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Characteristics of a Direct-Seeded Eastern White Pine Plantation on the Mid-Cumberland Plateau at Four Ages

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SUMMARY

Growth and yield of a direct-seeded eastern white pine (*Pinus strobus* L.) plantation established in 1959 on a broad undulating sandstone upland (Landtype 1) are summarized. Average heights of dominant and codominant pines were 35, 56, 65, and 76 ft at ages 15, 25, 30, and 34 years, respectively. Equivalent site indices (base age 25 years from seed) were 56, 56, 58, and 63 at those respective ages. At age 34, there were 418 pines per acre, which represents a survival rate of 25 percent based on a stocking of 1,650 stems at age 4. Other stand parameters at age 34 were quadratic mean diameter, 8.3 inches; basal area, 157 ft^2/acre; and merchantable yield (outside bark to a 3.0-inch top o.b., all trees ≥3.6 inches in d.b.h.), 5,229 ft^3/acre. Also 319 pines per acre were ≥3.6 inches in d.b.h., and 127 pines were ≥9.6 inches in d.b.h.. Hardwoods (≥0.6 inches in d.b.h.) numbered 254 and accounted for an additional 37 ft^2 of basal area. Dominant and codominant yellow-poplars (*Liriodendron tulipifera L.*), black cherries (*Prunus serotina* Ehrh.), and chestnut oaks (*Quercus prinus* L.) comprised 25 ft^2 of the hardwood basal area. Cubic yield of this direct-seeded white pine plantation on the Mid-Cumberland Plateau has been less than the average yield of planted plantations in the Southern Appalachians, and this study plantation has not grown as well as a nearby planted plantation. But site index is apparently at least 8 ft taller than the estimate for Landtype 1 in the regional forest site classification guide.

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INTRODUCTION

In the late 1950's, a major emphasis in forest management on the Cumberland Plateau in Tennessee was to convert poorly stocked, low-quality upland hardwood stands to loblolly pine (*Pinus taeda* L.). Although native to only the extreme southern end of the plateau, loblolly pine was favored for conversion because this species grew rapidly and was readily merchantable at an early age for pulpwood. Eastern white pine (*Pinus strobus* L.) was native to the central and northern portions of the plateau and some plantings had been made. Observations indicated that trees from selected seed sources grew as fast as loblolly pine. Because eastern white pine was more resistant than loblolly pine to injury from ice, snow, and cold, the former species was thought to have distinct advantages over loblolly pine.

Planting of bare-rooted stock was the typical method for establishing both species. Direct-seeding of the southern pines had been perfected but had not been tried on eastern white pine in this region. A test was begun in the spring of 1959 to determine if direct-seeding of eastern white pine would be a satisfactory method to convert the low-quality upland hardwood stands of the plateau to a more profitable condition; first-year results were reported by Harrington (1960).

In a final report of the same direct-seeding test at age 4, Russell (1964) stated that "low-yielding, economically marginal plateau hardwood stands (cross-tie orchards) could be converted to eastern white pine by direct seeding. Both repellent-coated and untreated seed produced acceptable stands when broadcast sown on disked sites. But by reducing seed losses to birds and rodents, the repellents almost doubled the number of surviving seedlings and significantly improved their distribution." The characteristics of that direct-seeded plantation at ages 15, 25, 30, and 34[1] years are summarized in this Research Note.

[1]The inventory at age 34 was conducted as an independent study by the junior author as partial fulfillment of the requirements for the degree of Bachelor of Science in Natural Resources at the University of the South, Sewanee, TN.

STUDY AREA

The 0.8-acre study area lies near the crest of a broad ridge at an elevation of about 1,880 ft above mean sea level on the property of the University of the South, Sewanee, TN. Slope is nearly level, and the area is classified as Landtype 1 (broad undulating sandstone uplands) in the strongly dissected southern subregion of the Mid-Cumberland Plateau (Smalley 1982). For this landtype, the estimated site index (base age 50 for natural stands) is as follows: upland oaks (*Quercus* spp.), 60; eastern white pine, 75; loblolly pine, 75; shortleaf pine (*P. echinata* Mill.), 65; and Virginia pine (*P. virginiana* Mill.), 70. Comparable site indices (base age 25) for eastern white pine, loblolly pine, and shortleaf pine plantations are 52, 50, and 45, respectively.

The soils are primarily the moderately deep Lily and deep Lonewood series (fine-loamy, siliceous, mesic Typic Hapludults). These soils are well drained and strongly to very strongly acid. Fertility is rated moderately low, and relative soil water supply is moderate.

Before establishment of the study, the area supported a low-density stand of small sawtimber and pole-sized trees. Dominant species were scarlet oak (*Q. coccinea* Muenchh.), black oak (*Q. velutina* Lam.), white oak (*Q. alba* L.), and hickories (*Carya* spp.). A fairly dense understory included sourwood [*Oxydendrun arboreum* (L.)DC], blackgum (*Nyssa sylvatica* Marsh.), flowering dogwood (*Cornus florida* L.), and black locust (*Robinia pseudoacacia* L.), and also reproduction of the overstory species.

METHODS

In mid-March 1959, the study area was lightly disked with farm equipment for about 1 hour. Disking broke up the continuous layer of hardwood litter, exposed mineral soil, and prepared a suitable seedbed with minimal disturbance to the site.

In early April, repellent-coated and uncoated eastern white pine seeds were mixed with sawdust and hand-broadcast at the rate of 10,500 full seeds (about 0.6 lb) per acre. Each treatment was tested on four 0.1-acre randomly chosen plots 0.5 by 2.0 chains in size. For the repellent treatment, 0.054 lb of Arasan 75 plus 0.01 lb of Endrin50W was applied per pound of seeds. The blended dry chemicals were applied over a latex sticker, and seeds then were lightly coated with aluminum powder for lubrication. The seeds, all from western North Carolina, were cold-moist stratified for 17 days before treating and sowing.

The seed lot averaged 95-percent full. Laboratory germination after stratification was 82 percent for untreated seeds and 81 percent for treated seeds. Normal field germination under screen-wire cones was 53 percent for treated and 64 percent for untreated seeds.

In early May, sawtimber and small poles were killed with 2,4,5-T applied with a tree injector.[2] The light disking to prepare the seedbed seldom controlled the small hardwoods, so a basal spray of 2,4,5-T was applied to the remaining stems larger than about 0.5 inch in diameter.

The test area, which is now (1996) a successful plantation, was remeasured at ages 15, 25, 30, and 34. No distinction was made between the treated and untreated plots because no differences in stand structure were evident (fig. 1).

The surrounding forest had affected the growth and development of the plantation. Consequently, at age 15, measurements were made on an interior 0.50 acre of the original 0.8-acre study area. At ages 25, 30, and 34, an interior 0.57-acre plot was inventoried.

At all four inventories, a 100-percent diameter tally of the eastern white pines was made, and total height was measured on a sample of trees in proportion to the number of trees in each 1-inch diameter class. At age 15, dominants and codominants were assumed to be those pines in the largest three 1-inch diameter classes. At ages 25, 30, and 34, crown class was assigned to each pine measured for height. Site index (base age 25 years from seed) was determined using the regression developed for old-field plantations in the Southern Appalachians (Vimmerstedt 1962).

To determine plot and per-acre yields of pine, the cubic foot volume outside bark, to a 3.0-inch top o.b. (Vimmerstedt 1962) was calculated for sample trees ≥ 3.6 inches in d.b.h. and the volumes summed. A volume/basal area ratio of sample trees was multiplied by the basal area of the plot (trees ≥3.6 inches in d.b.h.) and expanded to a per-acre basis.

At each inventory, all trees ≥0.6 inches in d.b.h. other than eastern white pines were tallied by d.b.h. class and species. At ages 25, 30, and 34 these trees were further assigned to one of two groups: (1) those projecting into the eastern white pine canopy or (2) those subordinate to the canopy. At ages 15, 25, and 30, no attempt was made to determine the cubic volume of the hardwood component because tree volume and yield regressions with common predictors and merchantability standards were lacking. However, at age 34, total height of all trees in group 1 was measured, and a rough estimate of cubic

[2]The herbicide 2,4,5-T has been withdrawn from the market by the Environmental Protection Agency.

Figure. 1—*A 30-year-old eastern white pine plantation established by direct-seeding on a broad undulating sandstone upland of the Mid-Cumberland Plateau in Tennessee. Note the random distribution of the pines and the lack of both shrub and herbaceous strata.*

volume was obtained by using a regression for "soft hardwoods" in the Southeast (outside bark to a 4.0-inch top o.b., all trees ≥4.6 inches in d.b.h.) (Clark and others 1986; table 110, p. 31).

RESULTS

Eastern White Pine

Survival.—Average stocking of eastern white pine seedlings at age 4 was 1,650 trees per acre, equivalent to a spacing of about 5 by 5 ft (Russell 1964). Survivals at ages 15, 25, 30, and 34 were 41, 29, 28, and 25 percent, respectively, of stocking at age 4 (table 1).

Diameter and Diameter Distribution.—Quadratic mean diameters at ages 15, 25, 30, and 34 were 3.7, 6.5, 7.4, and 8.3 inches, respectively (table 1). At age 15, the largest pines were in the 8-inch diameter class; at age 25, in the 13-inch class; at age 30, in the 15-inch class; and at age 34, in the 16-inch class (table 2). Discrepancies among diameter distributions were due to the vagaries of establishing and measuring temporary plots over time.

At age 15, 41 percent (282 pines) were ≥3.6 inches in d.b.h.; none were sawlog size (≥9.6 inches in d.b.h.) (table 3). At age 25, 78 percent (380 pines) were merchantable, and 12 percent (58 pines) were sawlog size. At age 30, 80 percent (370 pines) were merchantable, and 22 percent (100 pines) were sawlog size. At age 34, comparable values were 88 percent (368 pines) and 30 percent (127 pines), respectively.

Basal Area.—Basal areas of pines ≥0.6 inches in d.b.h. at ages 15, 25, 30, and 34 were 50, 114, 138, and 157 ft^2/acre, respectively (table 1). These values represent mean annual increments of 3.33, 4.56, 4.60, and 4.62 ft^2, respectively. Periodic annual increment (p.a.i.) was 6.40 ft^2 for the decade from ages 16 to 25. For the quinquennium, ages 26 to 30, p.a.i. was 4.80 ft^2; for the quadrennium, ages 31 to 34, p.a.i. was 4.75 ft^2.

Height and Site Index.—Mean heights of all pines at ages 15, 25, 30, and 34 were 27, 45, 51, and 58 ft, respectively (table 1). Mean annual height growth to age 34 was 1.7 ft and had varied little with age. The p.a.i. varied from 1.8 to 1.2 to 1.8 ft in the respective 10-, 5-, and 4-year periods.

Height of dominants and codominants averaged 35, 56, 65, and 76 ft at ages 15, 25, 30, and 34, respectively (table 1). These values translate to site indices of 56, 56, 58, and 63 at the respective ages.

Dominant and codominant pines grew at the annual rate of 2.24 ft for 34 years. This rate varied less than 0.1 ft after age 15.

Live Crown Ratio.—At age 34, height to base of live crown averaged 32 ft for all pines, an increase of 6 and 10 ft since ages 30 and 25, respectively. A comparable value for dominants and codominants at age 34 was 36 ft.

At age 34, live crown ratio (LCR) averaged 45 percent for all pines, a decrease of 4 and 8 percent after ages 30 and 25, respectively (table 1). The comparable LCR of dominants and codominants at age 34 was 52 percent.

Stand Volume.—At age 15, volume of merchantable pines was only 596 ft^3/acre because just 41 percent of the pines were of merchantable size (≥3.6 inches in d.b.h.) (table 1). In the ensuing decade, many pines grew to merchantable size, and residuals grew rapidly in height and diameter; cubic volume increased nearly four fold to 2,807 ft^3. In the following quinquennium, the plantation grew 1,271 ft^3; stand volume at age 30 was 4,078 ft^3. In the last quadrennium, the plantation grew 1,151 ft^3; stand volume at age 34 was 5,229 ft^3.

Mean annual increment continued to increase and averaged 154 ft^3 at age 34. And p.a.i. averaged 221, 254, and 288 ft^3 for the decade, quinquennium and quadrennium, respectively.

Table 1.— *Characteristics of a direct-seeded eastern white pine plantation on the Mid-Cumberland Plateau near Sewanee, TN, at four ages.**

Characteristic	Age 15	25	30	34
No. trees per acre	680 (1,696)†	484 (306)	465 (336)	418 (254)
Survival (percent of 1,650 seedlings at age 4)	41	29	28	25
Quadratic d.b.h. (inches)	3.7 (1.4)	6.5 (4.3)	7.4 (4.3)	8.3 (6.4)
Basal area (ft^2/acre)	50 (19)	114 (31)	138 (33)	157 (37)
Total height (ft)	27	45	51	58
Total height of dominants and codominants (ft)	35	56	65	76
Site index (base age 25 years from seed)	56	56	58	63
Live crown ratio (percent)	--‡	53	49	45
Volume outside bark, all trees ≥4.6 inches in d.b.h. to 3.0-inch top o.b. (ft^3/acre)	596	2,807	4,078	5,229

*Data are for all trees ≥0.6 inch in d.b.h., except data for volume of merchantable pines.

†Numbers in parentheses represent the hardwood component of the plantation.

‡Not measured.

Hardwood Component

At age 15, 1,696 hardwood stems per acre were interspersed among the eastern white pine saplings and poles, accounting for 19 ft^2 of the basal area (tables 1, 2). Slightly more than 50 percent of these stems—see table 2, "Other hardwoods"—were sassafras [*Sassafras albidum* (Nutt.) Nees] and sumac (*Rhus* spp.). Hickories and red oaks each comprised 14 percent; white oaks, 10 percent; yellow-poplar, 6 percent; and black cherry, 4 percent. With the exception of yellow-poplar, all were < 4.6 inches in d.b.h.

In the ensuing decade, yellow-poplar grew rapidly resulting in most of the increase of 12 ft^2 in hardwood basal area. Mortality of oaks, hickories, and "other hardwoods" exceeded 80 percent; all sumacs died. At age 25, hardwood stems numbered 306 per acre and represented 31 ft^2 of the basal area (tables 1, 2). Forty-eight percent of these stems were "other hardwoods," mostly sassafras, with some red maple (*Acer rubrum* L.), sourwood, blackgum, red mulberry (*Morus rubra L.)*, and flowering dogwood. Yellow-poplar and black cherry accounted for 39 percent and oaks, 12 percent. Many of the yellow-poplars and black cherries, plus a few oaks, were classified as dominants and codominants. Thirty-nine percent of the hardwoods were ≥3.6 inches in d.b.h.

At age 30, there were 336 hardwood stems per acre representing 33 ft^2 of basal area (tables 1, 2). Dominant and co-dominant yellow-poplars, black cherries, and oaks accounted for 21 ft^2. Fifty-seven percent of these stems were "other hardwoods," mostly sassafras and red maple, with some blackgum and flowering dogwood. Yellow-poplar and black cherry accounted for 22 and 11 percent, respectively. Thirty-nine percent of the hardwoods were ≥3.6 inches in d.b.h.

In the ensuing quadrennium, all hickories and most small oaks died. At age 34, the hardwood component numbered only 254 trees per acre, just 15 percent of the 1,696 stems recorded at age 15 (tables 1, 2). Hardwood basal area was 37 ft^2, an increase of 4 ft^2 after age 30. Hardwoods constituted 19 percent of the total basal area of the plantation. Sixty-eight percent (25 ft^2) of the hardwood basal area was contributed by only 23 percent of the hardwoods (42 yellow-poplars, 14 black cherries, 2 chestnut oaks, and 2 red maples) that were classified as dominants and codominants). And 63 percent of the trees were "other hardwoods," mostly sassafras and red maple, with some blackgum, flowering dogwood, sourwood, and black locust. The remaining 14 percent of the trees were intermediate and suppressed poplars, cherries, and oaks. Forty-six percent of all hardwoods were ≥3.6 inches in d.b.h. At age 34, the volume of hardwoods large enough

Table 2.— *Diameter distribution of a direct-seeded eastern white pine plantation on the Mid-Cumberland Plateau near Sewanee, TN, at four ages (Discrepancies among diameter distributions are due to vagaries of establishing and measuring plots over time)*

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
	Diameter class (inches)																
	No. trees per acre																
Age 15																	
Eastern white pine	110	144	144	120	88	48	22	4	--*	--	--	--	--	--	--	--	680
Yellow-poplar	26	20	32	18	4	2	--	--	--	--	--	--	--	--	--	--	102
Black cherry	18	22	20	4	--	--	--	--	--	--	--	--	--	--	--	--	64
White oaks†	112	34	16	4	--	--	--	--	--	--	--	--	--	--	--	--	166
Red oaks‡	196	38	4	--	--	--	--	--	--	--	--	--	--	--	--	--	238
Hickories	230	10	--	--	--	--	--	--	--	--	--	--	--	--	--	--	240
Other hardwoods§	804	68	12	2	--	--	--	--	--	--	--	--	--	--	--	--	886
Total	1,496	336	228	148	92	50	22	4	--	--	--	--	--	--	--	--	2,376
Age 25																	
Eastern white pine	--	37	67	75	54	60	40	53	40	30	19	7	2	--	--	--	484
Yellow-poplar	--	7	11	12	10	12	12	14	2	--	2	--	--	--	--	--	82
Black cherry	--	2	5	14	6	7	2	--	2	--	--	--	--	--	--	--	38
White oaks†	--	5	14	3	2	--	2	--	--	--	--	--	--	--	--	--	26
Red oaks‡	--	5	3	2	--	--	--	--	--	--	--	--	--	--	--	--	10
Hickories	--	2	2	--	--	--	--	--	--	--	--	--	--	--	--	--	4
Other hardwoods†	--	63	67	7	5	--	4	--	--	--	--	--	--	--	--	--	146
Total	--	121	169	113	77	79	60	67	44	30	21	7	2	--	--	--	790
Age 30																	
Eastern white pine	4	35	56	56	40	51	39	47	37	37	28	24	7	2	2	--	465
Yellow-poplar	2	2	9	12	5	5	12	9	14	2	--	2	--	--	--	--	74
Black cherry	--	2	3	9	9	7	2	2	--	--	2	--	--	--	--	--	36
White oaks†	--	2	7	4	2	--	2	--	--	--	--	--	--	--	--	--	17
Red oaks‡	2	--	4	--	--	--	--	--	--	--	--	--	--	--	--	--	6
Hickories	4	4	2	--	--	--	--	--	--	--	--	--	--	--	--	--	10
Other hardwoods**	46	69	50	20	6	2	--	--	--	--	--	--	--	--	--	--	193
Total	58	114	127	105	62	65	55	58	51	39	30	26	7	2	2	--	801
Age 34																	
Eastern white pine	3	19	28	49	35	53	28	37	39	25	40	25	25	7	3	2	418
Yellow-poplar	--	--	4	5	5	--	5	9	7	14	7	--	--	--	--	--	56
Black cherry	--	--	2	5	9	3	7	--	--	2	--	2	--	--	--	--	30
Oaks††	--	--	--	3	2	--	--	2	--	--	--	--	--	--	--	--	7
Other hardwoods‡‡	21	67	42	21	5	3	2	--	--	--	--	--	--	--	--	--	161
Total	24	86	76	83	56	59	42	48	46	41	47	27	25	7	3	2	672

*No trees of that particular species found in that diameter class.
†White oak and chestnut oak.
‡Scarlet oak and black oak.
§Mostly sassafras; some red maple, sourwood, flowering dogwood, blackgum, red mulberry, and sumac.
**Mostly sassafras, red maple, and blackgum; some flowering dogwood and sourwood.
††Chestnut oak and scarlet oak.
‡‡Sassafras, red maple, blackgum, flowering dogwood, sourwood, and black locust.

Table 3.— *Number of merchantable trees in a direct-seeded eastern white pine plantation on the Mid-Cumberland Plateau near Sewanee, TN, at four ages by threshold diameter and age*

	Threshold diameter (inches)						
Age	≥3.6	≥4.6	≥5.6	≥6.6	≥7.6	≥8.6	≥9.6
Years	*No. trees per acre*						
15	282	162	74	26	4	--*	--
25	380	305	251	191	151	98	58
30	370	314	274	223	184	137	100
34	368	319	284	231	203	166	127

*No trees found in this diameter.

to extend into the eastern white pine canopy was estimated to be 700 ft^3/acre.

DISCUSSION AND CONCLUSIONS

Site index of eastern white pine was 56 at ages 15 and 25 but increased to 58 and 63 at ages 30 and 34, respectively. Evidently, height growth of this unthinned, direct-seeded plantation on the Mid-Cumberland Plateau exceeded that of unthinned plantations in the Southern Appalachians originating from bare-rooted seedlings.

The plantation must be considered fully stocked (194 ft^2/acre) when both pines (157 ft^2) and hardwoods (37 ft^2) are included. The distribution of the surviving direct-seeded pines was not as uniform as if planted. Twenty-five square feet of hardwood basal area was contributed by just 23 percent of the trees—those that were codominant with the eastern white pines. These hardwoods became established early and had matched the pines in height growth. Most of these codominant hardwoods were desirable species—yellow-poplar and black cherry. In the future, only the larger hardwoods (poplar, cherry, maple, and oaks) will remain a dominant part of this eastern white pine plantation. The subordinate hardwoods will struggle to survive in the shade of the main canopy.

This direct-seeded plantation has not produced the cubic volume that planted plantations in the Southern Appalachians have produced. Using Vimmerstedt's (1962) model, appropriate ages, site indices, and a planting density of 1,650 trees per acre, predicted stand volumes (outside bark to a 3.0-inch top o.b., trees ≥3.6 inches in d.b.h.) were 1,707, 4,543, 5,989, and 8,004 ft^3 per acre at ages 15, 25, 30, and 34, respectively. Actual measured volumes were 596, 2,807, 4,078, and 5,229 ft^3/acre at those ages. The difference between the predicted and actual volumes increased with age and was accentuated by the increase in site index in the last quinquennium. Total stand volume (pines and codominant hardwoods) at age 34 was about 6,000 ft^3/acre or about 75 percent of the estimated yield of eastern white pine plantations in the Southern Appalachians. A possible reason for the reduced production of this study plantation is the inherently low fertility of the residual plateau soils compared to the generally more fertile soils of the Southern Appalachians.

The direct-seeded plantation has not grown as well as a planted plantation on the property of the University of the South (Smith and Baird 1979; good plot No. 3, unthinned). The planted plantation was established on an old field site that is also classified as Landtype 1 (Smalley 1982). The old field was part of a subsistence farm abandoned in 1948. The plantation was established in 1952 at a spacing of 6 by 6 ft using 2–0 stock grown from seeds collected in western North Carolina. At plantation age 27, there were 495 trees per acre (41-percent survival); mean quadratic diameter was 8.4 inches, basal area was 190 ft^2/acre, and stand volume (outside bark to a 3.0-inch top o.b., trees ≥3.6 inches in d.b.h.) was 4,600 ft^3/acre. By comparison, a comparable plantation in the Southern Appalachians is predicted to have a merchantable stand volume of 7,353 ft^3/acre. Very few hardwoods had invaded this plantation. Based on an average height of dominants and codominants of 72 ft, site index was calculated to be 65 (Vimmerstedt 1962). The better growth of this planted plantation established on an old field site compared to the direct-seeded plantation established on a converted site may be due to residual fertility from fertilizing the corn and soybean crops.

At age 34, site index of the direct-seeded plantation was 11 ft taller than the estimated value of 52 for Landtype 1 (Smalley 1982). Site indices of unthinned and thinned plantations on a similar site ranged from 60 to 65 (Smith and Baird 1979). Based on these observations, it is recommended that the site index (base age 25 from seed) of plantations of eastern white pine on Landtype 1 of the Mid-Cumberland Plateau be increased to 60. An increase in the estimated site index of 75 for natural stands of eastern white pine may be warranted but needs to be substantiated.

No final answer on the choice of direct-seeding vs. bare-rooted stock for establishing a plantation can be made from this single test. However, these data deserve close study because they show in detail the relative gains and losses in the numbers of trees and in the growth and yield of a plantation established by direct seeding following inexpensive site preparation. Eastern white pine shows considerable promise as an alternative to mixed

oak (Schnur 1937), loblolly pine (Smalley and Bailey 1974a), shortleaf pine (Smalley and Bailey 1974b), or Virginia pine (Smalley 1985) on Landtype 1 (broad undulating sandstone uplands) and probably other landtypes of the Mid- and Northern Cumberland Plateau regions (Smalley 1982, 1986). However, if sawlogs are the goal of management, then persistent dead limbs will have to be pruned to produce clear lumber. Seeding or planting eastern white pine on the Southern Cumberland Plateau (Smalley 1979) should be approached cautiously.

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