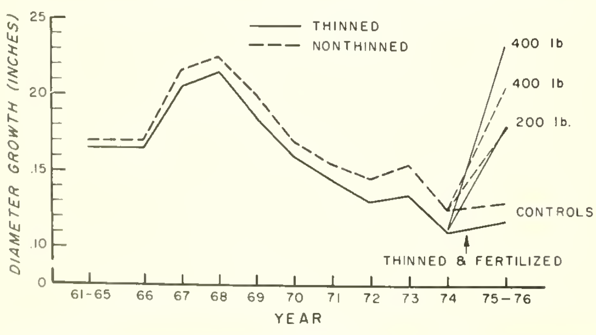

Figure 2.—*Mean annual diameter growth 1961-74 and response to fertilization for thinned and nonthinned red oaks.*

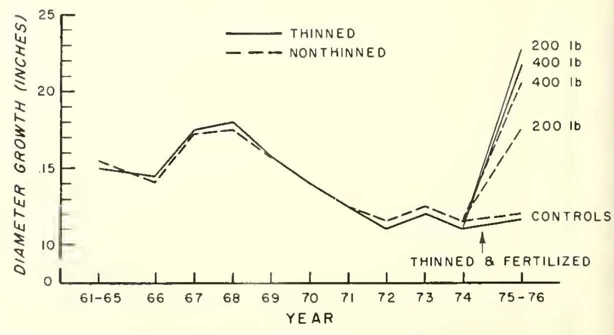

Figure 3.—*Mean annual diameter growth 1961-74 and response to fertilization for thinned and nonthinned white oak.*

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Southern Forest Experiment Station

Research Note

SO-244

1979

Bedding Improves Yellow-Poplar Growth on Fragipan Soils

JOHN K. FRANCIS

SUMMARY

Yellow-poplar can be grown on soils that have a shallow fragipan — but unless such sites are bedded, growth is likely to be extremely poor. In a Tennessee study, bedding increased height of planted yellow-poplar over 5 years, but fertilizer did not. Because of the cost of bedding and the availability of nonfragipan sites, it would ordinarily be better not to plant yellow-poplar on soils with shallow fragipans.

Additional keywords: *Liriodendron tulipifera* L., fertilization.

INTRODUCTION

Fragipan soils in middle Tennessee often support unproductive stands of blackjack (*Quercus marilandica* Muenchh.) and post (*Q. stellata* Wangenh.) oaks. A current proven management practice is to convert such sites to pine. The purpose of this study was to determine if intensive cultural treatments could make these shallow soils suitable for growing quality hardwoods. Because yellow-poplar (*Liriodendron tulipifera* L.) is site sensitive, it was chosen as the test species.

METHODS

The study area originally supported a stand of blackjack and post oaks. The soil (Dickson series, fine-silty, siliceous, thermic Glossic Fragiudults) had a fragipan at 15 to 20 inches. The site sloped about 2 percent to the south. All merchantable timber had been harvested from the site several years before. The resulting sprout stand was later burned, and in the following spring regrowth was treated with a mist-blower application of 2,4,5-T. In September, five beds about 4 feet wide, 12 to 18 inches high, and 360 feet long were prepared with a road grader. An unbedded area of equal size also was established, and both were set up in a split plot design with 10 replications. The beds and untreated rows were the major plots. Sixteen-tree row segments constituted the minor plots. Each received either no fertilizer, 150 lbs N/acre, or 150 lbs N/acre + 100 lbs P/acre. Fertilizer treatments were applied 1 month before planting.

Yellow-poplars (1-0 seedlings) grown from local seed were graded to a uniform root-collar diameter. Shoots were clipped to 12 inches; roots were pruned to 9 inches. Seedlings were hand-planted in April 1972 at a spacing of 6 feet within rows and 12 to 15 feet between rows. For 5 years, height measurements and survival counts were made each fall. Significance of the analysis of variance was tested at the .05 level.

RESULTS AND DISCUSSION

After 5 years, bedded yellow-poplar seedlings were considerably taller than unbedded seedlings (table 1). Height growth of bedded and unbedded seedlings was not improved by fertilization.

The average annual height growth of both bedded and unbedded seedlings appeared to increase at least through age 4 (table 2). At age 4, the growth of bedded seedlings was 2.8 times greater than that of controls — a 182 percent increase in growth. The increased rate of height growth due to bedding is likely to continue for several years.

Table 1.—*Average height of yellow-poplar*

	Bedded			Not bedded		
	No fert.	150N	150N+ 100P	No fert.	150N	150N+ 100P
	Feet					
Planting ht.	.90	.92	.90	.89	.79	.72
Year 1	1.07	1.26	1.10	1.00	1.05	.93
Year 2	1.97	2.19	1.50	1.26	1.52	1.26
Year 3	2.73	3.03	2.14	1.62	2.03	1.69
Year 4	4.57	4.89	3.55	2.11	2.72	2.32
Year 5	6.30	6.60	5.32	2.36	3.26	2.90

Table 2.—*Mean annual height growth and total height of bedded and unbedded yellow-poplar seedlings*

	Mean height growth			Mean total height		
Year	Not bedded	Bedded	Increase[1]	Not bedded	Bedded	Increase[1]
	Feet		Percent	Feet		Percent
1	.19	.23	21	.99	1.14	15
2	.35	.74	111	1.35	1.89	40
3	.43	.74	72	1.78	2.63	48
4	.60	1.69	182	2.38	4.34	82
5	.46	1.74	278	2.84	6.07	114

[1]Due to bedding.

After 5 years, survival was significantly better on the unbedded plots (table 3). On the bedded plots, using N + P fertilizer resulted in significantly lower survival than using either N alone or no fertilizer.

The soil on which this study was performed has a shallow fragipan. The hardness and poor internal drainage of the fragipan prevent trees from rooting deeply. Planting yellow-poplar on soil beds increased the depth to the fragipan and helped keep some of the roots above the saturated subsoil in winter and spring. Bedding also concentrated the richer topsoil into the planting row where seedlings could use it more effectively.

Insufficient packing of the beds probably caused the lowered survival rates. The beds were fluffy after being pushed up by the road grader and were not mechanically packed, although they were allowed to settle over winter. Broadfoot and others (1972) maintained that loosening the soil is not always desirable as some plants require dense soil for good root-soil contact. Root-soil contact is doubly important for newly transplanted seedlings.

Weeds, chiefly blackberries and grass, grew on all plots, especially fertilized beds, and might have con-

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Table 3.—*Fifth-year survival of planted yellow-poplar*

	Bedded			Not bedded		
	No fert.	150N	150N+ 100P	No fert.	150N	150N+ 100P
Percent survival	85.0	83.8	70.0	93.8	86.2	93.8

tributed to seedling mortality or prevented a response to fertilizer. Russell (1977) found that both weed control and fertilization were necessary for best growth of planted yellow-poplar.

In spite of dramatic growth increases caused by bedding, heights of bedded plots were similar to those of the poorest yellow-poplar plantations of the region on soils without fragipans. However, if management plans require growing yellow-poplar on fragipan soils, bedding should make it possible. Other valuable, but less site-sensitive hardwoods, might reach commercial growth rates on bedded fragipan soils.

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Southern Forest Experiment Station

Research Note

SO-245

1979

Estimates of Nutrient Drain by Dormant-Season Harvests of Coppice American Sycamore

B. G. BLACKMON

SUMMARY

Estimates of the amount of nutrients removed by dormant-season harvests of coppice American sycamore indicated that harvesting once (at age 4) or twice (at ages 2 and 4) removed 20-145 kg/ha of N, P, K, Ca, and Mg and small quantities of Mn, Zn, Fe, and Cu. Calculations of nutrient drain indicated that for N, gains through natural processes about equal losses, but losses exceeded gains for P and K. However, on the fertile Mississippi River floodplain site used in the experiment, drain does not appear to be serious. Nutrient drain was not detectable by analysis of soil samples taken at the beginning and end of the study. On less fertile Coastal Plain soils, drain may be significant, requiring fertilization to maintain site productivity.

Additional keywords: Nutrient removal, harvesting, site productivity, nutrition, fertilization, *Platanus occidentalis*.

INTRODUCTION

Recent shortages of fossil fuels have underscored the need for wood as an alternate of supplemental source of fuel. Plantations of closely spaced American sycamore (*Platanus occidentalis* L.) grown on short rotations can possibly yield the necessary large quantities of biomass. Kormanik and others (1973) report yields of 18 metric tons/ha per year in Georgia, Wittwer and others (1978) report 13-ton yields in Kentucky, and Kennedy (1975) reports 20-ton yields in Mississippi. However, since large quantities of nutrients accumulate in tree tissues, frequent harvesting could result in a net loss of nutrients from the soil and ultimately in significant site degradation.

In this paper, I estimate the amount of nutrient removal by dormant-season harvests of coppice sycamore in the Mississippi River floodplain based on my own nutrient concentration data and the yield data of Kennedy (1975).

METHODS

Seedlings, 1-0 stock of central Mississippi origin, were planted at 0.6 X 1.0- and 1.2 X 1.0-m spacing. Soil was a Commerce silt loam, a member of the fine-silty, mixed, thermic family of Aeric Fluvaquents, and the site is very good for sycamore (Site Index = 35 m in 50 years).

For determination of nutrient concentrations, dormant-season tree samples were taken for each spacing by cutting two trees of mean height and diameter from each of two plots and separating the stems and branches. Tree tissues were combined by component, and all material was dried at 70° C and ground to pass through a 20-mesh screen. Trees were harvested annually, and samples of 1-year-old tissue were taken in January of 1971, 1972, 1973, and 1974 for a total of four such blocks in time.

The concentration of nitrogen in tree tissue was determined by the semi-micro Kjeldahl method; P by colorimetry; and K, Ca, Mg, Mn, Fe, Zn, and Cu by atomic absorption spectrophotometry.

In a separate study, Kennedy (1975) measured the

Table 1.—*Dry matter production by cutting cycle and spacing for 4 years.*[1]

Spacing & cutting cycle	Component		
	Stem	Branches	Total
	t/ha		
0.6X1.5 meters			
1[2]	15.8	3.7	19.5
2	28.2	3.1	31.3
4	30.5	1.6	32.1
1.2X1.5 meters			
1	12.3	2.2	14.5
2	19.9	3.2	23.1
4	27.4	1.4	28.8

[1]Calculated from Kennedy (1975).
[2]Cutting cycles: 1 = 4 annual harvests, 2 = 2 biennial harvests, 4 = 1 harvest after 4 years.

dry weight of stems and branches of sycamore planted at two spacings — 0.6 X 1.5 and 1.2 X 1.5 m — and harvested after 1, 2, and 4 years (table 1). I estimated nutrients removed through harvesting over 4 years by multiplying my nutrient concentrations by Kennedy's dry weights (tables 2 and 3). This procedure seems to be justified since concentration of most nutrients was not related to spacing, the two studies were conducted on Mississippi River floodplain soils having very similar chemical and physical properties, and the studies received similar management.

Drain of N, P, and K was estimated by comparing expected nutrient gains from precipitation, mineralization, and weathering with nutrient losses through tree harvesting (Boyle 1975, 1976).

At the beginning of the study and after 6 years, soil samples were taken at depths of 0-30, 30-60, 60-90, and 90-120 cm from two points on each plot. These samples were analyzed for extractable P by the Mississippi soil test method (Soil Test Work Group 1974); for exchangeable K, Ca, and Mg by atomic absorption after extraction with 1 *N* NH_4OAc; for organic matter by chromic acid oxidation; for total N by the Kjeldahl method, and reaction with the glass electrode pH meter.

Table 2.—*Average nutrient concentrations in stems and branches at two spacings.*

Spacing	Nutrient concentration								
	N	P	K	Ca	Mg	Mn	Zn	Fe	Cu
meters	percent					ppm			
					Stem				
0.6X1.0	.448	.098*	.292	.300	.058*	8.68	6.00	12.88	6.38
1.2X1.0	.495	.123	.310	.320	.073	11.88	7.25	15.38	7.50
					Branches				
0.6X1.0	.555	.105	.318	.573	.078	13.63	9.75*	21.25	11.50
1.2X1.0	.573	.135	.328	.545	.100	19.38	8.25	20.13	11.50

*Indicates significant difference (.05) between spacings.

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Table 3.—*Total nutrient removal (branches & stems) during a 4-year period.*

Spacing & cutting cycle	Nutrient								
	N	P	K	Ca	Mg	Mn	Zn	Fe	Cu
	kg/ha								
0.6X1.5 meters									
1[1]	91.2	19.4	57.8	68.5	12.1	.185	.130	.281	.143
2	143.8	30.9	92.4	102.6	18.8	.289	.199	.431	.216
4	146.4	31.6	94.1	100.6	18.9	.290	.198	.426	.213
1.2X1.5 meters									
1	73.4	18.0	45.4	51.2	11.1	.188	.107	.233	.116
2	117.2	28.9	72.4	81.4	17.8	.298	.171	.371	.186
4	144.0	35.6	89.7	95.5	21.5	.353	.211	.450	.223

[1]Cutting cycles: 1 = 4 annual harvests, 2 = 2 biennial harvests, 4 = 1 harvest after 4 years.

RESULTS AND DISCUSSION

Nutrient accumulation and removal through harvesting

For all elements studied, concentrations in branches exceeded those in stems (table 2). With the exception of P and Mg in stems and Zn in branches, nutrient concentrations were not related to spacing.

I measured nutrient concentrations only for tissue harvested on an annual cutting cycle. Since nutrient concentration tends to be lower in older tissue (Steinbeck and others 1974), the contents I calculated for Kennedy's cycles of 2 and 4 years are perhaps slightly elevated.

During the 4 years, annual dormant-season harvests of trees grown at 0.6 X 1.5-m spacing removed 91 kg/ha of N, 19 of P, 58 of K, 68 of Ca, and 12 of Mg (table 3). Trees at the wider spacing removed 73 kg/ha of N, 18 of P, 45 of K, 51 of Ca, and 11 of Mg. Extending the cutting cycle from 1 year to 2 and 4 years increased nutrient removal by 50-60 percent at the closer spacing and 70-90% at the wider spacing (table 3). As Kennedy (1975) found with yield, there appears to be no difference in nutrient removal between the 2- and 4-year cutting cycles. Very small quantities of Mn, Zn, Fe, and Cu were removed, regardless of spacing or cutting cycle (table 3). Removal ranged from 0.11 kg/ha for Zn when trees were harvested annually for 4 years and spaced at 1.2 X 1.5 m to 0.45 kg/ha for Fe when trees were grown at the same spacing and harvested one time, at age 4.

Nutrient drain

Sycamores obviously remove nutrients from the soil, but the real question is whether or not this removal represents a net loss of nutrients from the site. To answer this question, I compared the losses of N, P, and K from harvesting with the gains that could be expected over the 4 years from weathering, mineralization, precipitation, and other sources (table 4).

Gains in soil N sometimes exceeded losses; the greatest net gain occurred when trees were harvested annually (table 4). Increasing the cutting cycle to 2 and 4 years yielded an index of 0.9 at the closer spacing, indicating a slight drain of N during the 4 years. At the wider spacing, the gain/loss index fell below 1.0 only with the 4-year cycle.

Losses of P exceeded gains by 9 to 27 kg/ha, depending on the cutting cycle and spacing. Gain/loss indices ranged from 0.3 to 0.5, with a tendency toward greater drain with longer cutting cycles. Of the three nutrients studied, P losses were greatest. These results are similar to those of Wood and others (1977), who found N removal to about equal gains and P removal to exceed gain. Potassium drain was intermediate between N and P. Gain/loss indices ranged from 0.5 to 1.0.

Besides gain/loss indices, nutrient reserves of a site must be considered. Although gain/loss indices indicate a drain of P and K, the study site has a reserve of 464 kg of P/ha and 1,148 kg of K. Assuming a maximum drain of 27 kg/ha of P over a 4-year rotation, about 17 rotations of 4 years each would be required to deplete the site of available P. Since the maximum drain of K is 49 kg and the soil has a reserve of 1,148 kg, it would take 23 rotations of 4 years each to deplete the available K. Yet, drain probably should not be considered in terms of time required to exhaust nutrient supplies. The soil would not supply adequate nutrition for tree growth long before total depletion. Also, if harvests were conducted during the growing season, removing foliage

Table 4.—*Soil nutrient reserves, expected gains, losses, and gain/loss indices for coppice sycamore harvested over a 4-year period.*

	Nutrient		
	N	P	K
0.6X1.5-m spacing	-------------kg/ha-------------		
Available soil reserve (0-30 cm)[1]	63	464	1148
Gains expected in 4 years[2]	134	9	45
Loss in harvest (by cutting cycle):			
1[3]	91	19	58
2	144	31	92
4	146	32	94
	------------Index------------		
Gain/loss index (by cutting cycle):			
1	1.47	.47	.78
2	.93	.29	.49
4	.92	.29	.48
1.2X1.5-m spacing	-------------kg/ha-------------		
Available soil reserve (0-30 cm)	63	464	1148
Gains expected in 4 years	134	9	45
Loss in harvest (by cutting cycle):			
1	73	18	45
2	117	29	72
4	144	36	90
	------------Index-------------		
Gain/loss index (by cutting cycle):			
1	1.84	.50	1.0
2	1.14	.31	.62
4	.93	.25	.50

[1]Nutrient reserves were determined by analysis of soil from the study site. Available N was estimated from total N, assuming 2% availability.
[2]Expected gains are those estimated by White (1974) for soils in south Alabama. Gains include inputs from mineralization, weathering, and precipitation.
[3]Cutting cycles: 1 = 4 annual harvests, 2 = 2 biennial harvests, 4 = 1 harvest after 4 years.

from the site, nutrient drain would occur at a more rapid rate.

Soil analyses did not reveal significant losses in nutrients, perhaps because of the inability to measure small changes in available forms of nutrients.

This study was conducted on a highly fertile soil. If the reserve of soil P were only 40 to 50 kg/ha, as in many soils of the southern Coastal Plain, two rotations could deplete the extractable P, assuming biomass production comparable to that observed in this study. Since the rate of biomass production and nutrient accumulation is usually lower on Coastal Plain soils, three or four rotations, or 12 to 16 years, might be required to deplete soil P. But sub-optimum nutrition would occur in a much shorter period. On such sites, fertilization would probably be necessary.

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U.S. GOVERNMENT PRINTING OFFICE 672-781 1979

Southern Forest Experiment Station

Research Note

SO-246

1979

YELLOW-POPLAR ROOTING HABITS

JOHN K. FRANCIS

SUMMARY

Although the configuration of pole-sized yellow-poplar root systems in Tennessee is quite variable, a branched taproot with several widely spreading laterals is typical. Rooting depth is particularly limited by clayey texture, wetness, and firmness of subsoils.

Additional keywords: *Liriodendron tulipifera* L., taproot, water table.

YELLOW-POPLAR ROOT SYSTEMS

The rooting habits of yellow-poplar *(Liriodendron tulipifera* L.) are not well known. Toumay (1929) described yellow-poplar seedlings as having rapidly growing, deeply penetrating taproots with wide-spreading lateral roots. Steinbeck and Kormanik (1968) observed that in sandy strata, roots of yellow-poplar seedlings were round, fleshy, and easily separated from the soil. When roots grew into clay lenses, they became flattened, somewhat flaccid, and more likely to cling to fine soil particles. Coile (1937) found that nearly all roots in a mixed yellow-poplar and sweetgum stand were in the upper 19 inches of the soil. Despite these observations, we lack a clear idea of the structure of yellow-poplar root systems and how they are affected by soil properties.

I have documented the rooting habits of 10 pole-sized yellow-poplars and tried to relate root development to soil properties.

METHODS

Ten soils in middle Tennessee were chosen for their widely varying chemical and physical properties, topographic setting, and parent material. On each soil a dominant or codominant yellow-poplar about 4 inches in diameter was selected for study. Trees chosen varied in age from 8 to 34.

After each tree was cut, a trench was dug up and down slope with one face about 6 inches from the stump. Trenches were long enough to expose most of the root extension and as deep as the deepest yellow-poplar roots. A full description was made of each profile. Laboratory analysis of the chemical and physical properties of each horizon was performed.

The soil was carefully picked away from the roots of the tree until the trench face had been advanced 16 inches. After a 12-inch string grid was installed, the root system was sketched and photographed.

RESULTS AND APPLICATION

Yellow-poplar root systems were quite variable. Root size appeared to be governed by tree size, not age. Although roots grew in response to soil horizon conditions, much of the configuration of each yellow-poplar root system seemed to be a meandering response to soil pores and structure. Both deep and shallow root systems were present, but no sample trees had abundant "feeder" roots at the interface between the forest floor and mineral soil as do many other forest species. The lack of abundant "feeder roots" makes yellow-poplar less likely than many of its associates to be weakened by disturbance of the forest floor by logging or cultivation.

Taproot and heartroot systems both occurred, but a several-branched taproot was more common (fig. 1). Lateral roots tended to grow parallel to the soil surface, whether sloping or flat; taproots and sinker roots grew down. The taproot or its branches extended much deeper into firm or wet subsoils than descending branches of lateral roots.

Roots in coarse-textured soil were round, long, little-branched, and fibrous. In clayey soil, roots were weak, fleshy, flattened, and more crooked and branched than in coarse soils. Clayey, wet subsoils caused dieback and subsequent branching of root tips (fig. 2). Dieback may have been caused by anoxia. The importance of good aeration to yellow-poplar roots, especially lateral roots, is illustrated in figure 3. After being buried by sandy alluvium, lateral roots of this yellow-poplar grew to near-surface positions and then spread out. However, the roots of some yellow-poplars can grow for a short distance into both seasonal and permanent water tables (fig. 4).

In shallow soils, yellow-poplars sometimes expanded their root systems laterally to make up for lack of rooting depth. Roots penetrated fragipans and other firm subsoils to a limited extent, but root growth was clearly reduced. Managers should avoid planting yellow-poplar where soils are wet and shallow, where water tables are high, or where fragipans or very firm subsoils exist.

Gravel in the soil did not alter root configuration and did not noticeably contort individual roots. Yellow-poplar can do well in skeletal soils, if soil depth is ample and the soil matrix is not hard. Old root channels were heavily used and may be important to root extension in dense soils. Where possible, plant near old stumps.

Although no changes were noted in rooting patterns, yellow-poplar generally did well where Ca and base saturation were high. Poor growth was observed where exchangeable Al was high and both Ca and base saturation were low. This pattern has been reported in many other species (Foy 1974).

For growing yellow-poplar, a manager should select a soil with no restriction to deep rooting, a soil able to supply ample moisture while being well aerated and containing abundant Ca and other basic cations.

Figure 1.—*Excavated root system of a yellow-poplar on Linker soil with typical root habit.*

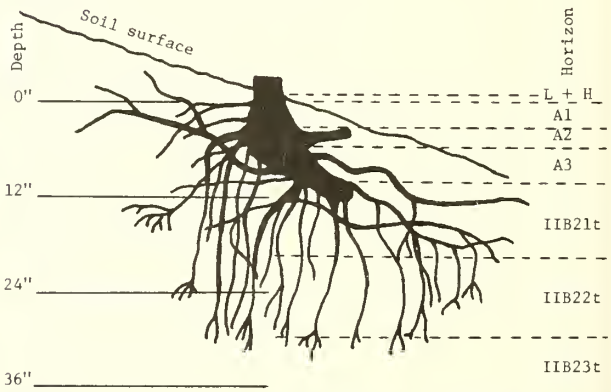

Figure 2.—*Excavated root system of a yellow-poplar on Swain soil showing root tips which have died back and branched.*

This research was done by John K. Francis at the Sewanee Silvicultural Laboratory, maintained at Sewanee, Tennessee, by the Southern Forest Experiment Station. Francis is now Associate Soil Scientist at the Southern Hardwoods Laboratory, which is maintained at Stoneville, Mississippi, by the Southern Forest Experiment Station, Forest Service — USDA, in cooperation with the Mississippi Agricultural and Forestry Experiment Station and the Southern Hardwood Forest Research Group.

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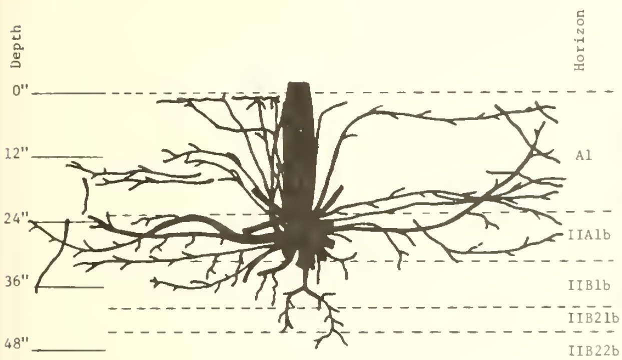

Figure 3.—*Excavated root system of a yellow-poplar on an unnamed soil. After burial, lateral roots have grown to shallower, better aerated positions.*

Figure 4.—*Excavated root system of a yellow-poplar on Guthrie soil. The taproot and sinker roots have extended more than a foot below the water table.*

OVERNMENT PRINTING OFFICE 672-802 1979

Southern Forest Experiment Station

Research Note

SO-247

1979

Combinations of Foliar- and Soil-Applied Herbicides For Controlling Hardwood Brush

JAMES D. HAYWOOD

SUMMARY

Triclopyr and 2,4,5-T esters at 1.0 lb a/A; and hexazinone, picloram, and tebuthiuron pellets at 3.0 lb a/A were applied either separately or in liquid and pellet herbicide combinations to 1/60-acre plots for mixed hardwood brush control. Only two treatments — triclopyr ester with picloram pellets and 2,4,5-T ester with picloram pellets — gave acceptable topkill of mixed brush through two growing seasons.

Additional keywords: 2,4,5-T ester, triclopyr ester, picloram, tebuthiuron, hexazinone.

INTRODUCTION

Reducing herbicide application rates would lower capital investment costs and reduce environmental risks in forest management. But it is difficult to control the numerous hardwood species with low dosages of a single herbicide. Herbicide combinations are one means of increasing the spectrum of weeds controlled without increasing the dosages used.

Earlier unpublished research[1] has shown topkills of 97 percent to hardwood brush by 2,4,5-T ester applied at 1 lb a[2]/A in late April followed by picloram at 4 lb a/A a month later. Tebuthiuron applied at 4 lb a/A on May 10 followed by triclopyr amine at 1.5 lb a/A on June 24 caused topkills of 75 percent. This study continued this work and tested several new combinations of herbicides for their effectiveness at low application rates.

METHODS AND MATERIALS

Previous work with hexazinone, picloram, and tebuthiuron pellets indicates that they should give 80 percent or better control of mixed hardwood brush in central Louisiana at a 6 lb a/A rate, while 2,4,5-T at 2 lb a/A is generally accepted as an effective rate. Lesser rates have been unsatisfactory. In this study, the pellet herbicides (hexazinone, picloram, and tebuthiuron)[3] were broadcast at a 3.0 lb a/A rate, and the liquid herbicides (2,4,5-T and triclopyr) were sprayed at a 1.0 lb a/A rate.

The herbicides were tested singly and in liquid-pellet combinations. Each treatment was randomly assigned to three 1/60-acre plots that were laid out in a completely randomized design. The study area was located on an upland sandy loam in central Louisiana in a stand of mixed hardwood brush composed primarily of flowering dogwood (*Cornus florida* L.), huckleberry (*Gaylussacia* spp.), red maple (*Acer rubrum* L.), sweetgum (*Liquidambar styraciflua* L.), and blackgum (*Nyssa sylvatica* Marsh.). Forty hardwood stems per plot were randomly selected and tagged from among the 21 species present.

The pellet herbicides were broadcast by hand on April 12, 1977, and the liquid herbicides were applied with a back pack mist blower on May 3, 1977. Water was used as the carrier, with a spray volume of 20 gallons per acre.

Treatment effects were determined in late summer by estimating percent topkill for each stem at the end of the first and second growing seasons. Values for the 40 plants sampled were then averaged to obtain a

[1]McLemore, B. F. 1977. Unpublished data. U.S. Dep. Agric. For. Serv., Southern Forest Experiment Station, Pineville, La.

[2]a — acid equivalent (2,4,5-T, triclopyr, picloram), active ingredient (hexazione, tebuthiuron).

[3]Hexazinone (3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4 (1H;3H)dione) as Velpar DPX-3674-10P.
Picloram (potassium salt of 4-amino-3,5,6-trichloropicolinic acid) as Tordon 10K.
Tebuthiuron (1-(5-tert-butyl-1,3,4-thiadiazol-2-yl)-1-3-dimethylurea) as EL-103.
2,4,5-T ester (propylene glycol butyl ether ester of 2,4,5-trichlorophenoxyacetic acid) as ESTERON 245.
Triclopyr ester (ethylene glycol butyl ether ester of 3,5,6-trichloro-2-pyridyloxyacetic acid) as DOWCO 233 (M-4021).

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percent topkill per plot. Percents were converted to arcsin proportion for statistical analysis (ANOV .05). Duncan's Multiple Range Tests were used to evaluate differences among treatment means.

RESULTS AND DISCUSSION

As mentioned earlier, average topkill of hardwood brush should be 80 percent or better. The triclopyr-picloram combination was the only treatment to meet this standard with a mean value statistically different from unacceptable results (table 1). Also, the triclopyr-picloram combination allowed no foliar recovery from the first to the second growing season. Foliar recovery of the 2,4,5-T-picloram combination was only 3 percent, which is acceptable. Visual evaluation during inspection confirmed that the triclopyr-picloram and the 2,4,5-T-picloram combinations both gave acceptable brush control through two growing seasons. All other treatments were unacceptable.

Table 2 reports the control by species for the two

Table 1.—*Average topkill of hardwood brush after one and two growing seasons*

Treatment	Rate of application	Topkill per growing season 1st	2nd
	Lb a/A	-----*Percent*-----	
Triclopyr ester + picloram	1.0 + 3.0	98	98[1] a
2,4,5-T ester + picloram	1.0 + 3.0	92	89 ab
Triclopyr ester + tebuthiuron	1.0 + 3.0	90	84 bc
Triclopyr ester + hexazinone	1.0 + 3.0	85	75 bcd
2,4,5-T ester + hexazinone	1.0 + 3.0	85	75 bcd
Triclopyr ester	1.0	80	70 cde
2,4,5-T ester	1.0	74	67 cde
2,4,5-T ester + tebuthiuron	1.0 + 3.0	79	67 cde
Picloram	3.0	66	60 de
Tebuthiuron	3.0	56	50 de
Hexazinone	3.0	51	46 e

[1]Percent topkills followed by the same letter are not significantly different at the 0.05 level.

Table 2.—*Topkill of hardwood species after two growing seasons*

Species	Topkill: Hexazinone pellets	Tebuthiuron pellets	Picloram pellets	Triclopyr ester	2,4,5-T ester	2,4,5-T +picloram	Triclopyr + picloram
	-----*Percent*-----						
Primary species:							
Cornus florida L.	73(16)[1]	72(18)	83(25)	70(7)	76(17)	100(6)	99(28)
Gaylussacia spp.	2(36)	4(36)	58(20)	49(16)	33(20)	80(24)	95(27)
Acer rubrum L.	42(18)	62(15)	41(35)	63(29)	54(33)	75(24)	98(16)
Liquidambar styraciflua L.	84(23)	65(12)	86(7)	93(30)	100(17)	96(30)	100(8)
Nyssa sylvatica Marsh.	81(7)	47(14)	100(6)	100(5)	100(5)	100(9)	100(12)
Beech family:							
Quercus stellata Wang.	—[2]	100(3)	—	55(2)	—	87(5)	—
Q. alba L.	68(3)	100(3)	—	100(2)	79(4)	100(1)	100(2)
Q. marilandica Muenchh.	40(1)	—	—	—	100(1)	—	—
Q. nigra L.	—	100(1)	100(1)	—	100(1)	100(1)	100(1)
Q. falcata Marsh. var. *falcata*	—	100(2)	12(2)	62(2)	15(1)	40(1)	100(5)
Carya spp.	5(6)	20(1)	15(1)	53(8)	79(4)	—	100(1)
Fagus grandifolia Ehrh	100(1)	—	10(1)	68(4)	55(3)	70(2)	100(6)
Minor species:							
Prunus serotina Ehrh	50(2)	78(8)	100(2)	62(10)	79(4)	100(5)	100(1)
Crataegus spp.	100(2)	100(3)	31(13)	62(2)	100(1)	100(3)	100(3)
Viburnum dentatum L.	100(1)	100(4)	72(6)	100(1)	82(5)	100(6)	100(1)
Ilex opaca Ait.	—	—	—	—	—	100(1)	—
Rhus copallina L.	100(3)	—	100(1)	—	—	—	100(5)
Lonicera japonica Thumb.	—	—	—	100(1)	—	100(1)	100(3)
Sassafras albidum (Nutt.) Nees	25(1)	—	—	—	100(3)	100(1)	100(1)
Callicarpa americana L.	—	—	—	—	35(1)	—	—
Diospyros virginiana L.	—	—	—	40(1)	—	—	—
Average	47(120)[3]	50(120)	60(120)	71(120)	68(120)	88(120)	98(120)

[1]Number of stems treated.
[2]No data.
[3]Differences in percent between table 1 and 2 due to rounding error.

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acceptable treatment combinations and for each single herbicide treatment. Hexazinone and tebuthiuron are included because our rate is similar to the full rate recommended by the manufacturers.

Hexazinone, picloram, triclopyr, and 2,4,5-T effectively controlled blackgum and sweetgum, and picloram also controlled flowering dogwood. Tebuthiuron did poorly with all the primary species. The 2,4,5-T-picloram combination successfully controlled all the primary species except red maple, while the triclopyr-picloram combination was successful with every species.

Not enough oak stems were treated to make valid conclusions, but both tebuthiuron and the triclopyr-picloram combination were consistently effective in controlling the few oaks present. The other treatments had varying results.

The two treatment combinations successfully controlled the minor mixed hardwoods, while results with the single herbicide treatments were erratic.

In conclusion, each herbicide applied alone controlled certain species, but none gave the overall brush control obtained with the two combinations.

This study confirmed positive results from earlier studies with low dosages of 2,4,5-T, triclopyr, and picloram. Site preparation using picloram pellets at 2 lb a/A followed by 2,4,5-T spray at 1 lb a/A should cost $70 per acre. If triclopyr were used, the cost would be higher; but it should be noted that triclopyr ester is not labeled for herbicide use at present.

This publication reports research involving pesticides. It does not contain recommendations for their use nor does it imply that the uses discussed have been registered. All uses of pesticides must be registered by appropriate State and Federal agencies before they can be recommended.

Caution: Pesticides can be injurous to humans, domestic animals, desirable plants, and fish or other wildlife – if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

☆ U.S. GOVERNMENT PRINTING OFFICE 1979—673-722/S0-247

Southern Forest Experiment Station

Research Note

SO-248

1979

Plantation Spacing Affects Early Growth of Planted Virginia Pine

T. E. RUSSELL

SUMMARY

Spacings ranging from 4 x 4 to 8 x 8 ft did not affect 15-year height growth of Virginia pines planted on a cutover Cumberland Plateau site. Wider spacings produced trees of larger diameters than did closer spacings; closer spacings had more basal area and volume. Although height to the base of the live crown increased as spacing narrowed, self-pruning was poor at all spacings.

Additional keywords: *Pinus virginiana* Mill., artificial regeneration of pines.

STUDY OBJECTIVES

The role of spacing in the early growth of planted pines has been researched in numerous studies throughout the South, but few spacing studies have included Virginia pine. Specific information on the response of this species to planting density is lacking for the Cumberland Plateau, where Virginia pine is an important commercial species.

In 1961, this study was started near Sewanee, Tennessee, to test the effects of spacings of 4 x 4, 6 x 6, and 8 x 8 ft on performance of unthinned Virginia pine over a 30-year rotation. Expecting that the 4 x 4 ft spacing would produce mainly trees of small diameter but anticipating that future markets might accept small trees, I included this unusually close spacing to get information on the yields obtainable at high planting densities. Also, self-pruning is notoriously poor in Virginia pine, so another goal was to see if self-pruning could be improved by planting at a high density. This note presents results halfway through the planned rotation.

STUDY AREA

The study was carried out on the Cumberland Plateau at an elevation of 1,940 ft. Plots are near the crest of a broad ridge, on gentle slopes with a west to southwest aspect. Soils are well-drained fine sandy loams of the Ramsey, Hartsells, and Lonewood series. Depth to bedrock varies from less than 20 inches to almost 4 ft. This area is typical of the thousands of acres of drier-than-average Plateau sites where Virginia pine is more productive than native hardwoods.

Before conversion to pine, the stand had about 50 ft^2 of basal area per acre mainly in either culls or low-grade chestnut oaks, scarlet oaks, and white oaks of sawtimber size. Besides reproduction of these species, the sparse understory contained blackgum, hickories, sourwood, hairy locust, and sumac. The area also had a fairly heavy but spotty ground cover of huckleberries.

STUDY METHODS

Virginia pine was bar planted in February. Seedlings were 1-0 stock grown by the Hiwassee Land Company at its Rose Island nursery. Seed had been collected in McMinn County, Tennessee, about 100 miles northeast of Sewanee, and from trees of above average form and growth rate. Within 1 month after planting, existing hardwoods were deadened by applying an oil-herbicide solution as a basal spray to stems under 4 inches d.b.h. or in frills to trees larger than 4 inches d.b.h. All sprouts or invading hardwood seedlings were cut each spring for 5 years after planting. A few scattered, large hardwoods that recovered from the initial treatment were eliminated by tree injection.

Spacings of 4 x 4, 6 x 6, and 8 x 8 ft were tested on 0.25-acre plots and replicated four times in randomized blocks. Measurements were taken on a central plot that was about 0.1-acre but varied slightly in size depending on spacing. Survival, diameter, and basal area data include all trees on the measurement plots. Total heights and stem characteristics are based on a sample. I selected this sample so that the numbers of trees measured in every 1-inch diameter class were proportional to the numbers of stems in the diameter class on an individual plot. Results were interpreted by analysis of variance; differences stated as significant were tested at the 0.05 level.

RESULTS

Survival

Survival 5 years after planting was 94 percent or better for all spacings. At 10 years survival averaged 84 percent for the 4 x 4 and 6 x 6 ft spacings and 93 percent for the 8 x 8 ft spacing, a significant difference. Mortality continued to be a factor in these stands. After 15 years, survival was 54 percent for 4 x 4, 74 percent for 6 x 6, and 86 percent for 8 x 8 ft spacings (table 1).

Table 1.—*Effects of spacing on survival, diameter, basal areas, and volumes after 15 years*

spacing (feet)	Survival	d.b.h.	Basal area	Volumes[1]
	Percent	*Inches*	*Ft^2 per acre*	*Ft^3 per acre*
4 x 4	54 a[2]	4.0 a	129 a	1830 a
6 x 6	74 b	4.7 b	108 b	1520 b
8 x 8	86 c	5.4 c	95 b	1300 b

[1]Cubic feet volumes per acre for entire stem, less bark.

[2]Means in each line followed by different letters are significantly different at the 0.05 level of probability.

Growth

Total heights averaged 32.7 ft and varied less than 1 ft among spacings. Despite considerable differences in soils among the 12 plots, mean heights from the poorest plot to the best plot varied by only 4.2 ft. Effects of site on height growth of Virginia pine may not be fully expressed by 15 years.

Planting at high densities failed to improve self-pruning. Dead branches persisted to within 1 ft of the ground for all spacings. Height to the base of the live crown, however, averaged only 15.2 ft for pines in the 8 x 8 ft spacing — significantly less than the 18.2 ft for pines planted at 4 x 4 ft.

Average d.b.h. increased uniformly from the closest to the widest spacing, but basal area was significantly higher only on plots planted at 4 x 4 ft (table 1). Total volumes corresponded closely with basal areas, increasing as plantation density increased. Volume per square foot of basal area averaged about 14 ft^3 at all spacings.

Diameter distributions

The distribution of diameters in this 15-year-old plantation further emphasizes the effect of planting density on the development of young Virginia pines (table 2). The 6 x 6 ft spacing yielded more trees per acre in the 5-inch and larger d.b.h. classes than either closer or wider spacings. However, there were over three times as many 7- and 8-inch stems at 8 x 8 than at 6 x 6 ft.

Table 2.—*Distribution of diameters as related to initial plantation spacing*

Spacing (feet)	d.b.h. class (inches)								
	1	2	3	4	5	6	7	8	All
	Trees per acre								
4 x 4	3	185	465	438	278	92	18	2	1481
6 x 6	-	40	160	220	290	155	25	2	892
8 x 8	-	9	31	127	175	156	76	14	588

On plots planted at 4 x 4 ft only 26 percent of surviving pines are 5 inches d.b.h. or larger and thus merchantable for pulpwood under current local standards. In stands planted at 6 x 6 and 8 x 8 ft merchantable stems averaged 53 percent and 72 percent of the stands, respectively. The proportion of planted trees that both survived and reached merchantable size in 15 years ranged from 14 percent for the 4 x 4 to 62 percent for the 8 x 8 ft spacing.

CONCLUSIONS

The 6 x 6 and 8 x 8 ft spacings produced about the same number of merchantable trees, but the wider spacing had more 7- and 8-inch trees and thus would be preferred under present marketing conditions. High basal area and a corresponding high biomass can be produced by young stands planted at 4 x 4 ft. But planting this many trees per acre is expensive and excessive early mortality of Virginia pine in such dense stands is likely. Extremely close spacings will be attractive only where stems smaller than 5 inches d.b.h. can be utilized and then only if rotations of not much longer than 10 years are planned.

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Southern Forest Experiment Station

Research Note

SO-249

1979

A SCALE FOR RATING FIRE-PREVENTION CONTACTORS

M. L. DOOLITTLE

SUMMARY

A scale is constructed to help fire-prevention program administrators determine if an individual contactor is effective at influencing people. The 24 items in the scale indicate the qualities that an effective contactor should have.

Additional keywords: personal contact, prevention-effectiveness.

INTRODUCTION

Research and field experience have shown that person-to-person contact is more effective than impersonal media for influencing people's opinions, beliefs, and actions regarding forest fire (Bertrand and Baird 1975). But efforts to influence others are not likely to succeed unless the person making the contacts is right for the job. How can a fire-prevention program administrator determine if an individual contactor is effective at influencing others? What are the attributes of an effective contactor? We tried to answer these questions by asking a large number of experienced fire-prevention people what attributes characterize an effective personal contactor. The result was the development of a scale for rating contactor effectiveness.[1]

[1]The technique used for constructing the scale was developed by L. L. Thurstone and his associates (Thurstone and Chave 1929). The clearest description of the technique is presented by Edwards (1957), p. 83–98.

SCALE DEVELOPMENT

We started with over 100 attributes of effective contactors, but after eliminating those that were ambiguous, redundant, or clearly irrelevant, we reduced the list to 34. Then we asked the original submitters to rate the importance of each attribute. The results of that inquiry allowed us to compute an average value, on a scale from 0 to 11, for each of the 34 items. We also determined how closely our "judges" agreed on the importance of each one, and we eliminated ten items on the basis of their disagreement. The final version of the scale was field tested with 100 contactor-employees of a state forestry agency. The results were consistent with other measures of effectiveness for these employees—namely fire occurrence trends and supervisor's rating. The 24 items and the value of each are shown below. Item values are in parentheses.

USING THE SCALE

To use the scale to rate a contactor, the rater simply indicates with a checkmark those attributes he thinks the contactor has and adds their values. The rating sum can be divided by the total of all values (233) to obtain a percent score. Although the scale was constructed with the supervisor of contactor personnel in mind, anyone familiar with an employee can rate him or her. In fact, an average score from several ratings will be more reliable than a single score.

Some of the items in the scale are "personality characteristics" (such as dependability, moral character, good sense of humor) and are difficult to alter. A contactor who lacks a number of these may never be effective. Conversely, some of the qualities can be learned, like knowledge about the community, fire history, and basics about fire prevention. The contactor who lacks learnable traits but has good personal attributes can be made more effective at influencing others by specialized training.

Fire Prevention Contactor Effectiveness Scale

1. Respect for the people being contacted (10.3)
2. Ability to communicate on the level of people contacted (10.1)
3. Respect from the people contacted (10.0)
4. Good personal hygiene (10.0)
5. Ability to listen effectively (10.0)
6. Persistence in performing a task (10.0)
7. Dependability (10.0)
8. Tact in dealing with others (9.9)
9. Moral character (9.9)
10. Commitment to the agency and job (9.9)
11. Desire to perform a task effectively (9.8)
12. Personal desire for achievement (9.8)
13. Knowledge about the community (9.8)
14. Knowledge of fire history of area (9.8)
15. Knowledge in the basics of fire prevention (9.8)
16. Personal desire for self-improvement (9.7)
17. Appreciation for the beauty of the forest (9.7)
18. Positive self-image (9.7)
19. Knowledge in general forestry (9 6)
20. Environmental concern (9.6)
21. Good sense of humor (9.6)
22. Active in community affairs (9.4)
23. Strong sense of responsibility (8.9)
24. Inquisitiveness (7.7)

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☆U.S. Government Printing Office. 1979 672-238

Southern Forest Experiment Station

Research Note

SO-250

1979

Site Index for Loblolly Plantations on Cutover Sites in the West Gulf Coastal Plain

T. W. Popham, D. P. Feduccia, T. R. Dell, W. F. Mann, Jr., and T.E. Campbell

SUMMARY

Functions used previously to derive height-age relationships for southern pines are compared in order to develop new site index curves for loblolly pine plantations on cutover sites in the lower West Gulf.

Additional keywords: *Pinus taeda,* height growth.

INTRODUCTION

Site index permits the timberland owner or manager to classify forest land by its productive capacity. Initial planting density, thinning regimes, cutting cycles, and rotation lengths can be adjusted according to the site index. Existing site index curves are not suitable for loblolly pine (*Pinus taeda* L.) planted on cutover sites in the West Gulf.

Curves for naturally regenerated loblolly (U.S. Forest Service 1929, Zahner 1962, Trousdell and others 1974) show a steady increase in estimated site index when measurement is repeated. The same is true of the Coile and Schumacher (1964) curves for planted loblolly on drainage classes d_1 - d_4. Site curves from Lenhart (1971) and Smalley and Bower (1971) are for loblolly planted on old fields. The Lenhart (1971) curve has heights greater at early ages and lower at older ages while the Smalley and Bower (1971) curve has heights lower at older ages than observed averages for plantations on cutover sites.

Myers' (1977) yield program for planted loblolly computes heights by combining Lenhart's (1971) old-field curve for ages 3 to 25 and Farrar's (1973) curve for natural stands for ages 25 and beyond. For site indices 30 to 100 (index age 25) and ages up to 70, Myers' program predicts taller trees than any of the anamorphic loblolly curves we investigated and for site indices 60 to 100 (index age 25) of the Trousdell and others (1974) polymorphic curves. Our paper presents new curves for estimating site index and height growth of loblolly pine plantations on cutover sites in the lower West Gulf Coastal Plain. The height-age relationship presented here was used in a system to generate yield tables in Feduccia and others (1979).

METHODS

A total of 787 age and height determinations were available from 293 permanent plots geographically distributed as shown in figure 1. Plots were measured from one to six times at intervals of 1 to 5 years. The height value used for each plot observation was the average of the dominant and codominant trees on the plot. Plots were located in plantations on cutover sites having no establishment problems or accidents that retarded growth. The age and site index distribution of the observations are shown in table 1.

Two basic mathematical models are frequently used to determine site index for the southern pines (table 2). Models 1a, 1b, 1c, 1d, and 2a were fitted to our data. The fitted regression of height on age

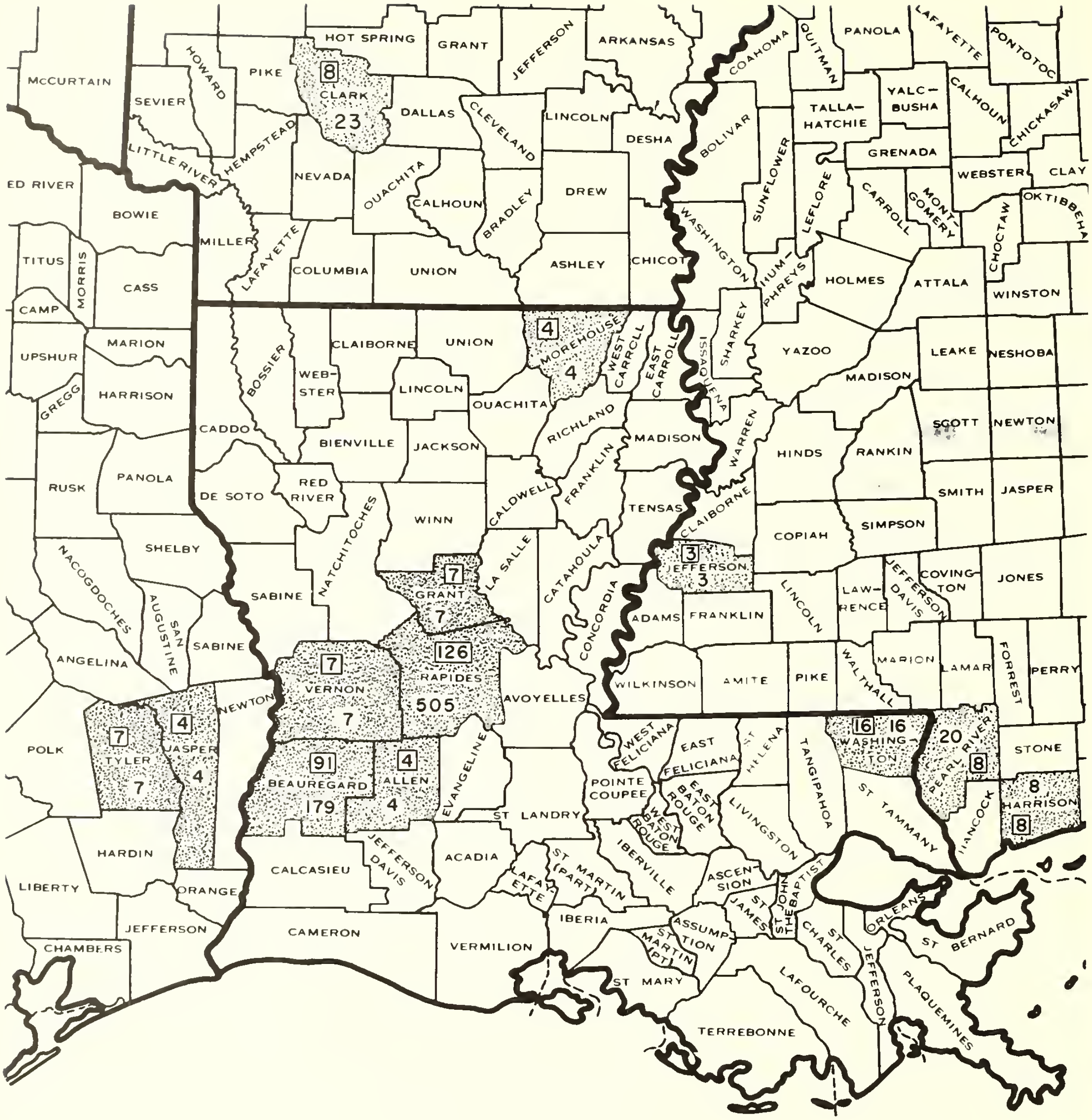

Figure 1—*Geographic location of 293 plots (numbers enclosed in boxes); 787 observations (numbers not enclosed in boxes).*

Popham is Mathematical Statistician; Feduccia, Research Forester; Dell, Mathematical Statistician; Mann, Chief Silviculturist; and Campbell, Silviculturist. All are employed by the Southern Forest Experiment Station, Forest Service—USDA, except Feduccia, who is assigned to the Southern Station by the Louisiana Office of Forestry.

Table 1.—*Number of observations classified by age and site index (index age 25)*

	Site Index							
Age	< 45	45-50	50-55	55-60	60-65	65-70	> 70	Total
5–7	6	----	1	1	7	7	9	31
8–12	7	1	9	16	5	8	14	60
13–17	7	3	17	46	62	11	3	149
18–22	1	9	16	74	40	46	9	195
25	2	10	28	27	9	----	----	76
30	----	2	16	38	11	2	----	69
35	----	2	10	39	15	3	----	69
40	----	----	13	34	19	3	----	69
45	----	----	4	41	23	1	----	69
Total	23	27	114	316	191	81	35	787

was required to approximate the data center of mass over the range of ages. Also, on plots measured more than once, site index of plots when they were older had to be consistent with the site index estimated when the plots were younger. This consistency was evaluated for each model by a combination of statistical procedures. The site index computed for a plot when it was older was plotted over the index computed for an earlier age in pairs of successive observations on a plot. A simple linear regression was fitted through the points to give a visual impression of possible bias. A chi-square procedure (Freese 1960) was used to evaluate the consistency of site index determination at progressing ages.

Remeasurement data were insufficient for a polymorphic approach to site curves as recommended by Curtis (1964), so anamorphic curves were used.

RESULTS AND DISCUSSION

The regression lines were well below the average height of the older plots when the models were fitted using unweighted regression. The longer a stand occupies a site the more accurately it represents the growth potential of the site. Obtaining data from age classes 30 to 50 years is difficult because of the scarcity of older plantations. Logically, the oldest data collected should have the greatest weight in fitting the relationship of height to age. Farrar (personal communication)[1] suggests weighted regression with the square of age as the weight. When fitting the relationship with the square of age as weight, it was impossible to distinguish between the models by using statistical criteria. Model 1c was selected because it best approximated the data center of mass for the older plots.

The coefficients for model 1c, fitted by weighted regression, are:

$$b_0 = 2.24283$$

$$b_1 = -21.0977$$

$$b_2 = 316.282$$

$$b_3 = -2443.84$$

$$b_4 = 6318.86$$

Site index for a given height and age is computed by equation 1 (fig. 2) and height for a given site and age is computed by equation 2 (fig. 2).

Estimates of site index or height beyond 45 years

[1]Robert M. Farrar, Jr. Research Forester, Southern Forest Experiment Station, Monticello, Ark.

Table 2.—*Frequently used models for relating height to age in southern pines*

MODEL	REFERENCE
1. Height= $10^{[b_0+b_1 \text{ (function of Age)}]}$ or Log_{10} Height= b_0+b_1 (function of Age)	
(1a) $H=10^{(b_0+b_1/A)}$ or $\text{Log}_{10} H=b_0+b_1/A$; b_0 and b_1 parameters to be estimated; H is observed height at age A.	Zahner (1962), Coile & Schumacher (1964), Lenhart (1971)
(1b) $H=10^{(b_0+b_1/\sqrt{A})}$ or $\text{Log}_{10} H=b_0+b_1/\sqrt{A}$; b_0, b_1, H, and A same as model (1a)	Smalley & Bower (1971)
(1c) $H=10^{(b_0+b_1/A+b_2/A^2+b_3/A^3+b_4/A^4)}$ or $\text{Log}_{10} H=b_0+b_1/A+b_2/A^2+b_3/A^3+b_4/A^4$; b_0, b_1, H, and A same as model (1a).	Farrar (1973)
(1d) $H=b_0+b_1(\text{Log}_{10} A)$; b_0, b_1, H, and A same as model (1a).	Larson & Moehring (1972)
2. Height= $a(1-e^{-b(\text{Age})})^c$; a, b, and c parameters to be estimated. Chapman-Richards generalization of Von Bertalanffy's equation.	Pienaar & Turnbull (1973)
(2a) $H=a(1-e^{-b(A)})^c$; a, b, and c parameters to be estimated, H is observed height at age A.	Bailey and others (1973)
(2b) $H=a(1-e^{-bA})^c$; Where $a=b_1+b_2S$, $b=b_3+b_4S+b_5S^2$, H and A are same as model (2a) and S=site index, 5 parameters to be estimated.	Graney & Burkhart (1973)
(2c) $H=a(1-e^{-bA})^{\frac{1}{1-m}}$; where $a=b_1+b_2S$, $b=b_3+b_4S+b_5S^2$, $m=b_6+b_7S+b_8S^2$, H and A are same as model (2a), and S=site index, 8 parameters to be estimated.	Trousdell and others (1974)

are an extrapolation beyond our data. The model cannot be used below age 6. The function reaches a minimum between 5 and 6 and goes to infinity as age approaches 0. Evaluation of site quality from observations of plots less than 10 years old cannot take into account long-term environmental conditions. Some situations, such as computer simulation, require computing a height for a specific site index regardless of age. The FORTRAN computer subprogram (fig. 3) provides for computing height when the age is less than 6 by linear interpolation between 0 height at age 0 and height at age 6 for the specific site index.

The data used in exploring the height-age relationship represent a broad area and a variety of conditions. The chosen function should, on the average, be good. Computer programs capable of linear and non-linear least-squares regression with weighting are readily available. Development of specific relationships using local data sets is more feasible than in the past.

To generate site index or height tables with our model, a computer program by Farrar (1975) can be modified easily by substituting the coefficients b_1, b_2, b_3, b_4 for those in line SOH 123. Also, line PRT 106 should be changed to remove M. P. 50 from the printed output.

Curves for site indices 30 to 80 (index age 25) where generated using equation 2 (fig. 2). The curves are shown in figure 4.

Equation 1.

$$S_I = H_D\,(10)^{\left[b_1\left(\frac{1}{I} - \frac{1}{A_p}\right) + b_2\left(\frac{1}{I^2} - \frac{1}{A_p^2}\right) + b_3\left(\frac{1}{I^3} - \frac{1}{A_p^3}\right) + b_4\left(\frac{1}{I^4} - \frac{1}{A_p^4}\right)\right]}$$

Equation 2.

$$H_D = S_I\,(10)^{\left[b_1\left(\frac{1}{A_p} - \frac{1}{I}\right) + b_2\left(\frac{1}{A_p^2} - \frac{1}{I^2}\right) + b_3\left(\frac{1}{A_p^3} - \frac{1}{I^3}\right) + b_4\left(\frac{1}{A_p^4} - \frac{1}{I^4}\right)\right]}$$

where:

A_p =plantation age (the number of growing seasons since the seedlings were planted),

H_D =average height of dominant and codominant trees at any given A_p,

I =reference or index age (plantation age to which site quality is referenced),

S_I =site index, the average height of dominant and codominant trees at a given reference age.

Figure 2.—*General equations for computing site index given height and age (equation 1) or height given site index and age (equation 2).*

```
      SUBROUTINE HTSI (CO,AI,X,SH,I,AL)
C--
C-- COEF IS A REAL ARRAY OF SIZE 4 WHICH CONTAINS THE MODEL COEFFICIENTS
C-- AI IS THE INDEX AGE
C-- X IS AGE AS A REAL VARIABLE
C-- SH IS EITHER THE SITE INDEX OR THE HEIGHT
C-- I IS AN INDICATOR VALUE, 1. COMPUTATION OF HEIGHT GIVEN SITE INDEX
C--                         -1. COMPUTATION OF SITE INDEX GIVEN HEIGHT
C-- AL IS THE LEAST INTEGRAL AGE AT WHICH FUNCTION SHOULD BE EVALUATED
C--      WITHOUT INVOKING INTERPOLATION OPTION.
C-- ALL ARGUMENTS ARE REAL VARIABLES.
C--
      REAL CO(4),AI,X,SH,I,AL
      V1=CO(1)/AI+CO(2)/AI**2+CO(3)/AI**3+CO(4)/AI**4
      IF (X.GE.AL) GO TO 10
      IF (I.LT.0)  GO TO 20
      V2=CO(1)/AL+CO(2)/AL**2+CO(3)/AL**3+CO(4)/AL**4
      TSH=(X*(SH*10.**(V2-V1)))/AL
      SH=TSH
      RETURN
10    V2=CO(1)/X +CO(2)/X**2 +CO(3)/X**3 +CO(4)/X**4
      TSH=SH*10.**(I*(V2-V1))
      SH=TSH
      RETURN
20    SH=0.
      RETURN
      END
```

Figure 3.—*Computer subprogram to compute height or site index given the other and age. CO(1), CO(2), CO(3), CO(4) should be set equal to b_1, b_2, b_3, b_4 respectively. AL should be set equal to 6*

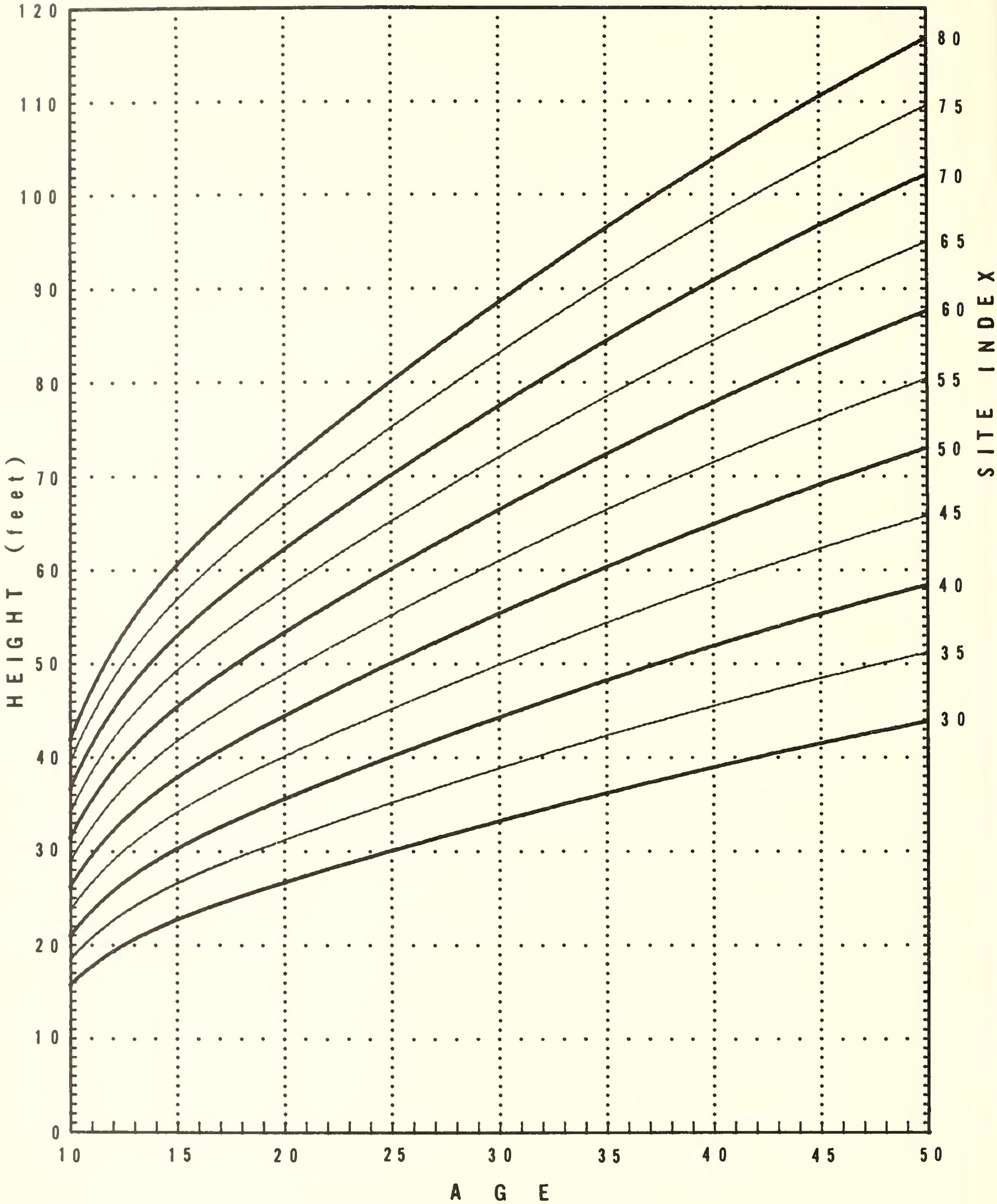

Figure 4 —*Loblolly site index curves (index age 25); plantations on cutover sites.*

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U S GOVERNMENT PRINTING OFFICE 1979—675-466

Southern Forest Experiment Station

Research Note

SO-251

1979

Soil Compaction Absent in Plantation Thinning

Tony King and Sharon Haines

SUMMARY

We examine the effects on soil bulk density by using a TH-105 Thinner Harvester and two forwarders in a mechanically thinned slash pine (*Pinus elliottii* Engelm.) plantation. Points in the machine tracks were sampled before and after harvesting at depths of 5 and 10 cm (2 and 4 in) for moisture and bulk density. Both the standard gravimetric method and a Troxler Model 3411 nuclear moisture-density gauge were used. Sample points were trampled at least seven times by wheels, each exerting a pressure in excess of 120.7 kPa (17.5 lb/in^2), but we detected no compaction at depths sampled. Soil water content was 13 percent during thinning.

Additional keywords: tree harvesters, thinning, soil compaction, soil density, plantation.

INTRODUCTION

Use of large logging equipment and the development of skidders permit year-round operations in most southern forests. As a result, the potential for site damage—compaction, puddling or displacement—has increased. But the effects of large equipment on the properties of forest soils have not been documented fully. In this study we evaluate the effects of the TH-105 Thinner Harvester[1] on soil compaction in a plantation thinning operation.

Increases in density resulting from compaction are greatest near the soil surface (Craul 1975): little compaction occurs below about 20 cm. The degree of compaction is greatest at the point with the most passes. Weaver and Jamison (1951) reported that the greatest increases in bulk density occurred during the first four passes.

Moehring and Rawls (1970), studying the effects of logging traffic in a 40-year-old even-aged loblolly pine stand during wet and dry soil moisture conditions, concluded that in dry weather neither tree growth nor physical soil properties were altered significantly by logging traffic. However, in wet weather, deep ruts on skid trails, compaction, and root damage were apparent. Drainage was impeded, and tree growth was reduced greatly. Resulting root damage decreased tree vigor and resistance to insect damage. Bulk density of soil in the skid ruts increased 13 percent.

[1] The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

Soil recovery after logging operations takes many years and depends on intensity of compaction. Hatchell (1969) detected no trend toward recovery from compaction on eleven soil types in the Atlantic Coastal Plain one year after logging. Under normal conditions, about 18 years is required for bulk density on log decks to return to that of undisturbed soil.

Omberg (1969) reported that soil compaction was minor when logging residues covered the ground, providing a mat for vehicular movement. This condition can occur when, for example, a harvesting machine delimbs a tree and the branches fall ahead of it.

Standard methods for monitoring soil bulk density are core sampling or radiation. Donnelly (1976) compared bulk densities measured by volumetric core samples with measurements for a nuclear surface-density probe. The latter slightly overestimated soil moisture and slightly underestimated soil bulk density. Hassan (1977), working with a light organic soil, found that a Troxler Model 3401 surface moisture-density gage gave much higher soil bulk density estimates than those obtained by the core sample method. Both methods are employed in our study.

PROCEDURE

The study site, provided by International Paper Company, Baldwin Timberlands, Bay Minette, Alabama, was in an 18-year-old slash pine plantation in the Coastal Plain of southern Alabama. Soils of the Bowie-Tifton-Sunsweet association predominated with a loamy sand topsoil about 10 cm (4 in) deep over a sandy clay loam subsoil. The site is generally flat, and a recent prescribed burn had left the mineral soil exposed in places. Soil moisture in the 0–10 cm layer at harvesting averaged 13 percent by weight.

The TH-105 harvester has 3 rubber-tired wheels and a single steering wheel at the rear. During thinning the machine straddles the row to be harvested while the felling head grasps a tree, shears it, pushes it forward, and lifts the butt end through a delimbing ring, feeding the stem toward the rear of the machine through a bucking shear. The stem is severed into bolts 2.13 m (7 ft) long, which fall into a cradle. When the cradle is full, about 1.2 m^3 (⅓ cord), it is lowered to the ground and the bolts are dumped for pickup by a forwarder. As the TH-105 moves down a row, tops and branches are deposited on the ground in front of the harvester. Trees in adjacent rows are selectively thinned.

The TH-105 weighs 9545 kg (21,000 lb) loaded. Assuming that the weight is evenly distributed, each tire supports a static load of 3100 kg (7,000 lb). The front tires of the harvester have a footprint of 2,480 cm^2 (400 in^2), indicating that the machine exerts a pressure of about 120.7 kPa (17.5 lbs/in^2) on the ground. The front tires track between tree rows while the rear steering tire treads on top of, or close to, the line of stumps. During harvest the machine moves over the same soil area at least three times, because it has to reverse with the felled tree to prevent it from hanging up in adjacent crowns. As a result, the TH-105 compressed each sample point with a pressure of at least 120.7 kPa (17.5 lb/in^2) a minimum of three times.

Pulpwood bolts were transported to the road by two forwarders. Each machine has a capacity of 7.2 m^3 (2 cords) loaded, about 12,300 kg (27,000 lbs). The forwarders tracked the same path as the TH-105 and passed over each sample point with two wheels at least twice.

The plantation had 1722 trees/ha (697 trees/acre) before thinning and 1104 trees/ha (447 trees/acre) after. Average height of 18 randomly selected trees was 10.1 m (33 ft); average d.b.h. was 12.95 cm (5.1 in).

A rectangular area 31 tree-rows wide and 122 m (400 ft) long, encompassing 0.93 ha (2.3 acres), was marked for the study. Fourteen randomly located plots were established, each containing three sample points: one in the left tire track, one in the right track, and one in the undisturbed area between adjacent thinned rows. At each point, undisturbed 44 cc (2.7 in^3) soil core samples were taken before and after harvesting from 5 cm and 10 cm (2 and 4 in) depths and placed in moisture-tight containers. For comparison with the gravimetric method, the Troxler surface moisture-density gage was used at or near the same points to obtain direct readings of bulk density and moisture at the same depths.

Samples were weighed at the Auburn laboratory and cores oven dried at 105°C. Bulk density and moisture percentages of each sample were calculated using the formulae:

$$\text{Bulk density} = \frac{\text{oven dry weight of soil (g)}}{\text{volume of soil (cc)}}$$

$$\text{Moisture Percentage} = \frac{\text{wet weight (g)} - \text{oven dry weight (g)}}{\text{oven dry weight (g)}} \times 100.$$

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Table 1.—Mean bulk density values (g/cm³) measured by soil cores[1] and by Troxler[2] before and after thinning at 5 cm and 10 cm depths

	Before thinning				After thinning			
	5 cm		10 cm		5 cm		10 cm	
	Grams per cubic centimeter							
	Core	Troxler	Core	Troxler	Core	Troxler	Core	Troxler
Left wheel track	1.51 (±0.11)	1.23 (±0.08)	1.67 (±0.09)	1.31 (±0.11)	1.52 (±0.11)	1.22 (±0.10)	1.65 (±0.10)	1.29 (±0.08)
Right wheel track	1.54 (±0.09)	1.21 (±0.08)	1.62 (±0.10)	1.29 (±0.06)	1.50 (±0.14)	1.27 (±0.06)	1.66 (±0.08)	1.34 (±0.06)
Undisturbed	1.49 (±0.12)	1.22 (±0.07)	1.66 (±0.12)	1.29 (±0.08)				

[1] Core bulk density values are mean of 14 observations.
[2] Troxler bulk density values are mean of 8 observations.

Table 2.—Mean soil moisture percentage values[1] measured by soil cores and by Troxler before and after thinning at 5 cm and 10 cm

	Before thinning				After thinning			
	5 cm		10 cm		5 cm		10 cm	
	Percent							
	Core	Troxler	Core	Troxler	Core	Troxler	Core	Troxler
Left wheel track	11.3 (±2.7)	15.1 (±3.6)	11.9 (±2.5)	14.0 (±3.1)	15.0 (±2.7)	21.4 (±3.4)	14.8 (±1.7)	20.1 (±3.7)
Right wheel track	12.3 (±4.3)	16.3 (±5.1)	12.6 (±3.0)	15.0 (±4.8)	17.9 (±5.2)	20.2 (±3.4)	15.4 (±2.9)	19.4 (±3.4)
Undisturbed	12.7 (±2.6)	15.2 (±3.3)	13.3 (±2.3)	14.9 (±2.8)				

[1] Core and Troxler moisture values are mean of 8 observations.

RESULTS AND DISCUSSIONS

We detected no damage to the soil. Little disturbance to the soil surface occurred, and no tire ruts appeared. There was little tire-to-soil contact anywhere since tree tops and branches formed a mat over the soil surface. Soil bulk density measurements confirmed that little soil disturbance had occurred.

Mean bulk density values of the soil measured either gravimetrically or with the Troxler before and after thinning did not differ significantly ($r = 0.05$) (table 1). However, standard deviation was greater by the former method (0.08 to 0.14) than by the latter (0.06 to 0.11) (table 1).

Bulk density at 5 cm (2 in) was significantly lower ($r = 0.05$) than at 10 cm (4 in) because bulk density increases with soil depth (Donnelly 1976). However, the TH-105 had no detectable impact on bulk density in the subsoil at 10 cm, even though the subsoil texture is finer than the surface texture.

Troxler bulk densities averaged 0.30 g/cc (18 lbs/ft³) lower than corresponding gravimetric determination. We assume the lower readings are a characteristic of its calibration. Soil moisture estimates with the Troxler averaged 3 percent and 5 percent greater than gravimetric means before and after harvesting (table 2).

Several factors probably contributed to the lack of detectable differences after thinning. Of major importance was the low soil moisture content (13 percent). Soil moisture and texture have considerable influence on the degree of compaction. Another mitigating factor was the layer of tops and branches deposited on the soil surface during the delimbing cycle. Tires seldom came into contact with the mineral soil surface. This layer of logging debris served to distribute the machine weight over a larger area and decrease compaction.

CONCLUSIONS

A TH-105 Thinner Harvester used with two forwarders to thin a slash pine plantation caused no detectable soil damage. Moderate ground pressure together with the distribution of branches on the soil in front of the machine contributed to the absence of soil compaction. The Troxler 3411 nuclear moisture density meter consistently overestimated soil moisture by 3 to 5 percent and underestimated soil bulk density by 0.3 g/cc (18.7 lbs/ft^3) compared to the gravimetric method.

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Southern Forest Experiment Station

Research Note

1979

SO-252

Five Years' Growth of Pruned and Unpruned Cottonwood Planted at 40- by 40-Foot Spacing

R. M. KRINARD

SUMMARY

Four pruning treatments have been applied for 5 years on cottonwood (*Populus deltoides* Bartr.) select clone Stoneville 66, planted at 40- by 40-ft spacing. As pruning severity increased, average diameter and maximum crown width decreased. Diameters ranged from 9.2 inches for trees pruned half of height yearly to 11.4 inches for unpruned trees; crown widths ranged from 16.5 to 24.6 ft.

Additional keywords: *Populus deltoides.*

INTRODUCTION

Cottonwood (*Populus deltoides* Bartr.) grows fast, but its potential maximum diameter increment has not been determined. If wide enough spacing were used at planting on site index 120+, crown development would not be restricted by competition from other cottonwood trees. And resulting diameter growth would serve as an upper limit for comparison to diameter growth at other spacings and would also tell us how fast sawtimber and veneer logs can develop. Widely planted cottonwood trees would need to be pruned for quality growth. A comparison of several pruning intensities would tell us how crown length influences diameter growth. This paper gives data on 5-year growth of widely spaced cottonwoods whose crown length has been controlled by pruning (fig. 1).

METHODS

The 9-acre study area (on Chicago Mill and Lumber Company land at Huntington Point, Bolivar County, Mississippi) was cleared in 1971, fallowed in 1972, and planted in 1973. Because of a 1973 flood, the study was replanted in January 1974. A matrix of 16 rows by 16 columns contained 256 planting spots. Spacing was 40 by 40 ft on Commerce silt loam soil. Three 18-inch cuttings of select Stoneville clone 66 (Land 1974)

Figure 1.—*General view of cottonwood trees, planted at 40-by-40 ft spacing, leafing out at start of sixth growing season. Tree nearest observer has been pruned to half its height, the next four trees in the row are pruned to a third of their height, and the next group of trees are unpruned.*

were planted at each spot and thinned to one tree per spot the first week of June.

A randomized complete block design was used, with four replications. Each plot per block was 4 rows by 4 columns. Data were analyzed at the 0.05 level of significance (Duncan's Multiple Range Test).

Disking controlled weeds during the five growing seasons.

Pruning treatments were: 1) no pruning (control); 2) pruning the bottom third of the tree yearly (third-height pruning); 3) pruning the bottom half of the tree yearly (half-height pruning); and 4) pruning the bottom 17 ft of the tree (17-ft pruning) when d.b.h. became >8.5 inches, as happened in the 4th year. Trees were pruned in the dormant season: January 1975, February 1976, March 1977, and March 1978. Trees were examined monthly during the growing seasons and any sprouts were removed. But the first examination was delayed until June 1975 because high water made trees inaccessible.

Height and d.b.h. of each tree were measured yearly. Cut limbs of the inside four trees in each pruning treatment plot were counted after the 1st year, and diameters of newly cut limbs were measured at the end of each year thereafter. Maximum crown width of all trees in both a north-south and east-west direction was measured after the 5th year. And, at that time, diameter outside bark at 17 ft of each plot's four inside trees was also measured.

Two replicates of clone 66 had also been planted in January 1974 at 10 by 10 ft in an adjoining study. At the end of the 5th year, the inside 8 trees per 10-tree replicate were measured for d.b.h., height, crown width, diameter outside

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by 10-ft spacing averaged. After 5 years, the 10- by 10-spaced trees were 4.9 inches smaller in d.b.h. and 1.9 ft shorter in height than were trees in the 40- by 40-spacing. Maximum tree measurements were 12.6 inches in diameter and 67 ft in height for the 40- by-40, 6.5 inches in diameter and 65 ft in height for the 10-by-10.

To determine cubic-foot volume, I used mean values of trees whose upper stem diameters were measured, and d.b.h.[2] times height times form as a cubic-foot volume indicator. Third-height pruned trees had 84 percent as much cubic-foot volume as unpruned trees had. Half-height pruned trees had 67 percent as much, 17-ft pruned trees had 88 percent as much, and trees at 10-by 10-ft spacing had 33 percent as much cubic-foot volume as unpruned trees had.

At the end of the 5th year, third- and half-height pruned trees had 73 percent and 57 percent as much crown as unpruned trees had, if crown length is considered crown size. If crown shape is considered conical, with the base an ellipse, then the lateral crown surface areas of third- and half-height pruned trees are only 59 percent and 39 percent as large as unpruned trees. Conical crown volumes are only 48 percent and 26 percent as large.

Crown length required for a given diameter growth cannot be determined from this study. For the 3d through 5th years, however, diameters of third-height pruned trees were 96, 93, and 90 percent as large as diameters of unpruned trees, while diameters of half-height pruned trees were 88, 84, and 81 percent as large.

Wide-spaced trees need pruning for quality growth. Pruning reduces diameter growth but not height growth. Because nearly a fourth of the half-height pruned trees suffered broken tops, half-height pruning is apparently too severe. Third-height pruning is more successful and results in only 1 inch (10 percent) less diameter in 5 years than half-height pruning produces. The 17-ft pruning produced results mathematically equal to those of third-height pruning. But boles and limbs pruned in the 17-ft treatment were larger than those pruned in the third-height treatment. So, 17-ft pruning produced a larger, lower quality core than did third-height pruning. Pruning was not effective in keeping branches off tree boles.

Although only one clone-type was used, and other types may have different crown shapes, unpruned trees of clone 66 maintained live limbs to the ground through 5 years. The widest part of an unpruned tree crown was generally near the bottom of the tree, and the crown tapered to the top. Maximum crown width measured in one direction was 30 ft for check and 29 ft for third-height pruned trees. Mean north-south crown widths were 27 ft. for check and 22 ft for third-height pruned trees. Cottonwood crowns do not mingle; so, as this study shows, a minimum spacing of 26–30 ft square is needed for maximum diameter growth through 5 years for trees receiving third-height pruning.

Cottonwood planted at 40 by 40 ft and pruned to a third of its height yearly can average 2 inches annual diameter growth through 5 years. Maintaining two-thirds of a crown has produced less diameter and stem volume than an unpruned tree would have but has improved tree form and quality. Growth over the next 5–10 years will determine the feasibility of producing sawlogs on a 10- to 15-year rotation. With wide spacing, intercropping seems a reasonable method of acquiring an early return to help offset clearing, planting, cultivating, and pruning costs.

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Table 2.—*Average values of pruned limbs by year and pruning treatment*

	Pruned 1/3 ht				Pruned 1/2 ht				Pruned 17 ft
	Year				Year				Year
	1	2	3	4	1	2	3	4	4
No. limbs cut/tree	13.0	13.7	14.5	13.5	17.8	18.4	14.1	19.5	46.2
Limb diameter (in)	*	1.2	1.5	1.5	*	1.0	1.2	1.1	1.8
Limb area (in²)/tree	*	16.6	28.2	28.7	*	15.1	18.1	22.7	129.7
No. limbs cut/ft pruned	3.8	3.3	3.5	2.8	3.3	3.0	2.4	2.7	2.7
Bole length pruned (ft)	3.5	4.2	4.2	4.8	5.4	6.1	5.8	7.2	17.0

* Not measured.

trees were larger than for half-height pruned trees (16.5 ft). For all treatments, crown width in a north-south direction was larger than in an east-west direction, where mean differences between directions were 4.9 ft for unpruned, 3.6 ft for 17-ft, 3.8 ft for third-height, and 2.9 ft for half-height treatments.

Pruning third and half heights is more severe than it might seem. Third-height pruning cut 56 percent of the branches, and half-height pruning cut 79 percent at the end of the 1st year. Throughout the study, third-height pruning removed fewer, larger limbs and so produced greater wound area per tree than did half-height pruning. The 17-ft pruning removed largest average limb size and produced largest aggregate wound area (table 2).

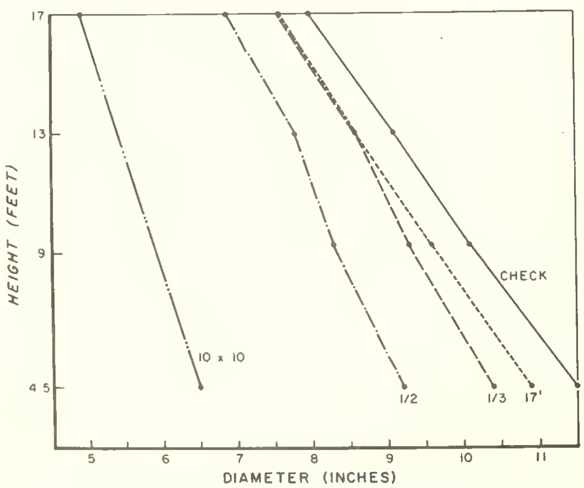

Figure 2.—*Average diameter at given stem heights for pruning treatments and for 10- by 10-ft spacing at age 5.*

Top breakage started in April of the 3d year. Proportion of trees with top breakage through 5 years was 0 for unpruned, 5 percent for third-height and 17-ft, and 23 percent for half-height pruning treatments. Storms caused breakage during the growing season. Stems snapped off from just below pruning height to 20 ft above. When one limb of a fork was pruned, the remaining limb was more likely to break. No signs were found of canker or borer damage on the broken tops.

In the 10- by 10-ft spacing, cottonwood averaged 1.2 inches d.b.h. and 11.5 ft tall after 1 year and 3.6 inches d.b.h. and 29.3 ft tall after 2 years. At age 5, trees averaged 6.5 inches d.b.h. (from 5.3 to 7.1 inches), 60.6 ft in height (from 56 to 65 ft), and 8.7 ft in maximum crown width (from 5 to 11 ft in either direction, 6.0 to 10.0 ft average of two directions). Average ratio of diameter at 17 ft to d.b.h. was 0.76 (from 0.72 to 0.79). All limbs to 17 ft were dead, and no natural pruning had occurred. Average ratio of live crown to total height was 0.32 (from 0.18 to 0.47).

DISCUSSION

As in earlier studies (Krinard and Johnson 1975), planted cottonwood has shown fast early diameter growth followed by a rapid drop in growth. For unpruned trees, diameter growth the 4th year was 75 percent of 3d-year growth; 5th-year growth was 75 percent of 4th-year growth and 56 percent of 3rd-year growth.

Where there was no pruning, trees at 40- by 40-ft spacing averaged 0.1 inch smaller d.b.h. and 0.8 ft shorter after 1 year, and 0.4 inch larger and 5.5 ft shorter after 2 years than trees at 10-

Table 1.—*Average height and height growth and d.b.h. and d.b.h. growth by year and pruning treatment*

Treatment	Height					Height growth			
	Year					Year			
	1	2	3	4	5	2	3	4	5
	feet					*feet*			
Check	10.5	23.8	36.9	49.9	62.5	13.2	13.2	12.8	12.6
One-Third	10.8	23.6	36.0	49.9	62.3	12.9	12.4	13.9	12.3
One-half	10.6	23.0	34.8	48.1	59.6	12.4	11.8	13.3	11.6
17-ft[1]	10.9	24.3	36.5	50.0	62.3	13.4	12.2	13.3	12.4
Average	10.7	23.7	36.0	49.5	61.7	13.0	12.4	13.3	12.2

Treatment	D.b.h.					D.b.h. growth			
	Year					Year			
	1	2	3	4	5	2	3	4	5
	inches					*inches*			
Check	1.1	4.0	7.2c[2]	9.6c	11.4d	2.9b	3.2c	2.4b	1.8d
One-Third	1.1	4.1	6.9b	8.9b	10.3b	3.0b	2.8b	2.0a	1.5c
One-half	1.1	3.8	6.3a	8.1a	9.2a	2.7a	2.4a	1.8a	1.1a
17-ft[1]	1.1	4.1	7.3c	9.6c	10.9c	3.0b	3.2c	2.4b	1.3b
Average	1.1	4.0	6.9	9.0	10.4	2.9	2.9	2.2	1.4

[1] Treatment applied after 4th year

[2] Means appearing with same letter not significantly different within each column at 0.05 level by Duncan's Multiple Range Test

bark at 17 ft, and length of live crown (Kennedy 1979). Because 10-by-10 spacing is common, these data were compared to 40-by-40 spacing results.

All measured trees were incuded in analyses except four trees replanted the 1st year and trees with broken tops. Where only inside trees were measured and one of these was damaged, an adjacent outside-row tree was measured instead.

RESULTS

Through 5 years no difference between treatments in either total height or height growth occurred in any year (table 1). To the nearest foot, and averaged over all treatments, height mean annual increment (m.a.i.) was 12 ft for the 2d through 5th years. Current annual increment (c.a.i.) was 13 ft in the 2d and 4th years and 12 ft in the 3d and 5th years. Mean height after 5 years was 62 ft.

Differences first occurred in d.b.h. growth during the 2d year (when half-height pruned trees grew less than did trees in other treatments). Total d.b.h. first differed after the 3d year (when unpruned trees were larger than pruned trees). Differences as small as 0.3 inch were significant (table 1). Trees pruned to 17-ft after the 4th year had less d.b.h. growth in the 5th year and smaller total d.b.h. after 5 years than unpruned trees had. Diameters at breast height of all treatments differed after 5 years, when average d.b.h.'s were 9.2 inches (half-height pruning), 10.3 inches (one-third pruning), 10.9 inches (17-ft pruning), and 11.4 inches (unpruned). Diameter at breast height m.a.i. peaked in the 3d year for third- and half-height pruned trees and in both 3d and 4th years for unpruned trees. Current annual increment peaked in the 2d year for pruned trees and 3d year for unpruned trees.

As a measure of form, ratio of diameter at 17 ft to d.b.h. was determined. The ratio was higher for third- and half-height pruning (0.73 and 0.74) than for 17-ft pruning and check (both 0.70). Taper decreased as pruning intensity increased (fig. 2).

Maximum crown width for unpruned trees (24.6 ft) was larger than for pruned trees; crown widths for 17-ft (19.2 ft) and third-height (19.9 ft) pruned

Southern Forest Experiment Station

Research Note

SO-253

1979

Using Bayleton (Triadimefon) to Control Fusiform Rust in Pine Tree Nurseries

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W. D. KELLEY, AND J. G. MEXAL

SUMMARY

Bayleton® was field-tested for fusiform rust control at eight pine tree nurseries during the spring of 1978. Four to six foliar sprays of this systemic fungicide were as effective as ferbam sprayed 16 to 36 times. Seed treatment with Bayleton reduced infection levels but did not significantly improve rust control in plots sprayed with Bayleton. At high rates, Bayleton sprays inhibited seedling growth and mycorrhizal development. However, proper application rates should minimize this problem and result in no loss of seedling quality.

Additional keywords: *Cronartium quercuum* f. sp. *fusiforme*, loblolly pine, slash pine, fungicide.

INTRODUCTION

The systemic fungicide Bayleton[1] (triadimefon), (1-[4-Chlorophenoxy]-3, 3-dimethyl-1-1-[1H-1,2, 4-triazol-1-yl]-2-butanone) is effective against several plant diseases including rust fungi attacking a wide variety of hosts (Siebert 1976). The chemical is translocated in plants, and application methods have included foliar sprays, soil drenches, and seed treatment to achieve both protective and curative control (Kaspers 1977). In recent greenhouse trials, Bayleton showed considerable promise for control of fusiform rust on slash (*Pinus elliottii* var. *elliottii* Engelm.) and loblolly (*Pinus taeda* L.) pine seedlings. As a seed treatment, Bayleton protects pine seedlings at least until after the plants shed their seed coats (Mexal and Snow 1978). Foliar sprays have been effective applied both before and after inoculation with *Cronartium quercum* (Berk.) Miyabe ex Shirai f. sp. *fusiforme* (Kelley 1979, Snow 1978).

Since fusiform rust is a serious problem in southern pine tree nurseries (Rowan 1977a) and more effective controls are needed, we tested Bayleton at pine tree nurseries in six southern States in 1978. Our purpose was to evaluate Bay-

[1]Bayleton is a registered trademark of Farbenfabriken Bayer GmbH, Leverkusen.

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This publication reports research involving fungicides. All uses of fungicides must be registered by appropriate State and Federal agencies before they can be recommended. Use fungicides only when needed and handle them with care. If fungicides are handled, applied, or disposed of improperly they may injure humans, domestic animals, desirable plants, pollinating insects, fish, or other wildlife, and may contaminate water supplies. Follow the directions and heed all precautions on the container label.

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leton under a wide range of environmental conditions, compare seed treatment with foliar sprays, establish a desirable rate for Bayleton sprays, and compare the material with ferbam, which has been commonly used for rust control in pine tree nurseries.

METHODS

We adopted a standard test procedure and followed it with minor variations at all the nurseries. The experimental design was a factorial of seed soak and spray treatment in a randomized complete block with three replications. Two seed treatments (untreated and Bayleton-treated) and five spray treatments were tested (table 1). A replication consisted of three adjacent nursery beds. In portions of these beds the combinations of seed soak and spraying were assigned at random. The beds were 1.22 m (4 ft) wide and spray plots were usually 15.25 m (50 ft) long. At the Ashe and Weyerhaeuser nurseries, the high dosage Bayleton-treated plots and the controls were reduced to 7.6 m (25 ft) long to avoid possible heavy losses from rust infection or phytotoxicity. Plots at the Beauregard nursery were 9.2 m (30 ft) long. The nursery beds were sown with slash pine seed at all nurseries listed in table 1, except at the Weyerhaeuser nursery where loblolly seed was sown. Similar experimental plots were also established in loblolly pine beds at the Hauss, Stauffer, and Miller nurseries in Alabama. Data from these tests are not presented because no trees were infected with fusiform rust.

Previously stratified seeds were soaked in an aqueous solution of Bayleton (25 or 50 WP, 800 mg. a.i./liter [.1 oz/gal]) at room temperature for 24 hours. Before planting, treated seed were air-dried and coated with bird repellent. Sprays were applied with tractor-driven power sprayers. For all Bayleton sprays, Agrodex surfactant was used at the rate of 1.3 ml/liter (1 pt/100 gal) of water. The first Bayleton sprays were applied after about 50 percent of the seed germinated and then at 2-week intervals. When long rainy periods occurred during the second week after a spray, the Bayleton application followed within 2 days after the rain. This spray date became the base for a new 2-week schedule. Dates for the last Bayleton sprays varied from the first week in June to the first week in July in 1978. Ferbam (76 WP) applications in the test followed the same schedule used for the rest of the nursery, usually 2 or 3 times a week from seed germination until the first week of July.

After the growing season (November-January), we lifted seedlings from three or five randomly selected .3 m × 1.2 m (1 ft × 4 ft) areas within all 30 plots. These seedlings were examined for fusiform rust galls, and an equal number of them from each plot were measured for height growth and weighed. Mycorrhizal development was assessed from sample seedlings lifted from experimental plots at nurseries in Florida, Georgia, and Mississippi in late summer of 1978 and in January 1979. Assessments were based on visual estimates of the percentage of feeder roots with ectomycorrhizae.

RESULTS

Relative to previous years (Rowan 1977b), rust infection was low at nurseries in Louisiana, Mississippi, and Georgia and was very low at nurseries in Alabama and Florida (table 1). Despite this low infection rate, fungicide evaluation was usually possible. At the Ashe, Beauregard, Davisboro, and Weyerhaeuser nurseries, the Bayleton seed treatment significantly reduced the incidence of fusiform rust. The effect of the seed treatment was less evident in plots sprayed with the fungicides; in plots sprayed with Bayleton differences attributable to seed treatment were not significant at any nursery.

Bayleton spray treatments gave better control than ferbam at the Ashe and Weyerhaeuser nurseries and were as effective at all others. The medium and high dosages of Bayleton appeared to be more effective than the low dosage spray in beds planted with untreated seed but differences among the three rates of Bayleton were not significant. Ferbam sprays alone significantly reduced rust incidence at the Ashe, Beauregard, and Davisboro nurseries but not at the Weyerhaeuser nursery. Statistical comparisons were not made of data from the Buckeye Cellulose, Walker, and St. Regis nurseries because of the low rust infection. The reader is invited to observe that

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Table 1.—*The effect of fungicidal sprays and seed treatment on fusiform rust incidence at seven pine tree nurseries*[1]

Nursery	Foliar spray and rate (a.i.) per hectare[2]	Number of sprays	Percentage of galled plants: No seed treatment	Percentage of galled plants: Bayleton seed treatment
W. W. Ashe Nursery Brooklyn, Miss.	Control	0	3.5 a[3]	2 c
	Ferbam 2.2 kg	31	2.1 b	6 c
	Bayleton .28 kg	4	.5 c	.1 c
	Bayleton .56 kg	4	.0 c	.1 c
	Bayleton .84 kg	4	.0 c	.0 c
Beauregard Nursery Beauregard, La.	Control	0	2.5 a	1.1 bc
	Ferbam 2.6 kg	12	0.8 bc	0.4 bc
	Bayleton .28 kg	3	1.0 bc	0.3 bc
	Bayleton .56 kg	3	1.2 b	0.4 bc
	Bayleton 1.12 kg	3	0.6 bc	0.5 bc
Davisboro Nursery Davisboro, Georgia	Control	0	5.3 a	2.0 b
	Ferbam 2.6 kg	36	0.5 c	0.1 c
	Bayleton .28 kg	5	0.9 bc	0.1 c
	Bayleton .56 kg	5	0.0 c	0.0 c
	Bayleton 1.12 kg	5	0.0 c	0.0 c
Weyerhaeuser Nursery Aliceville, Ala.	Control	0	.9 a	.5 ab
	Ferbam 2.2 kg	16	1.3 a	.5 ab
	Bayleton .28 kg	4	.3 b	2 b
	Bayleton .56 kg	4	.1 b	1 b
	Bayleton .84 kg	4	1 b	.0 b
Buckeye Cellulose Perry, Fla.	Control	0	0.2	0.0[4]
	Ferbam 2.6 kg	32	0.0	0.0
	Bayleton .28 kg	5	0.0	0.0
	Bayleton .56 kg	5	0.0	0.0
	Bayleton 1.12 kg	5	0.0	0.0
St. Regis Nursery Lee, Fla.	Control	0	0.3	0.2[4]
	Ferbam 2.6 kg	20	0.0	0.0
	Bayleton .28 kg	6	0.0	0.0
	Bayleton .56 kg	6	0.0	0.0
	Bayleton 1.12 kg	6	0.0	0.0
Walker Nursery Reidsville, Ga.	Control	0	0.2	0.2[4]
	Ferbam 2.6 kg	25	0.1	0.1
	Bayleton .28 kg	5	0.0	0.0
	Bayleton .56 kg	5	0.0	0.0
	Bayleton 1.12 kg	5	0.0	0.0

[1]Tests were on slash pine at all nurseries except Weyerhaeuser where loblolly pine was used.
[2]English equivalent of application rates are: .28 kg/hectare = 4 oz/acre; .56 kg/ha = 8 oz/acre; .84 kg/ha = 12 oz/acre, 1.12 kg/ha = 16 oz/acre; 2.2 kg/ha = 2 lb/acre and 2.6 kg/ha = 2.3 lb/acre.
[3]Values for the 10 means for each nursery followed by the same letter are not significantly different at the .05 level according to Duncan's multiple range test.
[4]Infection levels were too low to meet requirements of the Analysis of Variance so statistical comparisons among treatments are not presented.

Table 2.—*The effect of fungicidal sprays on seedling growth and ectomycorrhizal development at six pine tree nurseries*[1]

Nursery	Foliar spray and rate (a.i.) per hectare[2]	Average plant height (mm)		Average percentage of mycorrhizae development	
		8/78	1/79	8/78	1/79
Beauregard Nursery	Control		210.2 a[3]		48.0 a
Beauregard, La	Ferbam 2.6 kg		239.5 a		50.5 a
	Bayleton .28 kg		208.0 a		47.5 a
	Bayleton .56 kg		206.1 a		44.5 a
	Bayleton 1.12 kg		216.2 a		44.0 a
Buckeye Cellulose	Control	235.0 a	242.4 a	15.8 a	33.2 a
Perry, Fla	Ferbam 2.6 kg	241.5 a	235.1 a	14.4 ab	34.8 a
	Bayleton .28 kg	212.7 a	210.5 b	10.6 c	29.7 a
	Bayleton .56 kg	196.6 b	207.1 bc	11.3 bc	31.2 a
	Bayleton 1.12 kg	176.9 b	186.5 c	7.1 c	30.0 a
Davisboro Nursery	Control	210.6 a	232.1 a	13.3 a	27.7 a
Davisboro, Ga	Ferbam 2.6 kg	196.5 ab	236.6 a	16.8 a	27.5 a
	Bayleton .28 kg	201.5 a	220.3 ab	8.5 c	29.0 a
	Bayleton .56 kg	196.2 ab	212.6 b	4.5 c	27.3 a
	Bayleton 1.12 kg	191.5 b	205.0 b	11.4 b	31.4 a
St. Regis Nursery	Control	138.9 a	172.9 ab	15.0 a	43.0 b
Lee, Fla.	Ferbam 2.6 kg	141.6 a	182.5 a	18.0 a	46.4 ab
	Bayleton .28 kg	138.7 a	181.5 a	6.3 b	44.5 ab
	Bayleton .56 kg	111.9 b	163.2 b	7.6 b	51.6 a
	Bayleton 1.12 kg	78.2 c	149.4 c	5.2 b	46.4 ab
Walker Nursery	Control	218.0 a	231.1 a	14.0 ab	49.9 a
Reidsville, Ga.	Ferbam 2.6 kg	201.3 a	234.6 a	20.0 a	49.4 ab
	Bayleton .28 kg	205.3 a	207.7 b	16.2 a	49.6 a
	Bayleton .56 kg	174.5 b	205.7 b	11.3 b	47.2 ab
	Bayleton 1.12 kg	183.8 b	211.6 b	11.7 b	43.2 b
Weyerhaeuser Nursery	Control		211.5 a		
Aliceville, Ala.	Ferbam 2.2 kg		203.6 a		
	Bayleton .28 kg		207.3 a		
	Bayleton .56 kg		203.6 a		
	Bayleton .84 kg		199.7 a		

[1]Seed treatments did not affect growth or mycorrhizae and data represent a combination of both seed treatments.
[2]English equivalent of application rates are: .28 kg/ha = 4 oz/acre; .56 kg/ha = 8 oz/acre; .84 kg/ha = 12 oz/acre; 1.12 kg/ha = 16 oz/acre; 2.2 kg/ha = 2 lb/acre and 2.6 kg/ha = 2.3 lb/acre.
[3]Separately for each nursery and for each response variable the 5 means for each nursery followed by the same letter are not significantly different at the .05 level according to Duncan's multiple range test.

the most infection occurred at these nurseries in control plots and no infected trees were found in plots sprayed with Bayleton.

Bayleton sprays inhibited seedling growth and mycorrhizal development at nurseries in Florida and Georgia (table 2). By January, however, the differences in mycorrhizal development were no longer evident at the Beauregard, Davisboro, and St. Regis nurseries. A similar pattern of mycorrhizal development occurred at the Ashe nursery, but no differences in growth or color of the trees were observed that could be related to the spray treatments at the Ashe, Beauregard, Hauss, Miller, Stauffer, and Weyerhaeuser nurseries. The lower phytotoxicity at these six nurseries was probably due to the fewer sprays and, consequently, lower dosage applied.

Fresh weight of slash seedlings from beds with treated seed averaged 1.9 grams less than seedlings from untreated seed beds at the Ashe nursery while at the Weyerhaeuser nursery, loblolly seedlings grown from treated seed were 3.2 grams heavier than those produced from untreated seed. These differences in seedling size did not affect number of plantable seedlings at either nursery and were probably unrelated to treatment. Seedling growth was not affected by the seed treatment at the other nurseries. Treatments did not affect seedling stand density at any of the nurseries.

DISCUSSION

Bayleton promises to be an excellent fungicide for fusiform rust control in pine tree nurseries. One might conclude from these tests, particularly those at the Ashe and Weyerhaeuser nurseries, that the seed treatment alone would provide adequate control of fusiform rust throughout the 2- to 3-month infection season. We do not wish to convey this idea. Weather favorable for pine infection only occurred at the above nurseries during and soon after seed germination. If infection had occurred later, as was likely the case at the Beauregard and Davisboro nurseries, additional benefit would likely have been realized from the foliar sprays. Experiments are currently underway to determine the length of time that pine seedlings are protected by Bayleton seed treatment.

Although rate and method of application appear to be important to avoid reduction in the size of pine seedlings, Bayleton holds many advantages over ferbam:

1. When used as a seed treatment, Bayleton protects during germination while ferbam must be applied daily to provide equal protection.

2. Fewer sprays are required and this should reduce tractor pad compaction, manpower requirements, and nursery bed deterioration during wet weather.

3. Since Bayleton is a systemic fungicide, timing of sprays is less critical.

Bayleton is not currently available for commercial use in pine tree nurseries. It was recently registered in the United States for control of Azalea blight, and Mobay Chemical Corporation is seeking approval from appropriate federal and state agencies to label the compound for forestry uses.

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1980

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Research Note

SO-254

Coppice Sycamore Yields Through 9 Years

Harvey E. Kennedy, Jr

SUMMARY

Cutting cycle and spacing did not significantly affect sycamore dry-weight yields from ages 5-9 years (1974-1978). Longer cutting cycles usually did give higher yields. Dry-weight yields ranged from 2886 lb per acre (3233 kg/ha) per year in the 1 year, 4 × 5 ft (1.2 × 1.5 m) spacing to 4541 lb (5088 kg/ha) in the 4-year, 4 × 5 ft spacing. Survival averaged 67 percent in the 2 × 5 ft (0.6 × 1.5 m) spacings and 79 percent in the 4 × 5 ft spacings. Ratio of dry weight to fresh weight averaged 49 percent, and the stem accounted for 85 percent of the dry weight of the trees.

Additional keywords: *Platanus occidentalis*, sprouting, "silage concept"

INTRODUCTION

As demand for cellulose fiber grows, industrial needs will exceed the ability of natural and planted forests to supply it for pulp and fuel. Forest industries must find new methods to increase production rapidly. Intensive culture of hardwoods under short rotation cycles may help supplement conventional pulpwood and fuelwood sources. This technique is sometimes referred to as the "silage concept" because the cut wood resembles crops harvested for silage. This note reports how various cutting cycles and spacings affect growth and yield of coppice sycamore through nine growing seasons.

METHODS

In March 1970, nonrooted sycamore cuttings were planted vertically in subsoiled trenches at Huntington Point, near Greenville, Mississippi. The soil was Commerce silt loam, a good sycamore site.

Plots were eight rows wide (40 ft or 12.3 m) by 1 chain (66 ft or 20.3 m) long and were divided into two subplots, each four rows wide. Two spacings were randomly assigned on the subplots—2 × 5 (0.6 × 1.5 m) and 4 × 5 ft (1.2 × 1.5 m). Early in the first growing season, all blanks in the 4 × 5 ft spacings and consecutive blanks (two or more) in the 2 × 5 ft spacings were replanted with extra 16-inch (40 cm) cuttings established when the study was installed. Plots were weeded during the first growing season.

A randomized block split-plot design was used for this study. Cutting cycles were 1, 2, 3, and 4 years. Each combination of cutting cycle and spacing had four replications. The 1-year cycle has received eight cuttings; the 2-year cycle, four cuttings; the 3-year cycle, three cuttings; and the 4-year cycle, two cuttings. Cutting was done in January or February each year except 1974, when floodwaters delayed cutting until March.

For each subplot, growth and yield were measured on the central 50 ft (15.4 m) of the two center rows; the rest of the plot formed a border.

When trees were cut, stems plus branches of all trees within each measurement area were weighed on a balance at the study site (fig. 1). Fresh-weight yields per acre were calculated from this data.

Figure 1.—*Weighing freshly cut green trees at the plantation site.*

Fresh and dry weights of stems and branches separately, stump diameter at the point of cut, and stem length were measured on three trees (the northernmost trees on the west row) from each subplot. Dry weights were determined after plants were dried 48 hours in a forced-air oven at 105°C. Total aboveground weights were obtained, and ratios of total dry to fresh weight and of stems to branches (fresh and dry) were determined.

I calculated dry-weight yield per acre per year for each subplot by multiplying the fresh weight per acre by the ratio of dry weight to fresh weight in the sample. Data were analyzed with analysis of variance and Duncan's multiple range test at the 0.05 level of probability.

RESULTS AND DISCUSSION

Results through 4 years (1970–1973) were reported in Kennedy (1975). At that time the 2-, 3-, and 4-year cutting cycles yielded significantly more dry weight (slightly more than 7,000 lb) than the 1-year cutting cycle yielded (slightly more than 4,000 lb). The 2 × 5 ft spacing yielded significantly more than the 4 × 5 ft yielded. Interaction between spacing and cutting cycle was not significant. Ratio of dry weight to fresh weight averaged 43 percent, and the proportion of dry weight in the stem averaged 81 percent in the 1-year cutting cycle and 95 percent in the 4-year cutting cycle. Survival averaged 90 percent.

In the fifth through eighth growing seasons (1974–1977; 1-, 2-, and 4-year cutting cycle) and for the fifth through ninth growing seasons (1974–1978; 3-year cutting cycle), survival in the 2 × 5 ft spacing dropped to 67 percent, a reduction of 20–25 percent since the fourth growing season. The 4 × 5 ft spacing had 79 percent survival, a reduction of 5–10 percent. Other researchers have reported that stands planted at close spacings, 1 × 1 (0.3 × 0.3 m) to 4 × 4 ft (1.2 × 1.2 m), will gradually thin themselves to about 4 × 6 (1.2 × 1.9 m) to 5 × 5 ft (1.5 × 1.5 m) spacing. This self-thinning seems to be happening in the Huntington Point plantation; the original 2 × 5 ft spacing is now about 3 × 5 (1.0 × 1.5 m) and the 4 × 5 spacing is now about 5 × 5 ft.

Dry-weight yields did not differ significantly among treatments during 1974–1978 (table 1), probably because yields within replications differed greatly. Yields were much smaller than 1970–1973 yields (11 percent in the 1-year, 2 × 5 ft

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spacing to 42 percent in the 3-year, 4 × 5 ft spacing). During the second 4 years, longer cutting cycles still usually produced higher yields.

Yields during 1974–1978 were lower than ones reported by other researchers (Belanger and Saucier 1975, White and Hook 1975). Yet, even though yields in this study were lower, the highest yields were still in the longer cutting cycles.

Trees were significantly shorter in the 1974–1978 period than in the 1970–1973 period; diameters were not significantly smaller (table 2). A significant interaction among treatments for heights and diameters was caused by varying degrees of growth differences.

Trees were smaller and yields lower during 1974–1978 than during 1970–1973 for several reasons. Reduced survival could have led to lower yields because fewer trees were available. But the remaining trees should have grown more because of more growing space per tree. Climatic and insect conditions at the site might also have lessened yields. The Mississippi River flooded the plantation for several weeks early in the 1974 and 1975 growing seasons. Then the 1976 growing season was dry, and the 1977 growing season was extremely dry. Also, the sycamore tussock moth (*Halisidota harrisii* Walsh) completely defoliated plantation trees during July and August in 1976 and 1977. Results over the next 4 years should answer whether the reduction was caused by climatic and insect conditions at the study site or by the imposed treatments or by a combination of all these factors.

Ratios of dry weight to fresh weight and proportion of dry weight in stems were not affected by cutting cycle and spacing (table 1). Dry to fresh weight ratios average 49 percent, a gain of about 5 percentage points from the average after four growing seasons. These percentages are similar to the 50 percent dry to wet weight ratios reported by Steinbeck and May (1971). The proportion of dry weight in stems was probably not affected much by treatments. Over all treatments, proportion of dry weight in stems averaged 85 percent. This proportion is about 5 percent smaller than it was in 1970–1974, probably because the trees had more branches, as each tree had more growing space.

If forest managers are considering using short rotations and close spacings for sycamore, they should probably plant at 4 × 6 ft to 5 × 5 ft spacings and use cutting cycles of 4 to 5 years to maximize yields.

Table 1.—*Average annual dry weight, ratio of dry to fresh weight, and dry weight percentages of stems by spacing and cutting cycle for 1970–1973 and 1974–1978*

Spacing (*feet*) and cutting cycle (*years*)	Dry weight 1970–73	Dry weight 1974–78	Ratio dry to fresh weight 1970–73	Ratio dry to fresh weight 1974–78	Proportion of dry weight in stem 1970–73	Proportion of dry weight in stem 1974–78
	lb/acre/yr. (kg/ha/yr.)		*percent*			
2 × 5						
1	4349 (4875)	3702 (4149)	44	49	81	83
2	7001 (7847)	4260 (4775)	45	49	90	87
3	7210 (8081)	4164 (4667)	41	47	92	83
4	7161 (8026)	4448 (4986)	46	51	95	92
4 × 5						
1	3229 (3619)	2886 (3235)	46	47	85	84
2	5167 (5791)	3347 (3752)	41	48	86	83
3	6175 (6921)	4278 (4795)	43	50	91	79
4	6441 (7219)	4541 (5090)	42	49	95	88

Table 2.—*Diameters and heights by spacing and cutting cycle for 1970–1973 and 1974–1978*

Spacing (*feet*) and cutting cycle (*years*)	Diameters		Heights	
	1970–73	1974–78	1970–73	1974–78
	inches (cm)		*feet (m)*	
2 × 5				
1	1.0 (2.54)	0.9 (2.29)	9.4 (2.87)	9.3 (2.84)
2	1.8 (4.57)	1.3 (3.30)	17.0 (5.18)	12.6 (3.84)
3	2.1 (5.33)	1.5 (3.81)	20.4 (6.22)	13.2 (4.02)
4	2.0 (5.08)	1.8 (4.57)	23.6 (7.19)	17.7 (5.40)
4 × 5				
1	0.9 (2.29)	1.0 (2.54)	8.7 (2.65)	9.5 (2.90)
2	1.8 (4.57)	1.3 (3.30)	16.6 (5.06)	12.8 (3.90)
3	2.4 (6.10)	1.7 (4.32)	23.1 (7.04)	11.4 (3.47)
4	2.4 (6.10)	2.7 (6.86)	23.6 (7.19)	22.8 (6.95)

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Southern Forest Experiment Station

Research Note

1980

SO-255

Streamwater Contamination After Aerial Application of a Pelletized Herbicide[1]

James H. Miller and A. C. Bace, Jr.

SUMMARY

Concentrations of hexazinone and its metabolites were monitored in a Piedmont stream for 8 months after aerial application of a pelletized formulation (Velpar® Gridball™). Downstream water-users and fish are probably safe from toxic exposure if treatment areas have only small streams (less than 50 cm average channel width) and if labeled rates are not exceeded. Hexazinone concentrations were highest 30 minutes after application at 2.4 ppm, declining to less than half at 1 hour, 1.1 ppm, and half again at 2 hours, .49 ppm. No contamination was evident after the 5th-day sampling. Stream contamination from pellets was as much as 100 times the concentrations reported for foliar sprays, aerially applied over brush-covered streams at similar rates.

Additional keywords: hexazinone, Velpar® Gridball ™, chemical silviculture.

[1] Use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use is not an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

If herbicides are handled, applied, or disposed of improperly they may be injurious to humans, domestic animals, desirable plants, and pollinating insects, fish, or other wildlife, and may contaminate water supplies. Use herbicides only when needed and handle them with care. Follow the directions and heed all precautions on the container label.

INTRODUCTION

Soil-active herbicides in pelleted forms are gaining increased interest and use in silvicultural treatments. Velpar® Gridball ™, a large pellet of 10 percent active ingredient (a.i.) hexazinone, is now registered in all southern states for pine release and site preparation; but its widespread use is awaiting its widespread availability (Hamilton 1979, Parker 1979). Tordon 10K® (10 percent a.i. picloram) is commonly applied for kudzu (*Pueraria lobata*) control before reforestation, and further trials are examining the possible use for chemical site preparation (Mann and Haynes 1978). Other pelletized herbicides such as Graslan® (20 percent a.i. tebuthiuron) and Banvel XP® (10 percent a.i. dicamba) are now used in rangeland reclamation (Graslan) and right-of-way control (Banvel XP) and may become useful in forest management.

Pelleted chemicals are more likely than sprayed chemicals to land on the target areas because there is no spray drift. And soil active herbicide pellets do not need the stringent weather and foliage conditions required by foliar sprays. So, favorable application periods would be much longer than those for aerial sprays. Also, nonindustrial forest landowners could make ground applications without having to purchase expensive application equipment. Use of pellets could make herbicide applications in forestry more environmentally safe and operationally practical.

To find how much an aerial application of pelletized herbicide contaminates streamwater, we applied Velpar Gridball aerially on a recently harvested Piedmont watershed. The basal area of unharvested hardwoods was 3.5 m^2/ha (15 ft^2/acre). For the next 8 months, we monitored concentration of hexazinone and its metabolites in a small stream in the treated area. Also, we studied joint application of pine seed and the pelletized herbicide. Such a combination of operations would help minimize costs of establishing a plantation.

METHODS

On February 23, 1978, a helicopter fitted with a Simplex Airblown Seeder applied 0.8 kg/ha (3/4 lb/acre) loblolly pine seed coated with arasan, a bird repellent, and endrin, an animal repellent. Then, from the same seeder at the largest gate openings, Velpar Gridball was applied to a 0.8 ha (2 acre) rectangular plot—66 by 122 m (216 × 400 ft)—extending from ridge to ridge across the valley (fig. 1); 4.6 percent of the 17.4 ha (43 acre) watershed was treated. Because of crosswinds, the treatment plot was flown in four 30.5 m (100 ft) swaths, 66 m (216 ft) long, parallel to the stream. One swath was applied directly over the flood plain, and we saw pellets falling into the stream.

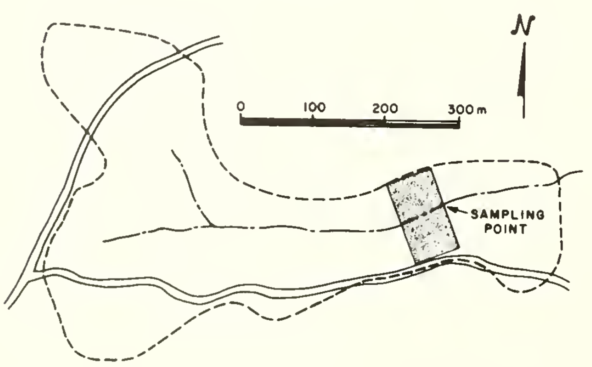

Figure 1.—*Rectangular plot of 0.8 ha aerially treated with 1.8 kg/ha a.i. hexazinone after a selective harvesting of the entire 17.4 ha watershed.*

The rate of application was 18 kg/ha (16 lb/acre) Velpar Gridball or 1.8 kg/ha (1.6 lb/acre) a.i. hexazinone. We made a pretreatment calibration of the seeder on an adjacent cleared area by using "blank" pellets. The stream channel was not over 1 m wide at pools and averaged 30 cm at rills. Herbs and shrubs grew along the edge, and leafless hardwoods along the banks provided partial channel cover.

Streamwater samples were collected and discharge measured at a point immediately downstream from the treatment plot (fig. 1). One sample and a measurement were taken after treatment at 1, 5, 15, and 30 minutes; 1, 2, and 3 hours; 1, 5, 10 and 46 days; and at 8 months. Polythene bottles were given a final rinse with a sample before collection. Samples were then kept frozen until analyses. Using a gas chromatographic technique and a nitrogen-phosphorus detector, the Biochemical Department at E. I. duPont deNemours & Co analyzed residues. This procedure quantifies hexazinone (3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine,2,4 (1H, 3H)-dione) and two of its most prevalent metabolites — Metabolite A is 3-(4-hydroxycyclohexyl)-6-(dimethylamino)-1-methyl-1,3,5-triazine,2,4 (1H,3H)dione, and Metabolite B is 3-cyclohexyl-6-(methylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)dione.

RESULTS AND DISCUSSION

Hexazinone concentrations in streamwater were highest 30 minutes after application, 2.4 ppm, and declined to less than half at 1 hour, 1.1 ppm, and half again at 2 hours, .49 ppm (fig. 2a). This concentration pattern is the same as that reported by Norris (1967) for a complete aerial spray application of 2.2 kg/ha (2 lb/acre) acid equivalent (a.e.) 2,4,5-T to a 5-acre watershed in Oregon's Coast Range (fig. 2b). But stream contamination from hexazinone pellets was about 100 times the concentrations from spray (Norris 1967).

In both cases, contamination resulted mainly because chemicals were applied directly to the stream surface. In our study, chances were slight

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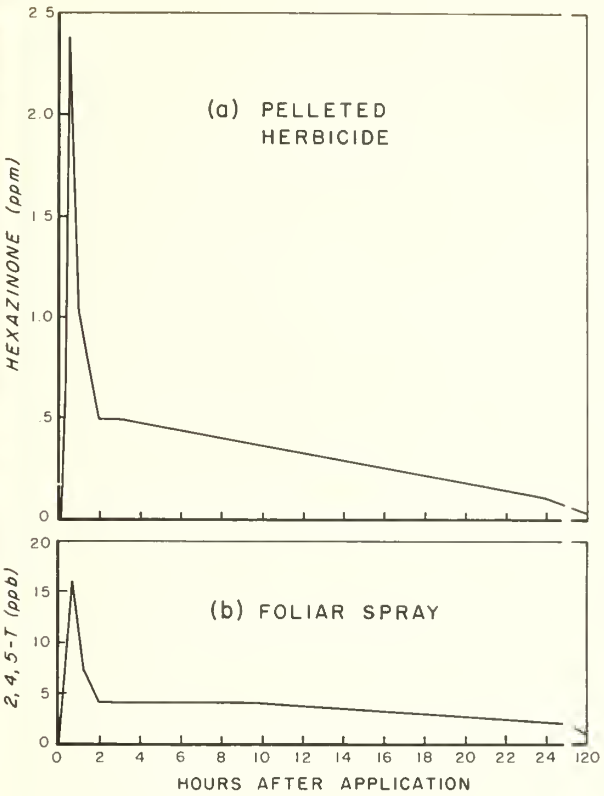

Figure 2.—*(a) Hexazinone concentrations (ppm) after aerial application of a pellet formulation in Alabama, (b) 2,4,5-T concentrations (parts per billion) after aerial spraying in Oregon (from Norris 1967).*

that hexazinone might have reached the stream by subsurface leaching through the soil, except where pellets landed close to the stream. In a 9-month study with ^{14}C labeled material, after heavy precipitation (191 cm or 75 in) on a silt-loam soil, hexazinone was leached only to the 30 cm (12 in) depth (Riggleman 1978). Because our study area had a clay-loam soil and 75 cm (30 in) of precipitation during the 8-month sampling period, downward or lateral leaching was probably much less than 30 cm.

Contamination might also enter the stream in surface runoff, which is usually negligible in forest soils (Hewlett and Nutter 1971). Observations in selected spots showed that pellets remained in place on sloping skid-trails and were 80 percent dissolved within the first 10 days. But, using analytical techniques with a .02 ppm detection limit, we found no stream contamination from hexazinone after the 5th-day sample. A 3.6 cm (1.4 in) storm occurred before the 5-day sampling, but no increase in concentration was caused by surface runoff or subsurface migration (fig. 2a). Precipitation was 1.3 cm (.9 in) before the 10-day sampling and 6 cm (2.5 in) before the 46-day sampling. Neither sampling had detectable hexazinone or its metabolites.

Total placement of hexazinone into the stream was 4.4 g, equivalent to 12.5 pellets landing in the water with .35 g a.i. each. We calculated this amount of loss by integrating concentration and discharge data. Stream discharge at the time of treatment was at low flow, .05 l/sec (.0018 ft^3/sec). The loss to streamwater is 1.2 percent of the herbicide we applied in the swath over the flood plain. This percentage approximates the percentage of the swath we estimated was occupied by the stream. So, most contamination resulted from pellets landing in the stream. One can estimate total amount of pelleted herbicide that will be placed in a stream system during a treatment by multiplying the application rate (kg/ha a.e. or a.i.) by the estimated surface area (ha) of the stream channel to be overflown.

Stream-cover interception apparently accounts for the difference in contamination concentrations between aerial sprays and pellets. The degree of contamination from pellets is apparently not influenced by brush and logging residues overhanging the stream channel. The foliar sprays reported by Norris (1967) were applied after full leaf development in a region with abundant shrub and herbaceous cover along and over the upland streams. Generally, low-volume sprays are applied so that foliar interception will be maximized. But rounded pellets aerially applied will not be stopped by foliage and will most likely land on the ground or in the stream. Therefore, aerial applications of pellets over a stream represent a greater potential for contamination than does aerial application of sprays.

ESTIMATE OF ENVIRONMENTAL HAZARD

The actual hazard of hexazinone contamination to downstream water-users and aquatic populations depends on peak and sustained concentrations. Peak concentrations are difficult to estimate since they depend on the rate that the pellets dissolve, streamflow, and the rate that the active ingredient is detoxified or adsorbed by bottom sediments. Prolonged exposure to a toxic substance is more hazardous in aquatic environments than are peak concentrations. Estimates of potential sustained concentrations can be made from this study's findings if we assume sustained concentrations to be additive. Because this study monitored low-flow conditions, we are using the most extreme situation with maximum concentrations for estimating potential environmental hazards.

For every 66 m (218 ft) of flood plain treated in a watershed, hexazinone contamination would have a 0.1 ppm increment and would remain at that level for about 96 hours at the streams' confluence. As figure 2a shows, the 0.1 ppm level was reached at 24 hours, and then concentration declined to .04 ppm at 120 hours. The sustained concentrate for the first 96 hours was about 0.1 ppm.

No-effect levels of hexazinone for commonly occurring fish species and 96 hour exposures have been determined[2]: 370 ppm for bluegill sunfish (*Lepomis macrochirus*), 240 ppm for rainbow trout (*Salma gairdneri*), and 160 ppm for fathead minnow (*Pimephales promelas*). Here, "no-effect levels" means the highest concentration having no visible effects and causing no mortality. The TL_{50} (concentrations in the water for 96 hours causing 50 percent mortality of test fish) for bluegill is $>$ 370 ppm and $<$ 420 ppm. A reliable estimate for the Piedmont's drainage density is 2.4 km perennial stream per 100 ha of land area (4 mi stream per mi^2 land).[3] For the most susceptible fish, fathead minnow, an assured no-effect size of treatment area within one watershed would be $\leq$ 4440 ha (10,971 acres). This figure assumes that all streams are the size treated in this study ($<$ 0.5 m width) and that larger streams would be avoided during application. Environmental hazards of such careful applications appear minimal for indigenous fish, because operational applications would be unlikely to treat 4440 ha.

[2] Data from *Toxicological Information*, Hexazinone by Haskell Laboratory for Toxicology and Industry Medicine, E. I. duPont deNemours & Co., Elkton, Md.

[3] John Hewlett. Personal conversation. School of Forest Resources, University of Georgia, Athens, Ga.

The potential for levels toxic to humans can only be estimated from toxicity data on laboratory animals. No-effect levels for rats and dogs have been determined as 1000 ppm hexazinone[2] in food, ingested daily for 90 days. This no-effect level was substantiated by numerous clinical tests and tissue examinations. Because treatment of 4440 ha with hexazinone would result in estimated concentrations of only 160 ppm for 96 hours, levels representing threats to human safety would not be approached in normal forestry practices.

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