# Survival and Growth of Loblolly Pine as Influenced By Seedling Grade: *13-Year Results*

**David B. South, James N. Boyer, and Leonard Bosch**

*ABSTRACT. Results from a northcentral Louisiana loblolly pine* (Pinus taeda) *site (site index 94, base age 25) showed that seedling grade affected survival, height, and volume production. Survival of Grade 1 seedlings was significantly greater than cull seedlings and volume production from Grade 1 seedlings was 17.5% greater than that of Grade 2 seedlings. The present value of the additional wood produced at age 13 by Grade 1 seedlings (over that of Grade 2 seedlings) ranged from $50 to $139 per thousand seedlings. Average volume production for Grade 1 seedlings exceeded 30 $m^3$/ha/yr (440 cubic feet per acre per year). To increase volume production, especially on high site land, Grade 1 seedlings should be planted. It is proposed that a portion of the nursery be sown at low densities (ca 200/$m^2$) to provide the field forester with the option of planting a high proportion of Grade 1 seedlings.*[1]

There have been numerous studies conducted on the effects of seedling grade on survival (Table 1). It was generally concluded that seedlings with larger diameters had increased initial survival. In a few cases, the studies were maintained for half the rotation age (Blair and Cech 1974, Autry 1972) and, in one case, for 34 years (Wakeley 1969). Results reported by Wakeley (1969) indicate that planting Grade 1 seedlings of slash (*Pinus elliottii*) and loblolly pine produced 26 and 59% more volume, respectively, than Grade 2 seedlings. However, volume differences among grades from these long–term studies can be accentuated by unequal competition resulting from the use of row plots (Wakeley 1969). Use of block plots rather than row plots may have increased the accuracy of such volume estimates.

A few seedling grade studies involving block plots have been reported in the South. Hatchell, Dorman, and Langdon (1972) reported on volume production of select (root collar >4.7 mm) and average seedlings planted in 40-$m^2$ block plots (12 trees per plot). Ten years after planting, the larger slash and loblolly pine seedlings produced 80 and 240% more volume, respectively, than the average seedlings. Sluder (1979) reported on volume production of large and average loblolly pine seedlings planted in 186- to 230-$m^2$ block plots (20 to 25 trees per plot). Fifteen years after planting, large seedlings produced an average of 20% more volume than average-sized seedlings. A similar study was established in Louisiana and involved 214-$m^2$ block plots (36 trees per plot). Thirteen-year results of that study are presented here.

## MATERIALS AND METHODS

Six wild sources of loblolly pine seed were sown separately in nurserybeds at the Continental Forest Industries Nursery at Hodge, Louisiana in 1966. Two sources were from woods collections and four were from seed production areas. In February 1967, seedlings were lifted from each source and classified into Grade 1 (root collar >4.7 mm), Grade 2 (root collar 3.2–4.7 mm) and Grade 3 (root collar <3.2 mm) seedlings according to Wakeley's (1954) criteria.

The six sources and three seedling grades made up a 6 × 3 factorial of 18 treatment combinations Four replications were established in a completely ramdomized design, with square plots of 36 trees at 2.4 × 2.4 m (8 × 8 ft) spacing. The planting site was located in Jackson Parish on the south side of State Highway 4 at the Continental Forest Industries seed orchard. Estimated site index (base age 25) for this area was 29 m (94 ft). The estimated site index was based on dominant and codominant heights of 19 m (62 ft) at age 13 and was computed from a southwide equation reported by Golden et al. (1981).

Measurements included survival and height at age 3 and survival, height, and diameter at age 13 years (on 1 June 1980). Volume (outside bark volume to a 7.5-cm outside bark top diameter) at age 13 was calculated using a formula derived from old-field plantation-grown loblolly pine (van Deusen, Sullivan, and Matney 1981). Data were analyzed using analysis

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**Table 1. Percent survival by seedling grade and diameter class for loblolly and slash pine.**

| Author | Age | Species | Location | Planting year dry? | Root-collar diameter class >6.3 mm | 5.5 mm Grade 1 | 4.8 mm Grade 2 | 4.0 mm | 3.2 mm Grade 3 | 2.4 mm | 1.6 mm (Cull) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | % Survival | | | | | | |
| Wakeley (1935) | 5 | slash | LA-MS | ? | | 90.0 | | 86.0 | | 84.0 | |
| | 5 | slash | LA-MS | ? | | 90.0 | | 78.0 | | 68.0 | |
| | 5 | loblolly | LA-MS | ? | | 95.0 | | 86.0 | | 86.0 | |
| | 5 | loblolly | LA-MS | ? | | 76.0[2] | | 90.0 | | 74.0 | |
| Silker (1960) | 3 | loblolly | TX | yes | | | 67.0 | | 58.0 | | 32.0 |
| | 3 | loblolly | TX | no | | | 84.0 | | 75.0 | | 54.0 |
| | 3 | loblolly | TX | yes | | | 54.0 | | 52.0 | | 55.0 |
| Shoulders (1960) | 1 | slash | LA | yes | 92.0 | 83.0 | 76.0 | | | | |
| | 1 | slash | LA | yes | | 43.0 | 38.0 | 51.0 | | | |
| | 1 | slash | LA | no | 98.0 | 92.0 | 91.5 | | | | |
| | 1 | slash | LA | no | 97.0 | 95.0 | 93.0 | | | | |
| | 1 | loblolly | LA | yes | | 89.0 | 80.0 | 77.0 | | | |
| | 1 | loblolly | LA | no | 100.0 | | 98.5 | 96.0 | | | |
| | 1 | loblolly | LA | no | 100.0 | 99.0 | 98.0 | | | | |
| Swearingen (1963) | 1 | slash | AL-MS | ? | | | 91.0 | 89.0 | | 82.0 | |
| | 2 | slash | AL-MS | ? | | | 82.0 | 73.0 | | 65.0 | |
| Meekins (1964) | 1 | loblolly | PA | ? | | | | 86.0 | 83.0 | 82.0 | 70.0 |
| Shipman (1964) | 1 | slash | SC | no | 97.4 | | 94.4 | 97.7 | | | |
| Jorgensen & Shoulders (1967) | 1 | slash-M[1] | LA | ? | | 83.0 | | 87.0 | | 66.0 | 46.0 |
| | 1 | slash-N | LA | ? | | 65.0 | | 59.0 | | 42.0 | 14.0 |
| | 1 | slash-M | LA | ? | | 93.0 | | 95.0 | | 87.0 | 66.0 |
| | 1 | slash-N | LA | ? | | 76.0 | | 73.0 | | 58.0 | 29.0 |
| | 1 | slash-M | LA | ? | | 91.0 | | 86.0 | | 70.0 | 45.0 |
| | 1 | slash-N | LA | ? | | 74.0 | | 60.0 | | 49.0 | 18.0 |
| | 1 | slash-M | LA | ? | | 87.0 | | 88.0 | | 76.0 | 57.0 |
| | 1 | slash-N | LA | ? | | 72.0 | | 79.0 | | 72.0 | 36.0 |
| | 1 | slash-M | LA | ? | | 81.0 | | 82.0 | | 71.0 | 51.0 |
| | 1 | slash-N | LA | ? | | 66.0 | | 71.0 | | 54.0 | 24.0 |
| Burns & Brendemuehl (1971) | 5 | slash | FL | no | | 63.0 | | 55.0 | | 42.0 | |
| | 5 | slash | FL | no | 78.0 | 75.0 | | 64.0 | | 38.0 | |
| | 5 | slash | FL | no | | 77.0 | | 73.0 | 63.0 | 50.0 | |
| | 5 | slash | FL | no | | 80.0 | | 77.0 | 66.0 | 58.0 | |
| Dierauf (1973) | 3 | loblolly | VA | ? | | 86.0 | 96.0 | 96.0 | 96.0 | 93.0 | 93.0 |
| | 3 | loblolly | VA | ? | | 77.0 | 91.0 | 93.0 | 90.0 | 90.0 | 88.0 |
| Blair + Cech (1974) | 1 | loblolly | AL | ? | | 86.0 | | 87.0 | | 75.0 | |
| | 1 | slash | GA | ? | | 60.0 | | 82.0 | | 75.0 | |
| | 1 | slash | GA | ? | | 94.0 | | 84.0 | | 64.0 | |
| | 1 | slash | FL | ? | | 81.0 | | 69.0 | | 61.0 | |
| | 1 | slash | FL | ? | | 55.0 | | 44.0 | | 14.0 | |
| Bacon, Hawkins & Jermyn (1977) | 1 | slash | Aus. | ? | 82.7 | | 65.9 | | 60.0 | | |
| | 1 | slash | Aus. | ? | 80.3 | | 66.7 | | 40.7 | | |
| | 1 | slash | Aus. | ? | 82.6 | | 75.8 | | 36.4 | | |
| | 1 | slash | Aus. | ? | 71.1 | | 57.8 | | 23.8 | | |
| Dierauf (1978) | 3 | loblolly | VA | ? | | | 95.0 | | | 77.0 | |
| | 3 | loblolly | VA | ? | | | 95.0 | | | 64.0 | |
| | 3 | loblolly | VA | ? | | | 93.0 | | | 72.0 | |
| | 3 | loblolly | VA | ? | | | 93.0 | | | 90.0 | |
| | 3 | loblolly | VA | ? | | | 100.0 | | | 95.0 | |
| Venator (1983) | 1 | loblolly | LA. | yes | | 50.2 | | 65.9 | | | 53.8 |

[1] Slash–M = Seedlings with mycorrhizae; slash–N = Seedlings without mycorrhizae.
[2] Mortality increased by action of scale insects.

of variance. When F tests proved significant, treatment means were tested using Duncan's multiple range test.

The design of this study was very similar to a study established in Georgia on a more average site (Sluder 1979). For this reason, data from the Georgia and Louisiana sites were compared.

## RESULTS

Differences among sources were not significant for either survival or height (Table 2). However, differences among seedling grades were significant for survival, height, and volume production. At 3 and 13 years after planting, survival of Grade 1 and 2

**Table 2. Probability of greater F-values for factorial effects.**

| Factor | Age 3 years Survival | Age 3 years Height | Age 13 years Survival | Age 13 years Height | Age 13 years Volume |
|---|---|---|---|---|---|
| | *Probability of a greater F value* | | | | |
| Source | .8790 | .8249 | .7369 | .2470 | .2252 |
| Grade | .0240 | .0001 | .0007 | .0006 | .0001 |
| Source* grade | .1482 | .0590 | .5466 | .3599 | .0658 |

seedlings was better than survival of Grade 3 seedlings (Figure 1). During the 10 years between measurements, survival of Grade 1 seedlings decreased by only 5 percentage points while Grade 2 seedlings and culls (Grade 3 seedlings) decreased 10 and 12 percentage points, respectively.

Height growth and volume production of Grade 1 seedlings at age 13 were greater than for Grade 2 seedlings. Volume growth for Grade 1 seedlings was 17.5% greater than for Grade 2 seedlings (Table 3). Average volume production per year for Grade 1 seedlings exceeded 30 $m^3$/ha (440 $ft^3$/a).

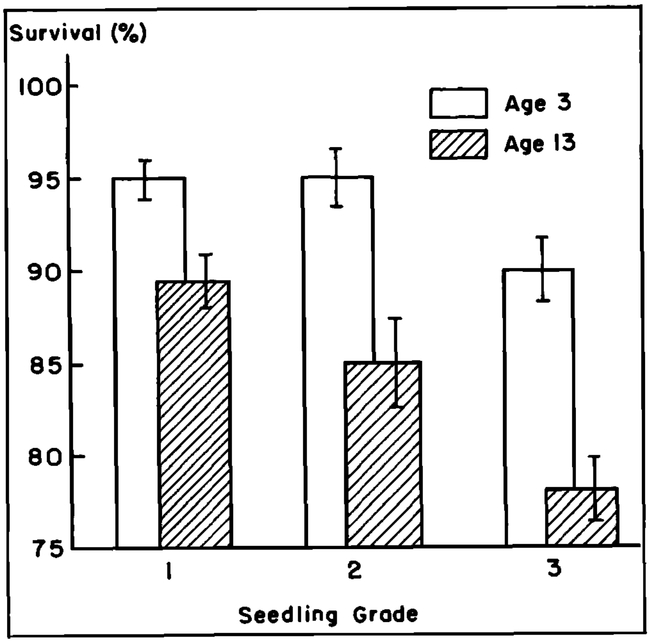


*Figure 1. Relationship between seedling grade at time of planting and field survival. Error bars represent the standard error of the mean.*

## DISCUSSION

The percentage increase in volume production resulting from planting Grade 1 seedlings was similar to that reported by Sluder (1979). On the Georgia site, volume production of select seedlings was 13 to 27% greater than that of average seedlings. However, the difference in site productivity between the Louisiana site and the Georgia site should be noted. Site index (base age 25) for the Georgia site was estimated at approximately 21 m (68 ft). Volume production on the Louisiana site after 13 years was over twice that of the Georgia site after 15 years (Table 3). This is due in part to the Louisiana plantation having over twice the stocking of the Georgia site. The higher stocking was due to a much higher survival rate and a higher initial planting density.

Although the percentage of volume increase resulting from planting Grade 1 seedlings may be similar for a range of sites, the total volume increase may be larger for the higher site land. At the Louisiana site, planting Grade 1 seedlings instead of Grade 2 seedlings from one seed source provided an in-

**Table 3. Survival and growth of seedling grades planted on sites in Louisiana and Georgia.**

| Seedling grade | Age 3 years Survival | Age 3 years Height | | Age 13–15 years Survival | Age 13–15 years Height | | Age 13–15 years Volume | % Volume increase over lower grade |
|---|---|---|---|---|---|---|---|---|
| | *... Percent ...* | *.. m...* | *... (ft) ...* | *... Percent ...* | *.. m...* | *... (ft) ...* | *.. m³/ha (ft³/ac) ...* | *........... Percent ..........* |
| LA[1] | | | | | | | | |
| Grade 1 | 95 a[2] | 2.8 | (9.2) a | 90 a | 17.8 | (58) a | 401 (5738) a | 17.5 |
| Grade 2 | 95 a | 2.4 | (7.8) a | 85 a | 17.3 | (57) b | 341 (4882) b | — |
| Grade 3 | 90 b | 1.9 | (6.4) b | 78 b | 17.0 | (56) b | 322 (4607) b | — |
| GA[3] | | | | | | | | |
| Select[4] | 76 a | 2.4 | (7.8) a | 62 a | 15.0 | (49) a | 144 (2071) a | 26.9 |
| Average[4] | 52 b | 2.2 | (7.1) a | 47 a | 14.3 | (47) ab | 114 (1632) c | — |
| Select[5] | 64 ab | 2.4 | (7.8) a | 55 a | 14.1 | (46) ab | 137 (1962) ab | 13.6 |
| Average[5] | 63 ab | 2.3 | (7.6) a | 54 a | 13.7 | (45) b | 121 (1726) bc | — |

[1] Average of six sources.
[2] Within a site, values in columns followed by the same letter are not significantly different at the 5% level as judged by Duncan's New Multiple Range Test.
[3] Georgia data from Sluder (1979).
[4] Medium-size seed.
[5] Large-size seed.

**Table 4. Survival and growth of seedling grades from one source (SPA #2—area 5) at age 13.**

| Seedling grade | Survival | Height | | Volume[1] | | Mean annual increment | |
|---|---|---|---|---|---|---|---|
| | ... *Percent* ... | *m* | ..... *(ft)* ..... | $m^3$*/ha* | .. *(ft³/ac)*... | .. $m^3$*/ha/yr*... | .. *(Cords/ac/yr)*[3] .. |
| 1 | 90 a[2] | 18.7 | (61.4) a | 425 | (6087) a | 33 | (5.7) |
| 2 | 84 a | 17.6 | (57.6) b | 347 | (4967) b | 27 | (4.6) |
| Cull | 83 a | 16.8 | (55.1) b | 291 | (4168) b | 22 | (3.9) |

[1] Merchantable volume to a 7.5-cm top.
[2] Values in columns followed by the same letter are not significantly different at the 5% level as judged by Duncan's New Multiple Range Test.
[3] Assuming 82 $ft^3$/cord.



crease in volume production of 6 $m^3$/ha/yr (1 cord/a/yr) (Table 4). Total production for Grade 1 seedlings from this source on this site exceeded 30 $m^3$/ha/yr (5 cords/a/yr). This growth is equivalent to the productivity of many fast-growing loblolly pine plantations in various regions of the world (Burns and Hu 1983).

Blair and Cech (1974) examined the relative worth of acceptable (Grades 1 and 2) and cull (Grade 3) seedlings by discounting the value of the difference in volume production at age 13 back to the planting date. Using $6.50 per $m^3$ ($15 per cord) as the stumpage value and an 8% interest rate, their calculations indicate that Grades 1 and 2 slash pine seedlings have a present value worth $79 per thousand more than cull seedlings. Similarly, their data indicate that on the average, Grade 1 slash pine seedlings were worth $36 per thousand more than Grade 2 seedlings.

Similar analyses were applied to data presented by Sluder as well as to our own (Table 5). On the poorer site in Georgia, the present value of select seedlings ranged from $30 to $74 more per thousand than average seedlings. However, on the higher site land in Louisiana, the present value of Grade 1 seedlings ranged from $50 to $139 more per thousand than Grade 2 seedlings. This points out that additional economic gains can be obtained by planting Grade 1 seedlings on higher site land.

It should be noted that in the South, the verbs *grade* and *cull* are often incorrectly used as synonyms. Presently no forest nursery in the South *grades* seedlings into three grades. Some nurseries *cull* small and diseased seedlings before shipping, but forest nurseries in the South do not sell or ship seedlings by grades as do nurseries in other regions of the United States. In regard to the large economic gains that can be realized by planting Grade 1 seedlings, it is surprising that so few Grade 1 seedlings are produced in southern forest nurseries. A survey of 53 nurseries by the Auburn University Southern Forest Nursery Management Cooperative indicated that 44 nurseries were producing less than 20% Grade 1 seedlings. In addition, about 35 were producing more than 30% cull seedlings.

To produce a high proportion of Grade 1 seedlings requires additional expenditures per seedling. Low-

**Table 5. Economic benefits of planting Grade 1 seedlings as determined by two seedling grade studies planted on sites in Louisiana and Georgia.**

| Location and source | Age | Growth difference between grade 1 and grade 2 seedlings[1] | | Increase in present value per thousand seedlings[2] | | Real internal rate of return[3] | |
|---|---|---|---|---|---|---|---|
| | | | | ........ *Real interest rate* ........ | | ....... *Additional cost*[4] ....... | |
| | | | | 6% | 8% | $5 | $10 |
| | .. *Years* .. | .. $m^3$*/ha* .. | .. *(Cords/acre)*... | ............. *Dollars* ............. | | ............ *Percent* ............ | |
| GA | | | | | | | |
| Medium seed | 15 | 30 | (5.2) | 74 | 56 | 27 | 21 |
| Large seed | 15 | 16 | (2.8) | 40 | 30 | 22 | 16 |
| LA | | | | | | | |
| Woods-area 3 | 13 | 54 | (9.5) | 98 | 77 | 33 | 26 |
| Woods-area 2 | 13 | 52 | (9.1) | 94 | 72 | 33 | 26 |
| SPA-area 2 | 13 | 77 | (13.4) | 138 | 108 | 37 | 30 |
| SPA #1-area 5 | 13 | 51 | (9.0) | 93 | 73 | 33 | 26 |
| SPA #2-area 5 | 13 | 78 | (13.5) | 139 | 109 | 37 | 30 |
| SPA-area 4 | 13 | 35 | (6.2) | 64 | 50 | 29 | 22 |

[1] For Georgia site, difference is between select and average seedlings.
[2] Assuming $6.50/$m^3$ ($15/cord). Planting density at Georgia site = 1075/ha; planting density at Louisiana site = 1680/ha.
[3] Net of inflation, net of real timber price increases, and before taxes. For example, in Georgia with medium-size seed the year 0 cost per hectare is either $5.38 or $10.75 and the extra benefit 15 years later is $195/ha, giving internal rates of return of 27% and 21%, respectively.
[4] Additional cost of growing a thousand Grade 1 seedlings instead of a thousand Grade 2 seedlings (Includes additional land, materials, and labor costs).

ering seedbed densities will increase the proportion of Grade 1 seedlings as well as increase cost of production (Mexal 1980). Nursery practices required for producing 80% Grade 1 seedlings in the seedbed might increase current production costs by as much as $5 per thousand. For example, lowering seedbed densities from 280 seedlings/m$^2$ to 200 seedlings/m$^2$ will increase use of materials such as herbicides, fungicides, fertilizers, and fuel. In addition, land and labor requirements would also increase. Even if a nursery wanted to increase the price of seedlings by 40% (in order to keep per hectare revenues the same) seedling costs per thousand for loblolly pine might increase by only $10 (from $25 to $35 per thousand). Assuming volume gains derived from planting Grade 1 seedlings were only 16 m$^3$/ha (2.8 cords per acre) after 15 years, and assuming as much as a $10 per thousand increase in seedling cost, the real internal rate of return would be greater than 15% (Table 5). When Grade 1 seedlings are planted on high site lands, the real internal rate of return could exceed 30%.

While the importance of seedling grade is recognized, the fact that shorter seedlings have performed as well or better than taller seedlings on occasion is also recognized, although not as well documented (Venator 1983). The reason for this stems in part from a strong interaction between seedling height and site. On sites with heavy vegetation, taller seedlings often outperform shorter seedlings, but on droughty sites, shorter seedlings with lower transpirational surface area often outperform taller seedlings (Baker, Idem, and Mexal 1979). On moist sites, seedling height may have little effect on either survival or first-year height increment. However, on droughty sites, taller seedlings (with a higher height/diameter ratio) may suffer greater summer mortality and grow less during the first season (a likely result of increased transplanting shock) (Beineke and Perry 1965). Therefore, the correlation between survival and height/diameter ratio (or shoot/root ratio—dry weight basis) will be low for sites and years when soil moisture is adequate and high when moisture is limited. Moisture was not limiting for the study reported here, as there was excellent survival of all seedling grades and near average rainfall patterns during 1967 (Table 6).

It has been suggested that prescription planting of seedling grades be made according to the likely summer moisture conditions on areas to be planted. Williston (1974) has suggested planting Grade 1 seedlings with 23- to 30-cm shoots on good moist sites. On drier sites, he recommends planting Grade 1 or Grade 2 seedlings with 15- to 23-cm shoots. Although he made these recommendations 10 years ago, for the most part nurseries have not provided a choice of seedling grades. Most nurseries sow at one density to produce a high proportion of Grade 2 seedlings. Southern nurserymen have not separated Grade 1 seedlings from Grade 2 seedlings, probably because of increased labor requirements and increased seedling exposure. We propose an alternate method of providing the field forester with a high percentage of Grade 1 seedlings. Precision sowing at low seedbed densities (resulting in 204 seedlings/m$^2$) and using staggered double drills produced seedlings with over 80% having diameters greater than 4.5 mm (Hassan 1983). By sowing at a low density, the nurseryman could provide Grade 1 seedlings with 15- to 23-cm shoots for planting on both good moist sites and drier sites. If the amount of nursery land is a limiting factor, sowing a portion of the nursery at a lower density would provide the field forester the option of planting Grade 1 seedlings on the better sites. Our data demonstrate the large increases in volume production possible from planting Grade 1 seedlings on sites of high quality. However, the economic gains will be realized only if nurseries utilize management practices which produce a high proportion of Grade 1 seedlings.

**Table 6. Monthly rainfall data.**

| Month | 1967 Hodge nursery | 1951–1980 normals Ruston | Winnfield |
|---|---|---|---|
| | mm | | |
| January | 58 | 129 | 131 |
| February | 102 | 111 | 114 |
| March | 48 | 125 | 139 |
| April | 132 | 128 | 113 |
| May | 302 | 151 | 150 |
| June | 89 | 90 | 98 |
| July | 165 | 126 | 134 |
| August | 56 | 72 | 85 |
| September | 28 | 104 | 114 |
| October | 79 | 69 | 70 |
| November | 48 | 104 | 104 |
| December | 257 | 124 | 135 |
| Total | 1364 | 1333 | 1387 |

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# Whole-Tree Harvesting Affects Pine Regeneration and Hardwood Competition

**James W. McMinn**

*ABSTRACT. Mixed upland hardwood-pine stands of low quality in the Upper Piedmont of Georgia were whole-tree harvested to 1-inch and 4-inch diameter limits in both winter and summer. Natural pine regeneration and hardwood sprouting were observed two growing seasons after harvesting. Early pine establishment was generally successful after winter harvesting but not after summer harvesting. Pine regeneration was excellent following the 1-inch winter harvest and acceptable following the 4-inch winter harvest. The treatment resulting in the best pine regeneration also produced the greatest coverage of hardwood sprouts.*[1]

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Upland forests in the Piedmont of the Southeast are dominated by low-quality hardwoods mixed with pines. These forests, which seeded in on abandoned fields, have been shaped by the forces of natural succession and high-grading (Boyce and Knight 1979, Boyce and McClure 1975, Boyce and McClure 1976). Forest production would be improved by replacing existing stands with more desirable ones. Logging for conventional wood products is not feasible, however, and expected returns are too low to stimulate investment in stand conversion or improvement, particularly on nonindustrial private land (Society of American Foresters 1979). Whole-tree harvesting for fuel chips promises to be an economic way of utilizing