Effects of Intensive Cultural Treatments and Seedling Size on Juvenile Growth of Sweetgum

Four-Year Results Highlight the Importance of Site, Root-Collar Size, Root Development, and Mulching

A. Kaszkurewicz and T. Keister

Respectively, Hardwood Research Specialist, La. Forestry Commission, and Assistant Professor of Forestry, L.S.U. School of Forestry and Wildlife Management

Broadfoot (1) and Broadfoot and Krinard (2) have reported that sweetgum *(Liquidambar styraci/la L.)* is tolerant of a wide variety of soils, but does best on moist, silty clay and silty clay foams, with moderate to good internal drainage, and with at least 10 pounds of exchangeable potassium per acre. Other than this information, little has been discovered about the early growth of planted sweetgum, although the species is one of the southeast's most valuable hardwoods.

An experimental sweetgum plantation was established near Clinton, Louisiana, in the spring of 1964 to determine if certain cultural treatments could cause a significant improvement in the early growth of planted sweetgum.

Procedures

An area (210 ft. X 222 ft.) near the foot of a hill with an approximately .1 percent slope along a diagonal was used for the planting site. The site was an abandoned pasture grown over by grass and weeds, but was mowed thoroughly before planting the sweetgum.

The cultural treatments tested included three mulching methods: no mulching (M1), black polyethylene pads (M2), and bedding of the soil in a double furrow (M3). Three weeding methods used were: no weeding (Wi), weed mowing (W2), and Amizine spray ' (W3). Four dibbleplanting methods were tested: the standard method in undisturbed soil (P l) ; and in mixed soil of auger-prepared holes 12 (P2). 21 (P3), and 30) P4) inches deep and 9 inches in diameter.

The test area was divided into 8 blocks, with a 3 X 3 X 4 factorial design used to apply all 36 treatment combinations to each block. Each combination in a block was represented by one 4-tree plot. The 114 trees in each block (8 rows of 18 trees) were planted at 6- by 6foot spacings. The blocks were 12 feet apart.

Seedlings were obtained from a nursery of the Louisiana Forestry Commission. They varied in height from 0.5 to 2.8 feet (1.3 ft. ave.). in root-collar diameter from 0.1 to 0.5 inch (0.19 in. ave.), and in root length from 0.4 to 1.0 foot (0.62 ft. ave.). The roots were trimmed while lifting the seedlings from the nursery beds, so they were not full size.

Planting was started on March 18, completed on April 8, 1964, and was done in a random manner so that no treatment would gain a time advantage. All seedlings were planted with their root collars at the ground level. After planting, the mulching and weeding treatments were applied.

Black polyethylene film pads 2 feet square, which had been cut from one side to a 1-inch square hole at the center, were placed collar-like around the base of a seedling, and were affixed to the ground surface by means of several soil blocks. This was done in mid-April 1964.

The soil-bedding treatment was repeated twice. The first was done on June 25, when the furrows on two sides of a seedling were made by a horse-drawn 6-inch turning plow. Plowing depth varied from 3 to 5 inches, and the spread of soil turned towards the seedlings was about 1foot wide at each side. A second bedding treatment was made on September 9, 1904. At that time a fourdisk tiller pulled by a wheel tractor was used. Two trips were made down each seedling row to crush the cloddy soil thoroughly.

Weed mowing was also repeated twice. The first time (in early June) a machete was used to cut clown all weeds and grass from a 3-foot square area around each tree. In early August a power mower was used to cut the competing vegetation on a 6-foot square area around each tree receiving this treatment.

Amizine spray was applied late in June. The Amizine was selected as the chemical agent for this study because of its pre-, and post-emergence action. One hundred and twenty grams of the chemical in 2[1]/> gallons of water was used to treat 4-foot square areas around each of 48 trees

'Trade name for a mixture of 15clo amitrol (3-amino, 1,2,4-triazole) and 451176 simazine (2-chloro-4. 6-bisethylamino-s.-triazine) produced by Amchem Products, Inc., Ambler, Pa.

assigned for this treatment in each block. The application rate was equivalent to 15 lbs. of Amizine in 140 gallons of water per acre. One month after treatment, all competing vegetation on sprayed areas was dead.

The soil was sampled from each 6-inch stratum to a depth of 3 feet from pits which were made at the center of each quarter of the plantation. Thus, each pit was representative of two blocks (i.e. one-fourth of the area). Mechanical analysis of the soil was made for each one-foot stratum, and the contents of extractable P, K, Ca, and Mg in ppm, and pH were determined for each 6-inch stratum down to 30 inches. The soil was classified as of the Providence series; its texture in the upper one foot was a loam, and in the lower two feet a clay loam. The pH of the soil varied by pit and stratum from 5.2 to 7.0. The pH of the upper foot of soil was about one unit higher than that of the deeper levels.

The presence of a hardpan was discovered while drilling the planting holes. It was 4 to 8 inches thick and was found at various depths within the second-foot soil stratum.

Tree heights at the end of the first, second, third, and fourth growing season were measured to the closest 0.1 foot. Breast high diameter was measured only after 4 years of growth, because at age 3, about 15 percent of trees in the plantation were shorter than 4.5 feet. Tree mortality w as recorded simultaneously with the measurements.

First-year-Results

The effects of mulches, planting methods, root lengths, and heights of seedlings on the first-year mortality, and the effects of planting methods on the first-year height increment were reported by Norwood (5). He found the mortality of seedlings planted by dibble in undisturbed soil (standard method) was significantly greater (P<.05) than that of seedlings planted in the soil mixed in planting holes, although hole depth was not significant.

The mortality of seedlings planted by the standard method and receiving bedding treatment was significantly greater (P<.05)than those either mulched with polyethylene pads or nonmulched.

No mortality occurred among the seedlings which were planted in the mixed soil in holes and were mulched with the polyethylene pads. The effect of seedling height on the mortality was nonsignificant.

Deep-hole (30 in.) planting was the only factor Norwood found that resulted in a statistically significant increase in first-year height growth. Norwood did not consider the effects of individual seedling sizes on the first-year height increment. All comparisons were made on the basis of treatment means.

Four-Year Results

Data for 4 years were analyzed in a linear model which considered treatment effects as well as the random effects of seedling height, root length, and root-collar diameter. Individual trees that survived through 4 years were used as observations. In this way the total number of observations was increased from the 288 used by Norwood to 1015 (137 trees died during 4-year period; the distribution of the mortality by treatments is shown in table 3). This increase in sample size, combined with the consideration of initial size of seedlings, improved precision in the analysis of results.

The root-collar diameter had a highly significant (P<.01) positive effect on tree heights at the end of each of .1 years and on dbh at the end of the fourth year regardless of treatment. This was in agreement with the findings of Webb (8).

The fact that the root-collar was such a significant factor implies that a proper selection of seedlings for planting can lead to increased early height and diameter growth, regardless of other cultural treatments used. Webb advised the control of seedling density in the nursery by regulating sowing rates or by thinning. Webb and Darby l9) concluded that 15 to 25 seedlings per square foot is an optimum density for maximum production of plantable seedlings.

Seedling height had a significant ıP<.01) positive effect on tree height for the first two years. Root length did not significantly affect tree height at the end of the first year, but was significant (P<.05) for the second and third year.

The authors are of the opinion that, besides a proper density of seedlings in the nursery, a selection of seed should also be considered. Since the number of sweetgum seed per pound varies from 65,000 to 90,000 (71, the selection of large seed for the nursery may result in further improvement of planting stock, saving nursery space, and reducing costs.

The dependence of seedling size on the weight of seed was shown by Novosiltzeva (6), who studied this relationship on Scots pine *(Pinus slyvestris* L. ı. She found that the average oven dry weight of the seedlings grown from 0.005 g seed was 1-1 g compared with 19.1 g of those grown from 0.011 g seed.

Contrary to the results of the Norwood anal-sis, the new analysis of the data showed highly significant IP<.01) differences among the first-year height increment of trees which received different mulching, weeding, or planting treatments. These differences were determined by the individual orthogonal comparisons made among the adjusted treatment means (table 1).

The first-year tree height was the greatest when seedlings were planted in the mixed soil in 30-inch deep holes and received bedding cultivation as a mulching treatment (table 2). The tree height was least when seedlings were planted by dibble in undisturbed soil, received no mulch, and were not weeded. In general, the tree height increased with the depth of planting hole. This response to the depth of planting hole was apparently due to the volume of the cultivated (mixed) soil which allowed better root development.

This conclusion is supported by the results of a study by Hollis (3) on yellow-poplar *(Liriodendron tulipifera L.),* sycamore *(Plantanus occidentalis L.),* and cow oak *(Quercus michauxii* Nutt.). Hollis found that the root systems and the growth of the trees planted in mixed soil in holes 14 inches in diameter and 3 feet deep were significantly greater (P<.05) than of the trees planted in 9-inch diameter holes of the same depth, and trees which were planted by the standard method in undisturbed soil (P<.01).

The effects of weeding treatments on first-year sweetgum growth depended on mulching methods. Chemical weeding was most effective when trees were either mulched with polyethylene pads or were not mulched at all, whereas the effect of no weeding was the best when bedding of the soil was applied. In this case "no weeding treatment" was purely a theoretical treatment because the bedding was effective not only as a mulching treatment, but also resulted in a complete eradication of weeds. Thus, the first-year height growth of sweet-um was the best when seedlings were planted in mixed soil in 30-inch deep holes, mulched and completely weeded by soil cultivation (bedding) in double furrows.

Highly significant differences (P<.01) were also found among the adjusted treatment-mean heights due to the effects of mulching at the end of the second-, third-, and fourthyear, on dbh at age four (table 2), and on height increments during the second, third, and fourth growing season (table 1). Although the bedding mulch treatment was best the first year, the polyethylene pads had the greatest effect on height and height increment during these last three years.

Two factors probably were responsible for such a reverse in the effects of these two treatments. First, the bedded soil dried and was not thick enough (about 4 inches) to conserve the moisture in the root zone. Second, the polyethylene pads continued to have the same moisture conserving capacity through all 4 years. It may be that if the bedded soil were mounded higher or if this treatment had been repeated each of the years until crown closure, the effect of the treatment would have been superior to that of the polyethylene pads. Use of such an improved bedding treatment would be especially advisable in large commercial plantations, where the application of polyethylene pads might be impractical.

The differences among the effects ofthree weeding methods and among four planting methods were significant (P<.01) on tree heights throughout the first 3 years (table 2). By the end of the fourth year, no significant differences in height were found among the planting treatment means. The means listed in table 2 indicate chemical weeding might have been best.

No individual differences among the effects of weeding methods on the fourth-year tree height were disclosed, but significant differences (P<.0l) were found among these effects on the fourth-year dbh (table 2). This may indicate different requirements in soil conditions (soil aeration, availability of moisture, or others) are necessary for the improvement of diameter growth than for the improvement of height growth. Kaszkurewicz (4) found such a differentiation in the requirements for dbh and height growth of cottonwood.

At the end of the fourth year, sweetgum trees in the plantation were significantly taller when they were mulched with the polyethylene pads, and appeared taller when weeded by Amizine spray. Fourthyear dbh was largest when trees were mulched with the polyethylene pads and weeded by Amizine spray. The shortest trees with the smallest dbh were those that received no weeding or mulching, regardless of the planting method used (table 2).

Among the trees receiving the best treatment combination, the tallest and those with the largest diameter were those which initially had the largest root collar. The smallest trees in the plantation were those planted by the standard method and with the smallest diameters at the root collar.

Both height and diameter of the trees in the plantation differed significantly (P<.O1) among the blocks. Though the area of the plantation was small (ca. one acre), there was a considerable variation in the productivity of sites among the blocks.

The site variation was due not as much to the soil texture as to slope. This obviously had an effect on soil moisture conditions, which were different in each quarter of the nearly square plantation area. The quarter down the slope, nearest a creek, had a water table about 40 inches deep (in April 1961), whereas in the quarter diagonally higher on the slope the water table was below 6 feet.

There was not much variation in the first-foot soil pH (5.6 to 5.8), and in Mg content (247-316 ppm) among the quarters of the area. However, considerable differences were found in the contents of extractable P 14.0-7.5 ppm), K 45 66 ppm), and Ca (262-612 ppm) among the quarters. The proportion of these three elements increased down the slope.

Average tree height at all ages was greatest on the blocks nearest the bottom of the slope, and shortest on blocks nearest the top of the slope. These height differences were highly significant P<.01.

With the exception of the polyethylene pads, the effects of the cultural treatments on growth did not persist very long. The effects from the polyethylene pads persisted because the pads persisted. We conclude from this that an annual soilbedding cultivation in double furrows would be effective as a means for improving growth, at least for as long as grass and weeds are the principal sources of competition for water. Such treatments will be of an economic importance only if they result in shorter rotations for sweetgum, or if they are combined with additional measures intended to improve the productivity of the site.

Probably the most significant conclusions drawn from the results of this study are that, if one wishes to improve the survival and early growth of planted sweetgum, he should carefully select a proper site, use seedlings with large root collars and well-developed roots, and use some means of mulching to control weed competition and conserve soil moisture.

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TABLE 1.—Significant differences among adjusted treatment means of sweetgum height increment during the first 4 years of growth

Treatment	Height increment 1st year	2nd year	3rd year	4th year
	Feet			
Mulch				
M 1	0.88[1]	1.41	2.58	3.41
M 2	1.09	1.70	2.94	3.80
M 3	1.19	1.32	2.78	3.49
Weeding				
W 1	1.01	1.35	2.76	3.55
W 2	1.03	1.44	2.69	3.63
W 3	1.12	1.63	2.83	3.51
Planting				
P 1	0.79	1.49	2.79	3.64
P 2	1.01	1.47	2.75	3.54
P 3	1.12	1.47	2.77	3.48
P 4	1.29	1.47	2.74	3.60

[1] Significant differences in the first orthogonal comparison are shown by separated lines on left side of column. The lines immediately on right and further to the right of column show the differences in the second and the third comparison, respectively. Heavy lines denote P<.05, and fine lines P<.01.

TABLE 2.—Significant differences among adjusted treatment means of sweetgum heights at each of the first four years and dbh at age four

Treatment	Tree height 1st year	2nd year	3rd year	4th year	Dbh 4th year
	Feet				Inches
Mulch					
M 1	2.22[1]	3.64	6.22	9.62	0.91
M 2	2.40	4.10	7.03	10.83	1.08
M 3	2.51	3.83	6.61	10.10	1.01
Weeding					
W 1	2.34	3.69	6.46	10.02[2]	0.98
W 2	2.36	3.80	6.48	10.12[2]	0.99
W 3	2.44	4.08	6.91	10.42[2]	1.04
Planting					
P 1	2.14	3.63	6.42	10.06	1.00
P 2	2.33	3.80	6.55	10.09	0.98
P 3	2.43	3.91	6.68	10.16	1.01
P 4	2.61	4.08	6.82	10.42	1.02

[1] Significant differences in the first orthogonal comparison are shown by separated lines on left side of column. The lines immediately on right side and further to the right of column show the differences in the second and the third comparison, respectively. Heavy lines denote P<.05, and fine lines P<.01.

[2] The analysis of variance indicated significant difference among these adjusted means. However the two orthogonal comparisons made (W1 vs. W2 and W3, and W2 vs. W3) failed to reveal these differences.

TABLE 3.—Four-year survival of sweetgum by treatments

Treatment	Mulching method (M)	Weeding method (W)	Planting method (P)
	Percent		
1	89.8	89.8	85.4
2	91.1	88.8	87.8
3	83.3	85.7	89.2
4	–	–	89.9

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perlite and 50 percent vermiculite as recommended by Hare (2). Threeby 3-inch peat pots are embedded in the medium. This allows transplanting of the rooted cuttings without severe disturbance of the root systems (fig. 2). After use, the medium can be sterilized with portable steam pipes by raising the temperature to 80°C and maintaining it at that level for 2 hours. After 1 year of use the medium is replaced.

Collection and Treatment Of Cuttings

The preferred length of cuttings is 6 inches, although occasionally cuttings as short as 4 inches are used. Since Grigsby (1) showed better rooting of cuttings which had been kept upright throughout all handling, this technique has been adopted. The cuttings are then treated with hormones. For details see van Buijtenen, *et al. (3).*

The cuttings are lifted after 3 months. Although the percentage of cuttings rooted in a given batch could be increased somewhat by maintaining the cuttings in the mist chamber for a longer period of time. lifting after 3 months gives the highest production of rooted cuttings per mist chamber over a year's period.

When the cuttings are lifted they are potted in 8-inch pots, kept in the greenhouse for 2 additional weeks and then transferred to a lathhouse for further hardening *off.* After 4 to 6 weeks in the lathhouse they are field planted. *No* field planting is done during July and August because of the hot and dry weather.

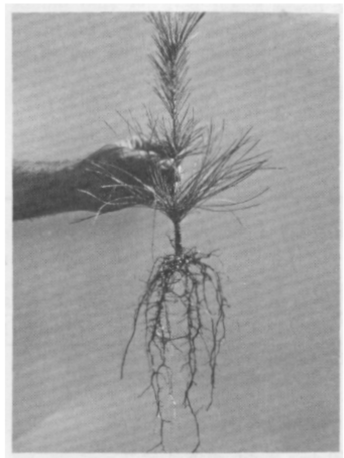

Figure 2.-Lifted cutting after careful removal from peat pot and washing shows the development of the *root* systems.

Results

Using this technique, rooting percentages ranging from 40 to 70 percent have been obtained consistently. The average is slightly less than 50 percent. The rooted cuttings are at present being used to establish hedges for the production of more cuttings and the buildup of clones. The first goal is to obtain sufficient material to screen for its suitability as understock for grafting. Once this goal is reached, additional cuttings will be field tested to determine the genetic gains that can be obtained by this method and to identify outstanding genotypes.

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