A COMPARISON OF A RANGE WIDE STUDY OF SWEETGUM PLANTED ON THREE DIVERSE SITES [1/]

By Jeffrey S. Prowant, Franklin C. Cech, Roy N. Keys, and Walter H. Davidson; Research Assistant, Professor of Forest Genetics, Research Technologist, West Virginia University, Morgantown, WV 26506; Research Forester, U.S. Forest Service, Princeton, WV 24740.

ABSTRACT -- Thirty-three sources with four mother trees per source were planted at three separate sites. On a forest site *we* found that those sources from the northern extent of the species range were tallest after one growing season. The southern sources had the greatest annual growth but suffered severely from winter dieback. Therefore, net growth was less for the southern sources than the northern sources. At the other two sites, one a reclaimed strip mine and the other a reclaimed deep mine waste pile, the northern sources were found to have superior survival. The southern sources had the greatest annual growth but had the shortest fall height.

SWEETGUM (LIQUIDAMBAR STYRACIFLUA L.) is a species tolerant of a variety of soil types. Sweetgum has been found to grow on heavy clay soils in Maryland and on poorly drained alluvial sites along the Mississippi River. The best growth occurs on well drained silty, clay loam ridges and on silty, clay flats along rivers (Fowells, 1965). The sweetgum range extends from southwestern Connecticut southward along the Atlantic coast to central Florida, and west to east Texas. The species extends northward up the Mississippi and Ohio River valleys to southern Illinois, Indiana, and Ohio. It is not found in the high southern Appalachian range from West Virginia to northern Georgia (Little, 1979). Sweetgum is found along the New, Tug, Kanawha, Ohio, and west fork of the Monongahela Rivers of west and south central West Virginia.

Williams and McMillan (1971) in a range-wide study of sweetgum found significant differences in several characteristics. They found that height was inversely related to latitude under controlled conditions. In addition, growth was shown to decrease as latitude increased. Latitude was also correlated from north to south for bud formation.

In a sweetgum source study conducted by Sprague and Weir (1973), significant differences were found among sources and planting site for frost damage. Sources from the Coastal Plain outgrew Piedmont sources in Piedmont plantations,

[1/] Partially funded with McIntyre Stennis funds.
Published with the approval of the Director of West Virginia Agriculture and Forestry Experiment Station as Scientific Article # 1790.

but Coastal Plain sources suffered terminal dieback when planted in the Piedmont. Sources from Alabama, Mississippi, Louisiana, and Texas were more susceptible to frost damage than sources from North and South Carolina. Coastal Plain sources were superior to Piedmont' sources in the Coastal Plain.

Three reports based on data from the same two plantations in Mississippi, one coastal and one inland, illustrate the response of sweetgum to different sites. Wilcox (1970) first noted that the sources in the inland plantation broke bud over a shorter period of time. Wilcox also noted that bud break occurred two to three weeks earlier at the inland plantation. Mohn and Schmidt (1973) showed that a statistically significant family-location interaction existed with respect to growth rate six years after planting. Ferguson and Cooper (1977) associated rapid early growth at the coastal plantation to abundant available moisture while the growth at the inland site was less due to a lack of available moisture.

Cech et al. (1980) observed several nursery characteristics that were significantly different due to seed source. It was observed that the tallest source was from Choctaw county, Mississippi and the shortest source was from Bucks county, Pennsylvania. Provenance and mother tree were found to be related to seedling height. Correlations were found to exist between height and seed weight and height and early germination. The relationships between height and latitude and longitude were found not to be correlated.

METHODS AND MATERIALS

Seed was obtained from Dr. Kim Steiner, Pennsylvania State Univeristy, as part of a NE-27 Regional Project provenance test. The seed was sown in the state nursery at Parsons, West Virginia. The 1-1 seedlings were lifted in Mid-April, 1981 and packaged by mother tree and replication. The trees were then stored in coolers at 40° Farenheit until planting.

The sources come from throughout most of the species range from 30.1°N to 40.5°N latitude and from 74.4° to 90.2° longitude (Table 1). Each source is comprised of four mother trees, from which half-sib progeny were planted.

Three separate planting sites were used;1) the West Virginia University Forest (WVU), 2) the Williams Mine Site #98 near Monongah, West Virginia (MON), and 3) a reclaimed mine site on Negro Mountain near McHenry, Maryland (NMT).

The WVU site consists of three separate areas. Two areas are approximately one acre in size, the third area is approximately four acres in size. The four acre area and one of the one acre areas face northeast. The other one acrea are faces slightly southwest. All three sites are at approximately 2200 feet above sea level. The areas warranting herbicidal treatment were sprayed with 2,4—D prior to planting.

The MON site is a reclaimed refuse pile containing approximately seven acres and is covered with fescue and crownvetch. This site faces slightly northwest at an elevation of 1100 feet above sea level. This area had no herbicide treatment before planting.

Table 1. Location of sweetgum seed sources.

Accession No.	County, State	Lat.	Long.
003	Kanawha, WV	38.1	81.1
033	Jasper, GA	33.2	83.7
053	Jones, NC	34.8	77.1
061	Fairfield, SC	34.4	81.4
077	Dorchester, MD	38.5	76.1
081	Covington, AL	31.1	86.6
085	Marshall, MS	34.9	89.6
097	Jefferson, IL	38.2	88.9
101	Tipton, TN	35.5	89.6
105	Humphreys, TN	35.9	87.8
109	Coffee, TN	35.5	86.0
117	Campbell, TN	36.3	84.2
121	Floyd, IN	38.3	85.8
125	Vanderburg, IN	37.9	87.6
129	Hopkins, KY	37.2	87.7
229	Choctaw, MS	33.3	89.1
241	Greenwood, SC	34.1	82.2
245	Madison, MO	37.5	90.3
257	Murray, GA	34.8	84.7
285	Bucks, PA	40.2	74.9
297	Burlington, NJ	40.0	74.6
313	MIddlesex, NJ	40.5	74.4
377	Jackson, IL	37.7	89.3
381	Henrico, VA	37.6	77.5
385	Lancaster, VA	37.8	76.5
445	Lawrence, AL	34.3	87.3
457	Montgomery, AR	34.7	93.8
461	Delaware, PA	39.8	75.5
473	St. Louis, MO	38.6	90.2
481	Union, IL	37.5	89.3
489	Scott, MO	37.1	89.6
545	Shelby, TN	35.3	90.1
549	Hardin, TN	35.3	88.3
553	Hardeman, TN	35.4	89.0

The NMT site is a reclaimed strip mine, containing approximately four acres and is covered primarily with redtop. It faces east at an elevation of 2600 feet above sea level. There was no herbicide treatment prior to planting.

An 8 x 8 planting design was used at the WVU and MON sites. The study was replicated six times at the WVU site. The 133 families were planted with 4-tree row plots per family. Seven replications were planted at the MON site. Here 128 families were planted with 4-tree row plots per family. The West Virginia source was only planted on the WVU and MON sites and contains only one mother tree. This source was planted as containerized seedlings while all the others were bare-root planted. Border trees were planted around each site. The NMT site was planted on a six foot square grid pattern. One hundred

twenty-three families were planted with 4-tree row plots per family. This site is planted in a totally randomized design.

Height measurements to the nearest centimeter (cm) were taken following the 1981 growing season at all sites. Spring 1982 heights were collected on May 24, 1982 at the WVU site for dieback analysis. The difference between the fall 1981 measurements and spring 1982 measurements were used to determine the amount of dieback. Growth was also calculated using the 1981 spring and fall measurements. Those seedlings which suffered from deer browse were not included in these results. Data were collected at all three sites for fall height, first year growth and survival.

STATISTICAL ANALYSIS

The General Linear Model procedure of SAS was used to determine differences between sites, among sources, and among mother trees. In the tests for differences among sources, latitude and longitude were added as covariates to determine their effect beyond that caused by source. A randomized complete block design was used at the WVU & MON sites. Fall height, first-year growth and survival were analyzed for both sites. A nested analysis of variance was used at the NMT site for fall height, first-year growth, and survival. The WVU and MON data were further combined in a split-plot design and analyzed for fall height, first year growth, and survival.

RESULTS

WVU, MON, and NMT sites

Fall Height. Heights at the end of the first growing season for all three plantations are listed in Table 2. These varied from 62.2 cm to 38.4 cm with a mean height of 51.6 at the WVU site, 39.0 to 17.4 with a mean of 30.2 cm at the MON site, and 48.7 to 26.2 with a mean of 38.0 cm at the NMT site.

Sources were found to be significantly different at the 1% level for height at the WVU and NMT sites, but were not significant at the MON site. This may be due to the small sample size as the result of the severe mortality at the MON site. Significant differences could be expected at the MON site because the variation in height among sources was similar to that at the WVU and NMT sites.

The WVU, MON and NMT sites all showed a relationship between source and latitude at the 1% level (r= .4431, r= .5513, and r=.7518, respectively). Longitude was not significant at any of the three sites. Differences in height among mother trees at the MON site were significant at the 5% level, but the NMT site failed to show significance. Replications were found to be statistically significant (1%) at the WVU and MON sites.

First-year growth. Growth varied from 11.5 cm for the Pennsylvania source 285, to 26.8 cm for the Alabama source 081 at the WVU site (Table 3).

Table 2. Fall Height (cm) of Sweetgum Sources at the West Virginia University Forest, Monongah, and Negro Mountain Sites.

Accession No.	LOCATION County, State	SITES WVU Height	WVU Rank	MON Height	MON Rank	NMT Height	NMT Rank
481	Union, IL	62.2	1	27.9	21	44.1	7
377	Jackson, IL	61.1	2	35.9	5	47.0	2
489	Scott, MO	57.3	3	32.3	12	41.1	11
129	Hopkins, KY	56.6	4	35.2	6	38.5	13
297	Burlington, NJ	56.5	5	39.0	1	48.7	1
385	Lancaster, VA	55.8	6	27.1	23	37.4	15
121	Floyd, IN	55.1	7	33.3	9	46.0	4
117	Campbell, TN	54.9	8	32.7	11	37.6	14
285	Bucks, PA	54.1	9	36.1	4	43.2	8
461	Delaware, PA	53.6	10	38.3	2	44.9	6
125	Vanderburg, IN	53.6	11	31.5	13	45.0	5
101	Tipton, TN	53.1	12	30.5	16	48.8	12
097	Jefferson, IL	52.9	13	36.8	3	41.3	10
077	Dorchester, MD	52.5	14	34.5	7	43.1	9
033	Jasper, GA	52.4	15	29.1	19	36.5	19
053	Jones, NC	52.3	16	31.0	15	33.2	24
381	Henrico, VA	52.1	17	26.8	25	36.7	17
313	Middlesex, NJ	51.9	18	31.4	14	46.9	3
061	Fairfield, SC	51.3	19	33.2	10	31.4	28
105	Humphreys, TN	51.2	20	28.0	20	37.1	16
553	Hardeman, TN	51.0	21	34.1	8	29.5	31
109	Coffee, TN	50.4	22	24.2	28	34.8	22
445	Lawrence, AL	50.0	23	27.0	24	31.9	26
473	St. Louis, MO	48.1	24	29.1	18	31.3	29
549	Hardin, TN	47.7	25	26.7	26	34.6	23
545	Shelby, TN	47.6	26	25.4	27	34.9	21
241	Greenwood, SC	47.0	27	23.0	30	32.6	25
245	Madison, MO	46.9	28	28.8	31	—	—
257	Murray, GA	46.8	29	29.6	17	35.6	20
229	Choctaw, MS	45.6	30	17.4	34	30.4	30
457	Montgomery, AR	44.5	31	23.3	29	31.5	27
085	Marshall, MS	44.1	32	27.2	22	36.6	18
081	Covington, AL	44.0	33	20.7	32	26.2	32
003	Kanawha, WV	38.4	34	18.9	33	—	—
	Mean Height	51.6		30.2		38.0	

Table 3. Growth (cm) of the Sweetgum Sources at the West Virginia University Forest, Monongah, and Negro Mountain Sites.

Accession No.	LOCATION County, State	SITES WVU Growth	WVU Rank	MON Growth	MON Rank	NMT Growth	NMT Rank
081	Covington, AL	26.8	1	8.3	2	12.2	2
053	Jones, NC	23.4	2	5.7	7	11.1	4
101	Tipton, TN	22.9	3	4.3	13	9.3	9
229	Choctaw, MS	22.8	4	7.4	3	7.6	20
457	Montgomery, AR	21.9	5	5.5	8	8.2	15
241	Greenwood, SC	21.8	6	3.8	18	9.0	10
549	Hardin, TN	21.3	7	4.7	12	7.6	22
085	Marshall, MS	20.9	8	6.8	5	10.4	7
061	Fairfield, SC	20.7	9	2.0	34	10.4	6
473	St. Louis, MO	20.0	10	4.1	14	7.2	23
105	Humphreys, TN	19.9	11	5.1	9	8.3	14
109	Coffee, TN	19.9	12	3.5	26	5.3	32
545	Shelby, TN	19.8	13	3.6	24	6.7	26
553	Hardeman, TN	19.3	14	5.0	10	11.3	3
033	Jasper, GA	19.2	15	6.5	6	6.7	24
445	Lawrence, AL	18.6	16	9.3	1	8.8	12
481	Union, IL	18.2	17	3.0	29	6.3	27
381	Henrico, VA	17.8	18	3.9	17	10.7	5
257	Murray, GA	17.7	19	3.7	22	13.4	1
125	Vanderburg, IN	17.3	20	4.0	16	6.1	28
077	Dorchester, MD	16.0	21	3.2	28	5.6	31
245	Madison, MO	16.0	22	2.9	30		
489	Scott, MO	15.9	23	4.1	15	8.0	16
297	Burlington, NJ	15.5	24	2.3	32	7.6	21
117	Campbell, TN	15.4	25	3.5	25	8.6	13
129	Hopkins, KY	15.3	26	4.9	11	7.8	18
377	Jackson, IL	15.3	27	3.8	19	5.8	30
121	Floyd, IN	14.7	28	3.7	21	7.9	17
385	Lancaster, VA	14.2	29	6.9	4	9.9	8
003	Kanawha, WV	14.0	30	3.8	20		
461	Delaware, PA	13.6	31	2.2	33	7.6	19
097	Jefferson, IL	13.6	32	3.2	27	8.9	11
313	Middlesex, NJ	13.4	33	3.7	23	6.0	29
285	Bucks, PA	11.4	34	2.9	31	6.7	25
	Mean Height	18.2		4.3		8.3	

Mean growth was 18.2 cm. A significant difference existed among sources for growth at the 1% level. At the MON site a significant difference existed among sources at the 5% level with a mean growth of 4.3 cm. There was no significant relationship between growth and source at the NMT site. Mean growth at the NMT site was 8.3 cm. Growth was significantly inversely correlated with latitude of the source for all sites at the 1% level (r= -.8427, WVU; r= -.6296, MON; and r= -.4751, NMT). Longitude was not significantly correlated with growth.

Mother tree difference were not significant at the MON and NMT sites. They were significant, however, at the WVU site (5%). Replication differences were highly significant at the WVU site (1%); while replication differences at the MON site were significant at the 5% level.

Survival: Survival averaged 95.4% at the WVU site with 20 of the 34 sources having a survival greater than 95%. The MON site had an average survival of 17.2% with 22 sources averaging less than 20%. Survival at the NMT site varied from 94.3% for the Missouri source 489 to 47.7% for the Tennessee source 545 with a mean of 72.2% (Table 4).

Survival differed significantly among sources at the 1% level at the MON site and at the 5% level at the NMT site. There was no significant difference for survival due to source at the WVU site. Latitude and longitude were not significantly correlated with survival at the WVU site. Survival was significant for the MON site at the 1% level for both latitude (r= .3207) and longitude (r= -.0611). At the NMT site latitude and longitude were significant at the 1% (r= .5770) and 5% (r= -.0010) levels, respectively. Survival by mother tree was significant at the MON site (5%), but was not at the WVU and NMT sites. Survival differed significantly by replication at both the WVU and MON sites (1%).

WVU-MON Combined Data

Fall height. Height related to source differed at the 1% level, and was also correlated with latitude at the 1% level (r=.4783). Longitude showed no significance with source for height. Mother tree and replication were significant at the 1% level. Site x source interaction was not significant. Sites were found to be significantly different at the 1% level. The WVU site has a greater mean height than the MON site.

First-year growth. Significance at the 1% level was found for growth related to source. Source was significantly related to latitude at the 1% level for growth (r=.8264); while longitude was not significant. Site x source interaction was significant at the 5% level. Mother tree and replication were significant (1%) for growth.

Survival. Significant differences in survival at the 1% level were found for: source, latitude (r=.3877) and longitude (r=.0178) mother tree, replication, site x source interaction, and site.

Table 4. Percent Survival of Sweetgum Sources at the West Virginia University Forest, Monongah, and Negro Mountain Sites.

Accession No.	LOCATION County, State	SITE WVU Survival	WVU Rank	MON Survival	MON Rank	NMT Survival	NMT Rank
377	Jackson, IL	100.0	1	17.9	18	88.6	3
245	Madison, MO	100.0	2	20.5	11		—
097	Jefferson, IL	98.9	3	29.5	4	84.4	6
461	Delaware, PA	98.9	4	30.6	3	79.2	11
109	Coffee, TN	97.9	5	18.8	16	63.6	25
553	Hardeman, TN	97.9	6	14.3	23	66.7	21
125	Vanderburg, IN	97.9	1	33.0	2	80.2	9
101	Tipton, TN	97.9	8	17.0	19	80.7	8
489	Scott, MO	96.9	9	28.6	5	94.3	1
285	Bucks, PA	96.9	10	21.4	10	86.4	5
129	Hopkins, KY	96.9	11	14.3	21	75.0	14
077	Dorchester, MD	96.9	12	22.6	8	79.7	10
061	Fairfield, SC	96.9	13	13.4	24	61.5	26
033	Jasper, GA	96.9	14	20.5	12	71.6	16
085	Marshall, MS	95.8	15	18.5	17	55.2	30
117	Campbell, TN	95.8	16	19.4	13	70.8	18
121	Floyd, IN	95.8	17	18.8	15	81.9	7
313	Middlesex, NJ	95.8	18	25.0	7	77.3	13
381	Henrico, VA	95.8	19	7.1	30	60.4	27
445	Lawrence, AL	95.8	20	16.1	20	64.6	22
481	Union, IL	94.8	21	18.8	14	89.1	2
457	Montomery, AR	94.8	22	6.5	33	63.9	23
081	Covington, AL	94.8	23	6.9	32	72.5	15
549	Hardin, TN	93.8	24	21.4	9	70.8	17
241	Greenwood, SC	92.7	25	12.5	25	59.3	29
105	Humphreys, TN	92.7	26	14.3	22	69.8	19
053	Jones, NC	92.4	27	11.6	27	63.8	24
545	Shelby, TN	91.7	28	12.0	26	47.7	32
473	St. Louis, MO	91.7	29	27.7	6	87.5	4
385	Lancaster, VA	91.7	30	7.1	29	59.4	28
297	Burlington, NJ	91.7	31	2.7	34	79.2	12
257	Murray, GA	90.6	32	10.7	28	67.0	20
229	Choctaw, MS	90.6	33	7.1	31	55.2	31
003	Kanawha, WV	83.3	34	100.0	1		
	Mean Survival	95.4		17.2		72.2	

DISCUSSION

Significant differences were not found for survival at the WVU site. All sources had excellent survival at this site. At the MON site survival was significant at the 1% level with the sources from the northern portion of the range having the greatest survival. The average survival at the MON site was low (17.2%). This was probably caused by two extremely dry periods during the summer. The first occurred approximately two weeks following planting, starting on June 15, 1981. This period lasted approximately one and

one-half weeks. The second period lasted 16 days and occurred in late August. The soil during these dry periods became severely cracked and extremely dry to a depth of about six inches. Since, under these severe conditions, the northern sources had the best survival it is possible that they may be more drought hardy.

Although many of the seedlings appeared to be of equal height at planting on the NMT site, the southern sources had suffered from winter dieback in the transplant bed. Therefore, seedlings with severe dieback initiated growth lower on the stem. With the thick grass on the NMT site, much of the new growth was shaded and apparently smothered, thus resulting in the death of many of the trees from the southern sources.

There were significant differences at the 1% level for first year height on the NMT and WVU site. The more rapid growth of the southern sources at the WVU site was not great enough to compensate for the loss in height they suffered from winter injury in the nursery. Therefore first year height was greatest for the northern sources due to their ability to withstand low winter temperatures.

Growth on the NMT site was less than that on the WVU site. The reduced growth is partially a result of the apparent infertility of the site. The soil on this site contains a large amount of clay which restricts water and air movement, thus affecting growth. A compounding factor is that of grass competition which emphasized source differences.

Source differences for growth were significant at the 5% level on the MON site. Growth on this site was less than on the other two sites, partially because of the late planting date, but also because of the two dry periods. Visible drought stress occurred, marked by leaf and stem dessication and necrosis.

As observed, the southern sources grew quite rapidly but were very susceptible to winter injury. Thus, instead of being the tallest trees they were often the shortest. The northern sources grew slower than the southern sources but suffered minimal dieback even with severely low temperatures. On strip mines, the results are similar, the northern sources were tallest but had the slowest growth. Sources from the northern latitudes also survived better on the strip-mine sites.

LITERATURE CITED

Cech, F. C., R. N. Keys, and K. K. Carter.
1980. GERMINATION AND EARLY GROWTH OF SWEETGUM SEED SOURCES IN THE NURSERY. 27th Northeastern For. Tree Imp. Conf. pp. 240-246.

Ferguson, R. B. and D. T. Cooper.
1977. SWEETGUM VARIATION CHANGES WITH TIME. 14th Southern For. Tree Imp. Conf. pp. 194-200.

Fowells, H. A.
1965. SILVICS OF FOREST TREES OF THE UNITED STATES. USDA Forest Service Ag. Handbook No. 271. Washington, D. C. 762p.

Little, E. L., Jr.
1978. CHECKLIST OF UNITED STATES TREES. USDA Forest Service Ag. Handbook No. 541. Washington, D.C. 375 p.

Mohn, C. and D. Schmitt.
1973. EARLY DEVELOPMENT OF OPEN-POLLINATED SWEETGUM PROGENIES. 12th Southern For. Tree Imp. Conf. pp. 228-232.

Sprague, J. and R. J. Weir.
1973. GEOGRAPHIC VARIATION OF SWEETGUM. 12th Southern For. Tree Imp. Conf. pp. 169-180.

Wilcox, J. R.
1970. INHERANT VARIATION IN SOUTHERN MISSISSIPPI SWEETGUM. Silvae Genetica 19(2-3): 91-94.

Williams, G. J., III and C. McMillan.
1971. PHENOLOGY OF SIX UNITED STATES PROVENANCES OF LIQUIDAMBAR STYRACIFLUA UNDER CONTROLLED CONDITIONS. American J. Bot. 58(1):124-131.