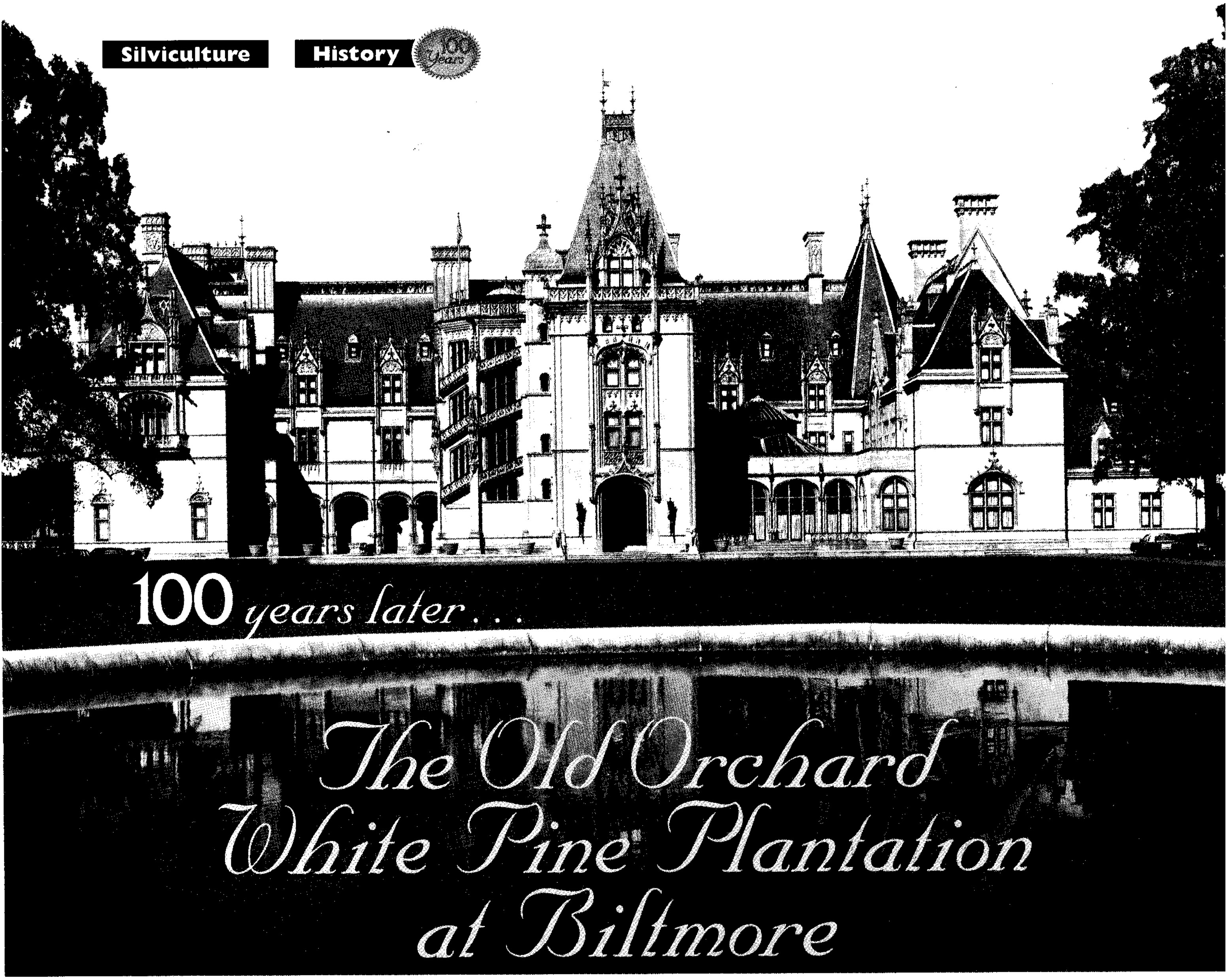

100 years later . . . The Old Orchard White Pine Plantation at Biltmore

A pioneering case study in the Old Orchard Plantation on Biltmore Estate near Asheville, North Carolina, considered current yields and the effects of periodic thinning on height and basal area growth, as well as cubic volume and board-foot yields. Established in 1899, one of three plots of this eastern white pine stand was first thinned in 1916. Beyond providing growth-and-yield data, the Old Orchard Plantation demonstrates the value of maintaining permanent forest research plots for long-term ecological and silvicultural studies.

By W. Henry McNab and Brian A. Ritter

In the late 1880s, George Washington Vanderbilt began acquiring small subsistence farms and parcels of cutover woodlands in the North Carolina mountains, near Asheville. By 1890, when construction of his residence, a 250-room French Renaissance chateau, was under way, Vanderbilt's land holdings had increased to more than 7,000 acres (William Alexander, pers. commun.). Uncertain how to manage his estate, which he called Biltmore, he sought the advice of famed landscape architect Frederick Law Olmsted. Upon seeing the poor, hilly, and badly eroded lands at Biltmore, Olmsted came up with a suggestion for his client:

> Such land in Europe would be made a forest; partly, if it belonged to a gentleman of large means, as a hunting preserve for game, mainly with a view to crops of timber. That would be a suitable and dignified business for you to engage in. It would, in the long run, probably be a fair investment of capital and it would be of great value to the country to have a thoroughly well organized and systematically conducted attempt in forestry made on a large scale (Cecil 1992).

With Vanderbilt's approval, Olmsted devised a plan with written instructions for improving the existing woodlands and planting the old fields. Under Olmsted's direction the first plantings of 300 acres of mostly eastern white pine *(Pinus strobus)* were made in

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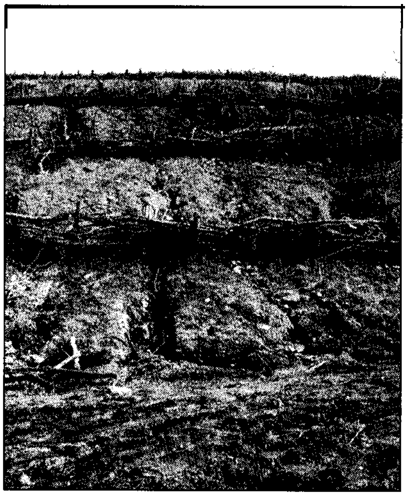
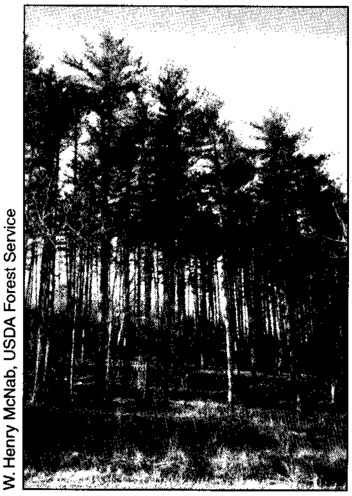


Courtesy of Bent Creek Experimental Forest Archives

E.H. Frothingham, USDA Forest Service



W. Henry McNab, USDA Forest Service

Above left: **The Old Orchard Plantation was an eroded hillside when 3,800 eastern white pine seedlings were hand planted in March 1899. *Center:* The thinning treatment began in fall 1916, when the Old Orchard Plantation was 18 years old and the trees were 22. Tree 460 (foreground), which was 3 inches dbh in 1916, was cut during the spring 1923 thinning, probably because it had not grown measurably in diameter. *Right:* The Old Orchard Plantation saw its eighth thinning in April 1999, at age 100.**

1890 by an Illinois nursery company (Frothingham 1941). Forestry operations at Biltmore advanced significantly with the hiring of Gifford Pinchot in 1892 and continued with his successor, Carl Alvin Schenck, from 1895 to 1909. Between 1892 and 1912, Pinchot, Schenck, and C.D. Beadle, Biltmore Estate's superintendent, in turn evaluated their successes and failures of seeding and planting almost 3,000 acres with 40 species of native and exotic pines and hardwoods (Haasis 1930). Eastern white pine was the primary pine species planted (Haasis 1930), probably because seedlings could be established with good survival, the species was tolerant of shade and responded to release, it had few insect and disease problems, its growth was unequaled on a range of site qualities, and mature trees had exceptionally good form and value.

The trees had been planted at close spacing almost throughout to ensure regeneration success on the low-quality sites; and it soon became evident that thinning the dense young stands was desirable to maintain satisfactory growth (Haasis 1930). In 1916 personnel from the Appalachian Forest Experiment Station (now the Southern Research Station) and Biltmore Estate began several thinning studies in three of the plantations, of which the Old Orchard Plantation is the only surviving site. The Old Orchard Plantation has been the source of periodic reports of stand development following thinnings (Frothingham 1941, 1942; Stevenson 1946; Wahlenberg 1955; Della-Bianca 1970, 1981) and incidence of disease (Hepting and Downs 1944). In March 1999 it was 100 years old.

Stand Establishment

The 5.6-acre Old Orchard Plantation was established in March 1899 in an abandoned pasture on a relatively steep, north-facing hillside with deep but severely eroded clay-loam soils. Plantation soils are Hayesville loam, a series consisting of well-drained, moderately permeable, gently sloping to moderately steep soils that formed in residuum from rocks such as gneiss and schist. About 3,800 three- and four-year-old seedlings were planted per acre in spade-dug holes (Frothingham 1941). The trees came from nurseries in Germany and the Biltmore Estate; the seed source is unknown, but according to Schenck (Haasis 1924), there were likely two sources, one local, as indicated by foliage coloration differences.

In fall 1916, when the trees were aged 22 years from seed and the plantation was 18 years old, a study was begun to investigate the effect of stand density on growth-and-yield. Three contiguous plots were established in a strip 2.25 chains wide that extended 7 chains along the hillside contour at about midslope. A buffer zone 0.5-chain wide surrounded each plot. The central plot (0.25 acre) was thinned; the adjacent plots (each 0.125 acre) were not. All live trees were measured for diameter at breast height (dbh) on all plots before each periodic thinning.

Basal area was reduced eight times: in fall 1916 at plantation age 18, and in spring 1923, 1929, 1936, 1942, 1953, 1970, and 1999, at ages 24, 30, 37, 43, 54, 71, and 100 years, respectively. Initial and subsequent thinnings in the plot and buffer zone removed trees of slow growth and lower quality and achieved uniform spacing (Haasis 1930). Total basal area removed averaged 24 percent and ranged from 10 to 39 percent. Information presented by Della-Bianca (1981) was the source of data for the seven previous thinnings. Total heights of the same dominant and codominant trees were available for each periodic thinning after age 30 except for the thinning of 1970, when an inventory made in spring 1967, at plantation age 68, was substituted. The plots were also measured but not thinned in spring 1947 and spring 1975, at plantation ages 48 and 76 years, respectively.

Site Indexes

Site quality varies among and within the three study plots. Unbiased estimation of site quality is difficult be-

Table 1. Stand data for study plots in the Old Orchard Plantation, Biltmore Estate, spring 1999, at plantation-age 100 years.

Plot treatment	Site index (feet)	Total height[a] (feet)	Density (trees/acre)	Basal area (fee&acre)	Mean dbh (inches)
Thinned	71	124	88	209.5	20.9
Unthinned	75	122	188	271.8	17.2
Unthinned	56	107	280	252.6	12.9

[a]*Measured at plantation age 96 years (age from seed = 100 years) and extrapolated to plantation age 100.*

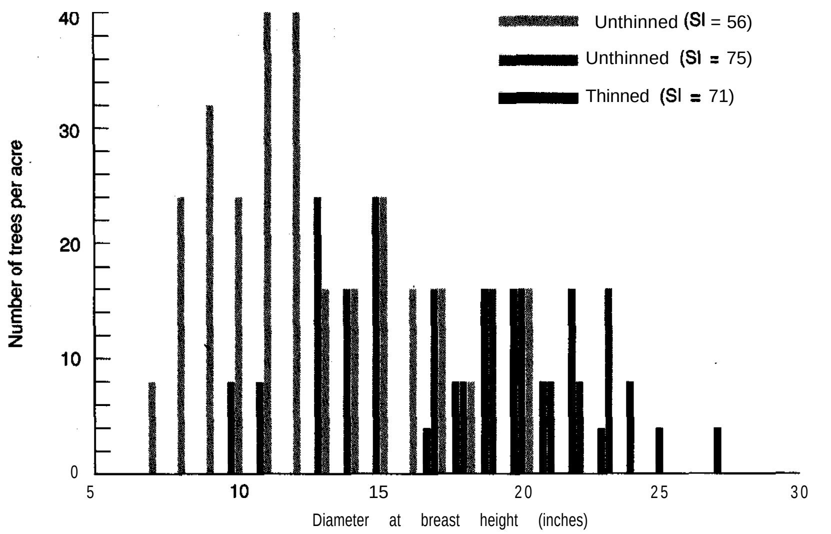


Figure I. **Diameter distributions of the total live tree stands on thinned and unthinned plots of varying site indexes (SI) in the Old Orchard Plantation at age 100.**

cause tree height is strongly associated with slope position (Della-Bianca 1970). Slope gradient averages 30 percent, and the tallest trees are on the lower third of the plots. Site index reported by Della-Bianca (1970) was used to facilitate comparison with previously reported results. Expressed as total tree height of the dominant stand at 50 years, site index averages 56 feet on an unthinned plot with convex surface shape and 75 feet on the other unthinned plot, which is slightly concave. The thinned plot, with a planar surface, has a site index of I-/l---about average for white pine elsewhere on Biltmore Estate. Della-Bianca (198 1) examined height growth on the two plots of similar site index and concluded there was little practical difference in site quality between them, which facilitated comparisons of stand development between the thinned and the unthinned silvicultural treatments.

Hereafter, each plot is identified by its site index (SI). Age references apply to the plantation, not the trees, which are assumed to be four years older.

The main disturbance during the past 100 years was construction of interstate 40. In spring 1965, at age 65, a small portion of the upper slope near the plantation's south-facing buffer zone was removed. In addition, the unthinned SI-75 plot may have been affected by reduction of the tree stand just beyond the outer buffer zone, perhaps altering the influence of wind and other environmental factors on the site. About half the trees cut during the 1999 thinning in the plot (three of seven) and in the buffer zone (nine of 14) showed evidence of heart rot in the stump, which was similar in characteristics to brown cubical butt rot *(Phaeolus scbweinitzii)* (Steven Oak, pers. commun.). The decay columns ranged from 3 to 6 inches in diameter on the stump surfaces and extended about 2 to 6 feet high into the trunks. Hepting and Downs (1944) noted the presence of this and two other fungi in the stand during the 1942 thinning, which had infected 62 percent of the cut trees. Lack of wind-thrown trees in the Old Orchard stand then and nowsuggests that the primary root systems were not infected.

Basal Area and Tree Height

Initial average tree density on the two unthinned plots has been reduced by natural mortality to 168 per acre on plot SI-75 and 280 per acre on plot SI-56 ***(table 1).*** No mortality has occurred from competition on the thinned plot since age 24. However, one 17.8-inch-dbh tree on the thinned plot was snapped just below the crown by wind in late summer 1998; it was cut and utilized during the thinning at age 100. Density of trees ≥ 20 inches dbh exceeded 40 per acre on both higher-quality plots *(fig. 1).* However, average stand dbh was larger on the thinned plot (20.9 inches) than on the unthinned SI-75 plot (17.2 inches).

The response of basal area growth to periodic thinning on plot SI-71 was relatively constant' from the third to seventh thinnings, averaging 4 square feet per acre annually *(fig.* 2). Between the seventh and eighth thinnings, however, periodic annual growth on this plot slowed to 2.9 square feet per acre. The reduced growth may be attributable to the combination of increasing stand age and incomplete utilization of site resources by fewer crop trees. Another contributing factor to the reduced basal area growth on the thinned plot likely resulted from increased competition of understory arborescent vegetation. Basal area of understory hardwoods > 1 inch dbh amounted to about 13.2 square feet per acre at the eighth thinning and consisted of about equal amounts of white ash ***(Fraxinus americana),*** yellow-poplar *(Liriodendron tulipifera),* and five other species. In addition, basal area of about 4 square feet per acre of white pine advance regeneration was present. Half the understory basal area was eliminated during logging. Understory vegetation was generally absent on the unthinned plots. Oriental bittersweet *(Celastrus orbiculatus),* an aggressive, woody, twining exotic vine, covers much of the herbaceous layer of the plot and will likely present serious problems to development of natural regeneration.

During the first half of the plantation's history, from 1899 to 1953, annual basal area increment averaged 3.6 square feet per. acre on plot SI-75, compared with 3.1 square feet per acre on plot SI-56. The situation reversed from 1954 to 1999, when mean annual increment was 1.8 square feet per acre on plot SI-56, compared with 1.6 square feet per acre on plot SI-75. Noteworthy is that between 1970 and 1975, periodic basal area growth slowed markedly on plot SI-75, allowing it to maintain an advantage of only about'7 square feet per acre over plot SI-56. The recent trend of decreasing periodic mean basal area increment on plot SI-56 suggests that it may be ap proaching the maximum I'evel of stocking sustainable on the site.

The trend in mean total stand height has been approximately linear on all plots since age 30 (*fig.* 3). In 1999, mean stand height on plot SI-75 was 122 feet, slightly less than on plot SI-7 1, where height averaged 124 feet. On these two plots, periodic mean annual height increment over the past 70 years has averaged about 1 foot, only slightly less than the mean annual growth of 1.2 feet since 1899. There is no indication of height growth culmination on any plot. However, periodic annual increments on plots SI-71 and SI-75 have decreased to about 0.7 foot during the past 24 years, slightly less than on plot SI-56, where height growth has averaged 1 foot. On plot SI-75, the effects of subtle environmental changes that might have resulted from highway construction in 1965 may be supposed but cannot be confirmed. Between spring 1967 and spring 1975, annual height growth averaged 1 foot on plot SI-75 but 1.7 feet on the other two plots.

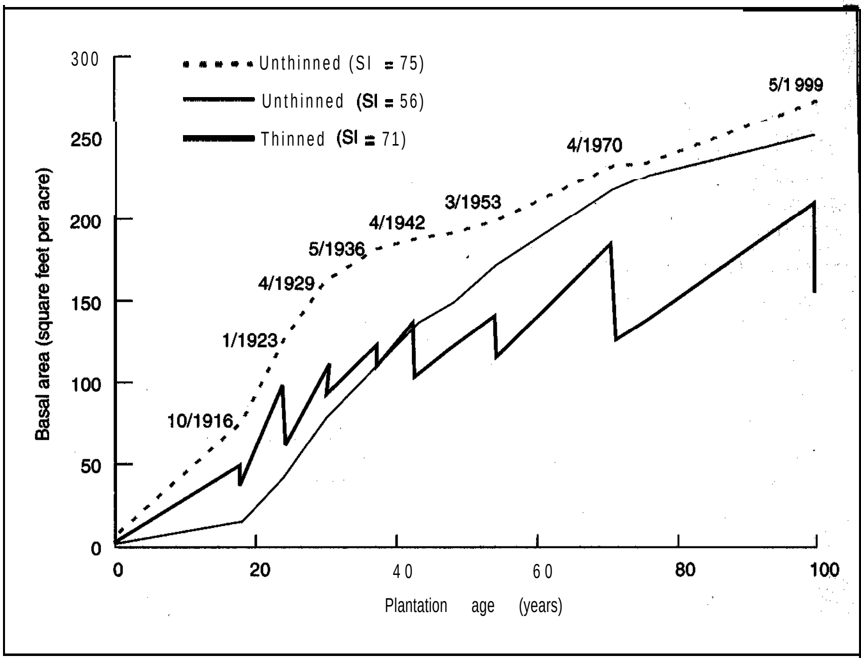


Figure 2. Periodic total basal area on thinned and unthinned plots of varying site indexes (SI) In the Old Orchard Plantation.The vertical dips show basal area removed during each of the eight thlnnlngs, which are identified by month and year.

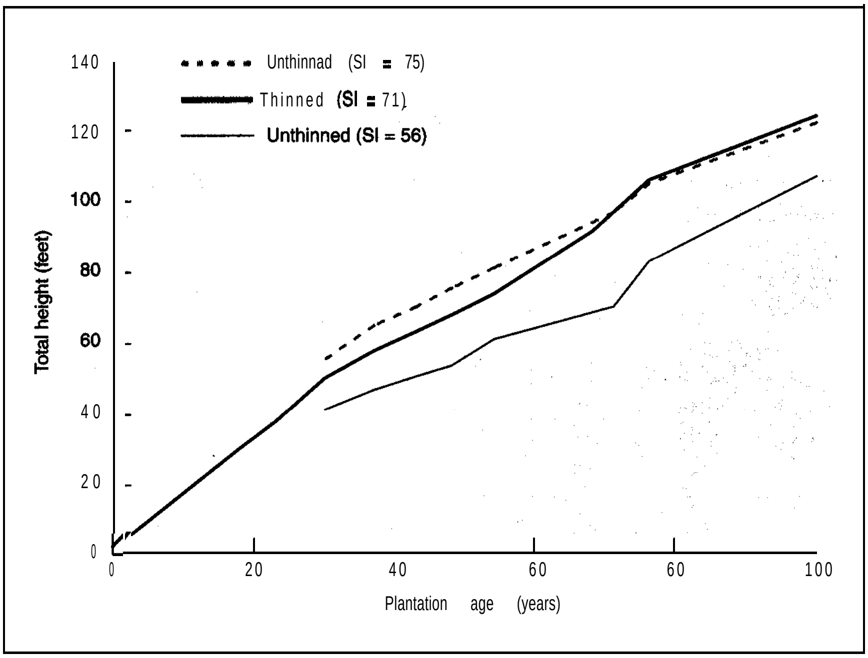


Figure 3. **Periodic mean total height of trees on thinned and unthinned plots of varying site indexes (SI) between ages 30 and 100 in the Old Orchard Plantation. At ages I8 and 23, height was measured on trees cut for thinning.**

Current Volume

Gross cubic volume (current standing volume plus previous thinnings and mortality) on the high-quality unthinned plot exceeded gross volume on the thinned plot by more than 3,500 cubic feet per acre (*table 2, p. 22*). Net cubic volume (gross volume less thinnings and mortality) was also greatest on the unthinned SI-75 plot. Surprisingly, net cubic volume of the low-quality unthinned SI-56 plot was only about 600 cubic feet per acre less than on the thinned, higher site index plot.

After 100 years, gross sawtimber board-foot volume was greater on the unthinned high-quality plot than on the thinned plot, but by less than 7,000 board feet per acre (*table* 2). The difference in net volume was much greater-more than 16,000 board feet. Annual yields averaged 973 board feet per acre

Table 2. Yields for study plots in the Old Orchard Plantation, Biltmore Estate, spring 1999, at plantation age 100 years.

Plot treatment	Site index (feet)	Net volume per acre[a]		Gross volume per acre[b]	
		Cubic feet[c]	Board feet[d]	Cubic feet[c]	Board feet[d]
Thinned[e]	71	17,924	76,067	24,514	90,598
Unthinned	75	22,609	92,552	28,070	97,301'
Unthinned	56	17,357	61,364	20,217	63,027

[a]Gross volume less all previous removals from thinning or mortality.
[b]Current standing volume plus all previous removals from thinning or mortality
[c]Cubic-foot volume of wood to a 4-inch top diameter inside bark for trees ≥ 5 inches dbh.
[d]Board-foot volume (international ¼-inch) to an 8-inch top diameter inside bark for trees ≥ 10 inches dbh.
[e]Mortality resulting from competition has not occurred in this plot.

on the unthinned, SI-75 plot and 906 board feet per acre on the thinned plot. This pattern of differences in yields between the thinned and the unthinned plots of similar site quality is consistent with that reported by Della-Bianca (1970) before the seventh thinning at 71 years in spring 1970.

Board-foot yields have been affected more by site quality than by thinning *(table 2)*. Net sawtimber yields on plots SI-71 and SI-7.5 differed by 16,500 board feet. However, the difference between the two unthinned plots of low and high site quality was 3 1,200 board feet. Gross board-foot volume differences were even larger.

Summary and Conclusions

Three conclusions are evident from evaluation of the Old Orchard Plantation at age 100:

- Total basal area has not culminated.
- Thinning has produced standing trees of larger dbh but has not increased cubic or sawtimber volumes.
- Wood production has been influenced more by site quality than by thinning.

Perhaps more important, the Old Orchard Plantation demonstrates the value of maintaining permanent forest research plots for long-term investigation into ecological and silvicultural relationships of arborescent species. Recent opportunities included investigating the influence of site factors on height growth (McNab and Ritter 1999) and testing site index equations (McNab et al. 2000).

Results from this case study are important not only for future management of forest stands at Biltmore but also for forest management throughout the southern Appalachians. Little information is available, about eastern white pine's response to thinning in the southern part of its range in the eastern United States. Results from the Old Orchard Plantation provide a check for experience-based decisions in this region and a comparison with selected findings from other regions.

Today, the largely forested landscape

of Biltmore Estate is considerably different than it was 100 years ago, when the Old Orchard Plantation was being established and American forestry was just beginning. Almost 1 million visitors annually make the estate a self-sustaining and profitable business. However, along with vineyards, a winery, livestock operations, and other agricultural enterprises, forestry continues to be an integral part of resource management on the estate. Eastern white pine remains an important species in #forestry operations on Biltmore's 5,000 acres of woodlands, although the better sites may be converted to all hardwoods or mixed species. The current management plan emphasizes goals of sustainable forest practices with a gradual shift from quantity production toward production of large, high-quality timber products that have been naturally or artificially pruned. Its certification for more than 50 years as a tree farm by the American Tree Farm System is evidence of the estate's long-term commitment to sound forest management practices-management based in large part on the pioneering efforts at Biltmore a century ago by Olmsted, Pinchot, Schenck, and Beadle.

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