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FOREST PLANTATIONS

AT BILTMORE, N.C.



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MISCELLANEOUS PUBLICATION NO. 61

Washington, D. C.

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FOREST PLANTATIONS AT BILTMORE, NORTH CAROLINA

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PIONEERING IN AMERICAN FOREST PLANTING

The forest plantations in the Biltmore Estate, near Biltmore and Asheville, N. C., represent one of the earliest large-scale reforestation projects under private initiative in this country. Planting and seed-sowing operations were begun there about 40 years ago, in 1890, and the work was continued until about 1911. The resulting stands present an excellent opportunity to study the success or failure of forest planting with a large number of species in this part of the southern Appalachian region. With the cooperation of the Biltmore Estate, the Appalachian Forest Experiment Station undertook, in 1921-22, a general study of the planted stands and of the more or less fragmentary historical records. The more general and outstanding results of this study are presented in this publication, together with a map and schedule of the planted stands which will serve as a guide to the plantations.¹ The ages and dimensions given apply to the trees at the time of the 1921-22 examination, except as otherwise indicated.

The Biltmore Estate is a tract of timber and farm land built up from many small holdings by George W. Vanderbilt, of New York, during the years 1890 to 1900. The present area is about 12,000 acres. It is located on the low hills and plateau land bordering the Swannanoa and French Broad Rivers, at elevations ranging from 2,000 to 2,300 feet above sea level. Its soils, derived chiefly from the disintegration in place of gneiss and schist, are generally stony loams, clay loams, or clay, with narrow strips of alluvial silt or sand in the

¹ The Forest Service wishes to acknowledge the courtesy of the Vanderbilt family and estate in granting the facilities and assistance that have made possible this study and the thinning experiments conducted on the estate since 1916.

stream bottoms. The average annual precipitation approximates that at Asheville, about 41 inches rather uniformly distributed throughout the year. This is less than is recorded in other parts of the southern Appalachian region, for rain-bearing winds lose some of their moisture in passing over the bordering mountains. Temperature extremes range from 96° to -6° F., the mean annual temperature being 55°; and the average frost-free period extends from the middle of April to the latter part of October. The wind, prevailing from the northwest, averages 8 miles an hour and rarely reaches a velocity of as much as 50 miles an hour. The sunshine received during the year is 57 per cent of the possible amount.

At the time of purchase most of the estate was covered with timber—a mixed growth of young and old trees, largely inferior in quality, the residuum of a long history of unregulated cutting and forest fire. The forest was mainly of such hardwoods as chestnut, oaks, hickories, and yellow poplar, with pines in lesser quantities—shortleaf, pitch, Virginia, and northern white. Near Biltmore house about 3,000 acres in the aggregate had been cleared, farmed, and then abandoned because of worn-out soil or serious gullying on the steep slopes.

The general purpose of the forestry work on the estate was to build up a forest combining utility and beauty. This program included the improvement of the native forest as well as the establishment of planted forest. The old, crippled, and otherwise inferior trees were removed from the native stands to favor the growth and reproduction of the better trees. The earlier planting, particularly that along the main roads, was largely in accordance with a plan for landscaping the estate. Later planting, however, was definitely directed toward the establishment of forest stands. Still later, when some of the plantations had reached an age of 18 or 20 years, experiments in thinning were started by the Forest Service on four groups of small sample plots; and these experiments are still under way. Otherwise, aside from a few earlier experiments on small areas, the pruning and thinning of some of the roadside plantings, the cutting of a few trees to combat bark-beetle attacks, and the removal of small trees for replanting elsewhere, the plantations have been left very much to themselves. Many of them would be in much better condition to-day if they had received an early thinning. Fire, however, has been almost entirely kept out of the plantations.

The first forest planting on the Biltmore Estate, in 1890, covered 300 acres and was done by an Illinois nursery company. The northern white pine,² which is native in the vicinity, was the species chiefly used. In 1895 a few plantations were added by Gifford Pinchot, then in charge of the forestry work on the estate. The greater part of the planting, however, was done under the direction of C. A. Schenck, who took over the work in 1895; from then until he left the estate in 1909, Doctor Schenck made annual plantings or sowings, using some 40 different tree species, about half of them conifers and half hardwoods. Between 1909 and 1912 some further planting was done by C. D. Beadle, superintendent of the estate, who put in several thousand Norway spruces. Of the plantings which have grown up

² Northern white pine (*Pinus strobus*) is the only species of white pine used in the Biltmore planting work and hereafter in this circular will be generally referred to simply as "white pine."

into successful stands, the majority are composed of white pine or short leaf pine.

If all this planting were summed up on the basis of area planted, the total might be as high as 3,000 acres, though this can never be more than a rough estimate because so few traces remain of the plantings that failed. Some early failures, inevitable because of the newness of the work in this region, occasioned considerable replanting. In addition, stands of native hardwoods were to some extent underplanted. The records of these operations obscure the facts as to total area planted, but it is probable that well-marked stands of planted timber never covered more than 1,000 acres in the estate. Stands which have been cut to make way for agriculture or were on land which has since been separated from the estate are not considered in this publication.

The literature dealing with the estate plantations and the other forestry work is practically confined to three small publications. In 1916 Verne Rhoades,³ of the United States Forest Service, prepared a booklet for the First Southern Forestry Congress, at Asheville, which discussed very briefly some of the more significant work. In 1908 Doctor Schenck⁴ issued a booklet entitled "A Forest Fair in the Biltmore Forest," giving an account of the planting completed at that time; and in 1908 and 1909 there appeared in the *American Lumberman* an article by an anonymous writer entitled "Three Days' Forest Festival on the Biltmore Estate."⁵ Previous to the writer's field work on this study, most of which was done in 1921 and 1922, observations had been made for the Forest Service by W. H. Lamb in 1913, by Verne Rhoades in 1915 and 1916, by E. H. Frothingham in 1916, and by C. R. Tillotson in 1920.⁶

STATISTICAL SUMMARY OF THE PLANTATIONS

The plantations upon which this report is based are listed in Table 1, together with the dates of origin, area, size of the average and dominant trees, and the species of which the plantations are composed. The distinctive names given the plantations are either those by which they are locally known or else relate to some notable feature connected with their history or composition. Many of the plantations consist of groups of separate stands, designated by number in the table. The locations of the plantations, (excepting those at Browntown, which were not mapped), are shown in Figure 1. Besides those listed in Table 1 are a good many stands and some plantations which for one reason or another have not been studied. Some, for instance, have been cut down, some grew so poorly that they could not be found, and many are white pine stands differing very little from others that were studied.

³ RHOADES, V. REPRESENTATIVE BILTMORE FOREST PLANTATIONS. 9 p. Privately printed. 1916.

⁴ SCHENCK, C. A., A FOREST FAIR IN THE BILTMORE FOREST. 55 p., illus. Biltmore, N. C. 1908.

⁵ ANONYMOUS. THREE DAYS' FOREST FESTIVAL ON THE BILTMORE ESTATE. *Amer. Lumberman*, (1750): 35-37; (1751): 43-44; (1752): 43-45; (1753): 50-52; (1754): 54-55; (1756): 52-54. 1908-9.

⁶ For a great deal of additional information the author is indebted to C. A. Schenck, who generously supplied original notes on the planting work and many helpful suggestions.

TABLE 1.—Billmore plantations and stands, 1921-22

Plantation group, and stand No.	Map refer- ence	Area Acres	Trees per acre	Crown density ¹	Average dimensions				Composition
					All crown classes		Dominants (1924)		
					Height Feet	Diameter breast high Inches	Height Feet	Diameter breast high Inches	
Apjary (1897-1900):									
Stand 1.....	D-5	0.4		0.5	35	45	7	Black cherry, black locust; a few trees of white oak, persimmon, sassafras.	
Stand 2.....	D-5	2.0		1.0		47	7	White pine, 40 per cent; shortleaf pine, 40 per cent; black cherry, chestnut, black locust, chestnut oak, persimmon, black walnut, 20 per cent.	
Stand 3.....	D-5	0.4	1,600	1.0	35	48	7	Sugar maple, white pine. (Pl. 11.)	
Stand 4.....	D-5	2.0	1,000	1.0	35	51	8	White pine. (Pl. 10.)	
Stand 5.....	D-5	0.2		0.9	35	55	10	Black cherry, 95 per cent; black locust, 5 per cent. (Pl. 4, B.)	
Stand 6.....	D-5	13.0		1.0	35	40	7	White pine, shortleaf pine; a few trees of black cherry, hickory, black locust, sugar maple, white oak, persimmon, and black walnut.	
Stand 7.....	D-5	2.0		1.0	35	5	8	White pine, shortleaf pine; a few trees of black cherry and black locust.	
Stand 8.....	D-5	0.2	2,500		30	44	5	Sugar maple. (Pl. 5, B.)	
Stand 9.....	D-5	0.4	2,500	0.9	30			Sugar maple; a few trees of white pine.	
Stand 10.....	D-5	0.3	2,900	0.9	30			Sugar maple; a few trees of white pine.	
Stand 11.....	D-5	0.1		0.7				Douglas fir, European silver fir, blue spruce, and Sitka spruce.	
Approach Road (1895-1905, ?), stand 1.....	F-2	6.0	2,800	0.7		37	6	Black cherry, shortleaf pine, yellow poplar. (Pl. 5, A.) A few trees of river birch, haws, hickory, oak, persimmon.	
Bent Creek Road (1907):									
Stand 1.....	C-8	5.0	1,800	0.9	20	2	5	White pine; a few trees of shortleaf pine and hardwoods.	
Stand 2.....	C-8	4.0	1,800	0.8	15	2	5	White pine.	
Stand 3.....	C-8	8.0	1,600	0.9	30	4	7	White pine; a few trees of black locust, shortleaf pine.	
Black Walnut (1897-1900):									
Stand 1.....	D-4	1.0	2,700	0.9	20	2	35	Black walnut. (Pl. 6.)	
Stand 2.....	D-4	3.0	1,700	0.9	25	4	6	Pitch pine, shortleaf pine; understory of black walnut and other hardwoods. (Pl. 6.)	
Border (1909):									
Stand 1.....	A-3	2.0	1,400	1.0	30	4		White pine.	
Stand 2.....	A-3	3.0	1,800	1.0	30	4		White pine.	
Stand 3.....	A-3	0.4	1,800	1.0				Sugar maple, white pine	
Brick House (1896):									
Stand 1.....	E-6	2.0	3,100	0.9	35	4	8	White pine; a few trees of other species.	
Stand 2.....	E-6	0.3	2,400	1.0	20	2		Sugar maple.	
Stand 3.....	E-6	0.1		1.0	20	2		Black cherry.	
Brownstown (1905), (stands not shown on map):									
Stand 1.....	G-5							64 acres planted to Oregon ash, white ash, black cherry, chestnut, cucumber, magnolia, bigleaf maple, sugar maple, chestnut oak, scarlet oak, white pine, shortleaf pine, and yellow poplar.	
Cherokee Drive (1908), stand 1.....	E-6	2.0	1,800	0.8	35	4	6	White pine; a few trees of other species.	

FOREST PLANTATIONS AT BILTMORE, N. C.

Location	Stand	Acres	Age	Height	Species	Notes
Douglas (1890):	Stand 1	300	45	10	White pine; narrow roadside strip.	White pine; narrow roadside strip.
	Stand 2	300	40	9	White pine; understorey of scattered hemlocks; narrow roadside strip.	White pine; understorey of scattered hemlocks; narrow roadside strip.
	Stand 3		45	8	White pine; narrow roadside strip.	White pine; narrow roadside strip.
	Stand 4	300	45	8	White pine; narrow roadside strip.	White pine; narrow roadside strip.
	Stand 5	300	45	9	White pine; a few trees of black cherry, Douglas fir, black locust, white oak, yellow poplar. (Pl. 1, A.)	White pine; a few trees of black cherry, Douglas fir, black locust, white oak, yellow poplar. (Pl. 1, A.)
	Stand 6	400	45	10	White pine; a few hemlocks.	White pine; a few hemlocks.
	Stand 7	400	45	11	White pine; trees pruned to height of 10 to 20 feet.	White pine; trees pruned to height of 10 to 20 feet.
	Stand 8	300	45	10	White pine; a few trees of eastern red cedar, hemlock and other species; trees pruned to height of 15 feet.	White pine; a few trees of eastern red cedar, hemlock and other species; trees pruned to height of 15 feet.
	Stand 9	200	45	11	White pine; trees near paved roads pruned to height of 15 to 20 feet.	White pine; trees near paved roads pruned to height of 15 to 20 feet.
	Stand 10	400	45	8	White pine; trees near paved roads pruned to height of 15 to 20 feet. (Pl. 1, B.)	White pine; trees near paved roads pruned to height of 15 to 20 feet. (Pl. 1, B.)
	Stand 11	400	45	9	White pine; trees near paved roads have been pruned.	White pine; trees near paved roads have been pruned.
	Stand 12	300	35	10	White pine; few black locust trees and a scattered understorey of eastern hemlock; trees near paved road have been pruned.	White pine; few black locust trees and a scattered understorey of eastern hemlock; trees near paved road have been pruned.
	Stand 13	500	45	8	White pine; trees pruned to height of 10 feet.	White pine; trees pruned to height of 10 feet.
	Farmacia (1905):	Stand 1	2,000	35	3	White pine, shortleaf pine.
Stand 2		1,800	40	6	White pine, shortleaf pine, yellow poplar; understorey of sugar maple.	White pine, shortleaf pine, yellow poplar; understorey of sugar maple.
Stand 3		2,900	30	4	White pine.	White pine.
Ferry Farm (1900-1902):	Stand 1	2,000	30	4	Shortleaf and pitch pine (chiefly shortleaf) 70 per cent; white pine 30 per cent.	Shortleaf and pitch pine (chiefly shortleaf) 70 per cent; white pine 30 per cent.
	Stand 2	2,000	30	4	White pine, pitch pine, shortleaf pine.	White pine, pitch pine, shortleaf pine.
	Stand 3	2,600	30	3	White pine, shortleaf pine; trees small and stunted.	White pine, shortleaf pine; trees small and stunted.
	Stand 4	1,700	13	1	White pine; a few trees of eastern red cedar, black locust, red maple, black oak, shortleaf pine, sourwood, black walnut, and yellow poplar.	White pine; a few trees of eastern red cedar, black locust, red maple, black oak, shortleaf pine, sourwood, black walnut, and yellow poplar.
Horse Stable (1906-1908):	Stand 1	300	30	4	White pine; a small patch of shortleaf pine and a few trees of several other species.	White pine; a small patch of shortleaf pine and a few trees of several other species.
	Stand 2	300	30	3	White pine, yellow poplar.	White pine, yellow poplar.
	Stand 3	300	35	5	White pine, shortleaf pine; scattered trees of Virginia pine. (Pl. 7.)	White pine, shortleaf pine; scattered trees of Virginia pine. (Pl. 7.)
Lone Chimney (1907); Stand 1; Long Ridge (1895-1905):	Stand 1	41.0	25	4	White pine, Scotch pine, shortleaf pine; scattered trees of ailanthus, white ash, basswood, butternut, black cherry, chestnut, dogwood, haw, black locust, red maple, chestnut, oak, red oak, white oak, jack pine, serviceberry, black walnut, and yellow poplar. (Pl. 2, C.)	White pine, Scotch pine, shortleaf pine; scattered trees of ailanthus, white ash, basswood, butternut, black cherry, chestnut, dogwood, haw, black locust, red maple, chestnut, oak, red oak, white oak, jack pine, serviceberry, black walnut, and yellow poplar. (Pl. 2, C.)
	Stand 2	0.3	15	4	Douglas fir, Japanese larch.	Douglas fir, Japanese larch.
	Stand 3	1.0	4	26	Douglas fir. (Pl. 8, B.)	Douglas fir. (Pl. 8, B.)
	Stand 4	1.0	35	4	Sugar maple; a patch of Norway spruce and a few trees of white pine.	Sugar maple; a patch of Norway spruce and a few trees of white pine.
Old Dairy (1905):	Stand 1	2,300	25	2	Black cherry; a few trees of white pine and shortleaf pine.	Black cherry; a few trees of white pine and shortleaf pine.
	Stand 2	4.0	30	4	Shortleaf pine; a few trees of sugar maple and white pine. (Pl. 8, A.)	Shortleaf pine; a few trees of sugar maple and white pine. (Pl. 8, A.)
	Stand 3	1.0	25	2	White pine.	White pine.
Old Nursery (G-8), stand 1:	Stand 1	25	25	2	White ash, white oak, white pine; a nursery abandoned in 1905.	White ash, white oak, white pine; a nursery abandoned in 1905.
	Stand 2	25	25	2	White ash, white oak, white pine; a nursery abandoned in 1905.	White ash, white oak, white pine; a nursery abandoned in 1905.

TABLE 1.—Biltmore plantations and stands, 1921-22—Continued

Plantation group, and stand No.	Map refer- ence	Area Acres	Trees per acre	Crown density ¹	Average dimensions				Composition	
					All crown classes ²		Dominants (1924) ³			
					Height	Diameter breast high	Height	Diameter breast high		
Old Orchard (1899):										
Stand 1.....	E-2	5.0	5,400	0.9					6	Pitch pine, shortleaf pine, mostly the former; an understory of white ash, buckeye, haw, white oak, and persimmon.
Stand 2.....	E-2	7.0	1,600	1.0	35	5	46		7	White pine. (Pl. 9.)
Old Schoolhouse (1906):										
Stand 1.....	A-3	8.0	1,800	0.9			41		6	Sugar maple, white pine; a few trees of shortleaf pine, yellow poplar; maple overtopped by pine.
Stand 2.....	A-3	1.0	2,700	0.4	25	2			7	Sugar maple; shrubs; stand near a small stream.
Persimmon Heights (1906), stand 1.....	C-5	4.0	700	0.9	30	4	39			White pine; a few trees of shortleaf and Virginia pine.
Rice Place (1908-1906):										
Stand 1.....	D-11	8.0	2,900	0.9	25	2	20		5	White oak; a few trees of beech, river birch, persimmon, short-leaf pine, and yellow poplar. (Pl. 4, A.)
Stand 2.....	D-11	1.0	2,500	0.9	8	1	11		6	White oak.
Stand 3.....	D-11	1.0	4,400	0.6	20	1	32		5	White ash; a few trees of yellow poplar.
Stand 4.....	D-11	2.0	3,500	0.8	25	2	30		5	White ash; white oak.
Riverview (1905), stand 1.....	B-3	2.0	1,000	1.0			37		7	White pine; understory of sugar maple.
Sheep Pen Road (1911), stand 1.....	D-5	1.0	2,200	1.0	25	3				White pine.
Sheep Pen Road (1911), ?.....	D-2	4.0	2,200	0.5	8	1	10		4	Norway spruce; a few shrubs.
Stand 1.....	E-2	0.3	2,200	0.9	11	1				Norway spruce.
Stand 2.....	E-2	4.0	1,100	0.5	6		12		2	Norway spruce; scattered trees of haw, hickory, black locust, shortleaf pine, privet, and yellow poplar; part of this stand was burned in May, 1920.
Stand 3.....	E-2								1	Norway spruce.
Swanano (1896):										
Stand 4.....	E-2	9.0	2,700	0.5	5		10		2	Norway spruce.
Stand 5.....	E-2	6.0					12		1	Norway spruce.
Stand 1.....	E-2	1.0	1,700	0.9	35	3	43		6	Butternut, 4 per cent; sugar maple, 90 per cent; black walnut, 6 per cent.
Stand 2.....	E-2	1.0		0.4	15	2	18		3	Black cherry; a very poor stand. (Pl. 4, C.)
Truck Farm (1909, ?), stand 1.....	E-2	2.0	1,700	0.9	25	3	32		4	White pine; a large part of this stand was burned in May, 1920.

¹ Crown density is an expression of the relation of the crown area (or crown cover) to the land area below and is a measure of the extent of shading exercised by the crowns with due regard to the habits of the species, site, and age. Crown density is usually expressed in tenths, a complete cover being unity.

² Crown class is a rough estimate of the relative position of a tree in the crown cover, and generally of the vigor of the tree. Four crown classes are usually observed. These are, in the order of importance, dominant, codominant, intermediate, and suppressed. The crowns of dominant trees receive full light, those of the codominants light mainly from above, and those of the intermediates partial light from above but none from the sides, while the suppressed trees have their crowns entirely below the general forest canopy and receive no direct light.

³ "White pine," in this table, as elsewhere in the publication, is the northern white pine (*Pinus strobus*).

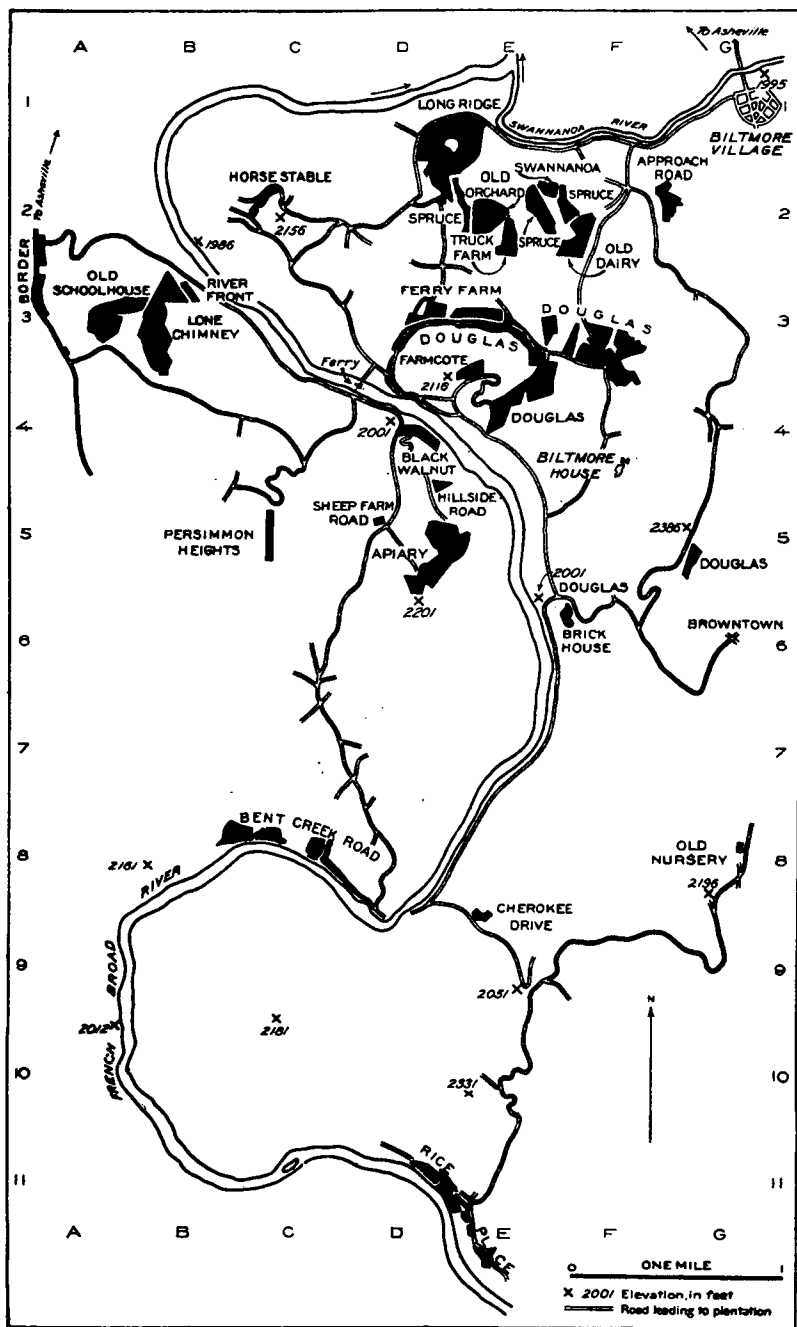


FIGURE 1.—Location of forest plantations near Biltmore, N. C.

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SOME NOTEWORTHY PLANTATIONS

A number of the plantations that are typical or of special interest have been selected for the brief descriptions that follow. More detailed information on these and other plantations may be obtained from the Appalachian Forest Experiment Station at Asheville, N. C.

DOUGLAS PLANTATIONS

The scattered stands which make up the Douglas plantations, so named for the nursery company that established them, are in several respects the most impressive in the estate. They are the oldest, dating from 1890, and contain the largest trees. The fact that they have grown up less densely than most of the other plantings has tended to increase relatively the diameters of the individual trees. Many of the stands are located conspicuously along the principal roads, and from these the dead trees have been removed some distance back from the road and the unsightly dead branches on the living trees pruned to a height of 10 to 25 feet, setting forth the long, clear trunks and extending the view into the plantations. Characteristic views of the stands are shown in Plate 1.

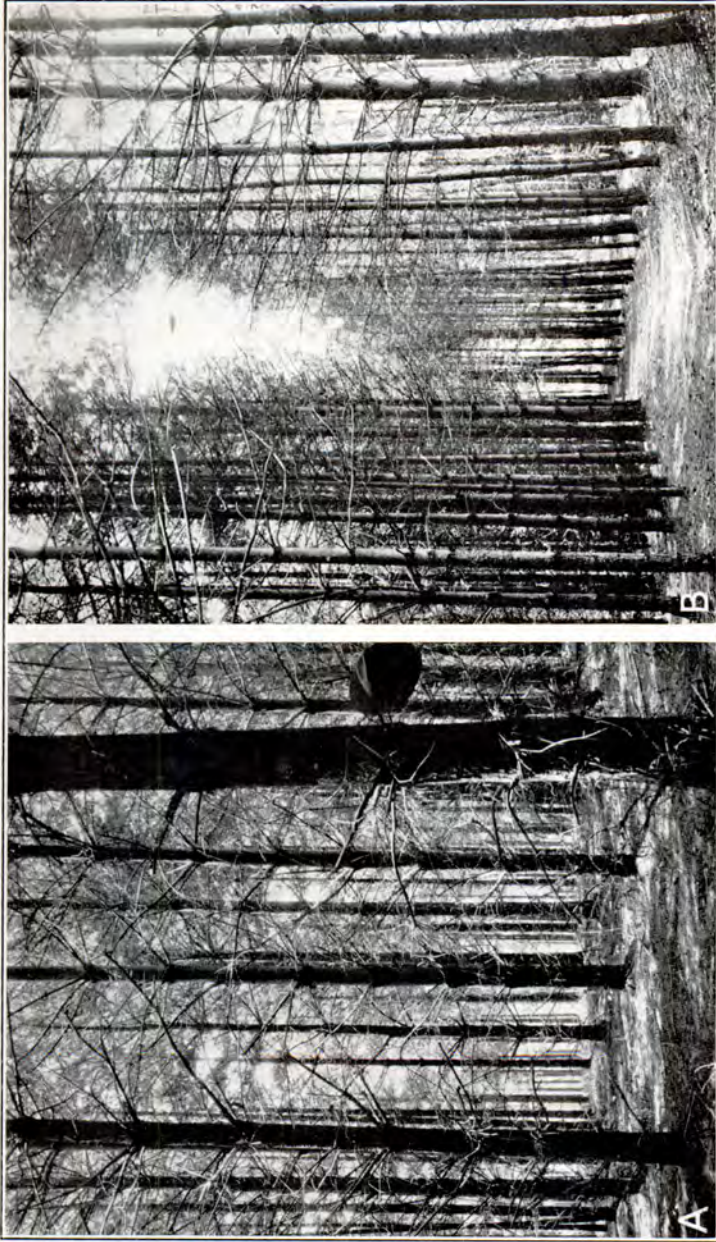
These stands are composed mainly of white pine with a few scattered trees of other species, mostly hemlock, black locust, and black cherry. The trees average about 400 to the acre. The pines average 45 feet in height and 9 inches in diameter, but some of the dominants are 65 or 70 feet high and a foot and a half in diameter, breast high. Height growth has generally been rapid and there are long sections of clear boles between the branch whorls. Except near the roads, where they have been artificially pruned, the trees retain their dead branches almost to the ground—as is characteristic of white pine in young, pure stands—and give the stands a very ragged appearance.

The ground under the denser stands is as a rule nearly bare of vegetation, as the photographs show. Where the crown cover is less dense the ground in some places is almost covered with honey-suckle, while at some other spots poison ivy grows in abundance. On the edges and in small openings in the stands white pine seedlings are beginning to come in.

The planting done in 1890 was carried through under a very formal contract which provided that not less than 300 acres should be plowed in strips running across the slope of the ground and should be planted with not less than 1,200 trees on each acre, of which not less than 75 per cent should be white pine. The resulting plantations did very well for a couple of years, but five years after planting they were overgrown with briars and appeared to be total failures. This early competition, however, seems to have been beneficial to the stand rather than otherwise for it undoubtedly assisted in the thinning-out process which reduced the stands from the original 1,200 to the present 400 trees to the acre and resulted in improved opportunity for growth for the remaining trees.

LONG RIDGE PLANTATIONS

The plantations on Long Ridge are of peculiar interest because, while the stands are now predominantly of pine, it was on this hill that Schenck made some of his most extensive trials with hardwoods. There



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WHITE PINES IN BILTMORE'S OLDEST PLANTATION

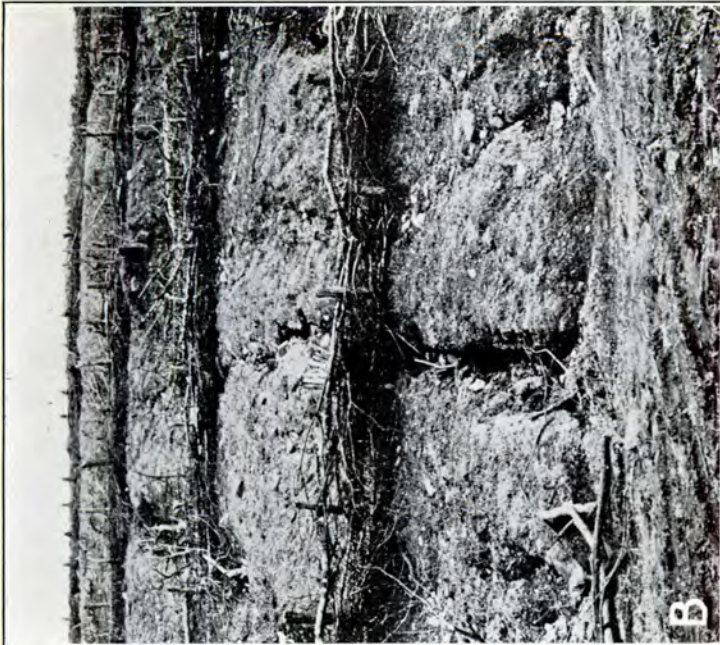
These pure stands of 33-year-old white pine in the Douglas plantation constitute about a third of the trees planted. Noteworthy are the persistence of dead branches and the lack of any vegetation on the forest floor.



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PINE PLANTATIONS ON LONG RIDGE

The hill shown in A and B had been cleared 50 years and abandoned as farm land 20 years before hardwoods were sown and planted here in 1895-1899. Heavy losses among the hardwoods prompted a replanting with pines in 1900. Most of the trees of the present stands are from this later planting, white pines being the most numerous. In places (C) white pines planted under the shade of chestnut have died out or are badly stunted. The chestnut in the right foreground is 39 inches in diameter; the pines marked with tags range from 0.5 to 2.7 inches.



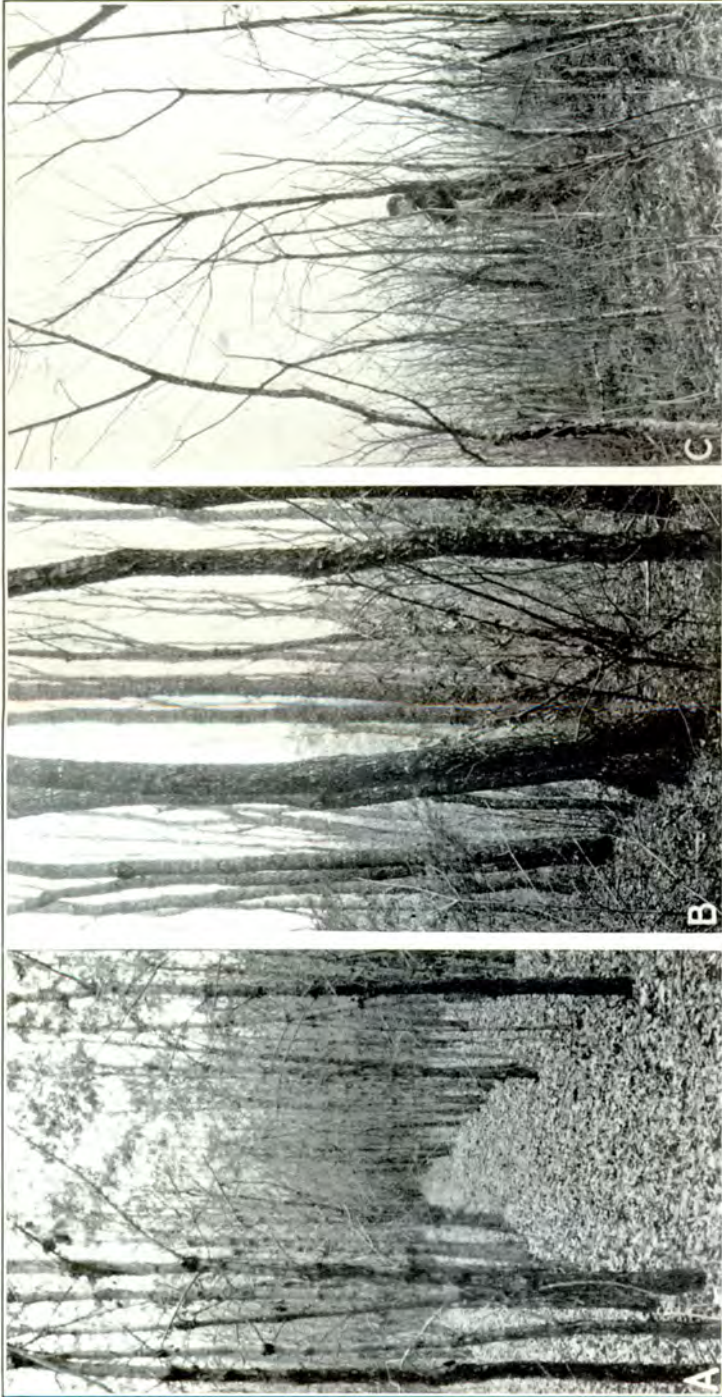
TREATMENT OF ERODING PLANTING SITE

On the Old Orchard and some other planting sites wattles and brush were used to check the gullying before planting was begun.



PERSISTENCE OF SUPPRESSED OAK

Planted oaks about 10 feet high were cut as brush at the time of a cleaning out of much taller insect-infested pines. Now the oaks are promptly filling in the opening. The persistence of greatly overtopped oaks and other hardwoods has been very common at Baltimore. The sprouts illustrated are about a foot and a half high.



GOOD OAK AND GOOD AND POOR CHERRY

The best of the planted oaks (A) are on the Rice Place plantation. At 18 years of age these trees averaged 25 feet tall, 2 inches in diameter, and 2,900 to the acre. This is one of the few successful hardwood plantations on the Biltmore estate. In contrast, the black cherries (C) in the Swannanoa plantation averaged only 15 feet high when 26 years old. A much more successful stand of planted cherry in stand 5, A piary plantation (B), was 55 feet high and 10 inches in diameter at the same age. Note the suppressed chestnut of an earlier planting.

are, indeed, within the limits of the 45-acre tract a few small stands and scattered individuals of various hardwood species as well as some odd conifers, notably an acre patch of the best Douglas fir on the estate (pl. 8, B), but the ridge as a whole is covered with pines, chiefly white pine.

The pines of these stands average 25 feet in height and 4 inches in diameter, the dominant trees being about 45 feet tall and 7 or 8 inches in diameter. On the ground beneath the continuous crown cover is a dense leaf litter and a very scanty vegetation in which spotted wintergreen is one of the commonest species.

Scattered through the pine stands are crooked oak trees with their crowns well up among the pine crowns, distorted by the competition but still struggling to get their heads free. If anything should destroy the pines, these hardwoods would be ready to take their place. At the southern end of the plantation is a particularly interesting patch of greatly suppressed white oaks. These trees, liberated by a cutting of shortleaf pine to check an attack of southern pine beetles, at once began to fill up the opening which had been made in the pine stand. This persistence for many years of small suppressed oaks is one of the most striking things in the Biltmore plantations. (Pl. 3, A.)

The reforestation of the steep slopes of Long Ridge was one of the first jobs that Doctor Schenck undertook on the Biltmore Estate. The land was an old field which had been abandoned in 1875, after 30 years of farm use. In 1895, when the forest planting was begun, this hill was largely covered with beardgrass. The white pine planted 5 years before in the Douglas plantations appeared at this time to have failed, and Schenck therefore decided to plant this site with hardwoods, regarding their presence in the native stands as an indication that they would succeed. Seeds and transplants of a dozen species were planted in an attempt, which lasted 5 years, to establish the hardwoods. The results were mostly discouraging. Chipmunks dug up the nuts, mice ate the new roots, rabbits fed on the tops, and weeds and beardgrass gave serious competition. After these 5 years of effort, the conclusion appeared to be obvious that not much was to be expected of hardwoods, especially not as long as the rodents were so plentiful. After 1899, therefore, the planting policy was changed, and during the next 6 years conifers, mostly white pine, were put in over the larger part of Long Ridge. In all, during the 11 planting years, about 30 species were tried, evenly divided between the hardwood and conifer groups.

Views of Long Ridge as it appeared in 1924 are shown in Plate 2, A, B. These pictures are particularly interesting in view of the fact that at the time of planting gullying was so bad on the site illustrated that it was necessary to set wattle fences there similar to those on the Old Orchard plantation. The Long Ridge planting was very close. Some of the hardwoods were planted at the rate of 6,000 to 7,000 to the acre. The big conifer replanting was at the rate of 1,900 trees to the acre, the trees being spaced, on the average, less than 5 feet apart. As a result the trees of the present stands, like those of many others of the Biltmore plantations, are seriously crowding each other.

OLD ORCHARD PLANTATION

On a moderate northerly slope southeast of Long Ridge is the Old Orchard plantation. This plantation consists of a dense, practically pure stand of white pine (7 acres), nearly surrounded by a stand of pitch pine (5 acres), containing a few shortleaf pines and a low, struggling understory consisting of planted white ash, buckeye, and white oak, and natural reproduction of persimmon and hawthorn.

In 1899, when the planting was begun, this site was an abandoned pasture with deep soil but badly eroded surface. To check the erosion small wickerwork fences, illustrated in Plate 3, B, were set in the gullies, previous to the planting. About 50,000 seedling trees, more than half of them white pine and the rest hardwoods, were set out, the average number to the acre being thus over 4,000. The white pines grew well but not the hardwoods, and after a few years the hardwood part of the plantation was reinforced by yellow pine⁷ seedlings 1 year old. In 1922 the yellow pines averaged 30 feet in height, while the slightly older hardwoods were about 12 feet high. The average height of the white pines was 35 feet. The yellow pine stand then contained about 1,700 trees to the acre, mostly pitch pine, while the white pine stand averaged 1,600 trees to the acre. The suppression of the hardwoods by pitch and shortleaf pines planted afterwards has been the rule at Biltmore.

The white pine stand was chosen for one of the experiments in thinning started by the Forest Service in 1916 which will be discussed later. The volume of wood per acre in the living trees computed at the time the thinnings were made, was about 2,700 cubic feet in 1916 and about 3,200 cubic feet in 1923. In the unthinned part of the stand the trees are very crowded, and there has been a heavy mortality of the smaller ones as a result of the severe competition.

SWANNANOA PLANTATION

The Swannanoa plantation, on a steep northerly slope northeast of the Old Orchard stands, is one of the older hardwood plantations which was never replanted with pines. Two distinct stands resulted—one of sugar maple with scattered black walnut and butternut trees, the other of black cherry. The sugar maple and the few butternuts and walnuts have made good growth and at 26 years of age averaged 35 feet high and from 4 to 7 inches in diameter, breast high. The black cherry, however, is stunted, crooked, and unhealthy and was only 15 feet high when 26 years old. It is illustrated in Plate 4, C.

The cause for the poor performance of this cherry has not been definitely ascertained. Black cherry does not grow wild in pure stands and for the most part has not done well at Biltmore when planted pure. Perhaps the failures are usually to be attributed to inability to develop well in pure stands on the poorer sites. The good stand of pure cherry in the Apiary plantation (pl. 4, B), to be mentioned later, is apparently located on an exceedingly good patch of soil.

⁷ The term "yellow pine" is applied to the pines with relatively hard, pitchy wood (also called "hard pines") as distinguished from the soft-wooded white pines. The yellow pines mostly used in the Biltmore plantings were shortleaf and pitch pines.

APPROACH ROAD PLANTATION

An excellent example of the overtopping of hardwoods by pine of a later planting—a result to be frequently noticed in the Biltmore plantations—is afforded by the Approach Road plantation. Yellow poplar and black cherry were planted here by Gifford Pinchot in the spring of 1895, both being spaced 4 by 4 feet. The poplar planting stock averaged 5 feet high, the cherry $3\frac{1}{2}$ feet. The spring of 1895 was wet and warm and very favorable for tree growth; but the summer was unusually dry, and the plants began to dry out. About July 1 the plants with dried tops were cut back. Most of these promptly put out new shoots, but 40 per cent of the plants thus cut back had died within two years after planting. Eight years later the plantation was regarded as a total failure, and 1-year-old shortleaf pine seedlings were accordingly put in to take the place of the hardwoods.

Despite the 10-year handicap which the pines had to overcome they have for the most part overtopped the remaining hardwoods, averaging about 5 feet taller. Dominant hardwood trees occur here and there in the stand, and scattered through it are some of the best of the planted yellow poplars at Biltmore. (Pl. 5, A.) As a rule, however, planted yellow poplar trees have not done as well at Biltmore as those that started naturally from seed blown in upon the site.

FARMCOTE PLANTATION

Another example of the suppression of hardwoods by pine is the Farmcote plantation, established in 1905. In part of this plantation two rows of sugar maple were planted to every row of pine, the pine rows being alternately of white pine and shortleaf. Thus the single rows of pine were flanked on each side by double rows of maple. Even with this arrangement the maples have not been able to compute successfully with the pines and the stand is now made up of wide-spaced alternating rows of white and shortleaf pines with a few small maples between. The pines at 18 years of age averaged 35 feet high, where as the average for the maples was 8 feet, and some were only a foot high.

In another part of this plantation is a stand of alternate rows of white and shortleaf pine, a little more than 5 feet apart, the trees averaging 3 feet apart in the rows. The two species are about even in size but with the white pine slightly larger, contrary to the usual relation between the two species at Biltmore. The trees at 18 years of age stood 2,600 to the acre, which is only 58 per cent of the number originally planted.

BLACK WALNUT PLANTATION

The Black Walnut plantation, on the west side of the French Broad River, not far from the ferry, contains the only black walnut stand resulting from the many plantings and sowings of this species at Biltmore. In this small stand the black walnuts at 24 years of age averaged 20 feet high and $2\frac{1}{2}$ inches in diameter. Some of the biggest were 40 feet high, and 6 or 7 inches in diameter.

In contrast with this fairly successful stand are the plantings higher up the slope on poorer walnut soil, where the walnuts have never done at all well. After these poorer trees had struggled along

for two years Schenck added shortleaf and pitch pines in the hope of stimulating the growth of the walnuts. Instead, the pines have now taken the lead and average 25 feet high, while the walnuts average only 5 feet. These two stands are shown in Plate 6.

APIARY PLANTATION

The Apiary plantation, west of the French Broad River, includes some of the best planted maple on the estate and also one of the best stands of cherry. Plate 5, B, shows a small 25-year-old stand of sugar maple on the Apiary plantation, averaging 30 feet in height and 1½ inches in diameter, some of the biggest trees being 5 inches in diameter and over 40 feet high. This stand averages 2,500 trees to the acre. In a near-by stand of mixed sugar maple and white pine the maples outgrew the pines and by 1916 had killed or badly suppressed all but a few whose tops still remained in the crown cover. Here the maples rather than the pines were favored in a thinning experiment started by the Forest Service in 1916. (See p. 29.) Another experimental thinning was made in a small pure stand of white pine in which the dominant trees when 20 years old were about 40 feet high and from 6 to 9 inches in diameter, breast high.

The 21-acre Apiary planting site, an abandoned field, level or sloping gently to the southeast, was mostly poor stony soil covered with beard-grass. An exception was a small patch of good soil near the site of an old farmhouse, and this apparently is where the very successful stand of black cherry was planted. (Pl. 4, B.) Some of the trees of this stand were 10 inches in diameter and 55 feet high when 25 years old. As on Long Ridge, Doctor Schenck first planted a good many hardwoods on the Apiary site. After three years, however, he made a big replanting in 1900 with 48,000 pines, half white and half shortleaf. This replanting was at the rate of nearly 2,300 trees to the acre.

BROWNTOWN PLANTATION

The Browntown plantation was established in 1905 on 64 acres now within the town limits of Biltmore Forest. No studies have been made of the stands since 1920, but because of the large amount of shortleaf pine planted pure and in different mixtures with other species the history of the plantation is of considerable interest.

Of the 319,000 trees planted there in the spring of 1905 nearly half were shortleaf pines. Some of these were planted almost pure, with merely a few white pines. Others were mixed with white pine, or with sugar maple and white pine in such proportions that sometimes the planting was essentially of shortleaf pine and maple. Altogether a dozen species were used in these plantings, all but two of them hardwoods, notwithstanding the fact that hardwood planting on the Long Ridge and Apiary sites had been discontinued five years before. The hardwoods used included chestnut oak, scarlet oak, and two Oregon species, Oregon ash and bigleaf maple.

The trees were planted in rows 5 feet apart at the rate of nearly 5,000 to the acre. One planting of 10,000 each of white pine, sugar maple, and chestnut was at the rate of more than 7,000 to the acre. The smallest number to the acre was 1,200 in a 3-acre planting of white ash.

The two Oregon species died within three years. After eight years the pines averaged 15 or 20 feet in height and about twice the height of the sugar maples. At 15 years of age the pines were 10 feet taller and still twice the height of the maples. The maples varied more in size than the pines, some of them having their tops up among the pine crowns while others were only a foot high.

RICE PLACE PLANTATIONS

The Rice Place plantations are on level sandy bottom land near the French Broad River in the southern part of the estate. White ash and white oak were planted there in 1903-1905 and not replanted with pines. Part of the oak is in pure stands and has made good growth. The trees shown in Plate 4, A, were 25 feet high and 2 inches in diameter at 18 years of age.

In another part of this plantation the oaks at 20 years were much smaller, averaging 8 feet in height and an inch in diameter. Because of the open character of this stand practically all the trees were dominant, but the tallest were less than 20 feet high. Only a few trees have died in this stand, presumably because of the lack of crowding due to the slow growth, whereas among the larger trees of the adjacent stand the death rate has been about 15 per cent.

It is not clear why there should have been such a marked difference in growth between the trees of these two stands. Although considerable sand was laid down in the stand of smaller trees during a flood in 1916, yet it is unlikely that this is solely responsible for the difference in growth rate, a matter of something like 15 feet in six years. The slower growth of these trees is probably due to some unfavorable soil condition in effect prior to the 1916 flood.

Another stand is of ash and oak. There the ash is 10 feet taller than the oak, which is smaller than in the better of the pure oak stands. Some of the largest ash trees were 35 feet high at 20 years of age. In another stand, where the ash is pure, the growth of the ash has not been quite so good. Judging by these stands, therefore, ash may be expected to make better growth in mixture with oak than when planted pure, but oak apparently will do better when ash is not mixed with it. Further observations would be needed thoroughly to establish such relations.

PLANTING COSTS

From such records as are available, it appears that the cost of the forest plantations at Biltmore varied from \$6.30 an acre for the cheapest work, carried out in the Lone Chimney plantation, to \$135 an acre for one particularly expensive small planting of 10-year-old white pines in the Brick House plantation. At times the actual cost of the planting considerably exceeded estimates made before the work was begun. Schenck expected to plant Long Ridge at a cost of \$5 an acre, but, with the very closely spaced replantings which he made, it came to more than \$30. The same was true of the Apiary plantation. In both these plantations, however, a good deal of the cost should be charged to experimental work. If the failures in the cases of replanting are ignored and the costs are computed for the successful plantings only, the Long Ridge plantations would come to about

\$13 an acre, and the Apiary to \$10 or \$11. With the close spacing that was used, \$10 an acre is about the lowest that would have been possible at that time. The wider spacing now generally favored would make planting possible to-day for the same amount or less, in spite of the higher cost of labor and stock.

RESULTS WITH THE SPECIES PLANTED

In appraising the value for planting of the species used at Biltmore one outstanding fact is the general success of the pines, and the failure, or at least the difficulty and delay, commonly experienced in the attempts to establish hardwood plantations. The decision to use hardwoods, chiefly the native species, was made after a few years, when the first pine plantation appeared to have failed. The thrifty white pine stands of the Douglas plantation witness the error of this early judgment. When failure after failure had convinced Schenck of the unsuitability of hardwoods, the planting of pines was resumed and thousands of white, shortleaf, and pitch pines were put in, very close spacing being used to insure a stand.

Sometimes the pines were used to replant areas already planted with hardwoods; or they were set out on the old fields that had not previously been planted. The results were much the same in both cases, the pines generally took possession of the land, overtopped the hardwoods, and formed satisfactory stands of pine with or without a hardwood understory.

The hardwood plantings, however, were not entirely unsuccessful. Small hardwood stands of excellent growth and condition are found scattered among the pine stands in many of the plantations. The understory hardwoods, usually survivors of the plantings that were regarded as total failures and replanted with pine, are sometimes greatly suppressed but are for the most part sufficiently vigorous to spring up, fill the gaps, and produce hardwood stands wherever the pines are cut or killed by fire, insects, or disease.

NORTHERN WHITE PINE

Of the planted stands on the estate, those of northern white pine are the most extensive and important. Some of these stands are exclusively of white pine; in others the white pine is mixed with one or more species of hardwoods or with other conifers. The best are the pure stands of the Douglas plantings, (pl. 1), now nearly 40 years old. For some of these, when 25 to 30 years old, Rhoades and Tillotson estimated yields of 10,000 to 12,000 board feet to the acre. Some of the younger stands of white pine and of white and shortleaf mixed are also making very satisfactory progress.

Although a good many growth figures are available for stands of many ages, these include no records tabulated systematically through a long period of years. Table 2 gives approximate figures for pure stands of white pine at Biltmore, based on records of a great many stands of various ages, on various sites and with various spacings.

TABLE 2.—Average growth in pure northern white pine stands at Biltmore

Age	Average height (all crown classes)	Average diam- eter breast high (all crown classes)	Average vol- ume per acre ¹
	Feet	Inches	Cubic feet
Years:			
10.....	20	2	500
15.....	25	3	
20.....	30	4	3,000
25.....	35	5	
30.....	40	7	4,000
35.....	45	9	

¹ Computed by using an assumed form factor of 0.5.

The dominant trees vary from 10 feet taller than the average at the younger ages to 20 feet taller for the 35-year-old trees. They are an inch or two greater than the average in diameter.

For pure white pine stands in the Old Orchard and Apiary plantations the sample plot measurements made by the Forest Service in 1916, 1922, and 1928, in the unthinned control plots, provide somewhat similar figures, as given in Table 3.

TABLE 3.—Growth and stocking in pure northern white pine stands on the Old Orchard and Apiary plantations ¹

Old Orchard plantation					Apiary plantation		
Age of planta- tion	Good site (plot 1b)		Poor site (plot 1c)		Age of planta- tion ²	Good site (plot 4b)	
	Volume per acre	Trees per acre	Volume per acre	Trees per acre		Volume per acre	Trees per acre
Years:	<i>Cubic feet</i>	<i>Number</i>	<i>Cubic feet</i>	<i>Number</i>	Years:	<i>Cubic feet</i>	<i>Number</i>
18.....	3,110	1,984	2,310	3,176	20.....	4,680	1,425
24.....	3,600	1,424	2,770	2,384	26.....	5,060	962
30.....	3,730	872	2,960	1,696	32.....	5,980	725

¹ Volumes were computed by the use of an assumed form factor of 0.5.

² Approximate.

Although on plots 1b and 1c the average annual death rates for the past 12 years of observation were 93 and 123 trees per acre, respectively, the stand remains much too dense for the best growth. This overdensity is probably responsible for the slowing down of volume growth noticeable in the last six years. In plot 4b, which is somewhat less dense, with an average annual mortality of 58 trees for the 12-year period, the volume growth in the last half of the period considerably exceeded that during the first half. The heights of the dominant trees in 1928 were about 53 feet in plot 1b, 41 feet in plot 1c, and 63 feet in plot 4b. The volume growth of these plots should be compared with that of the thinner companion plots discussed on a later page under "Thinning Operations."

The growth of these planting stands at Biltmore compares very favorably with that of second-growth white pine in New Hampshire, figures for which are given in Table 4.

TABLE 4.—Yield per acre of second-growth white pine, site quality 1, New Hampshire¹

Age	Volume per acre	Age	Volume per acre	Age	Volume per acre
Years:	<i>Cubic feet</i>	Years:	<i>Cubic feet</i>	Years:	<i>Cubic feet</i>
10.....	800	25.....	3,000	35.....	5,200
15.....	1,400	30.....	4,000	40.....	6,500
20.....	2,100				

¹ FROTHINGHAM, E. H. WHITE PINE UNDER FOREST MANAGEMENT. U. S. Dept. Agr. Bul. 13, 70 p. illus. 1914.

Where white pine is growing with pitch, shortleaf, or Scotch pine, all the species are usually of very nearly the same size. Where there is an appreciable difference the yellow pines are generally but not always the larger.

In the Lone Chimney plantation white and shortleaf pines 15 years old both averaged 30 feet in height, which is more than the average for pure white pine stands. The tallest white pines were a little taller than the tallest shortleaf pines, but, on the other hand, the average diameter at breastheight of the white pines was 3 inches, as compared with 4 inches for the shortleaf. Scotch pine, in the one stand in which it is found, is a little larger than white pine growing in mixture with it.

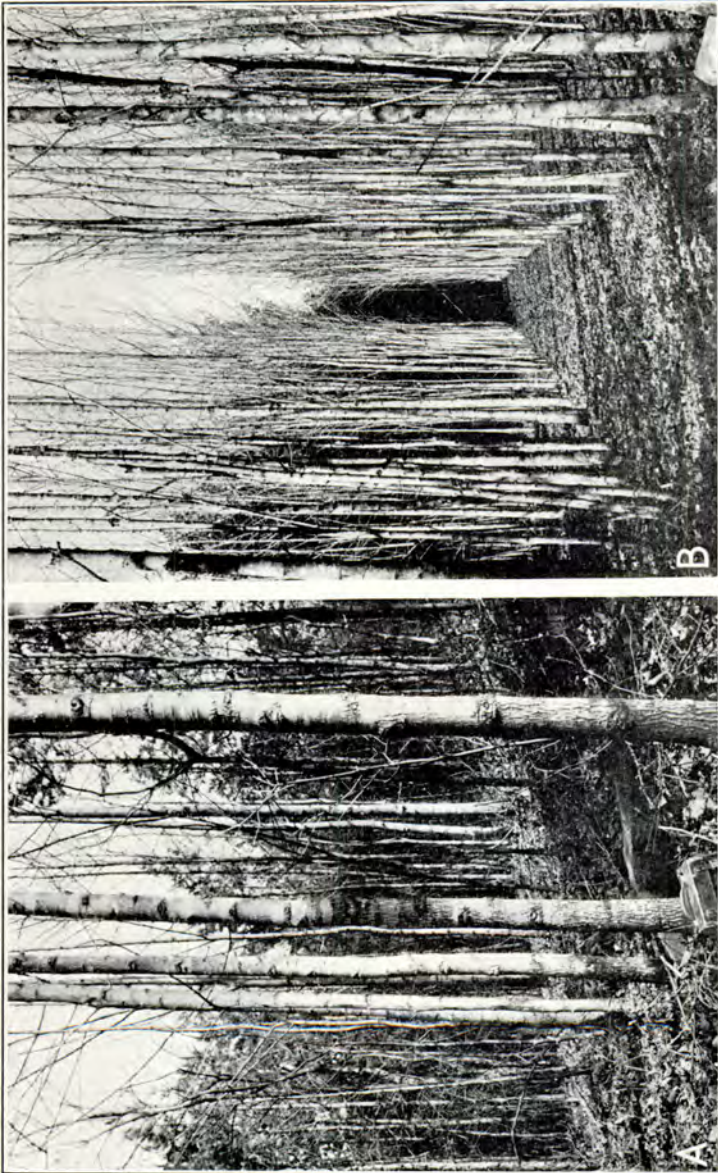
Other species planted with white pine or with white and shortleaf pines have sometimes been entirely shaded out or reduced to a low understory. In such cases the stands differ little if at all from what they would be if the trees of the understory were absent. Sugar maple has been thus suppressed by white and shortleaf pines in the Farmcote plantation, and the white pines of the Douglas stands have greatly overtopped eastern hemlock, Carolina hemlock, and Douglas fir. In the Persimmon Heights plantation western yellow pine is entirely gone, leaving white pine in pure stands.

White pine and sugar maple in mixture have given varied results. In some places the pine is well in the lead; in others the growth of the two species is very much the same. Again, white pine planted after sugar maple has sometimes been very much suppressed by the maple.

In the Riverfront and Old Schoolhouse plantations, on the west side of the French Broad River, two rows of white pine were planted to one row of sugar maple. As at Browntown, the pines after 15 or 16 years were twice the height of the maples, though the pine crowns were not yet closing over the maple rows. Probably the fact that the maples were greatly damaged by rabbits early in life had a good deal to do with the lead gained by the pines.

Maple is competing successfully with white pine in one of the Apiary stands. (Pl. 11, A.) In such instances the densely leafy pine boughs suffer considerable injury from whipping by the slender and elastic maple branches.

When planted under older trees of several species, white pine has grown poorly at Biltmore. Even with sugar maple and black cherry planted only a few years before, it has sometimes not grown well, as is exemplified in two of the Long Ridge stands. On Long Ridge, too, white pine has grown very poorly under the shade of old chestnut trees which were on the land at the time of planting. (Pl. 2, C.)



WELL-DEVELOPED HARDWOODS

Some planted yellow poplar in the Approach Road plantation (A) made fairly good growth. At 29 years of age the tree in the middle foreground is 4 inches in diameter. Poplar has generally been more successful when seeded in naturally. The sugar maple in the Apiary plantation (B) averaged 30 feet high at 25 years of age. The heavy leaf litter and absence of ground cover and underbrush are characteristic of a dense maple stand.



F-17486

TWO DIFFERENT RESULTS WITH BLACK WALNUT

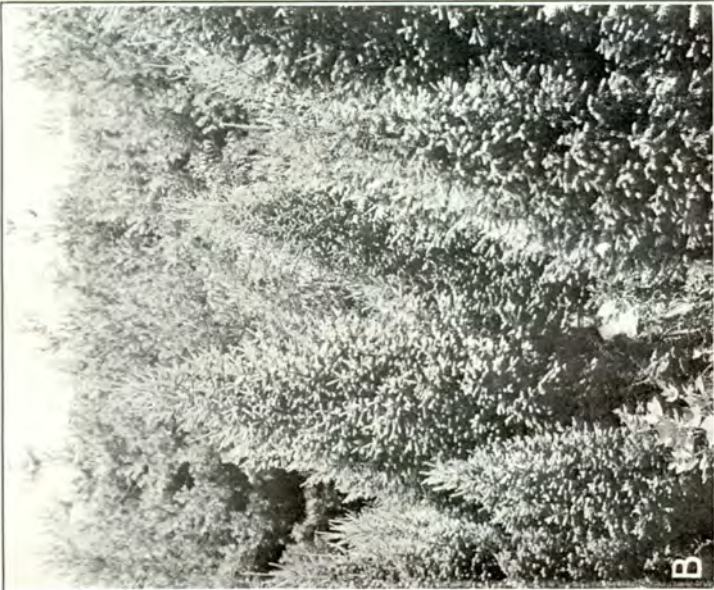
In the stand at the left pitch and shortleaf pines planted two years after the walnuts have dominated the stand and reduced the walnut to a small, unimportant understorey. On the right on lower ground the walnut has made much better growth, and the stand contains no pine. The black walnuts here are 26 years old.



F-185744 AND 185745

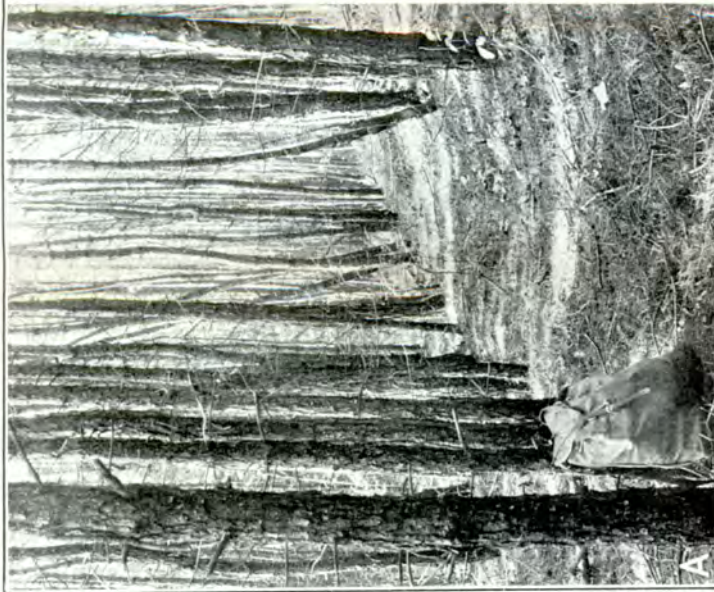
VIRGINIA PINE WOLF TREE DOMINATING PLANTED WHITE PINE

Scattered Virginia pines, about 5 feet tall at the time the white pine was planted, have reached 10 inches in diameter and an average crown spread of 21 feet. The more valuable white pines would have fared better if the older trees had been cut before the planting was done.



PRIZE DOUGLAS FIR ON LONG RIDGE

This Douglas fir stand, about 20 years old, is the best stand of this species on the estate. The trees vary a good deal in size. In the background is white pine.



SHORTLEAF PINE IN THE OLD DAIRY PLANTATION

These trees, when 20 years old, averaged 2,300 to the acre, 30 feet high, and 4 inches in diameter, breast high.

Sometimes it has been advance growth of shortleaf or Virginia pine which has interfered with the growth of the white pine. Virginia pine has been especially harmful in the Lone Chimney plantation, where shortleaf and white pines were planted at the rate of 3,500 to the acre under a stand per acre of some 150 Virginia pines. Fifteen years afterwards a great many Virginia pines were still present, big-boled, low-branched, sprawly, and crowding and overtopping the planted species. (Pl. 7.)

SHORTLEAF AND PITCH PINES

The common native pines, shortleaf and pitch, jointly referred to as "yellow pines," have done very well when planted at Biltmore. Since these two species seed in freely on abandoned farm land in this region, their success in the plantations was to be expected. In one case 35 per cent of the shortleaf pines were reported to have died the first season after planting; but aside from time this there have been few, if any, failures. They were rarely planted pure. Sometimes they were planted in mixture with white pine or with hardwoods; sometimes they were used for replantings where hardwood plantations were not making satisfactory growth. Schenck thought that by adding the pines he would be able to help the hardwoods, but for the most part they have outdistanced and overtopped the hardwoods and sometimes actively suppressed them. The resulting stands are pure yellow pine in the upper story with a low, unimportant understory of the hardwoods.

In the Black Walnut plantation the yellow pines at 22 years of age averaged 25 feet in height, whereas the walnuts, planted on the same site two years before, averaged only 5 feet. (Pl. 6.) In the Approach Road plantation shortleaf pine was planted about 10 years after black cherry and yellow poplar. Eighteen years later the pines averaged 5 feet taller than the hardwoods, though all three species had the same average diameter. Yellow pines were planted two or three years after hardwoods in the Old Orchard plantation, and now greatly overtop the hardwoods. Average figures of height and diameter at breastheight for this stand in 1922 are given in Table 5.

TABLE 5.—Average height and diameter of hardwoods and yellow pines in the Old Orchard plantation, 1922

Species	Age	Height	Diameter
	Years	Feet	Inches
White ash	23	11	0.6
Buckeye	23	13	1.1
White oak	23	13	0.9
Yellow pine	20 (?)	30	4.4

Although some of the hardwoods were as much as 20 or 25 feet tall none were dominant. Some of the pitch pine dominants were nearly 40 feet tall, and their average height was 36 feet.

In the Browntown plantation 8-year-old shortleaf pine was twice as high as sugar maple planted with it. This is one of the plantations where shortleaf pine has done a little better than white pine. In a couple of stands where these two species were in alternate rows the shortleaf pine averaged from 1 to 3 feet taller than the white.

In another stand three species planted together had the following average heights: Shortleaf pine, 17 feet; white pine, 12 feet; sugar maple, 5 feet. C. R. Tillotson reported that in a Browntown stand 15 years old white and shortleaf pines were twice as tall as sugar maple. The pines at that time averaged 25 or 30 feet high. Some of the maples were only a foot high. The maples averaged an inch in diameter, the white pines 2 inches, and the shortleaf pines 4 inches. It was not evident that the maple had done the stand any good.

In a pure stand of shortleaf pine, 8 acres in extent, in the Old Dairy plantation (pl. 8, A) the living trees 20 years after planting averaged 30 feet high and 4 inches in diameter and would yield perhaps 3,000 cubic feet to the acre. The average spacing was at that time 3.5 by 5.5 feet, 2,300 to the acre, half of the planted trees having died. In 1913 William H. Lamb reported 8-year-old shortleaf pine in pure stands at Browntown averaging 15 or 20 feet high and 3 inches in diameter. Their later progress was not observed in 1921-22 because at that time many of the trees had been felled.

SPRUCE

Of the several species of spruce that were planted at Biltmore the only one now present in any considerable numbers is Norway spruce. This species was planted in several small patches near the Approach Road, Swannanoa, and Old Orchard plantations in 1911 or thereabouts. Growth has been slow in these relatively young stands, but the trees are now beginning to produce longer leaders and show considerable promise. At about 12 years after planting these trees averaged 5 or 10 feet in height, some being only 3 feet high and others more than 20 feet. Their best growth has been in bottoms near small streams, but they are also doing well on higher land. Very few of them have died.

JAPANESE LARCH

A small patch of Japanese larch (100 trees) was planted on the flank of Long Ridge. The trees made a fairly good growth in height and diameter, but sprouted profusely along the boles. In 1928, only one or two of the trees remained alive. The dead trees had been removed so promptly that the cause of death could not be ascertained.

DOUGLAS FIR

Douglas fir was planted in only a few places on the estate. The best trees of the 5,000 planted by Schenck are now found in a small patch on the side of Long Ridge. (Pl. 8, B.) There a few of the trees have reached a fair size. The stand, however, varies a great deal in the size of the trees, in their spacing and crown density, and in the density of the ground cover. At about 26 years of age these trees averaged 15 feet in height and 4 inches in diameter at breast-height; but some were only 3 feet high.

WESTERN YELLOW PINE

Western yellow pine was a pronounced failure. About 9,000 transplants were set out in the Horse Stable, Long Ridge, and Persimmon Heights plantations. No reports have been found for the Long Ridge trees after planting. Three months after they were

planted, only 10 per cent were living in the Horse Stable plantation, and two months after that they were nearly all gone. None were found in 1922, 16 years after planting.

In the Persimmon Heights plantation they held on a little longer. Two years after planting 50 per cent were left, but at 9 years all but 5 per cent were gone. In 1921, 16 years after planting, none were found. At 9 years the trees were only 3 or 4 feet high, whereas the white pine planted with them were 12 to 15 feet high.

HEMLOCK

Eastern hemlock and Carolina hemlock persist chiefly as small trees under white pine planted at the same time. In one of the Douglas stands, 32 years after planting, they were only 15 feet high and 3 inches in diameter, as compared with the pine, which averaged 35 feet in height and 10 inches in diameter.

SUGAR MAPLE

In some plantations, for example the Swannanoa, sugar maple has grown as tall as white and shortleaf pines of the same age. Oftener, however, the maple is about 5 feet shorter than the pines, and sometimes the growth has been very much poorer. Even when of the same height, the maple is characteristically more slender than the pines, having a diameter an inch or two less at 25 or 30 years of age. In the unthinned sample plot in the Apiary plantation the growth of planted sugar maple has been like that shown in Table 6. A good stand of pure sugar maple is shown in Plate 5, B.

TABLE 6.—Growth in a near-by pure stand of sugar maple ¹ in the Apiary plantation

Age	Height, dominant trees	Diameter breast high (all crown classes)		Living trees per acre
		Feet	Inches	
Years:				
20 (1916)	37		2.5	2,070
26 (1922)			2.8	1,650
32 (1928)	54		3.1	1,320

¹ Plot 3b, which contained a few white pines.

A good many of the maples were planted with pines. In such associations, the maples have generally been suppressed and have reached a height only half that of the pines. The Browntown plantation has given several first-class examples of this, with shortleaf pine, and with shortleaf pine and white pine. In the Farmcote plantation, also, even with two rows of sugar maple planted to one row of pine, the shortleaf and white pines are far in the lead. Indeed, at 18 years of age the maples averaged only one-fourth the height of the pines, and none of them were dominant. Maple is very persistent, however; the death rate is often low, even when the trees have been suppressed for a long time, and maple will sprout repeatedly, even after being damaged by rodents.

In a few stands, maple is holding its own with white pine (pl. 11), and once in a while has been able to outgrow white pine planted five years or so afterwards.

BLACK CHERRY

In the Apiary and Douglas plantations are a few fairly large trees of black cherry, but these are mostly crooked or forked. The cherry trees in the Apiary plantation are in a small pure stand, (pl. 4 B), which at 25 years of age averaged 35 feet in height, and 7 inches in diameter breast high (dominant trees 55 feet and 10 inches)—a little larger than white pine of the same age. In the Douglas plantations the cherry trees are scattered in a white pine stand and are not quite as large as the pines.

Black cherry in the pure stands on Long Ridge and in a mixed stand in the Approach Road plantation has not done so well. In the latter plantation it has grown as thriftily as associated yellow poplar of the same age, but much more poorly than shortleaf pine planted 10 years later.

In the Swannanoa plantation the black cherry was a marked failure. (Pl. 4, C.) These trees 26 years after planting were on an average only 15 feet tall, and the biggest dominants were less than 25 feet. Sugar maples planted at the same time on the same hillside were twice the height and diameter of the cherries.

During the first season after planting the cherry grew very well in the pure plantings of the Long Ridge and Swannanoa plantations and not more than 5 per cent died. Two years later, however, their progress was less satisfactory, and at 20 years from planting comment was made on the very poor growth of the Swannanoa trees.

Schenck believed that pines helped the cherry along. He wrote that cherry would grow slowly for several years and then make a fresh start even though the pines had a lead of as much as 10 feet. Good large cherry trees are, indeed, found in the Long Ridge and Douglas plantations, and it may be partly because of the crowding by the pines that they have grown well. In nature cherry is seldom found in pure stands, and it would not be surprising if it failed when planted without other species in mixture. But the good stand of cherry in the Apiary plantation is essentially pure, and conversely, the Approach Road cherries do not seem to have been helped much by the pines.

OAK

Planted oaks have, for the most part, grown poorly at Biltmore. The death rate among newly planted trees was frequently large. In one of the Long Ridge plantings 30 per cent of the chestnut oaks died within two months after planting. After another two months 15 per cent more were gone; and by the next spring 60 per cent of the trees planted were gone. Of the white oaks, 10 per cent died in the first two months, and by the following spring only 50 per cent were left.

The best planted oaks at Biltmore are in the Rice Place plantation. (Pl. 4, A.) There, in one 8-acre pure stand of white oak, the trees at 18 years of age were only about 5 feet shorter than white pine of the same age. Like sugar maple, however, they were more slender than the pine, having a diameter only half as great. Fifteen per cent of the trees of this stand have died.

A near-by 1-acre stand is much poorer, the trees being only a third as tall. The reason for this dwarfing is not obvious, but presumably it is due to some unfavorable soil condition which has not

been ascertained. In this stand there has been almost no mortality, probably because of the lack of crowding.

In another of the Rice Place stands there is a mixture of white oak and white ash. There the oaks are not as tall as those in the better of the pure oak stands, and they are 10 feet shorter than the ash trees. The diameters are about in proportion to the heights. At about 20 years after planting, some of the oaks were only 5 feet high, but the smallest ashes were more than 20 feet high.

When planted with pines, the oaks, like other hardwoods, have generally grown much more poorly than the pines. Sometimes they are slender and crooked, trying to get their heads up through the pine-leaf canopy. Often they are hardly more than low shrubs. There is one place on Long Ridge where some shortleaf pines were cut and burned because of bark-beetle attacks. In the opening so made little sprouts of white oak have grown from the 1-inch stumps of small trees that were evidently about 5 to 10 feet high when at the time that the much taller pines were cut, they were cleared out as underbrush. Now that the pines are gone, the oaks are promptly beginning to fill the opening. (Pl. 3, A.) Similarly, in one part of the Apiary plantation rows of chestnut oaks 2 to 4 feet high are persisting under pine planted a couple of years after the oaks, but now 30 feet high. In the Old Orchard plantation the oaks and other hardwoods have been overtopped by yellow pines planted about three years afterward.

WHITE ASH

The best ash in the Biltmore plantations is in the mixed stand of oak and ash in the Rice Place group. Here the white ash at about 20 years of age was 30 feet high, or equal to pines of the same age. The diameter, however, was only half that of pines of this height.

In a near-by pure stand of white ash this species was less successful. At about 20 years from planting the ash trees averaged only 20 feet high and an inch and a half in diameter. Some of them were only 9 feet high and the tallest only 33 feet.

Sometimes, when the ashes did not seem to be growing well in early life, yellow pines were added, and these promptly overtopped the ashes just as they did other hardwoods under like conditions.

YELLOW POPLAR

Yellow poplar has grown better at Biltmore when self-seeded from native trees than when the small nursery-grown plants were set out. A month after planting, about 75 per cent of the trees of this species in the Horse Stable plantation were dead or seemed likely to die before long. They were cut back in May and by June were developing good shoots; but 16 years later only a few were found. These were on an average 25 feet tall and 2½ inches in diameter and were practically as large as white pines of the same age.

In the Approach Road plantation the yellow poplar was reported as doing well two years after planting; but at about 10 years it was considered a total failure, and Schenck added 1-year-old shortleaf pines to replace the planted hardwoods. At about 18 years of age these pines were far ahead of their associates, although a few of the yellow poplars were larger than the pines. Some of the yellow poplars of the Approach Road plantation are shown in Plate 5, A.

BLACK WALNUT AND BUTTERNUT

Whether starting from plants or seeds, black walnut and butternut have not done well in these plantations, especially when planted alone. In some of the stands are a few dominant trees of these species 35 to 45 feet high, but they are not common although black walnut especially was used a good deal.

A small part of the Black Walnut plantation shows fair growth, but the trees are only a little more than half as large as white pine of the same age. In most of this plantation the walnuts were never successful, and yellow pines were soon added to help the walnuts along. This they did not do, but rather took possession of the ground themselves. Plate 6 shows the two stands of this plantation as they looked in 1923.

Black walnut was chosen for this site because there were on the ground two large old trees of this species; but part of the area was undoubtedly too far up on the slope for the best walnut development. Perhaps if the poorer trees had been left alone for a few years longer they would have grown better than they have with the pine competition.

In some of the other plantations a quarter of the walnuts and butternuts had died by the end of the first summer. Those that survived grew very well for a year or two but had heavy losses later on.

In nature, black walnut and butternut are not trees of pure stands, and it might be thought that they are not adapted to growing so. But black walnut has been grown elsewhere in pure plantations. And at Biltmore this species has failed in mixed as well as in pure stands. Frost is probably one of the main reasons for the poor showing made. It is likely also that rodents took most of the seeds from the fall sowings.

CHESTNUT

Chestnut was even less successful than walnut. This species is native to the region and reaches large size in wild stands but, although both seeds and nursery-grown plants were used liberally, very few trees of this species survived. In 1895 and 1898, Schenck planted 25 or 30 bushels of chestnuts on Long Ridge. The next year after planting the stand was very poor, and now there are only a few small planted chestnut trees there. Yet on this ridge are wide-spreading chestnut trees 30 or 40 inches in diameter which were left on the land at the time it was cleared 80 years ago.

BLACK LOCUST

Black locust is another species which has not been very successful, though a few good-sized trees, sometimes as much as 60 or 70 feet high, are found here and there in the Apiary, Douglas, and Long Ridge plantations. Tillotson estimated in 1920 that 24-year-old locusts in the Apiary plantation would yield three to five 7-foot fence posts to the tree.

HICKORY

For the first two years after planting and sowing, the Apiary hickories grew very well. A few years later it was reported that mice had damaged them badly. Now there are only a few small hickories in this plantation, and it is not entirely certain that they are planted hickories. On Long Ridge, 40 per cent of them were gone a little over a year after planting, and in 1921 no hickories were found.

BASSWOOD

Two years after planting the basswoods in the Apiary plantation were reported to be in very poor condition. None were seen at Biltmore during the 1921-22 study.

BUCKEYE

Two years after planting a report was made that buckeyes in the Apiary plantation were in very good condition. Aside from this, no reference has been found. The only planted trees of this genus seen during the 1921-22 study of the Biltmore plantations were a few small trees in the Old Orchard plantation.

ALANTHUS

Ailanthus was another unsuccessful species, although it is rather common as an ornamental in Asheville. The first season after planting 25 per cent of these trees that Schenck planted died; and during the first few winters the frosts kept killing the rest of them back. Only one tree of this species was seen at Biltmore during the 1921-22 study.

FACTORS AFFECTING THE SUCCESS OF THE PLANTED TREES

The successes and failures of the trees planted at Biltmore give a good general idea of what species ought and ought not to be used in making forest plantations in this region. An analysis of the causes of these successes and failures will, however, put one in a yet better position to make a wise choice.

With the native forest of the region consisting largely of hardwoods, Schenck concluded that hardwoods would be the most likely to succeed in his plantings, but it can now be seen that he was overlooking one or two very important facts.

First of all, he was planting, not under a stand of hardwoods nor on land from which hardwoods had just been taken, but on old fields which had been cleared many years before. Even though parts of the old forest were still standing next to his planting sites, they could not be relied on as guaranteeing that the same species could be successfully planted. During the time that these fields were cultivated and pastured and then left to run wild it is clear that the condition of the land became very different from what it was just after the forest was taken off. Because of poor handling and erosion, most of the humus was gone, as well as a good deal of the topsoil.

The pines, on the other hand, are trees which in this region are normally characteristic of poor soils and old fields. A commonly observed succession in the southern Appalachian region following such abuse of the land as has just been mentioned is, first, pines, chiefly hard pines, and later an invasion of the native hardwood species. The precise causes for this type of succession are still to be ascertained. Undoubtedly the exposure of the cleared site to sun and wind is one of them, sites so exposed being drier and warmer. Possibly, also, there may be a smaller supply of mineral nutrients in the worn-out soils. And certainly the superior mobility of the wind-borne pine seeds is yet another significant influence.

There are many examples at Biltmore of hardwoods failing when old trees of the same species were present on or near the planting site.

Oaks on Long Ridge and in the Apiary plantation, chestnuts on Long Ridge, and black walnut in the Black Walnut plantation illustrate this. Sometimes the seed was destroyed or the plants died when very young. In other instances, the trees have kept growing as a suppressed understory. In the latter case, it is to be expected that a good many of the hardwoods will finally take the place of the pines that drop out for one reason or another.

Another thing that Schenck had not reckoned on in planting hardwoods was the large number of rodents present on or about the planting sites. Rodents are notorious seed destroyers in planting areas, and their conduct at Biltmore was no exception. No conifer seed was sown here, so all such losses were among the hardwoods. The losses of black walnut and chestnut seeds, two species which were very unsuccessful, have been mentioned by Schenck as particularly severe.

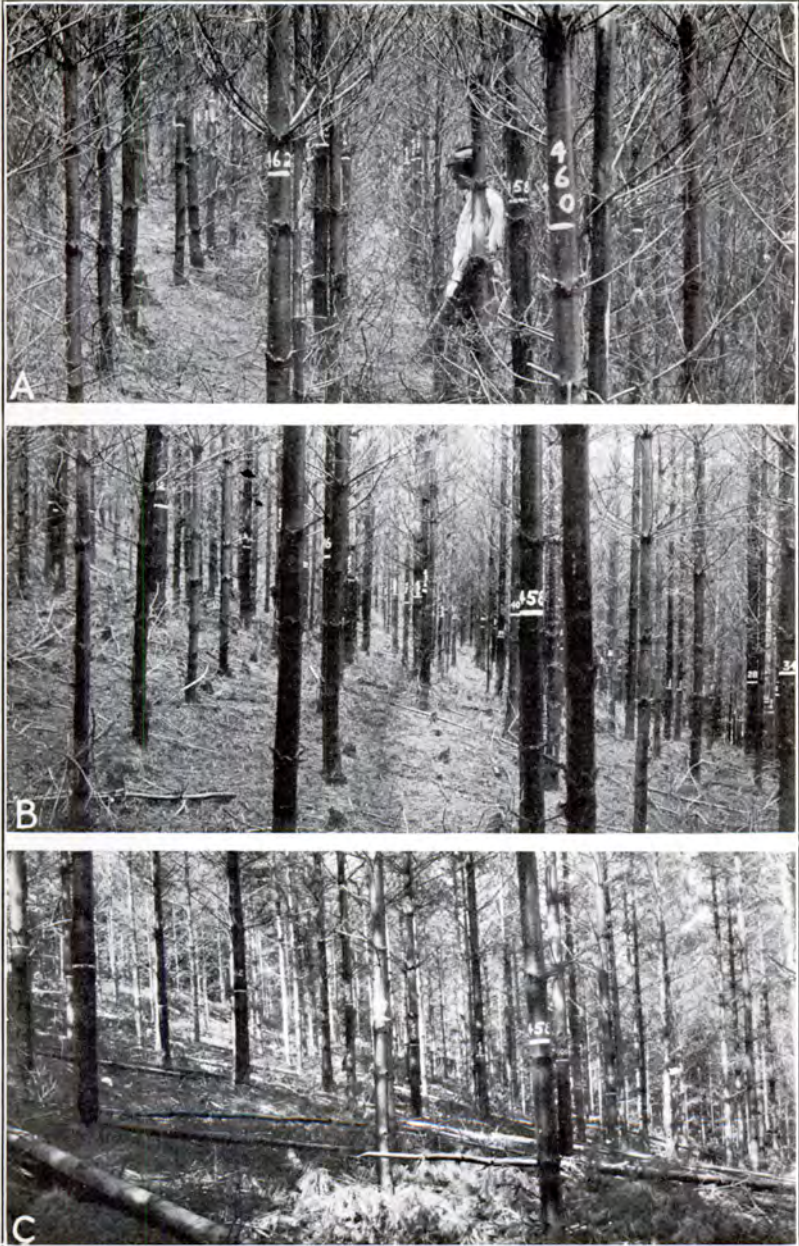
After the seed had sprouted, many of the plants were killed by ground mice. Schenck records that whole rows of hickory and oak were destroyed by these animals working underground; and that they destroyed half of all the locust plants.

But of all the rodents, the rabbits were the most troublesome. Hardwoods that started to grow well were kept back solely because of nibbling by rabbits. Rabbits were very destructive to oaks in the Apiary plantation; elsewhere, sugar maples were attacked. Sugar maple and oak in these plantations have been much less successful than pines. On the other hand, yellow poplar has also been unsuccessful, but it is not recorded that rabbits injured the trees. Apparently none of the conifers were attacked by either mice or rabbits.

While rodents have worked against the hardwoods, the greatest damage to the pines was from insects. The southern pine beetle (*Dendroctonus frontalis* Zimm.) has worked in shortleaf pine of two plantations—Long Ridge and Ferry Farm—and another bark beetle, (*Ips* sp.), has appeared in Scotch and shortleaf pines. In the Ferry Farm plantation the attack included part of one of the Forest Service sample plots and forced a change in the marking for thinning some years after the establishment of the plot. In this stand the white pines were much inferior to the shortleaf at the time the plot was established; but since white pine is less subject than shortleaf to attack by southern pine beetles it may ultimately supplant the shortleaf should the attack be extended throughout the stand. Hardwoods growing under a stand of pine attacked by the bark beetle will be given a chance for development of which they are likely to take prompt advantage.

The most common insect in the Biltmore plantations is the pine bark aphid (*Adelges pinicortis* Fitch), which infests the smooth bark of white pine. Sometimes the boles are fairly white with them. They are much more plentiful in the plantations than they were 10 years ago, and are also very common on ornamentals in Asheville, but, as far as is known, they cause no serious injury to the tree.

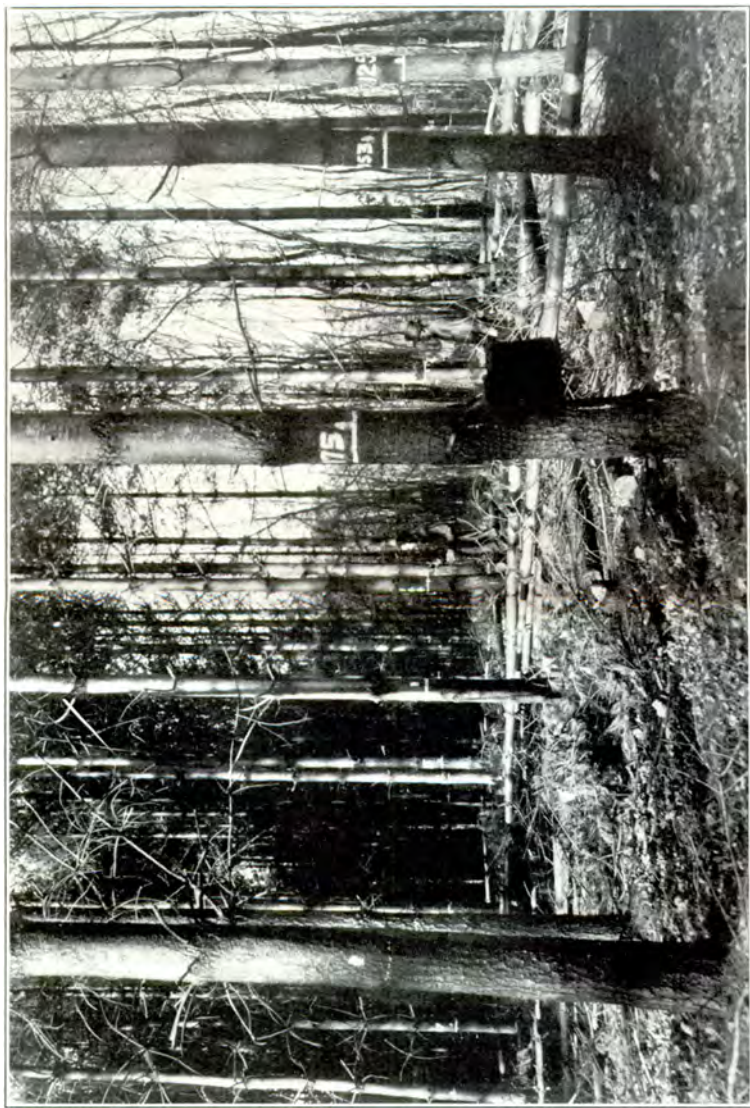
The white pine weevil (*Pissodes strobi* Peck) has not greatly damaged the white pine on the estate. From counts of several plots taken at random in the planted white pine stands, H. J. MacAloney, forest entomologist with the Northeastern Forest Experiment Station, estimates the proportion of the trees injured by weevils at about 5 per cent. No injury to the planted black locusts from the locust borer (*Cyllene robiniae* Forst.) or the locust leaf miner (*Chalepus dorsalis* Thumb.) was observed.



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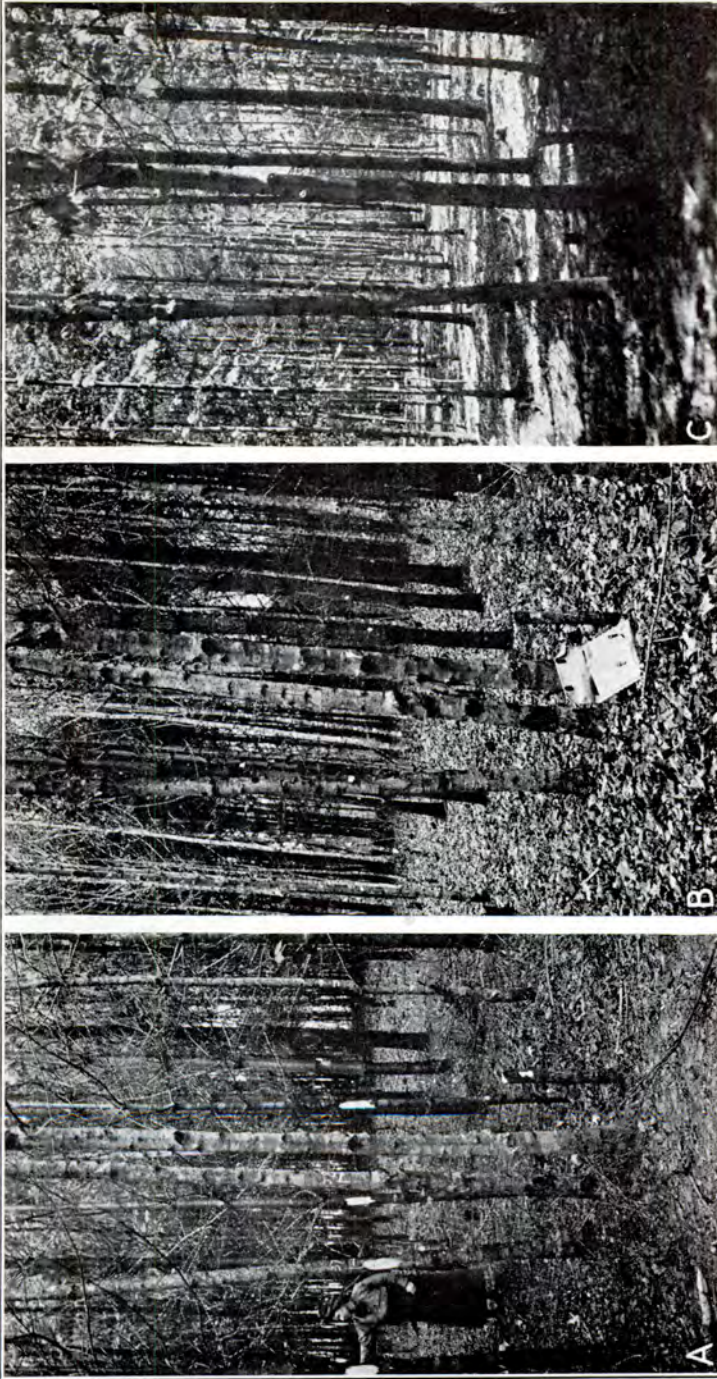
EXPERIMENTAL THINNING IN PURE WHITE PINE, OLD ORCHARD PLANTATION

A, The 18-year-old stand just before thinning; B, the 24-year-old stand just before the second thinning; C, the stand just after the second thinning.



EXPERIMENTAL THINNING IN PURE WHITE PINE. APIARY PLANTATION

A corner of sample plot 4a after the very heavy second thinning, in 1923, which reduced the total volume by about 40 per cent. The unthinned control plot is in the left background.



EXPERIMENTAL THINNING IN SUGAR MAPLE AND WHITE PINE. APIARY PLANTATION

A, The 20-year-old stand just before thinning; B, the 20-year-old stand just before the second thinning; C, the same stand after the second thinning. This is one of the few stands on the estate where maple is growing satisfactorily side by side with pine. In the thinning operations the best maples were preserved. The first thinning took one-half of the living trees; the second thinning one-quarter.

In plantations as young as those at Biltmore, tree diseases are not likely to be very conspicuous. Butt rot due to pine root fomes (*Fomes annosus* (Fries) Cooke) was found in a few of the white pines cut in the thinning plots in 1923; and it is hard to tell how common this disease may be until more cutting is done in the plantations or until the fruiting bodies of the fungus develop. It is a disease which is very likely to be common in such dense stands as are many of those at Biltmore, and it attacks conifers more often than hardwoods. Its effect in a mixed stand, therefore, or in a pine stand with hardwood understory, is, like that of bark beetles, to favor the hardwoods by killing the pines.

Rhoades discovered a 100 per cent infection of a rust (*Peridermium cerebrum* Peck) on the western yellow pines on Persimmon Heights, and believed that this fungus might have been an important contributing factor in the failures of western yellow pine at Biltmore. This is a common disease of shortleaf, pitch, Virginia, and other yellow pines. The disease alternates, in distinct forms, between pines and oaks.

White pine blister rust (*Cronartium ribicola* Fisch.) has not been found at Biltmore. Gooseberries and currants, the alternate hosts of the fungus causing this disease, are not common in this region.

The age and size of the stock planted, the methods used in planting, and the weather at the time of planting are likely to have some effect on the success of planted trees. While these things all varied during the 20-odd years of the planting work at Biltmore, in very few instances were the differences such that the results can be fairly compared. When, for instance, different-aged stock of a given species was used in any one year, the trees were usually planted not side by side, but on entirely different sites. The same holds true for the other factors.

Whether 2, 3, 4, or 10 year old white pine stock was used seems to have made no difference in the stands produced, except possibly in one instance, in the Apiary plantation, where it has been thought that 4-year-old plants outgrew 2-year-olds planted in alternate rows. But even here it is not quite certain that it is the 4-year-old plants that are the survivors; and, furthermore, one set was raised in Germany, the other at Biltmore.

The young trees were planted in plowed furrows and in holes dug in the sod, and several small variations were tried, such as adding forest soil to the hole before planting; but none of these practices seems to have made any difference in the growth of the trees. A few of the pines were transplanted with balls of earth about the roots, but since it is not certain just where these were planted, results can not be compared with those in connection with which other methods were followed.

In accordance with the teachings of that day, most of Schenck's planting was very close. On Long Ridge the trees of the big replanting were given an average spacing of less than 5 feet apart each way. Sometimes rows 5 feet apart were used with very close spacing in the rows. Many of the trees at Browntown, for instance, were only a foot or two apart in the row.

In some stands enough of such closely planted trees have died to give room for development to the rest; elsewhere one species in a mixture has been overtopped; and in other instances very crowded

stands have developed. Plate 9, A, is a view of a crowded stand of white pine in the Old Orchard plantation. In stands like this the tree crowns are closed, many trees have died, and the long-persisting dead branches make passage between the trees difficult. In photographic work in such stands an exposure of 40 seconds is needed as against 0.04 second in the open, under otherwise similar conditions.

Some of the hardwoods were cut back the first season after planting. Whenever this work was done in the spring, the plants so treated generally developed good shoots. Summer cutting back was less satisfactory. But even when the first year's growth was good, most of the plants cut back did not grow well thereafter. The black cherry shown in Plate 4, C, for instance, made very good growth immediately after being cut back, but is now worthless.

Most of the planting at Biltmore was done with native species, but a number of plants of more than a dozen species, mainly conifers, from other parts of the country and from Europe and Asia, were used in a few of the plantings. Most of these exotics have died. Of those that lived, Scotch pine, Norway spruce, Japanese larch, and Douglas fir are the best.

Schenck considered that the Douglas fir raised from Washington seed made better growth than that from Colorado seed, though neither was an outstanding success.

Some of the white pine was brought in as seedlings or transplants from Germany. Their growth was not noticeably different from that of the trees raised in the Biltmore nurseries.

Ailanthus, one of the few exotic hardwoods used, was much damaged by frost.

The greatest part of Schenck's planting was in the spring—February, March, and April. One planting of white pine (Cherokee Drive plantation), was made in November. These trees show no difference in growth from those planted in the spring. The latest of the spring plantings was the Norway spruce of the Spruce plantations, put in after Schenck left the estate. Although it was the middle of June before this planting was finished, there have been almost no losses.

Schenck's earlier records have several references to weather conditions at the time of planting or just after. Mostly the weather was favorable for planting or tree growth, but it needed more than this for most of the hardwood plantings to produce good stands.

While the planting sites varied greatly in the direction and steepness of slope, the effects of topography are not clear because of other factors entering in at the same time.

Although the United States Bureau of Soils has distinguished several soil types on the Biltmore Estate, it has not been possible to relate these to differences in growth of the planted trees. The plantations, on their part, through the formation of litter cover and development of interlacing roots, have checked gullyng on the steep slopes, while the tree crowns have intercepted the rain and decreased the amount of light reaching the forest floor.

One of the results of these changed conditions has been a great change in the ground cover. Many of the stands had a severe struggle with weeds, grass, and greenbrier for the first few years after planting. In the white pine stands of to-day, however, because of the weak light, there are very few plants on the ground, and these are

chiefly of such shade-loving species as spotted wintergreen and rattlesnake plantain.

On the Lone Chimney planting site there was a scattered stand of Virginia pines about 5 feet tall, 150 to the acre. These trees have kept well ahead of the planted white pines and are interfering with their development. It would have been better for the planted trees if these scrubby pines had been cut before the planting was done.

THINNING OPERATIONS¹

A great many of the Biltmore plantations are very much in need of thinning. Systematic thinning should have followed the very dense spacing that was used in much of Schenck's work; and this indeed seems to have been his intention. But save for the small-scale experimental thinnings by the Forest Service, nothing has been done beyond the removal of occasional trees because of an insect infestation, to improve the appearance of a roadside, or for planting elsewhere.

The thinning experiments now being conducted by the Forest Service are in four sets of permanent sample plots, located in three of the plantations. Two of these experiments are in pure white pine stands in the Old Orchard and Apiary plantations, respectively, one in a mixture of shortleaf and white pines in the Ferry Farm, and one in mixed white pine and sugar maple in the Apiary. In all of these the first thinning was made in October, 1916, and a second in January, 1923. All were remeasured in November, 1928, prior to a third thinning.

The principal purpose of the thinnings is to make the stands produce just enough large trees to occupy the site fully and no others, this condition being gradually brought about by successive thinnings. A second object is to salvage a great many small trees which otherwise, as a result of the competition, would die and rapidly decay. The early thinnings in the mixed stands had additional objects which will be mentioned in discussing the thinnings in those stands.

At the time the experiments were started in the Old Orchard and Apiary white pine, the stands were 18 and 20 years old, respectively. The Old Orchard stand was then extremely dense; if the sample plot numbered *1a* had not been thinned, its growth would undoubtedly have fallen off, as did that in the unthinned control plots *1b* and *1c*, discussed earlier in this publication under the heading "White Pine." The appearance of this plot before and after the first thinning and after the second thinning is shown in Plate 9. The white pine in the Apiary plantation was exceptionally thrifty, probably because every other row of the planted pines had died, giving the trees of the surviving rows added space in which to develop. The thinned sample plot in the Apiary white pine is numbered *4a*; it is the companion of the unthinned plot, *4b*, discussed under "White Pine." The volume and number of living trees, on an acre basis, for these plots before and after the two thinnings and in the fall of 1928 are shown in Table 7.

¹This section is largely the contribution of E. H. Frothingham.

TABLE 7.—Record of thinning experiments in Old Orchard and Apiary plantations, 1916–1928¹

Date of record	Old Orchard plantation				Apiary plantation			
	Volume per acre		Trees per acre		Volume per acre		Trees per acre	
	Plot 1a	Control ²	Plot 1a	Control ²	Plot 4a	Plot 4b	Plot 4a	Plot 4b
Before first thinning, October, 1916.....	Cubic feet 2,710	Cubic feet 2,710	Number 2,304	Number 2,580	Cubic feet 4,680	Cubic feet 4,680	Number 1,760	Number 1,425
After first thinning.....	1,980	-----	1,136	-----	3,550	-----	952	-----
Before second thinning, January, 1923.....	2,670	3,186	1,056	1,904	4,290	5,060	832	962
After second thinning.....	1,760	-----	508	-----	2,530	-----	336	-----
Last examination, September, 1928.....	2,570	3,345	504	1,284	3,460	5,980	336	725

¹ Volumes were computed by the use of an assumed form factor of 0.5.

² Average of plots 1b and 1c.

The difference in growth rate between the thinned and control plots in the Old Orchard white pine is very marked. In the thinned plot the annual growth between the first two thinnings was at the rate of 115 cubic feet per acre, while in the six years following the second thinning it amounted to 135 cubic feet. In the two control plots, combined, the annual growth for the corresponding periods was at the rate of only 79 and 27 cubic feet per acre, respectively. In the thinned plot, also, there was removed in the two thinnings a useful volume of wood equivalent to 1,640 cubic feet per acre; in the control plots, of course, there was a total loss of at least some of this wood volume through death and decay. The thinned plot, with 504 trees per acre in 1928, and an increase in total yield of 865 cubic feet per acre, is in a much more efficient condition for growth than the unthinned, overdense control plots with 872 and 1,696 trees per acre, respectively.

In the Apiary white pine, the annual growth rate between the first two thinnings (123 cubic feet per acre), was about double that for the corresponding period in the unthinned plot (63 cubic feet per acre); but for the six years following the second thinning the growth rate of the thinned and unthinned plots was about equal (150 cubic feet per acre per year in round numbers). Evidently the second thinning was considerably too heavy and left the stand too thinly stocked for efficient production. It should be noted, however, that the growth of the unthinned stand was distributed among small trees at the rate of 725 to the acre, while that of the thinned stand was concentrated on carefully selected thrifty trees at the rate of only 336 to the acre. The thinned plot as it appeared after the heavy thinning of 1923 is shown in Plate 10. Sample plots 4a and 4b contained 0.125 and 0.08 acre, respectively.

The mixed pine stand in the Ferry Farm plantation was 17 years old when the thinning experiments were begun. In this stand the shortleaf pine had considerably outgrown most of the white pine without killing it, and one object of the experiment was to attempt to preserve the mixed character of the stand. Of the taller trees in the thinned plot, 95 per cent of the white pines were therefore left standing and only 74 per cent of the shortleaf pines, while of the

shorter trees 85 per cent of the white and only 4 per cent of the short-leaf pines were left. As yet the white pines have not made sufficient growth to justify the advantage given them. The procedure has, however, proved fortunate in another way; for when a bark-beetle attack killed several of the shortleaf pines, the smaller white pines were in readiness to fill up the blanks caused by the death of the larger trees. The thinned and control plots have an area of 0.1 acre each.

The plot of mixed pine and maple was put in in one of the 20-year-old Apiary stands, and here the maples were growing so well that it seemed worth while to encourage maple at the expense of all but a very few of the best pines. Most of the pines were, in fact, suffering from the competition of the maples. In 1916, 52 per cent of the living trees were cut; in 1923, 25 per cent. (Pl. 11.) As the area of this stand is only 0.4 acre, the sample plots had to be very small—one-twentieth of an acre for the thinned plot and one-thirtieth for the control.

THE PLANTATIONS AS A GUIDE TO FUTURE PLANTING

Although many of the details of planting and much of the subsequent history of the resulting stands are unrecorded or have been obscured by time, certain conclusions are obvious from a study of the present plantations and available records.

Evidence points very clearly, for example, to the unwisdom, in replanting old fields, of selecting a species merely because of its prevalence in the virgin forest of the region. Schenck's efforts to reestablish hardwoods on the old fields that he planted did not take into consideration the changes in the soil and other environmental conditions which the removal of the forest, the farming of the land, and its subsequent abandonment had involved. It was because of this that the few individual trees left from the original forest proved misleading indicators of the species that would do best under the conditions obtaining at the time of planting.

The Biltmore plantations clearly demonstrate the suitability of northern white pine for planting in this region and also the desirability of planting the native yellow pines in mixed stands. Of the hardwoods that have survived, sugar maple is the best and oaks second. Oak as an understory of pine can evidently be counted upon to persist and to step readily into the place of the pines when these are removed. Of the exotic species tried at Biltmore, Norway spruce has given the best results.

Clearly, the close planting favored by Schenck and others of that period is not justified unless it is followed up with systematic thinnings. The results of the experimental thinnings made by the Forest Service afford convincing evidence of the value of silvicultural thinnings in all plantations of such closely spaced trees.

TABLE 8.—List of native trees mentioned in the text or used in the plantations

Common name	Scientific name	Plantation
Ailanthus ¹	<i>Ailanthus altissima</i>	Long Ridge. ²
Ash, Oregon ²	<i>Fraxinus oregona</i>	Browntown. ²
Ash, white	<i>Fraxinus americana</i>	Border, Browntown, ² Long Ridge, ² Old Nursery, Old Orchard, ² Rice Place.
Basswood	<i>Tilia</i> sp.	Apiary, ² Douglas. ²
Beech	<i>Fagus grandifolia</i>	
Birch, river	<i>Betula nigra</i>	
Birch, yellow	<i>Betula lutea</i>	Douglas. ²
Buckeye	<i>Aesculus</i> sp.	Apiary, ² Long Ridge, ² Old Orchard. ²
Butternut	<i>Juglans cinerea</i>	Long Ridge, ² Swannanoa. ²
Cedar, eastern red	<i>Juniperus virginiana</i>	Douglas. ²
Cherry, black	<i>Prunus serotina</i>	Apiary, Approach Road, ² Brick House, ² Browntown, Douglas, Long Ridge, Swannanoa. ²
Chestnut	<i>Castanea dentata</i>	Apiary, ² Browntown, Douglas, ² Long Ridge. ²
Dogwood	<i>Cornus florida</i>	
Douglas fir ²	<i>Pseudotsuga taxifolia</i>	Apiary, ² Douglas, ² Long Ridge.
Fir, balsam ²	<i>Abies balsamea</i>	Long Ridge. ²
Fir, European silver ¹	<i>Abies pectinata</i>	Apiary, ² Long Ridge. ²
Fir, southern balsam	<i>Abies fraseri</i>	Long Ridge. ²
Fir, white ²	<i>Abies concolor</i>	Long Ridge. ²
Hawthorn	<i>Crataegus</i> sp.	
Hemlock, Carolina	<i>Tsuga caroliniana</i>	Douglas. ²
Hemlock, eastern	<i>Tsuga canadensis</i>	Douglas. ²
Hickory	<i>Hicoria</i> sp.	Apiary, ² Black Walnut (?), ² Hillside Road (?), ² Long Ridge. ²
Larch, Japanese ¹	<i>Larix leptolepis</i>	Long Ridge. ²
Larch, Siberian ¹	<i>Larix sibirica</i>	Apiary, ² Long Ridge. ²
Locust, black	<i>Robinia pseudacacia</i>	Apiary, Douglas, ² Long Ridge. ²
Magnolia, cucumber	<i>Magnolia acuminata</i>	Browntown.
Maple, bigleaf ²	<i>Acer macrophyllum</i>	Browntown. ²
Maple, red.	<i>Acer rubrum</i>	
Maple, sugar	<i>Acer saccharum</i>	Apiary, Border, ² Brick House, Browntown, Farmcote, ² Horse Stable, ² Long Ridge, Old Dairy, Old Schoolhouse, Rice Place, Riverfront, Swannanoa.
Oak, black	<i>Quercus velutina</i>	
Oak, chestnut	<i>Quercus montana</i>	Apiary, ² Black Walnut (?), ² Browntown, Hillside Road(?), ² Long Ridge, ² Old Orchard. ²
Oak, red	<i>Quercus borealis</i> , or <i>Q. borealis maxima</i> .	Black Walnut (?), ² Hillside Road (?), ² Long Ridge, ² Old Orchard. ²
Oak, scarlet	<i>Quercus coccinea</i>	Browntown.
Oak, southern red	<i>Quercus rubra</i>	Apiary, ² Black Walnut (?), ² Hillside Road (?), ²
Oak, white	<i>Quercus alba</i>	Apiary, ² Black Walnut, ² Long Ridge, ² Old Nursery, Old Orchard, ² Rice Place.
Persimmon	<i>Diospyros virginiana</i>	
Pine, jack ²	<i>Pinus banksiana</i>	Long Ridge. ²
Pine, northern white	<i>Pinus strobus</i>	Apiary, Approach Road, Bent Creek Road, Border, Brick House, Browntown, Cherokee Drive, Douglas, Farmcote, Ferry Farm, Hillside Road, Horse Stable, Lone Chimney, Long Ridge, Old Dairy, Old Nursery, Old Orchard, Old Schoolhouse, Persimmon Heights, Riverfront, Sheep Farm Road, Truck Farm.
Pine, pitch	<i>Pinus rigida</i>	Apiary (?), Black Walnut, Ferry Farm, Old Orchard.
Pine, Norway ²	<i>Pinus resinosa</i>	Douglas. ²
Pine, Scotch ¹	<i>Pinus sylvestris</i>	Long Ridge.
Pine, shortleaf	<i>Pinus echinata</i>	Apiary, Browntown, Farmcote, Ferry Farm, Long Ridge, Lone Chimney, Old Dairy, Rice Place (?). ²
Pine, Swiss stone ¹	<i>Pinus cembra</i>	Long Ridge. ²
Pine, Virginia	<i>Pinus virginiana</i>	
Pine, western yellow ²	<i>Pinus ponderosa</i>	Horse Stable, ² Long Ridge, ² Persimmon Heights. ²
Pine, yellow	(Planting records give only the group name "yellow pine.")	Ferry Farm, Long Ridge, Old Orchard, Rice Place.
Sassafras	<i>Sassafras variifolium</i>	
Serviceberry	<i>Amelanchier canadensis</i>	
Sourwood	<i>Oxydendrum arboreum</i>	
Spruce, blue ²	<i>Picea pungens</i>	Apiary, ² Douglas, ² Long Ridge. ²
Spruce, Norway ¹	<i>Picea excelsa</i>	Apiary, ² Long Ridge, Old Dairy, ² Spruce.
Spruce, red	<i>Picea rubra</i>	Long Ridge. ²
Spruce, Sitka ¹	<i>Picea sitchensis</i>	Apiary. ²
Walnut, black	<i>Juglans nigra</i>	Apiary, ² Black Walnut, Ferry Farm, ² Hillside Road (?), ² Long Ridge, ² Old Orchard, Swannanoa. ²
Yellow poplar	<i>Liriodendron tulipifera</i>	Approach Road, Browntown, Douglas, Farmcote, ² Horse Stable, ² Long Ridge. ²

¹ Foreign trees.² Species unsuccessful, rare, or no longer present in this plantation.³ American trees not native to the region.