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Structure and Productivity of an Eastern White Pine Plantation on Two Mid-Cumberland Plateau Landtypes at Ages 33 and 44

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Abstract

We examined the growth of an eastern white pine (*Pinus strobus,* L) (EWP) plantation established in 1964 at 6- by 6-foot spacing on an abandoned pasture. Our study was located about 30 miles south of the botanical range of EWP on the mid-Cumberland Plateau in south-central Tennessee (35º13' N; 85º56' W). It extended across two landtypes (LT) (LT-1, undulating sandstone uplands and LT-5, north-facing sandstone slopes) with similar site indexes. Stand characteristics (survival, quadratic mean diameter, mean total height, site index, cubic and board foot volumes) at ages 33 and 44 were compared with those from an earlier measurement at age 15. Measured cubic volumes were compared with predicted values from two growth and yield models developed for EWP plantations in the Southern Appalachian Mountains of North Carolina. At age 44, stand characteristics were similar between the two LTs and were in close agreement with model predictions. Results of this long-term, unreplicated study suggest that EWP may be a species for consideration by private landowners when converting medium-quality upland sites populated with low-value hardwoods to faster growing conifers on the mid-Cumberland Plateau.

Keywords: Growth and yield, mid-Cumberland Plateau, site index, species conversion.

INTRODUCTION

Forests of the 16-county area of the Tennessee Cumberland Plateau region occupy 3.1 million acres and are primarily (72 percent) in private ownership (Oswalt and others 2012). Although 86 percent of Cumberland Plateau timberlands are in the upland hardwood management type, about one-third of that type is poorly stocked or nonstocked with a timber stand capable of achieving the potential productivity of the sites (Oswalt and others 2012). On forest sites of lower quality, such as ridges and southerly facing slopes, McGee (1980) and Hopper and others (1995) suggest maintaining a canopy of pines to increase productivity of merchantable products. Kaetzel and others (2009) reported that nonindustrial private forest landowners take advantage of conservation assistance programs to increase productivity of merchantable products in understocked forest lands on the Cumberland Plateau. Compared with other native conifers including loblolly pine (*Pinus taeda,* L), shortleaf pine (*P. echinata* Miller), and Virginia pine (*P. virginiana* Miller), EWP is a minor species in forests of the plateau (Oswalt and others 2012), but it is well suited for management on many low-quality sites (McGee 1980). Clatterbuck and Ganus (2000) developed a guide with financial analysis for landowners considering management of EWP on sites of marginal quality for hardwoods on the Cumberland Plateau and elsewhere in Tennessee. However, little information is available for landowners to evaluate potential productivity of planted stands of EWP with other species and management options on the Cumberland Plateau.

Vimmerstedt (1962) and Hepp and others (2015) present information on growth and yield of EWP plantations in the Southern Appalachian Mountains, but the applicability of their relationships for the mid-Cumberland Plateau is unknown (Smalley 1982). The main objective of this study was to utilize new data from a long-term study (Smith and Baird 1979) to compare the stand structure and productivity at two ages of an EWP plantation that extended across two landtypes. A secondary objective was to compare the measured stand parameters of the plantation with the predicted values using Vimmerstedt (1962) and Hepp and others (2015).

STUDY SITE

The plantation is 2.49 acres on former farmland at the University of the South, Sewanee, TN (35º13' N; 85º56' W). Elevation is 1,900 feet. Geographically, the plantation is about 30 miles south of the botanical range of EWP on the Cumberland Plateau (fig. 1). The study area had been in pasture for at least 25 years before it was planted at a 6- by 6-foot spacing with 2-0 seedlings in the spring of 1964. Records indicate that EWP seedlings from a western North Carolina source were utilized (Smith and Baird 1979). There was little or no site preparation prior to planting. Approximately 110 potential crop trees per acre were pruned to the base of the live crown after the 11th growing season, and grape vines (*Vitus* sp.) were controlled. At age 13, the plantation was free thinned (i.e., the cutting of trees to control stand spacing and favor desired trees). The number and volume of trees cut to thin the stand are unknown. Stand characteristics at plantation age 15 were reported by Smith and Baird (1979, see table 3). Gaps, which developed in the canopy from early mortality, are occupied by hardwoods.

The forest floor is covered with pine needles and dead branches and devoid of all herbaceous plants except scattered spotted wintergreen [*Chimaphila maculata* (L.) Pursh]. Since 1997, Nepalese browntop [*Microstegium vimineum* (Trin.) A. Camas], an exotic, shade-tolerant, Asian, C4 grass (Miller 2003), has become established in the adjacent plantations. It crept into four to six rows of the west side of the plantation in which our study was located, but the dense shade from the EWP crowns seems to be limiting its spread within the measurement area.

METHODS

Two large plots were defined and surveyed in the subject plantation (fig. 1). One plot (LT-1, 1.107 acres) was on undulating sandstone upland (Smalley 1982). The second plot (LT-5, 0.741 acre) was on a north-facing sandstone slope with a gradient of 11 percent (Smalley 1982). The plots share a common boundary which separates the two landtypes. Soil series are Lily and Lonewood (fine-loamy, mixed, semi-acid, mesic Typic Hapludults). Lily soils are moderately deep, and Lonewood soils are deep (> 40 inches) to sandstone parent material. Lonewood soils are more common on LT-1, while Lily soils are more common on LT-5 (Soil Survey Staff 2008).

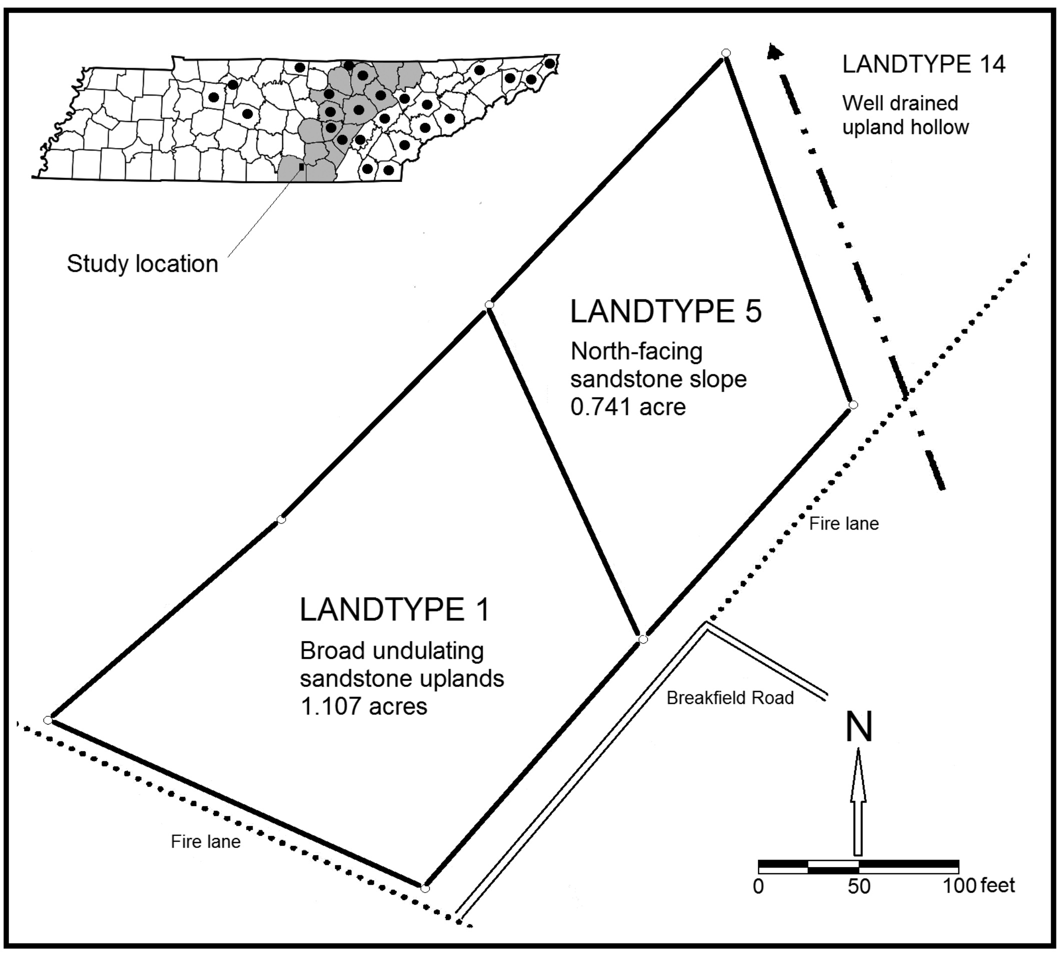

Figure 1—The study site is an old-field planting of eastern white pines that extends across two landtypes: broad undulating sandstone uplands (LT-1) and north-facing sandstone slopes (LT-5). The inset map of Tennessee shows the study location in Franklin County; counties with gray shading delineate the Cumberland Plateau region (Schweitzer 2000), and counties with a black dot indicate the natural occurrence of eastern white pine (Little 1971). The northeast side of LT-5 borders on a well-drained upland hollow (LT-14), which occurs as a narrow strip along an intermittent drainage, indicated by the dashed and dotted line.

At ages 33 and 44, we tallied diameter at breast height (d.b.h.) of all living pines. We also measured total height on 10 percent of the pines in each 1-inch d.b.h. class. Each of these measured pines was assigned a crown class and the height to live crown was determined. We recorded species and d.b.h. for all hardwoods. Summary data for each LT include number, percent survival, basal area, quadratic mean diameter (QMD), mean height of dominants and codominants, and live crown ratio of the pines; species, basal area, and QMD of the hardwoods. Site index was based on relationships developed by Vimmerstedt (1962) and Hepp and others (2015). To determine the yield of the pines, cubic foot volume outside bark (o.b.), to a 3.0-inch top o.b. (Vimmerstedt 1962) was calculated for all sample trees ≥ 3.6 inches d.b.h. and the volumes summed. A volume/basal area ratio of sample trees was multiplied by the basal area of each LT and reported on a per-acre basis.

We compared measured basal area with predictions using growth and yield tables for EWP that were developed for the Southern Appalachian region by Hepp and others (2015). Our volume results were then compared to Vimmerstedt's (1962) and Hepp and others' (2015) predicted values. Board-foot volumes calculated using Vimmerstedt's (1962) board foot per cubic foot ratio produced spurious values. We estimated saw-log production using Hepp and others' (2015) predictive model; their predictive models for basal area, cubic volume, and board-foot volume were developed using whole stand model procedures as opposed to the Weibull distribution model employed by Smalley and Bailey (1974a, 1974b) for loblolly pine and shortleaf pine old-field plantations. Hepp and others (2015) used Vimmerstedt's EWP data set. Vimmerstedt's (1962) site index and yield regressions were based on age from seed. Hepp and others (2015) used plantation age in their models. Unless otherwise noted, all data are reported on a per-acre basis. All references to age are plantation age, except as noted. No volumes were calculated for the hardwoods.

RESULTS AND DISCUSSION

Survival

Following the 1977 thinning at age 13, survival of the entire plantation was 21 percent, or 250 EWP per acre of the initial stocking of about 1200 EWP per acre (Smith and Baird 1979). At age 33, stocking was 20 percent (238 pines) on LT-1 and 25 percent (306 pines) on LT-5. At age 44, stocking was 16 percent (200 pines) on LT-1 and 17 percent (206 pines) on LT-5 (table 1).

Quadratic Mean Diameter and Diameter Distributions

Following the thinning in 1977, QMD of the entire plantation was 8.2 inches (Smith and Baird 1979). At age 33, QMD was 12.2 and 11.3 inches on LTs 1 and 5, respectively (table 1). These values indicate a substantial growth in the 18-year interval since thinning. Individual diameters ranged from 5 to 18 inches at age 33. At age 44, QMD was 14.0 and 13.3 inches on LTs 1 and 5, respectively. Individual diameters ranged from 6 to 20 inches at age 44. At ages 33 and 44, diameter distributions for both LTs resemble normal distributions, typical of even-aged stands (figs. 2 and 3). Eighty-three percent of the pines on LT-1 and 71 percent on LT-5 were sawlog-size (≥ 10-inch class) at age 33. At age 44, these respective percentages were 96 and 91.

Basal Area

Basal area (BA) of the plantation averaged 93 square feet after thinning at age 15 (Smith and Baird 1979). At age 33, BA was 194 square feet on LT-1 and 213 square feet on LT-5 (table 1). At age 44, BA was 213 square feet on LT-1 and 200 square feet on LT-5. Predicted BA (Hepp and others 2015) at age 33 were 171 square feet and 182 square feet and at age 44 were 183 square feet and 189 square feet for LT-1 and LT-5, respectively. All predicted BA values were less than measured.

Live Crown Ratio

Live crown ratios were nearly the same on both LTs at age 33 (table 1). Eleven years later, live crown ratios averaged only about one-fourth of total tree height. The crop trees that had been pruned to the base of the live crown averaged at least a clear 16-foot log.

Height and Site Index

Mean height of dominant and codominant trees at age 15, following thinning, averaged 41 feet, corresponding to a site index of 58 (base age 25 years from seed). Note that the reported value of 62 feet by Smith and Baird (1979) was not comparable. At age 33, mean heights were essentially the same for both LTs: 70 feet on LT-1 and 71 feet on LT-5. These heights translate to respective site indices of 57 and 58 (base age 25 from seed). Mean annual height growth from age 15 to 33 was 1.67 feet. At age 44, mean height was slightly different: 82 feet on LT-1 and 85 feet on LT-5. These heights translate to respective site indices of 59 and 61 (base age 25 from seed). Mean annual height growth from age 33 to 44 was about 1 foot. Site indices based on plantation age (Hepp and others 2015) were 2 feet taller than those based on total age (Vimmerstedt 1962).

Table 1—Characteristics of an eastern white pine plantation on mid-Cumberland Plateau landtype 1 and landtype 5 at ages 33 and 44 years near Sewanee, Franklin County, Tennessee

	Landtype 1[a]		Landtype 5[a]	
Site and stand characteristic	**33 years**	**44 years**	**33 years**	**44 years**
Number of trees per acre				
Eastern white pines	238	200	306	206
Hardwoods	9	9	20	18
Survival–based on trees planted (*percent*)	20	16	25	17
Quadratic mean diameter (*inches*)				
Eastern white pines	12.2	14.0	11.3	13.3
Hardwoods	11.7	13.8	11.5	14.0
Basal area (*square feet per acre*)				
Measured–eastern white pines	194	213	213	200
Measured–hardwoods	7	9	14	19
Predicted–eastern white pines (Hepp and others 2015)	171	183	182	189
Live crown ratio (*percent*)	39	22	38	26
Average total height of dominants and codominants (*feet*)	70	82	71	85
Site index–base age 25 (*feet*)[b]				
Age from seed (Vimmerstedt 1962)	57	59	58	61
Plantation age (Hepp and others 2015)	59	60	60	62
Calculated volume trees ≥ 4.6 inches d.b.h. to 3-inch top o.b. (*cubic feet per acre*)				
Vimmerstedt (1962)	6,401	8,220	7,272	8,256
Predicted volume trees ≥ 4.6 inches d.b.h. to 3-inch top o.b. (*cubic feet per acre*)				
Vimmerstedt (1962)	6,324	8,085	6,584	8,724
Hepp and others (2015)	5,900	6,864	6,298	7,320
Predicted volume trees ≥ 6.0 inch top i.b. (*board feet per acre*)[c]				
Hepp and others (2015)	35,645	42,148	35,595	46,348

[a] Area of study sites: landtype 1=1.107 acres; landtype 5=0.741 acre.

[b] Site index (base age 50) may be estimated by multiplying site index (base age 25) by 1.4335 (Vimmerstedt 1962).

[c] International 1/4-inch rule.

o.b. = outside bark; i.b. = inside bark.

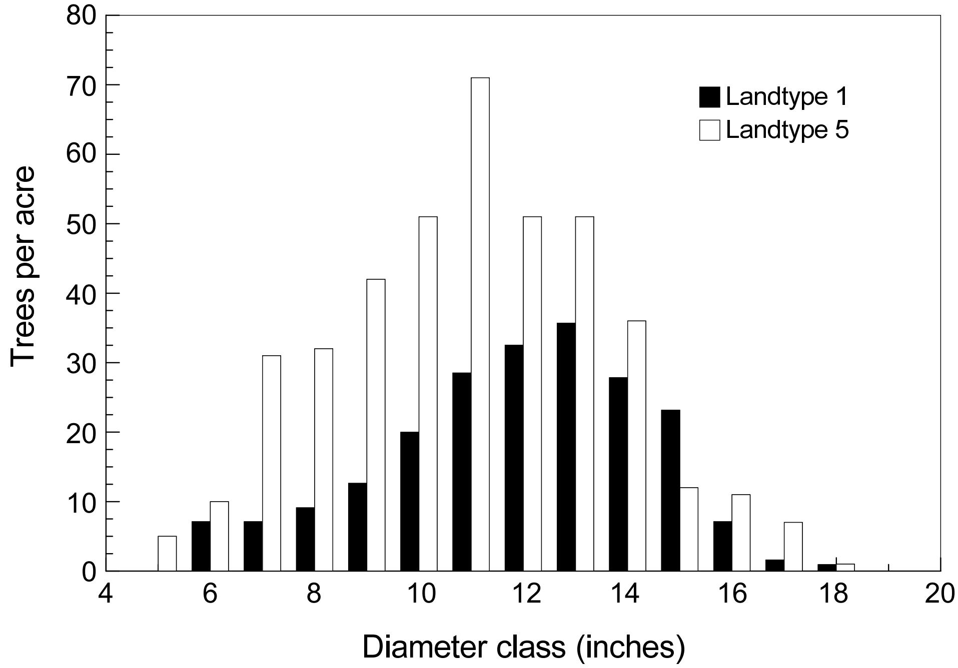

Figure 2—Diameter distributions of an old-field eastern white pine plantation on the Cumberland Plateau near Sewanee, TN, at plantation age 33 on landtype 1 (undulating sandstone uplands) and landtype 5 (north-facing sandstone slopes).

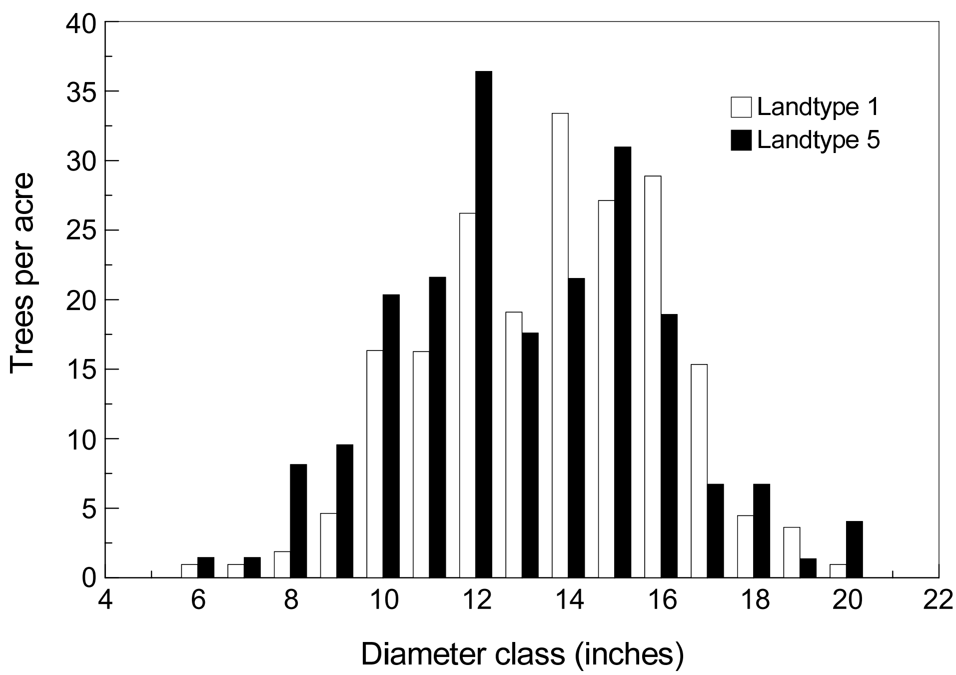

Figure 3—Diameter distributions of an old-field eastern white pine plantation on the Cumberland Plateau near Sewanee, TN, at plantation age 44 on landtype 1 (undulating sandstone uplands) and landtype 5 (north-facing sandstone slopes).

Cubic Foot Volume

Following thinning, cubic volume of the plantation at age 15 averaged 2,300 cubic feet (Smith and Baird 1979), equal to a mean annual increment of 153 cubic feet. By age 33, volume had increased to 6,401 cubic feet on LT-1 and to 7,272 cubic feet on LT-5 (table 1) representing periodic annual growth rates in excess of 225 cubic feet. At age 44, volume was 8,220 cubic feet on LT-1 and 8,256 cubic feet on LT-5. As expected, both Vimmerstedt's (1962) and Hepp and others' (2015) predicted volumes for both LTs were similar because the only variable affecting their calculation was site index, which differed by 2 feet or less between sites. Hepp and others' (2015) predicted values were less than the measured values. The differences in both calculated and predicted cubic volumes between LTs is attributed to the better survival on LT-5 compared to LT-1.

Board Foot Volume

At age 33, Hepp and others' (2015) regression predicted nearly equal board-foot volumes: 35,645 board feet per acre on LT-1 and 35,595 on LT-5 (table 1). At age 44, predicted board-foot volumes were 42,148 board feet per acre on LT-1 and 46,348 on LT-5. The slightly greater number of trees and higher site index explains the approximately 4,000 board-foot advantage of LT-5 over LT-1.

Hardwoods

At age 33, there were nine hardwood trees with a QMD of 11.7 inches on LT-1 and 20 trees with a QMD of 11.5 inches on LT-5 (table 1). Comparable basal areas were 7 and 14 square feet, respectively. At age 44, there were nine trees with a QMD of 13.8 inches on LT-1 and 18 trees with a QMD of 14.0 inches on LT-5 (table 1). Comparable basal areas were 9 and 19 square feet, respectively. Black cherry (*Prunus serotina* Ehrh.) was most prevalent. Other species were red maple (*Acer rubrum* L.), hickories (*Carya* spp.), hackberry (*Celtis occidentalis* L.), black oak (*Quercus velutina* Lam.), southern red oak (*Quercus falcata* Michaux), and white oak (*Q. alba* L.). Hardwoods probably exerted significant competition as nearly all of the hardwood crowns extended into the pine canopy. A cluster of large cherry trees in LT-5 near the common LT boundary contributed to considerable pine mortality.

SUMMARY AND RECOMMENDATIONS

These data, although from an unreplicated study, deserve close examination because they show in detail the stand development, growth, and yield of an EWP plantation on sites commonly found on the Cumberland Plateau. There was essentially no difference in the productivity of these two LTs as measured by site index and cubic-foot volume, although the predicted saw-log volumes show an approximate 4,000 board feet per acre advantage of LT-5 over LT-1. Soils on both LTs provide ample soil moisture storage and rooting volume to support a potential maximum stand BA of about 220 square feet per acre of EWP and hardwoods. Separation of north-facing slopes (LT-5) from undulating uplands (LT-1) is predicated mostly on management restrictions caused by the sloping terrain. Site index for old-field EWP plantations on LT-1 and LT-5 had previously been estimated at 52 feet (plantation age 25) (Smalley 1982); it will now be tentatively revised to 60 feet based on results of this study.

It is important to note that productivity of this plantation is likely less than what could be expected from a EWP plantation established with minimal site preparation on a former pasture. The cubic-foot and board footage production of this plantation certainly would have been higher had the competing hardwoods been controlled and thinned with regards to growth reallocation to desirable EWP. Recall that the volume of trees removed by free thinning at age 15 is unknown.

Eastern white pine appears to have commercial potential as a plantation species on the Cumberland Plateau south of its current botanical range. A predicted mean annual growth around 1,000 board feet per acre at age 44 is impressive. EWP resists ice damage relatively well (Burton and Gwinner 1960). White pine blister rust (*Cronartium ribicola* Fischer), white pine weevil (*Poissoides strobi* Peck), and pales weevil (*Hylobius pales* Herbst) are not serious threats in this area. EWP is an added option to loblolly pine (Smalley and Bailey 1974a) and shortleaf pine (Smalley and Bailey 1974b) to reforest abandoned agriculture land on LTs-1 and 5 and probably other LTs on the mid-Cumberland Plateau (Smalley 1982).

Also, EWP is a species option along with loblolly, shortleaf, and Virginia pines to convert medium-quality upland Plateau sites occupied with cut-over stands of low-value hardwoods to faster growing conifers (Kuers 2007, McGee 1986, Smalley 1985). EWP regeneration will normally require additional release from competing hardwoods to ensure full stocking because of its early slow height growth (McGee 1982). Although, EWP has been successfully seeded (Smalley and Hollingsworth 1997), this method of regeneration requires excessive amounts of seed and is inconsistent compared to planting seedlings. If quality saw logs are desired, thinning and pruning should be considered (Smith and Seymour 1986).

Results from our unreplicated long-term study supplement the small amount of information available on other EWP plantings in central Tennessee. Based on 30-year data of a species-spacing test, EWP along with loblolly pine was recommended for planting on LT-12, broad silty uplands (Smalley 1982), and in the "barrens" of the eastern Highland Rim (Schubert and others 2004). This test was located about 14 miles west-northwest of our study at an elevation of 1,010 feet and about 30 miles south of the natural range in Tennessee (Little 1971). Also, several EWP plantings were established by the Civilian Conservation Corps during the 1930s and on the Bankhead National Forest during the 1950s, in northwest Alabama, but results from these sites have not been reported. These plantations are on the southern end of the Cumberland Plateau at about the same latitude as the southern extent of the natural range in the Southern Appalachian Mountains of northern Georgia, but 125–150 miles farther west (Little 1971). Planting EWP on the southern Cumberland Plateau (Smalley 1979) should be approached cautiously until additional information is available to assess the long-term survival and growth of the species on a range of sites beyond its natural range.

Elsewhere in Tennessee, EWP outgrew shortleaf pine and yellow-poplar (*Liriodendron tulipifera* L.) in plantings on abandoned fields that were in various stages of soil erosion and reduced fertility following cultivation (Hohanshelt 1985). These plantings, at 6- by 6-feet spacing, were located on the Central Peninsula between the Clinch and Powell Rivers (Norris Lake) in the Ridge and Valley physiographic province (36º13' N; 83º55' W). Soils were derived from limestone, dolomite, and shale. Average merchantable volumes of these unthinned EWP plantations at ages 30 and 46 were 6,084 and 10,091 cubic feet, respectively, which compare favorably with our results (table 1).

In closing, we quote Smith and Baird (1979): "The exigencies of time and fortune, it would seem, leave only compound interest and fire to contend with to date. But aren't these risks common to any long-term crop?"

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We examined the growth of an eastern white pine (*Pinus strobus,* L) (EWP) plantation established in 1964 at 6- by 6-foot spacing on an abandoned pasture. Our study was located about 30 miles south of the botanical range of EWP on the mid-Cumberland Plateau in south-central Tennessee (35º13' N; 85º56' W). It extended across two landtypes (LT) (LT-1, undulating sandstone uplands and LT-5, north-facing sandstone slopes) with similar site indexes. Stand characteristics (survival, quadratic mean diameter, mean total height, site index, cubic and board foot volumes) at ages 33 and 44 were compared with those from an earlier measurement at age 15. Measured cubic volumes were compared with predicted values from two growth and yield models developed for EWP plantations in the Southern Appalachian Mountains of North Carolina. At age 44, stand characteristics were similar between the two LTs and were in close agreement with model predictions. Results of this long-term, unreplicated study suggest that EWP may be a species for consideration by private landowners when converting medium-quality upland sites populated with low-value hardwoods to faster growing conifers on the mid-Cumberland Plateau.

Keywords: Growth and yield, mid-Cumberland Plateau, site index, species conversion.

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