1925

Studies of Connecticut Hardwoods: The Treatment of Advance Growth Arising as a Result of Thinnings and Shelterwood Cuttings

Louis J. Leffelman

Ralph C. Hawley

YALE UNIVERSITY · SCHOOL OF FORESTRY

BULLETIN NO. 15

STUDIES OF CONNECTICUT HARDWOODS

THE TREATMENT OF ADVANCE GROWTH ARISING AS A RESULT OF THINNINGS AND SHELTERWOOD CUTTINGS

BY

LOUIS J. LEFFELMAN

Research Fellow, Yale University

AND

RALPH C. HAWLEY

Professor of Forestry, Yale University

NEW HAVEN

Yale University

1925

A Note to Readers
2012

This volume is part of a Bulletin Series inaugurated by the Yale School of Forestry & Environmental Studies in 1912. The Series contains important original scholarly and applied work by the School's faculty, graduate students, alumni, and distinguished collaborators, and covers a broad range of topics.

Bulletins 1-97 were published as bound print-only documents between 1912 and 1994. Starting with Bulletin 98 in 1995, the School began publishing volumes digitally and expanded them into a Publication Series that includes working papers, books, and reports as well as Bulletins.

To celebrate the centennial of publishing at the school, the long out-of-print Bulletins 1-97 were scanned to make them available as pdfs to a broader audience. *A caution: the scanning process is not perfect, especially for print documents as old as some of these, so the readers' indulgence is requested for some of the anomalies that remain despite our best efforts to clean them up.*

Everything published from 1912-present is available on the School's website (**http://environment.yale.edu/publications**) for free download. Nothing in the Series requires copyright permission for reproduction when intended for personal or classroom use.

Bound copies of everything published in the Series from 1912 to the present are also available in the Yale University libraries and archives and can best be accessed by contacting the School of Forestry & Environmental Studies librarian.

CONTENTS

The authors wish to acknowledge their indebtedness to Dr. George E. Nichols} Associate Professor of Botany, Yale University, for helpful suggestions in reference to growth forms and lor his aid in photographing the various root systems shown in Figures 3,4,5,8,9, 10, 11, *and IS.*

STUDIES OF CONNECTICUT HARDWOODS

THE TREATMENT OF ADVANCE GROWTH ARISING AS A RESULT OF THINNINGS AND SHELTERWOOD CUTTINGS

BY LOUIS J. LEFFELMAN AND RALPH C. HAWLEY

PURPOSE OF THE INVESTIGATION

THE typical hardwood stand with which the silviculturist in Connecticut has to deal is even-aged in form. The causes which operated in the past to create stands of this character are thoroughly understood and do not require consideration in this study. That even-aged stands, particularly when densely stocked and composed of comparatively intolerant species, require thinning to develop the most vigorous individuals and to obtain maximum production, is an accepted principle of silviculture.

As the practice of forestry started during the last quarter-century, initial thinnings and improvement cuttings were made. In many cases the operation was repeated two or more times, at intervals of five to fifteen years. In older stands reproduction cuttings of the shelterwood type sometimes followed or were substituted for thinnings. Salvage cuttings of the chestnut leaving the other species (an operation forced by the ravages of the chestnut blight) resembled either thinnings or shelterwood cuttings. As experience was acquired, it became evident that all of these cuttings, thinnings, improvement cuttings, salvage cuttings, and shelterwood cuttings were followed by prolific reproduction of trees and shrubs, either sprouts from cut stumps, root suckers, or seedlings. Even the lightest thinning among the living trees had this effect.

The reproduction in most cases originates many years before it is wanted. It remains under cover for long periods, during which many of the individual stems die, while others are badly injured or deformed. Eventually the old stand is removed by a final shelterwood cutting or by a clearcutting.

TREATMENT OF ADVANCE GROWTH

The remnants of the reproduction, which originated at intervals during a period of several decades, now are freed and left in a position to dominate all or portions of the area. Young seedlings developed by the later shelterwood cuttings, or sprouts arising after the clearcutting, must compete with the older (and possibly more undesirable) elements of the reproduction.

The early treatment of this young, relatively irregular stand, composed of individuals of varying shape, species (both trees and shrubs), origin, vigor, age, and rate of growth, with the object in view of obtaining the most promising combination for future timber production, constitutes a silvicultural problem of large importance. The authors have studied the problem intensively in the attempt to determine the relative value, as components of the future stand, of all elements in the reproduction, particularly those which originated prior to the final removal of the old stand. Preliminary conclusions are set forth in the present report.

The term "advance growth" has been applied in this study to all reproduction, both trees and shrubs, which originates on a given area prior to the final removal of the old stand. It is recognized that this use of the term does not agree exactly with the terminology adopted by the Society of American Foresters.[1] According to the definition adopted by this Society, "advance growth" is recognized as "young trees which have sprung up spontaneously in openings in the forest, or under the forest cover (before reproduction fellings are begun)."

It was found that the time of origin of the reproduction—whether it started previous or subsequent to the first reproduction cutting—was not a determining factor in the relative value of this reproduction in the future stand. Moreover, in hardwood stands repeatedly thinned and later reproduced by the shelterwood method there will always be difficulty in fixing exactly the line of demarkation between the two types of cuttings. For these reasons a broader definition of the term "advance growth" appeared desirable.

The study separates logically into five parts:

1. A system of classification for the woody vegetation.
2. Amount, character, and distribution of the advance growth and of reproduction arising subsequent to the last cutting.
3. Growth in height of the various elements composing the young stand.
4. Conclusions as to the probable composition of the future stand and the relative value of the individuals which it will contain.

[1] Forest Terminology. Terms in Forestry compiled by a committee of the Society of American Foresters. *Journal of Forestry*, Vol. 15, 1917, p. 71.

5. Treatment advised to improve the future stand.

The field of this investigation was restricted to the hardwood stands growing on the better drained soils. This excluded swamps and the wetter bottomlands. The latter classes of land comprise only a small and relatively unimportant portion of Connecticut's woodlands.

METHODS OF STUDY

Representative areas, where repeated cuttings had been made and advance growth Was abundant, were selected near New Haven, Conn. Upon these areas the forest cover was studied intensively. The results were checked by less intensive work on other areas luore widely distributed. Measurements on an area basis were necessary in determining amounts and distribution of the different classes of vegetation. Other factors, such, for example, as height growth, required study on an individual tree basis. The field work occupied the greater portion of one man's time during the period from September, 1924, to June, 1925.

To obtain data regarding the amount and distribution of the vegetation, the transect method was selected as furnishing better averages than the quadrat method. Continuous transect strips six feet in width were run across the ridges and streams, thus bisecting and sampling all of the main sites and types. A total of 24,600 linear feet of transects were run. In addition t\velve one-quarter acre quadrats, distributed over the various sites, were measured. Comparison of these quadrats with the transects showed a difference of only 2 to 10 per cent in the amount and distribution of the vegetation as determined by the two methods. Several smaller quadrats \vere used fOl: special studies of the sprout activity of the various growth forms.

On the transects and quadrats a complete tally was made of all the woody vegetation according to the classification which is shown later. The total height and age of each individual also were recorded. This involved the measurement of over 43,000 stems. In addition many individuals were sectioned and the ages at intervals above ground counted to enable computation of height growth. Besides the measurements taken on the transects and quadrats, over 4,500 additional stems were measured forage, height growth, and physical condition.

Age was determined by cutting just above the root collar. As a practical field problem, it is impossible with the hardwood species definitely to locate the terminal bud-scars which represent the limit of a season's gro\vth. This is true of the oaks especially.

TREATMENT OF ADVANCE GROWTH

The range of site (swamps excluded) was divided into three classes. Site I indicates conditions for maximum growth, Site II for average growth, and Site III for poorest growth. The site qualities were determined by ocular observation, using the height growth of trees and shrubs as an indicator. This was checked subsequently by field examinations of the soil. The soil was found to vary in depth in direct proportion to the observed or estimated quality of the site.

A review of the literature bearing on the subject of advance growth was made. This revealed the fact that very little (and this of a superficial character) has been written concerning advance growth.

DESCRIPTION OF THE AREAS INVESTIGATED

The areas which were studied intensively are located within four miles of the city of New Haven. A tract of seventy-five acres fairly representative of the region in physiography, composition, and character of the forest cover furnished most of the data. (See Figure 1.) This area is located upon the eastern rim of the Western Highland.[2] Numerous rocky ridges, small flats, and occasional swamps characterize the topography. A layer of yellowish-red glacial till, mixed with rock fragments of chlorite schist, quartz, serpentine, and occasional sandstone boulders of varying size, is the usual soil covering. Oaks predominate in the forest cover. This is typical of the Connecticut hardwood type now that chestnut has succumbed to the blight. Other hardwoods form approximately 25 per cent of the composition.

In 1902 the seventy-five-acre tract, with the territory adjoining, was placed under forestry management. A first thinning was made in that year. Additional thinnings and salvage cuttings, for the removal of dead chestnut, followed in 1905, 1908, 1910, and 1913. These extended over all or large portions of the area. Several cuttings, both thinnings and salvage cuttings, were made over small portions of the area in other years of the period from 1902 to 1921. During the winter of 1921 the remainder of the mature timber, at that time seventy-five years of age, was removed.

One consequence of the repeated cuttings from 1902 to 1921 was that prolific sprout and seedling reproduction originated on the area beneath the old stand. Indeed, scarcely a single year passed during the twenty-year period without the start of new seedlings or sprouts. Thousands of

[2] GREGORY, H. E., and ROBINSON, H. H.: *Preliminary Geological Map of Connecticut.* Bulletin No. 7, State of Connecticut Geological and Natural History Survey. 1907.

these young stems died from natural causes under the partial cover maintained by the thinned stand. Others were deformed, while still others developed vigorously up to the date of the final removal of the old stand.

The removal of the remaining older trees in the winter of 1921 left all this advance growth, of diverse character and condition, in a dominating position.

Subsequent to the final cutting, sprouts started from the newly-cut stumps and seedlings sprang up, thus supplementing the advance growth already present and increasing the total reproduction. (See Figure 2.) These seedlings originated from seeds either derived from the 1920 seed crop on mature trees just felled or blown in from trees outside the area. The total reproduction, made up as just described of advance growth plus reproduction originating subsequent to the final cutting, was sufficient to constitute a fully stocked stand.

The area afforded an exceptional opportunity to study intensively the relative value of the different elements constituting the reproduction. More extensive studies, which, however, included the taking of measurements, were made on twenty-nine other areas selected as representative of the Connecticut Hardwood Region.

A SYSTEM OF CLASSIFICATION FOR THE WOODY VEGETATION

The nature of the problem required classification of the woody vegetation with reference to species, site, age, total height, origin and relative position, shape and thrift of crown. For this purpose, as a prerequisite step to the gathering of data, it became necessary to devise a system of classification which could be used in tallying and measuring all stems: a classification so arranged that it could be applied in bringing out the relative future values of the various individuals.

GROWTH FORMS

Origin was found to be of importance in influencing the rate of height growth of the individual stem and in determining the chance of its ultimate survival.

The term "Growth Form" will be used throughout this report to designate the various types of origin. Considered from this standpoint it is customary to divide woody vegetation into two classes, namely, seedlings

and sprouts. Thus there may be distinguished the "seedling" growth form and the "sprout" growth form and, as will be demonstrated, several other growth forms.

A preliminary survey disclosed the need for improving and clarifying the present classification of origin to permit of a more accurate use under field conditions. Before a satisfactory system of classification on the basis of origin could be established, considerable special field work had to be completed and a review made of the literature bearing on the subject. The importance of origin as a factor influencing survival made the revision of existing definitions and terms imperative.

The growth forms recognized by the Society of American Foresters[3] are as follows:

1. "A sprout is a tree which has grown from a stump or root. (A sucker is a tree growing from a root.)"
2. "A seedling is a tree grown from seed."
3. "A seedling sprout is a sprout resulting from the cutting of a seedling or small sapling. This is differentiated from coppice sprout or shoot because of its subsequent behavior."

Using these definitions an attempt was made to identify the reproduction in the field. True sprouts were easily identified in the field, with the exception that an arbitrary diameter limit at the ground had to be established, in order to separate sprouts from seedling sprouts. Without considerable experience it is impossible in the majority of cases to distinguish with certainty seedlings from seedling sprouts. After experience gained through the study of the appearance and characteristics of these two growth forms they may be distinguished with reasonable accuracy provided a careful inspection on each individual is made of the stem and region about the root collar.

After thorough investigation, a new classification of growth forms was drawn up which, it is believed, will enable quicker and more accurate field identification. This classification is inserted here, and a discussion of the reasons which led to its adoption is given in the following pages.

Classification of Growth Forms.

1. A sprout is a tree which has grown from a stump over two inches in diameter at the ground line. (See page 13.)
2. A seedling is a tree grown from a seed.

[3] Forest Terminology. Terms in Forestry compiled by a committee of the Society of American Foresters. *Journal of Forestry,* Vol. 15, 1917, pp. 91 to 94.

Dormant buds are present at or just below the root collar. (See Figure 3.) The roots of the seedling radiate in all directions from the main stem, and it has comparatively rough bark while the single seedling sprout has a smooth bark surface along the entire length of the stem.

3. A single seedling sprout is a tree with a single stem which has grown from a stump two inches or less than two inches in diameter at the ground line. (See page 13.)

Single seedling sprouts have a growth rate of two to four feet for the first year, as compared to one foot or less in true seedlings. (Compare Figure 6 with Figure 8.) One or more small partly decayed stubs near the ground line with the bark of the present stem developing a callus around the stub are present always in young single seedling sprouts. (See Figures 4 to 8.) So far as surface indications go, the roots of seedling sprouts do not radiate in all directions from the main stem. This often may be judged by the swollen base on one side of the tree. The side from which the new generation originates appears to be free from large roots. (Contrast Figure 3 with Figure 4.)

Seedling sprouts (both single and multiple) are characterized by sharper and more pronounced crooks in the main tap root just below the ground line than are found in seedlings. (Contrast Figure 3 with Figure 4.)

4. A multiple seedling sprout is a tree with more than one stem, which has grown from a stump two inches or less than two inches in diameter at the ground line. (See page 13.)

Multiple seedling sprouts grow nearly as fast as single seedling sprouts, but differ from the latter in having several stems instead of one. The number of these stems varies from two to ten in the young stage. Later this number usually is reduced to a single stem or to two stems. (See Figures 9 to 14.)

5. A root sucker is a sprout from a root. Root suckers were found only in two unimportant species, beech and aspen.

An intensive study of the root systems of seedlings, single and multiple seedling sprouts, and sprouts was made, involving the digging up of over 400 plants. The roots of the single and multiple seedling sprouts were much thicker than those of true seedlings. A comparison of the relative health and vitality of the root systems, and the general physical condition

of the tree, indicated that seedlings ranked first, single seedling sprouts next, then multiple seedling sprouts, and lastly sprouts.

Origin and Development of Growth Forms.

In the beginning all trees in the region originated from seed. Each year thousands of new stems originate in this manner. The other gro\vth forms develop from true seedlings or from one another. (See Figure 15.) The process of development from one form to another may be observed in every hardwood stand.

The plant may continue as a seedling throughout life. On the other hand, one of the following calamities may occur and result in the dying back or removal of the aerial stem of the seedling:

1. Drought or winter killing may cause the seedling to die back to the ground line.

2. Mechanical injuries may break or cut off the main stem. (See Figures 9 and 12.) Intentional cuttings are included here.

3. Fires may destroy the aerial stem.

4. Rodents or cattle may damage the seedling so badly that it will die back to the ground line.

Any circumstance which causes the death of the aerial portion of the seedling prepares the way for the development of sprout growth on the old root system. Injuries which do not kill the stem down to the ground line leave the individual still a seedling.

After the original seedling dies back to the ground line, the process of regeneration may result in the development of anyone of the growth forms. Root suckers rarely arise, being produced by only a few unimportant species.

Dormant buds located at or just below the root collar are present in the hardwoods of the region. (See Figure 3.) The removal or death of the stem causes one of the following reactions:

(a) A single bud may start to function and produce a shoot to replace the stem of the previous generation. This will develop into a single seedling sprout. (See Figure 15.)

(b) Several dormant buds become active, giving rise to the multiple seedling sprout form. (See Figures 9 to 14.)

Competition and other environmental factors often reduce the number of sprouts to one. Thus a multiple seedling sprout may turn ultitnately into a single seedling sprout. To determine the proportion of stems developing into single seedling sprouts as compared to the multiple form, 100 young

trees from one to two inches in diameter at the ground line were cut off in the fall of 1924. The stumps of these trees were inspected in the following spring. A count showed that 21 per cent of the total number of stumps produced single seedling sprouts while the remainder produced multiple seedling sprouts. Determination why a single bud rather than several buds becomes active is a laboratory problem, involving a physiological investigation of the functions of dormant buds.

Where the stump of the original seedling was over two inches in diameter at the ground line, the new shoot (or shoots) would be classified under the sprout growth form. The true basis of separation between (a) sprouts, and (b) single and multiple seedling sprouts, is the root system. Sprouts form a root system independent of that of the previous generation. Portions of the old root system may be incorporated into the root system of the new plant, but never the entire old system. The portions of the old root system not so incorporated decay quickly and carry decay back into the heart of the new tree. This accounts for the decay which is characteristically found in the butts of sprout trees.

Seedling sprouts (both single and multiple) use the root system of the previous generation in its entirety. The old root system is completely enclosed, lives on and functions as part of the new plant. There is no easy entrance for decay below ground. The stub of the old stem is callused over quickly and completely. In consequence the seedling sprout approaches the true seedling in freedom from butt rot. The ability of the new shoot to utilize the old root system and to callus over the dead stub of the stem depends upon the size of the root system and stem. This varies widely with species and with natural factors. An arbitrary size limit cannot be taken as a fully satisfactory basis of classification.

From the practical standpoint an arbitrary diameter limit is necessary, since the extent to which the old root system is utilized by the new shoot cannot be seen definitely without digging around the root system of each individual. In most cases where stems are over two inches in diameter at the ground line the old stub fails to callus over completely before rot enters and the old root system is not entirely utilized by the new plant. Two inches was taken finally as the dividing size limit between seedling sprouts and sprouts.

The plant may undergo several calamities at intervals one year or more apart. After each calamity the same process of regeneration is repeated. Where killing back (particularly by fires) has taken place repeatedly over a period of years, the stems are likely to be spindling and feeble, while

the root system becomes thickened, knotty, and susceptible to decay, with more the appearance of an underground stem than of a root. Under normal conditions, where stems are removed in cuttings or are killed back to the ground at occasional intervals, the process of regeneration from existing root systems into growth forms of both seedling sprouts and sprouts can continue indefinitely without loss of vitality. (See Figure II.)

Previous Work on Growth Forms.

Gro\vth forms have received only superficial attention from foresters in the past. The presence of a growth form intermediate between a seedling and a sprout has been noted, but only a few writers have tried to describe it. The first attempt to classify this intermediate form is found in a report by G. Frederick Schwarz.[4] Under the heading, "Forms of Reproduction," he says:

"Reproduction in sprout forests consists mainly of young sprouts, although seedlings find entrance here and there and ultimately grow into the stand. In addition to these two forms there is a third, commonly found throughout the most of our second-growth deciduous forests, which may be said physiologically to stand between the two others. For want of a better name it Inay be called 'seedling-sprouts.'"

Schwarz apparently encountered the extreme type attained by this growth form. He mentions the abnormally thickened root system, the presence of stubs from the previous generations., but does not mention having found specimens which showed a healthy vigorous growth rate. His conclusions are that "Seedling reproduction is limited in sprout forests on account of dense shade, injury and suppression through fallen branches, fires, browsing of cattle, nibbling of rodents, etc. Most of the seedlings are ultimately transformed, by repeated attempts at sprouting, into 'seedling-sprouts.'" Another mention of the term "seedling-sprouts" is made by P. L. Buttrick.[5] He says that "seedlings killed back, often sprout again. They are then called seedling-sprouts, and it is often difficult to tell them from seedlings. It is the writer's observation that fully half the seedling reproductibnin parts of the state consists of seedling-sprouts." His general conclusions are that, if the seedling is burned to the ground line, sprouting results, usually with the development of more than one stem, but that repeated

[4] SCHWARZ, G. FREDERICK: The Sprout Forests of the Housatonic Valley. *Forestry Quarterly,* Vol. 5, 1907, p. 134.

[5] BUTTRICK, P. L.: The Effect of Forest Fires on Trees and Reproduction in Southern New England. *Forestry Quarterly,* Vol. 10, 1912, p. 13.

fires finally result in the death of the entire plant. He also brings out the point that the accelerated growth is over in two or three years, and thereafter development is that of a seedling rather than a sprout.

Both single and multiple seedling sprouts are produced by certain conifers. Although the names were not used, these growth forms are described accurately in a study of shortleaf pine by W. R. Mattoon.[6] Similar growth forms develop in pitch pine reproduction and probably in redwood.

In European literature, reference to seedling sprouts is made by Bagneris.[7]

This writer noticed the repeated efforts of a seedling to throw up shoots strong enough to resist forest fires, until finally a single stem develops into a tree. In reference to this fact he says: "Many of our so-called seedling trees of the broadleaved species have originated thus." A. C. Cline and C. R. Lockard,[8] working with pine and hardwoods in northern Massachusetts, have used recently (1925) a classification of sprout growth forms based on diameter of the stool. According to their terminology seedling sprouts are those arising from stools one-half inch or less in size, small sapling sprouts from stools three-quarters inch to one and one-half inches in size, large sapling sprouts from stools two and three inches in size, small pole sprouts from stools four to seven inches in size, large pole sprouts from stools eight to eleven inches in size, and standard sprouts from stools twelve to twenty-four inches in size.

Miscellaneous Factors

All trees and shrubs were tallied under their own common names. The one exception was chestnut. This species was not tallied, since it is already practically eliminated from the stand, due to the continued ravages of the chestnut blight. While occasional clumps of chestnut sprouts may be found, they are rapidly being overtopped by the other species.

A complete list of the species tallied is given, showing both their common and scientific names. Sargent's nomenclature has been followed in the scientific names of the tree species.

[6] Mattoon, W. R.: *Life History of Shortleaf Pine.* Bulletin No. 244, U. S. Dept. of Agriculture, 1915, pp. 20 to 29.

[7] Bagneris, G.: *Elements of Silviculture,* 1882, p. 113.

[8] Cline, A. C., and Lockard, C. R.: *Mixed White Pine and Hardwood.* Bulletin No. 8, Harvard Forest, 1925, p. 22.

Scientific Name	Common Name
Populus grandidentata	Large-tooth Aspen
Juglans cinerea	Butternut
Carya cordiformis	Bitternut Hickory
Carya ovata	Shagbark Hickory
Carya alba	Mockernut Hickory
Carpinus caroliniana	Blue Beech
Ostrya virginiana	Ironwood
Betula lenta	Black Birch
Betula lutea	Yellow Birch
Betula populifolia	Gray Birch
Fagus grandi/olia	Beech
Quercus borealis	Red Oak
Quercus coccinea	Scarlet Oak
Quercus velutina	Black Oak
Quercus alba	White Oak
Quercus montana	Chestnut Oak
Ulmus americana	White Elm
Liriodendron tulipifera	Yellow Poplar
Sassafras officinale	Sassafras
Hamamelis virginiana	Witch Hazel
Amelanchiercanadensis	Shad Bush
Prunus serotina	Black Cherry
Acer saccharum	Hard Maple
Acer rubrum	Red Maple
Tilia glabra	Basswood
Cornus florida	Dogwood
Fraxinus americana	White Ash
Fraxinus nigra	Black Ash
Viburnum acerifoliu?n, L.	Maple-leaved Viburnum

Site was a factor of primary importance in the classification. Three site classes, I, II, and III (as mentioned previously), were recognized. On the transect lines the extent of each site quality was noted, and the vegetation tallied separately by sites. Quadrats were located so as to sample a single site.

The age of each individual stem was ascertained. In the final tables only two general age classes were recognized: (a) all stems one to four years of age, (b) stems over four years of age. This division served to differentiate

between the reproduction originating subsequent to the final cutting, and the advance growth. Since the final cutting occurred in the winter of 1921, all reproduction originating later was four years old or less when tallied in the fall of 1924. One-half foot height classes were employed in tallying the vegetation. The total height of each stem was recorded to the nearest half foot.

The relative position of its crown is of vital importance in judging the probable future value of the individual stem. For this reason each stem was classified as either free or overtopped. The crowns were further classified on the basis of shape under three divisions:

Well-formed normal crowns; crowns which are well rounded and proportionate to the length of stem. (See Figures 16 and 17.)

Flat-topped crowns (Umbrella tops); crowns flat on top which are thin, fairly wide and extend only one-eighth to one-quarter of the length of the main stem.

Abnormally-spreading crowns (Wolf trees); crowns formed by large lateral branches which begin low down on the stem, extend to a relatively great distance, and often give the tree a bush-like appearance.

This applied only to advance growth, not to reproduction which started after the final cutting, since the latter was too young to show differentiation into a variety of crown shapes. The presence or absence of injuries resulting from the attacks of either insects or fungi also was noted for the advance growth.

At first an effort was made to classify all stems on the basis of relative vigor. This additional complication finally was deemed unnecessary, since the division of the stems into free or overtopped and into well-formed, flat-topped, or abnormally-spreading crowns gave a direct indication as to the health and vigor of the plant.

THE AMOUNT, CHARACTER, AND DISTRIBUTION OF THE ADVANCE GROWTH AND OF THE YOUNGER REPRODUCTION

Before consideration of treatment of the advance growth a knowledge of the amount, the character, and the distribution of the different elements on the areas to be treated is essential. Tables 1 to 4 summarize the field data secured which bear on the subject. Results are shown separately for each of the three important Site Qualities I, II, and III in Tables 1 to 3. A condensed summary of the values on each Site and for all three Sites combined is given in Table 4. From these tables of basic data Tables 5 to 21 have been compiled to illustrate particular points.

TABLE 1

SHOWING THE AMOUNT AND CHARACTER OF THE REPRODUCTION ON SITE I

Species	*Growth Forms*																				
	Seedlings					*Multiple seedling sprouts*					*Single seedling sprouts*					*Sprouts*					*All growth forms*
	Younger reproduction		*Advance growth*			*Younger reproduction*		*Advance growth*			*Younger reproduction*		*Advance growth*			*Younger reproduction*		*Advance growth*			
	Free	*Over-topped*	*Free*	*Over-topped*	*Total*	*Free*	*Over-topped*	*Free*	*Over-topped*	*Total*	*Free*	*Over-topped*	*Free*	*Over-topped*	*Total*	*Free*	*Over-topped*	*Free*	*Over-topped*	*Total*	
	Number of Stems Per Acre																				
Oaks																					
Black Oak	33	14	52	13	112	99	8	41	12	160	30	24	28	9	91	22	3	4	7	36	399
Chestnut Oak	24	54	13	6	97	39	13	19	2	73	32	10	21		63	4		7		11	244
Red Oak	34	22	51	34	141	82	24	51	6	163	53	35	19	8	115	66	11	12	2	91	510
Scarlet Oak	96	58	104	60	318	101	73	80	23	277	133	63	128	33	357	67	1	12		80	1032
White Oak	121	202	68	36	427	204	410	94	32	740	121	131	136	113	501	52	15	36		103	1771
Other Hardwoods																					
Ash	197	104			301						208	49	36		293	4				4	598
Aspen	81	16	41	9	147											2					147
Basswood																2				2	2
Beech																212	86	63		361	361
Blue Beech	166	94	40		300	226	189	104	14	533	99	34	20		153	78	14	15		107	1093
Black Birch	67	28	21	10	116	82	14	16		112	14		3		17	37		20		57	302
Gray Birch	78	43			121	236	100			336						6				6	463
Yellow Birch	20				20	31				31											51
Butternut	32	19			51											2				2	53
Black Cherry	31	19	10	3	63	144		6		150	18		10		28	21		21		42	283

SHOWING THE AMOUNT AND CHARACTER OF THE REPRODUCTION ON SITE I (continued)

Species	Growth Forms																				
	Seedlings					Multiple seedling sprouts					Single seedling sprouts					Sprouts					All growth forms
	Younger reproduction		Advance growth			Younger reproduction		Advance growth			Younger reproduction		Advance growth			Younger reproduction		Advance growth			
	Free	Over-topped	Free	Over-topped	Total	Free	Over-topped	Free	Over-topped	Total	Free	Over-topped	Free	Over-topped	Total	Free	Over-topped	Free	Over-topped	Total	
	Number of Stems Per Acre																				
Dogwood	299	301			600	263	112			375	91	75	30		196	107		33		140	1311
Hickory	53	12	26		91	41		12		53	39		37		77	15		1		16	237
Ironwood	31	27	2		60	79	52	6		137	14	19			33	15				15	245
Hard Maple	15	8	14	6	43	51	4	2		57	28		10		38	17		8		25	163
Red Maple	164	111	40	2	317	340	107	172	9	628	201	44	40		285	141		34		175	1405
Sassafras	106	164			270	42	19			61	391	60	43	31	225	14				14	570
Tulip Tree	21	10	14		45	14				14	52				52	31		17		48	159
Woody Shrubs																					
Hazel	38	56			94	82	60			142											236
Viburnum	1044	951			1995	1555	1002			2557											4552
Witch Hazel	75	50			125	220	181			401											526
Total Stems	2826	2363	496	179	5854	3931	2368	603	98	7000	1244	545	561	194	2524	913	130	283	9	1335	16713

TABLE 2

SHOWING THE AMOUNT AND CHARACTER OF THE REPRODUCTION ON SITE II

Species	Growth Forms																				
	Seedlings					Multiple seedling sprouts					Single seedling sprouts					Sprouts					All growth forms
	Younger reproduction		Advance growth			Younger reproduction		Advance growth			Younger reproduction		Advance growth			Younger reproduction		Advance growth			
	Free	Over-topped	Free	Over-topped	Total	Free	Over-topped	Free	Over-topped	Total	Free	Over-topped	Free	Over-topped	Total	Free	Over-topped	Free	Over-topped	Total	
	Number of Stems Per Acre																				
Oaks																					
Black Oak	27	15	14	9	65	80	15	63	8	166	27	5	11		43	22	9	6		37	311
Chestnut Oak	243	381	260	120	1004	191	289	186	54	720	290	488	239	68	1085	32		8		40	2849
Red Oak	20	30	39	7	96	103	38	9		150	71	14	20		105	61	5	3		69	420
Scarlet Oak	14	36	38	29	117	71	45	47	22	185	92	65	106	27	290	115	29	18		162	754
White Oak	31	78	32	22	163	101	194	51	27	373	109	121	67	50	347	62	23	23	6	114	997
Other Hardwoods																					
Ash	31	65			96						3	4	5	2	14	12	3			15	125
Aspen			32		32																32
Basswood						3				3						6				6	9
Beech																63	20	10	2	95	95
Blue Beech	71	45	12		128	71	43	69	31	209	26	13	15		54						391
Black Birch	34	14	16		64	30	41	21		92											156
Gray Birch	31				31	167	84			251					42	19		4		65	347
Butternut	9	10			19	10	6	3	4	23											42
Black Cherry	67	21	7		95	21	9	38	18	86	3		5		8	2		4		6	195
Dogwood	58	48	20		126	130	64	49	12	255	31	47	10		88	33		10		43	512

SHOWING THE AMOUNT AND CHARACTER OF THE REPRODUCTION ON SITE II (continued)

Species	*Growth Forms*																				
	Seedlings					*Multiple seedling sprouts*					*Single seedling sprouts*					*Sprouts*					*All growth forms*
	Younger reproduction		*Advance growth*			*Younger reproduction*		*Advance growth*			*Younger reproduction*		*Advance growth*			*Younger reproduction*		*Advance growth*			
	Free	*Over-topped*	*Free*	*Over-topped*	*Total*	*Free*	*Over-topped*	*Free*	*Over-topped*	*Total*	*Free*	*Over-topped*	*Free*	*Over-topped*	*Total*	*Free*	*Over-topped*	*Free*	*Over-topped*	*Total*	
	Number of Stems Per Acre																				
Elm						21	2	2		25											25
Hickory	31	14	29	2	76	21	6	17	2	46	20		31	2	53	9	3	3		15	190
Ironwood	21	19			40	30	48	19		97											137
Hard Maple	17	11	6		34	10	7	3		20	8	4	9		21	11		1		12	87
Red Maple	41	111	34	29	215	121	65	114	14	314	48	10	22	6	86	27	3	22		52	667
Sassafras	41	15			56	31	45			76	61	19	53	45	178	3				3	313
Tulip Tree	4		4		8											9		3		12	20
Woody Shrubs																					
Hazel	74	60			134	103	63			166											300
Viburnum	401	472			873	477	904			1381											2254
Witch Hazel	44	61			105	114	149			263											368
Total Stems	1310	1506	543	218	3577	1906	2117	686	192	4901	789	790	593	200	2372	509	114	115	8	746	11596

TABLE 3

SHOWING THE AMOUNT AND CHARACTER OF THE REPRODUCTION ON SITE III

Species	*Growth Forms*																				
	Seedlings					*Multiple seedling sprouts*					*Single seedling sprouts*					*Sprouts*					*All growth forms*
	Younger reproduction		*Advance growth*			*Younger reproduction*		*Advance growth*			*Younger reproduction*		*Advance growth*			*Younger reproduction*		*Advance growth*			
	Free	*Over-topped*	*Free*	*Over-topped*	*Total*	*Free*	*Over-topped*	*Free*	*Over-topped*	*Total*	*Free*	*Over-topped*	*Free*	*Over-topped*	*Total*	*Free*	*Over-topped*	*Free*	*Over-topped*	*Total*	
	Number of Stems Per Acre																				
Oaks																					
Black Oak	13	17	31	13	74	49	23	36	14	122	12	6	4		22	19	6	5		30	248
Chestnut Oak	49	53	98	144	344	181	119	397	119	816	83	21	325	99	528	67		10		77	1765
Red Oak	22	18			40	29	12	7	2	50	21	6	2		29	40	5	3		48	167
Scarlet Oak	22	29	30	15	96	57	48	24	2	131	24	5	36	14	79	24	2	9	3	38	344
White Oak	21	18	16		55	118	55	71	12	256	32	17	44	8	101	50	19	12		81	493
Other Hardwoods																					
Ash													18		18						18
Basswood																		2		2	2
Beech																8		3		11	11
Blue Beech	27	14			41	64	21	20	5	110	53	26	41		120	6	8			14	285
Black Birch	11	5	17	4	37	30	24	20		74								4		4	115
Gray Birch	14				14	17	3	6		26											40
Yellow Birch	27	7			34			14		14											48
Black Cherry	3	4			7											7				7	14
Dogwood	15	11			26	51	24	27		102						14	1	12		27	155
Hickory			51		51	16	4	18	5	43	7	2	6	4	19	13	3	4		20	133

SHOWING THE AMOUNT AND CHARACTER OF THE REPRODUCTION ON SITE III (continued)

Species	*Growth Forms*																				
	Seedlings					*Multiple seedling sprouts*					*Single seedling sprouts*					*Sprouts*					
	Younger reproduction		*Advance growth*			*Younger reproduction*		*Advance growth*			*Younger reproduction*		*Advance growth*			*Younger reproduction*		*Advance growth*			*All growth forms*
	Free	*Over-topped*	*Free*	*Over-topped*	*Total*	*Free*	*Over-topped*	*Free*	*Over-topped*	*Total*	*Free*	*Over-topped*	*Free*	*Over-topped*	*Total*	*Free*	*Over-topped*	*Free*	*Over-topped*	*Total*	
	Number of Stems Per Acre																				
Ironwood	17	2	7		26	4	8	7		19											45
Hard Maple		3			3	7	2			13											16
Red Maple	14	5	10		29	117	41	34	2	194	26		10		36	56	14	30	3	103	362
Shadbush	14		10		24	7				7											31
Woody Shrubs																					
Viburnum	123	99			222	355	125			480											702
Witch Hazel	18	16			34	37	9			46											80
Total Stems	410	301	270	176	1157	1139	518	681	165	2503	258	83	486	125	952	304	58	94	6	462	5074

TABLE 4

SHOWING SUMMARY OF THE AMOUNT AND CHARACTER OF THE REPRODUCTION ON SITES I, II, AND III, EXPRESSED IN PERCENTAGES

Species	Growth Forms																				
	Seedlings					Multiple seedling sprouts					Single seedling sprouts					Sprouts					All growth forms
	Younger reproduction		Advance growth		Per cent of all growth forms	Younger reproduction		Advance growth		Per cent of all growth forms	Younger reproduction		Advance growth		Per cent of all growth forms	Younger reproduction		Advance growth		Per cent of all growth forms	
	Per cent Free	Per cent Over-topped	Per cent Free	Per cent Over-topped		Per cent Free	Per cent Over-topped	Per cent Free	Per cent Over-topped		Per cent Free	Per cent Over-topped	Per cent Free	Per cent Over-topped		Per cent Free	Per cent Over-topped	Per cent Free	Per cent Over-topped		
Oaks	47	53	66	34	28	53	47	79	21	36	59	41	70	30	28	86	14	88	11	8	100
Other Hardwoods	58	42	85	15	34	72	28	92	8	34	73	27	88	12	19	87	13	100		13	100
Woody Shrubs	52	48	45	55	58	59	41			42											
Oaks	39	61	67	33	27	48	52	76	24	30	46	54	76	24	35	81	19	90	10	8	100
Other Hardwoods	55	45	83	17	30	61	39	79	21	45	67	33	73	27	15	81	18	96	4	10	100
Woody Shrubs	46	54			38	38	62			62											
Oaks	47	53	51	49	20	63	37	75	25	46	75	25	78	24	25	85	15	92	8	9	100
Other Hardwoods	74	26	96	4	22	71	29	90	10	47	75	25	100		16	80	20	95	5	15	100
Woody Shrubs	55	45			33	75	25			67											100

TREATMENT OF ADVANCE GROWTH

The situation on each site merits individual discussion, and will thus be considered beginning with Site I.

Site I.

The young growth on Site I is distributed between approximately twenty-five species of trees and woody shrubs. The white, scarlet, and red oaks, white ash, soft maple, dogwood, and blue beech are all abundant. Woody shrubs, with viburnum predominating, form an important part of the cover. A dense stand, averaging over 16,000 stems to the acre with numerous species well represented, is characteristic. The number of stems per acre of each species of tree and shrub is shown in Table 1. To bring out more vividly the actual situation all species of trees and shrubs were combined into three groups as follows:

A. The Oaks: comprises red, white, scarlet, black, and chestnut oaks.

B. Other Hardwoods: contains hickory, red and hard maples, black, yellow, and gray birches, black cherry, tulip tree, beech, butternut, white and black ash, basswood, large-tooth aspen, elm, sassafras, blue beech, ironwood, shadbush, and dogwood.

C. Woody Shrubs: includes viburnum, witch hazel, and hazel.

TABLE 5

SHOWING THE AMOUNTS EXPRESSED IN PER CENT OF THE TOTAL NUMBER OF STEMS FORMED BY OAKS, OTHER HARDWOODS, AND WOODY SHRUBS ON SITES I, II, AND III

Species	*Site I Per cent*	*Site II Per cent*	*Site III Per cent*
Oaks	24	46	59
Other Hardwoods	45	29	26
Woody Shrubs	31	25	15
Total	100	100	100

This division, which is applied not only on Site I but on the other two sites also, corresponds roughly to the silvicultural value of the different species. In general, the oaks are to be favored. The other hardwoods are likely to be of secondary importance or classed as inferior species, while

the shrubs are distinctly weed species. The percentage of the stand formed by each of these divisions is given in Table 5. For comparison, percentages for the other two sites are included. It is evident from this table that the shrubs and a variety of hardwoods other than the oaks compose a larger proportion of the stand on Site I than on Sites II and III.

The vegetative cover on the area fell into the four growth forms, seedlings, single seedling sprouts, multiple seedling sprouts, and sprouts. Table 6 indicates the amount of each growth form in the three groups of species.

TABLE 6

SHOWING FOR SITE I THE AMOUNTS OF THE DIFFERENT GROWTH FORMS EXPRESSED IN PER CENT FOR EACH GROUP OF SPECIES

Species	*Growth Forms*				
	Seedlings	*Single Seedling Sprouts*	*Multiple Seedling Sprouts*	*Sprouts*	*Total*
	Percentage of total stand				
Oaks	28	28	36	8	100
Other Hardwoods	34	19	34	13	100
Woody Shrubs	58	0	42	0	100

The small percentage of sprouts is noteworthy. Seedling sprouts predominate, but a large proportion of seedlings are in evidence. The woody shrubs have a much higher percentage of their stems in the seedling growth form than do the oaks and other hardwoods. Of the growth forms represented, the seedlings, single seedling sprouts, and multiple seedling sprouts are of higher future value than the sprouts. It will be seen that 92 per cent of the oaks and 87 per cent of the other hardwoods are of these better growth forms.

For best future prospects a stem, no matter of what species or growth form, must have a free position. In other words, it must not be overtopped by one or more stems which have secured a dominant position. In

Table 7 the percentages of the stems of each growth form and group of species occupying a free position are given. The sprouts, due to their greater height growth in early youth, have the highest proportion of free stems. There is not much difference between seedlings and seedling sprouts. The woody shrubs have a slightly lower percentage free than the oaks and other hardwoods.

TABLE 7

SHOWING PERCENTAGE OF EACH GROWTH FORM AND GROUP OF SPECIES OCCUPYING A FREE POSITION ON SITE I

Species	*Growth Forms*				
	Seedlings	*Single Seedling Sprouts*	*Multiple Seedling Sprouts*	*Seedlings and Seedling Sprouts Combined*	*Sprouts*
	Percentage occupying a free position				
Oaks	54	62	57	58	88
Other Hardwoods	61	79	75	70	90
Woody Shrubs	52		59	57	

A further division was made into (a) advance growth and (b) reproduction arising subsequent to the final cutting. The latter will, for the sake of brevity, be termed "younger reproduction." On the areas intensively studied, where the data given in Tables 1 to 3 were gathered, the final cutting had taken place 4 years previous to the investigation. Consequently all stems 4 years old or younger were classed as younger reproduction, and the stems over 4 years of age as advance growth. The advance growth ranged in age from 7 to 22 years and in height from 5 to 28 feet. None of it was over 6 inches in diameter at breast high. The reproduction arising subsequent to the final cutting ranged from 2 to 14 feet in height and from 1 to 4 years in age. (See Figure 2.) The relative amounts of the two classes are shown in Table 8.

TABLE 8

SHOWING RELATIVE AMOUNT OF ADVANCE GROWTH AND YOUNGER REPRODUCTION ON SITE I

Species	*Advance Growth*	*Reproduction arising subsequent to the final cutting (younger reproduction)*	*Total*
		Percentage of the total stand	
Oaks	35	65	100
Other Hardwoods	14	86	100
Woody Shrubs		100	100
All Species	15	85	100

Younger reproduction predominated over advance growth in both the oak and other hardwood groups. In the oaks there is a large proportion of advance growth. In order to bring out how much of the advance growth and younger reproduction of the principal growth forms is free, Table 9 is presented. A larger proportion of the advance growth than of the younger reproduction is in a free position. This is a result of their difference in height and age.

TABLE 9

SHOWING THE PERCENTAGES OF ADVANCE GROWTH AND YOUNGER REPRODUCTION OCCUPYING A FREE POSITION ON SITE I

Species	*Advance Growth*		*Younger Reproduction*	
	Growth Forms			
	Seedlings and Seedling Sprouts	*Sprouts*	*Seedlings and Seedling Sprouts*	*Sprouts*
	Percentage occupying a free position			
Oaks	70	88	51	87
Other Hardwoods	89	100	67	87
Woody Shrubs			56	

TREATMENT OF ADVANCE GROWTH

Nearly all of the reproduction has excellent form and is of a desirable character. (See Figures 2, 16, and 17.) The exceptions to this rule are found:

(a) In the case of the suppressed stems already dominated by other elements of the reproduction. This situation needs only passing comment, since it is merely an example of the natural struggle for existence which should take place in every young stand.

(b) In the case of certain older individuals in the advance growth, which were suppressed for years previous to the final cutting by the trees of the previous generation. Such individuals are likely to be found now in a dominant position and to have flat-topped crowns and crooked stems.

(c) In the case of other individuals, in the advance growth which had exceptional opportunities to develop rapidly without side crowding. These individuals are likely to have crowns of abnormal spread and with relatively heavy branches extending down to the ground.

In measuring advance growth, all stems were tallied on the basis of the form and character of their crown and bole into one of three classes: trees with well-formed, with flat-topped, or with abnormally-spreading crowns. Table 10 shows for Site I the results of this classification.

TABLE 10

SHOWING THE CHARACTER OF THE CROWNS OF ADVANCE GROWTH EXPRESSED IN PERCENTAGES OF THE NUMBER OF STEMS IN EACH GROUP OF SPECIES ON SITE I

Species	*Crown Character*			
	Well-formed	*Flat-topped*	*Abnormally-spreading*	*Total*
	Per cent of total number of stems			
Oaks	82	3	15	100
Other Hardwoods	51	12	37	100
All Species	68	7	25	100

The proportion of poorly formed stems in the oak group is small, but for the other hardwoods amounts to 49 per cent of the stems. A general average of all tree species reduces this to 32 per cent. The possibility that

many of these flat-topped and abnormally-spreading trees may grow into trees of considerable future value will be discussed later.

The distribution of the various elements of the reproduction is uniform over the area whether species, growth forms, condition of crown, or other factors involved are considered.

In Tables 5 to 10 the relative number of stems expressed in percentages has been used as the basis for bringing out the distinctions between the different classes in the reproduction. By properly applying the percentages contained in these tables it can be shown that there are at least 1100 oak and 3000 other hardwood stems per acre standing in a free position, of the more promising growth forms (seedling and seedling sprouts) and with well-formed crowns. This is a sufficient number of stems fully to stock Site I areas.

An expression as to the number of stems per acre is less significant than one which indicates the percentage of the land area occupied by each of the various classes of stems. This is most difficult to determine exactly because of the small size, large number per acre, and intimate contact of the individuals dealt with. The areas can be only approximated, mainly on the basis of observation and judgment. The values in Table 11 have been arrived at on the basis of careful observation and judgment, and are offered as approximate averages of the area occupied on each of the three sites by various classes of reproduction.

TABLE 11

SHOWING PERCENTAGE OF AREA ON EACH SITE OCCUPIED BY WELL-FORMED, FREE SEEDLINGS AND SEEDLING SPROUTS, AND BY OTHER CLASSES OF REPRODUCTION

	Site I	*Site II*	*Site III*
	Percentage of total area		
Oaks, well-formed, free seedlings and seedling sprouts	20	35	35
Other Hardwoods, well-formed, free seedlings and seedling sprouts	30	25	20
Sprouts, all species, and poorly formed seedlings and seedling sprouts	25	25	35
Woody Shrubs	25	15	10
Total	100	100	100

TREATMENT OF ADVANCE GROWTH

On Site I 50 per cent of the area is occupied now by oak and other hardwood stems of good character, while half the area is covered by woody shrubs or less promising classes of oak and other hardwoods.

Site II.

As contrasted with Site I, the predominance of chestnut oak (see Tables 1 and 2) is the outstanding feature on Site II. Oaks as a whole have nearly doubled as compared with Site I (see Table 5), and here form 46 per cent of the stand. While practically the same species of trees and woody shrubs occur as on Site I, the hardwoods other than oak are less prominent, forming only 29 per cent, and the woody shrubs have decreased to 25 per cent. The total number of stems per acre is less than 12,000. This amount provides a dense, fully stocked stand.

In the oak group white oak and scarlet oak follow next in numbers to the chestnut oak. Red maple and dogwood are most numerous in the other hardwoods group. Viburnum composes nearly 80 per cent of the woody shrubs. Table 12 gives the percentages of the different growth forms within each group of species. There is very little difference between Sites I and II in this respect (see Table 6), with the exception that woody shrub seedlings are less numerous, and multiple seedling sprouts more abundant on Site II.

TABLE 12

SHOWING FOR SITE II THE AMOUNTS OF THE DIFFERENT GROWTH FORMS EXPRESSED IN PER CENT FOR EACH GROUP OF SPECIES

Species	*Growth Forms*				
	Seedlings	*Single seedling sprouts*	*Multiple seedling sprouts*	*Sprouts*	*Total*
	Percentage of total stand				
Oaks	27	35	30	8	100
Other Hardwoods	30	15	45	10	100
Woody Shrubs	38		62		100

Table 13 states the percentage of each growth form occupying a free position. A point of interest is the much lower percentage of woody shrubs

in a free position on Site II—42 per cent for all growth forms combined—as contrasted with 57 per cent on Site I (see Table 7).

TABLE 13

SHOWING PERCENTAGE OF EACH GROWTH FORM AND GROUP OF SPECIES OCCUPYING A FREE POSITION ON SITE II

Species	*Growth Forms*				
	Seedlings	*Single seedling sprouts*	*Multiple seedling sprouts*	*Seedlings and seedling sprouts combined*	*Sprouts*
	Percentage occupying a free position				
Oaks	49	59	57	54	83
Other Hardwoods	60	70	67	65	85
Woody Shrubs	47		38	42	

The proportion of advance growth to younger reproduction remains practically the same in the oaks, but in the other hardwoods is nearly double that found on Site I. (See Table 8.) Table 14 shows the relative amount of advance growth and younger reproduction on Site II.

TABLE 14

SHOWING RELATIVE AMOUNTS OF ADVANCE GROWTH AND YOUNGER REPRODUCTION ON SITE II

Species	*Advance Growth*	*Younger Reproduction*	*Total*
	Percentage of the total stand		
Oaks	32	68	100
Other Hardwoods	26	74	100
Woody Shrubs		100	100
All Species	22	78	100

In Table 15 is shown the percentage of advance growth and younger reproduction which stands in a free position. Approximately three-

quarters of the advance growth and one-half of the younger reproduction of seedling and seedling sprout form is free.

TABLE 15

SHOWING THE PERCENTAGE OF ADVANCE GROWTH AND YOUNGER REPRODUCTION WHICH IS OCCUPYING A FREE POSITION ON SITE II

Species	*Advance Growth*		*Younger Reproduction*	
	Growth Forms			
	Seedlings and seedling sprouts	*Sprouts*	*Seedlings and seedling sprouts*	*Sprouts*
	Percentage occupying a free position			
Oaks	72	90	45	81
Other Hardwoods	79	96	55	81
Woody Shrubs			41	

The classification of advance growth on the basis of crown development, as given in Table 16, indicates that over two-thirds of it is well formed. Trees with abnormal crown spread are relatively somewhat more abundant on Site II than on Site I. (See Table 10.)

TABLE 16

SHOWING CHARACTER OF THE CROWNS OF ADVANCE GROWTH EXPRESSED IN PERCENTAGES OF THE NUMBER OF STEMS IN EACH GROUP OF SPECIES ON SITE II

Species	*Crown Character*			
	Well-formed	*Flat-topped*	*Abnormally-spreading*	*Total*
	Percentage of total number of stems			
Oaks	64	2	34	100
Other Hardwoods	66	4	30	100
All Species	65	3	32	100

The distribution by species is not so regular on Site II as on Site I. On the former, chestnut oak often occurs in fairly pure groups. Scarlet oak to a smaller degree has the same tendency. The other species occur in scattered distribution.

Approximately 1100 oak and 1000 other hardwoods with free, well-formed stems of seedling and seedling sprout origin occur on the average acre on Site II. They occupy 60 per cent of the area (see Table 11), woody shrubs occupy only IS per cent, while seedlings and seedling sprouts of undesirable character, together with sprouts, have possession of the remaining 25 per cent of the area. Oak seedling and seedling sprouts alone cover 35 per cent of the area as compared with 20 per cent on Site I.

Site III.

Nearly as many species are represented on Site III as on the other two sites, but in far different proportions. Table 3 gives the distribution of stems by species and growth forms. Chestnut oak is the chief species and forms even a larger proportion of the oak group and of the total stand than on Site II. Thirty-five per cent of all stems are chestnut oak, which dominates the stand. White oak and scarlet oak rank next in number among the oaks. Red maple and blue beech are the best represented among hardwoods other than oak. Viburnum still remains the chief woody shrub, but greatly reduced in numbers and importance as compared with Sites I and II.

Fifty-nine per cent of the total stems are included in the oak group, 26 per cent in the other hardwoods group, and 15 per cent are woody shrubs.. With the change from Site Ito III the oaks have more than doubled in relative numbers, while woody shrubs and other hardwoods have decreased nearly 100 per cent.

Total number of stems per acre is approximately 5000. This appears to be a small number when the 16,000 stems per acre on Site I are considered. On the other hand, the number is ample for full stocking and must within a few years be substantially reduced in the struggle for existence.

Table 17 gives the distribution of the four growth forms. In studying this table in connection with similar tables (6 and 12) for the other sites, there may be discerned: as the site becomes poorer, a decrease in the proportion of seedlings, an increase in the proportion of seedling sprouts, and a nearly constant ratio of sprouts.

TABLE 17

SHOWING FOR SITE III THE AMOUNTS OF THE DIFFERENT GROWTH FORMS EXPRESSED IN PER CENT FOR EACH GROUP OF SPECIES

Species	*Growth Forms*				
	Seedlings	*Single Seedling Sprouts*	*Multiple Seedling Sprouts*	*Sprouts*	*Total*
	Percentage of total stand				
Oaks	20	25	46	9	100
Other Hardwoods	22	16	47	15	100
Woody Shrubs	33		67		100

A higher percentage of free stems, in all three groups of species, was found on Site III than on Sites I and II. The values in Table 18 when compared with those in Tables 7 and 13 illustrate the point. The explanation of this situation probably lies in the much smaller number of trees per acre on Site III.

TABLE 18

SHOWING PERCENTAGE OF EACH GROWTH FORM AND GROUP OF SPECIES OCCUPYING A FREE POSITION ON SITE III

Species	*Growth Forms*				
	Seedlings	*Single Seedling Sprouts*	*Multiple Seedling Sprouts*	*Seedlings and Seedling Sprouts*	*Sprouts*
	Percentage occupying a free position				
Oaks	50	77	70	68	87
Other Hardwoods	83	83	76	79	85
Woody Shrubs	55		75	68	

TREATMENT OF ADVANCE GROWTH

Site III has a much higher percentage of advance growth in the reproduction than either of the other two sites. The values are given in Table 19. Compare with Tables 8 and 14.

TABLE 19

SHOWING RELATIVE AMOUNT OF ADVANCE GROWTH AND YOUNGER REPRODUCTION ON SITE III

Species	*Advance Growth*	*Younger Reproduction*	*Total*
		Percentage of the total stand	
Oaks	53	47	100
Other Hardwoods	31	69	100
Woody Shrubs		100	100
All Species	39	61	100

A large share of the seedlings and seedling sprouts in both the advance growth and the younger reproduction occupy a free position. Table 20 gives the percentages for each class.

TABLE 20

SHOWING THE PERCENTAGE OF ADVANCE GROWTH AND YOUNGER REPRODUCTION WHICH IS OCCUPYING A FREE POSITION ON SITE III

Species	*Advance Growth*		*Younger Reproduction*	
	Growth Forms			
	Seedlings and Seedling Sprouts	*Sprouts*	*Seedlings and Seedling Sprouts*	*Sprouts*
	Percentage occupying a free position			
Oaks	72	92	62	85
Other Hardwoods	93	95	71	80
Woody Shrubs			68	

TREATMENT OF ADVANCE GROWTH

In the advance growth 82 per cent of the oak group and 42 per cent of the other hardwoods group are well formed. Table 21 shows the distribution by character of crowns.

TABLE 21

SHOWING CHARACTER OF THE CROWNS OF ADVANCE GROWTH EXPRESSED IN PERCENTAGES OF THE NUMBER OF STEMS IN EACH GROUP OF SPECIES ON SITE III

Species	*Crown Character*			
	Well-formed	*Flat-topped*	*Abnormally-spreading*	*Total*
	Percentage of total number of stems			
Oaks	82	6	12	100
Other Hardwoods	42	31	27	100
All Species	64	11	25	100

The chestnut oak is distributed over all parts of Site III. In some places this species forms solid blocks, in others it occurs in mixture with the other trees and shrubs. The stand of reproduction on the average acre on Site III includes at least 1100 oak (principally chestnut oak) and 500 other hardwoods, all free, well formed, and of seedling sprout origin. As a conservative estimate 55 per cent of the area is occupied by these 1500 trees. Table 11 shows the area occupied by each group of species.

GROWTH IN HEIGHT OF THE VARIOUS ELEMENTS COMPOSING THE YOUNG STAND

In the preceding pages the amount, character, and distribution of the reproduction now on the ground has been described. It has been shown that the better species and better growth forms now occupy a large portion of the area. The presence and relative importance in the reproduction

stage of given elements in the reproduction is not necessarily proof that these elements will maintain the same relative position in later stages of the stand's development.

The value of advance growth or any other element in the reproduction is contingent more upon its relative position and importance in the mature stand than during the reproduction stage. Given the amount, character, and distribution of the reproduction, height growth more than any other natural factor will determine the final relative position and importance of each element now present. For this reason it was essential that height growth should be investigated.

Every stem on the transects was measured to determine its height growth. However, it was deemed unnecessary to show in this report the height growth of all the species growing on the area. Instead, representatives of each of the three principal groups of species-namely, oaks, other hardwoods, and woody shrubs—were selected. These selections were made on the basis either of present abundance on the area, or of a rapid rate of height growth. Within the oak group measurements are presented for each species; namely, black, chestnut, red, scarlet, and white oaks. Among other hardwoods, red maple and hickory were selected—the former because of its abundance and because it was the fastest growing species of its class; the latter because, although only sparsely represented, nevertheless it appeared to be a persistent companion of the oaks. Taken together, the oaks, red maple, and hickory predominate in the upper canopy. In the third group, viburnum was selected because it was more abundant and had a faster rate of height growth than the other woody shrubs.

The height growth of younger reproduction and that of advance growth were kept separate, as well as that of each of the various growth forms. Data were computed for each of the three site classes.

HEIGHT GROWTH OF YOUNGER REPRODUCTION

The best opportunity to compare directly the height growth of the different species is found in the case of younger reproduction. All of this has come up on cut-over areas in full light and serves as an excellent expression of the comparative ability in rate of height growth possessed by the individual species. The results are shown in Table 22. Each figure in this table is the average for fifty dominant stems of the particular species and growth form. The mean annual rate of height growth for stems four years of age is given.

TABLE 22

SHOWING HEIGHT GROWTH OF YOUNGER REPRODUCTION BY SITE, SPECIES, AND GROWTH FORM

Species	*Growth Forms*				
	Seedlings	*Multiple Seedling Sprouts*	*Single Seedling Sprouts*	*Sprouts*	*Average all growth forms*
	Mean annual height growth in feet of four-year old stems				
SITE I					
Oaks					
Black Oak	.90	1.63	1.85	2.10	1.62
Chestnut Oak	.98	1.75	1.98	2.53	1.82
Red Oak	1.03	1.90	1.98	2.60	1.88
Scarlet Oak	.90	1.35	1.68	2.38	1.58
White Oak	.88	1.40	1.55	2.00	1.46
Other Hardwoods					
Red Maple	.97	1.95	1.85	2.43	1.80
Hickory	.95	1.63	1.55	2.08	1.55
Woody Shrubs					
Viburnum	.68	.95			
SITE II					
Oaks					
Black Oak	.80	1.38	1.50	1.93	1.40
Chestnut Oak	.88	1.40	1.83	2.35	1.61
Red Oak	.88	1.60	1.73	2.15	1.59
Scarlet Oak	.80	1.10	1.53	2.08	1.38
White Oak	.80	1.15	1.23	1.73	1.23
Other Hardwoods					
Red Maple	.88	1.68	1.73	2.23	1.63
Hickory	.85	1.55	1.40	1.93	1.43
Woody Shrubs					
Viburnum	.53	.75			
SITE III					
Oaks					
Black Oak	.70	1.08	1.28	1.48	1.13
Chestnut Oak	.80	1.40	1.83	2.35	1.59
Red Oak	.75	1.18	1.35	1.73	1.25
Scarlet Oak	.70	.98	1.13	1.55	1.09
White Oak	.60	.88	1.15	1.50	1.04
Other Hardwoods					
Red Maple	.73	1.15	1.23	1.75	1.21
Hickory	.75	1.15	1.18	1.68	1.19
Woody Shrubs					
Viburnum	.40	.65			

Each average figure is based on 50 four-year old dominant stems.

This table brings out in striking manner the difference in rate of height growth of the four growth forms. In order of rapidity they range from sprouts as the fastest, through single seedling sprouts artd 'multiple seedling sprouts, to seedlings as the slowest. This relation is independent of site. Only three sets of values in the table are coritradictory, and these exceptions serve simply to emphasize the rule. They occur in the case of red maple on Site I, and hickory on Sites I and II, and apply only to single seedling sprouts as contrasted with multiple seedling sprouts. Multipleseedling sprouts in these exceptional instances show a slightly higher growth rate than single seedling sprouts.

The more rapid growth of a seedling sprout as compared with a seedling can be explained on the basis of the larger root system of the former. This gives the seedling sprout a greater absorbing area and provides a store of reserve food material. Forced growth takes place and continues until the aerial stem or stems are large enough to utilize fully the excess food supply in the roots. As a result, the growth approximates that of a sprout rather, than that of a seedling. The greater number of stems dependent on the same root system accounts for the somewhat slower growth of the multiple as compared with the single seedling sprouts. (Compare Figure ı ı with Figure 4.)

On all sites, red oak, chestnut oak, and red maple are the three fastest growing species. Hickory, black oak, and scarlet oak grow at a somewhat slower pace, while white oak is the slowest of the tree species in the list. Viburnum comes last with a rate of height growth approximately twa-thirds that of the white oak. The relative position of the species in the first two classes is ,influenced by site. On Site 'I red oak slightly exceeds chestnut oak in height growth, while chestnut oak in turn 'is just above the red maple. There is less than 5 per cent difference between any of 'the three. The desirable species, red oak and chestnut oak, should be able to maintain their position in competition with the maple. The black and scarlet oaks grow in height better than the hickory on Site I and less vigorously than the maple.

On Site II the height growth of red oak, chestnut oak, and red maple is nearly identical. While irregular fluctuations in different growth forms can be noted, the averages for the three species differ by only 0.04 of a foot. Hickory on Site II grows a little faster than the black and scarlet oaks.

Chestnut oak is the most rapid growing species on Site III, with 'a rate more than 20 per cent above its nearest competitor, red oak. Maple is

slightly below red oak. Hickory does nearly as well on Site III as red maple. Black oak, scarlet oak, and white oak follow in the order named.

The data in Table 22 refer specifically only to younger reproduction four years or less in age. The question naturally arises whether the differences in rate of height growth found for the various growth forms and species will continue as the stand grows older. Studies made in older stands indicated that the relative rate of height gro\vth for the different species remained approximately the same throughout life, but that for different growth forms decided changes took place. The conclusion was reached that in the development of the average stand the relative growth rates of the different growth forms constantly vary as compared with one another, in such a manner that ultimately seedlings, single and multiple seedling sprouts, and sprouts all attain equal total heights and from that time on continue to grow in height at the same rate.

Before arriving at this conclusion typical specimens of each growth form were selected, felled, and analyzed to determine height growth.

In stands twenty years old, single seedling sprouts were found to have approximately the same total height as sprouts. At thirty years, single and. mUltiple seedling sprouts and sprouts were of the same total height, with seedlings three to six feet below the level of the other growth forms. After the fortieth year no essential difference in total height or rate of gro\vth of the four growth forms could be discerned.

Why the relatively rapid growth of the sprout should cease and the slow growth of the seedling become more rapid within such a short span of years is not known with certainty. Possibly the presence of decay in the sprouts may be of importance in this connection. Twenty-eight per cent, even of the young four-year old sprouts, showed traces of decay which had entered from the old decaying stump or roots. No evidence of such injury was noted in either single or mUltiple seedling sprouts. In seedling sprouts, a complete fusion usually results between the new growth and the old root system of the previous generation, effectually preventing decay. Indeed, a single seedling sprout is, so far as health goes, a true seedling, yet with a rate of height growth nearly as rapid as that of a sprout.

HEIGHT GROWTH OF ADVANCE GROWTH

So far the height growth of younger reproduction only has been considered. Younger reproduction has been defined previously for the purposes of this bulletin as reproduction which originated on the area subsequent to the final cutting. Part of the area is occupied by advance growth com-

posed of individuals \vhich started during the twenty-year period just before the final cutting. The advance growth consequently may have a considerable advantage in height in competing with the younger ,reproduction for position in the new stand. At the time of the final cutting the advance ,growth left on the area ranged from three to eighteen feet in height. Four years after cutting, the, younger reproduction ranged in height from two to fourteen feet and the advance growth from five to twenty-eight feet.

Consideration of the height growth made by the advance growth previous to the final cutting is irrelevant. Its growth since the final cutting is of vital interest in determining the outcome of the competitive struggle between advance growth and younger reproduction. Over 10,000 individuals of the advance growth were analyzed to determine their growth in height. Table 23, computed from the data secured, gives the periodic annual growth in height which the advance growth has made during the four years subsequent to the final cutting.

Two facts of interest are brought out. One of them is, that the rate of height growth for a given species does not vary with the growth form. All four growth forms grow at practically the same rate. Compare with Table 22, rate of growth, of younger reproduction, which shows great variation between growth forms. Sprouts in particular, as compared with seedlings of younger reproduction, grow more than twice as fast. It is evident that whatever advantage sprouts and seedling sprouts have over seedlings in ability to grow in height has already disappeared in the advance growth.

This confirms the conclusion derived in another way (see page 41), that ultimately differences in height growth between the four growth forms will be overcome. The advance growth measuredrariged from 3 to 19 years of age at the time of the final cutting. Rate of height growth following this cutting proved to be the same for advance growth of all ages within the 3 to 19 year range.

The partial shading for a number of years before the final cutting doubtless has had an effect in evening off the difference in initial vigor due to origin and has placed all four growth forms on an even basis for future growth.

The second fact of interest is that the differences between species have been leveled off. Such differences in the younger reproduction were srrlaller than the differences between the growth rates of the four growth forms. ,(See Table 22.) In the advance growth, differences due to species are less than the similar differences in the younger reproduction., White oak and hickory

TABLE 23

SHOWING FOR ADVANCE GROWTH THE RATE OF HEIGHT GROWTH SINCE THE FINAL CUTTING, CLASSIFIED ACCORDING TO SITE, SPECIES, AND GROWTH FORM

Species	*Growth Forms*				
	Seedlings	*Multiple Seedling Sprouts*	*Single Seedling Sprouts*	*Sprouts*	*Average all growth forms*
	Mean annual height growth in feet				
SITE I					
Oaks					
Black Oak	1.00	.95	1.03	1.01	.99
Chestnut Oak		1.03		.99	1.00
Red Oak	.97	1.04	1.05	1.04	1.02
Scarlet Oak	.98	1.04	.98	.95	.99
White Oak	.96	.98	.99	1.06	1.00
Other Hardwoods					
Red Maple	.84	.96	.94	.94	.92
Hickory	.95	.94	1.01	1.03	.98
SITE II					
Oaks					
Black Oak	.80	.96	.93	.88	.89
Chestnut Oak	.93	.90	.97	.96	.95
Red Oak	.89	.87	.96	.90	.90
Scarlet Oak	.78	.83	.85	.82	.82
White Oak	.90	.89	.89	.95	.92
Other Hardwoods					
Red Maple	.75	.91	.94	.93	.87
Hickory	.87	.81	.89	.87	.87
SITE III					
Oaks					
Black Oak	.63	.65	.63		.64
Chestnut Oak	.71	.66	.67	.70	.69
Red Oak	.64	.57	.65	.60	.62
Scarlet Oak	.65	.40	.69	.77	.66
White Oak	.73	.77	.50	.87	.76
Other Hardwoods					
Red Maple	.68	.63		.63	.64
Hickory	.75	.63	.63	.58	.66

Each average figure is based on from 15 to 500 dominant stems. Only in three instances is an average figure based on less than 50 stems.

appear to be growing faster both in actual amount and as compared with their associates. Red maple in comparison with its associates does not quite so well as in the younger reproduction.

The actual growth rate maintained by the advance growth since the final cutting is approximately the same as that made by younger reproduction of seedling origin. On Sites I and II the advance growth is growing slightly faster than seedlings of the younger reproduction, while on Site 1.11 the reverse is the case. Evidently all gro\vth forms of the advance growth \vhen aided by the extra total height \vhich they possessediour years ago can compete on at least equal terms \vith the younger reproduction. The seedling sprouts and sprouts alllong the younger reproduction, growing from 50 to 150 per cent faster than the advance growth, mayovertake and pass many of the advance growth stems. In some cases this has already taken place.

All three classes of stems based on crown character (namely, well-formed, fiat-topped, and abnormally-spreading crowns) wereana.lyzed to 'determine their height growth. No difference in rate of height growth could be discovered among these three classes. Even the fiat-topped have grown as well since the final cutting as trees of the other two classes. This should not be taken as implying necessarily for hardwood species an ability to recover quickly from the effects of heavy and prolonged shading. The overhead cover under \vhich the advance gro\vth on thinned areas develops is not dense.

CONCLUSIONS AS rro THEPROBABLE COMPOSITIONOF THE FUTURE STAND AND THE RELATIVE VALUE OF THE INDIVIDUALS WHICH IT WILL CONTAIN

The amount, character, and distribution of the reproduction, and its height growth being known, conclusions can now be drawn concerning the ultimate composition of the stand which the reproduction now on the ground will produce. In addition, the future value of each element in the reproduction can be appraised. This can best be ıplished by considering the situation on each site separately. Before this several things of general application on all sites, in reference to the relations between different species, growth forms, and adyance growth versus younger reproduction, should be discussed.

THE SPECIES IN THE FUTURE STAND

The future stand promises to be predolninantly oak. Among the oaks,

red oak and chestnut oak will be prominent; the former particularly on Sites I and II, because of its rapid growth, the latter on Sites III and II, because of its great abundance and rapid growth. The only undesirable oak is the scarlet oak, which, due to its susceptibility to heart rot and to the knottiness and low technical value of the wood produced, must be ranked far below the other four oaks.

Among the other hardwoods are some species, such as the tulip tree, white ash, and basswood, which grow fast and are of high technical value. They form a very small percentage of the reproduction. On Sites I and II occasional individuals will keep a dominant position until maturity, and on the better soils may be more desirable than the oaks. The remaining tree species are all either of lesser technical value, or slower in height growth than the oaks.

Study of height growth proves that the oaks find among the other hardwoods and woody shrubs only one serious competitor for dominance in the future stand. This competitor is the red maple, which in rate of height growth compares favorably with the oaks, is found in abundance on certain sites, and is of shade-enduring habit. Silviculturally the red maple is better adapted to the region than most of the hardwood species. In the early reproductive stages its root system can adapt itself to any site. On better soils, a shallow root system adequate to meet the requirements of the trees is developed. On poorer soils a long tap root is developed, penetrating the soil to approximately the same depth as is reached by the oaks. Red maple is responsible for nearly all the suppression of oaks which occurs on the area.

Relative Value of the Growth Forms

The four growth forms range in order of desirability from seedlings down through single seedling sprouts and multiple seedling sprouts to sprouts, the least valuable form. Seedlings are the most desirable elements in a stand. Although characterized by slow growth during the early stages of development, they finally catch up with the more rapid sprout and seedling sprout growth and ultimately become dominant and codominant trees. From a physical standpoint they lead all other growth forms. The root system is uniformly distributed, radiates in all directions, and ensures a maximum absorption area and attachment to the soil.

Single seedling sprouts are the next most desirable elements in the stand. They are practically equal to seedlings in their freedom from decay and general physical condition. Due to the one-sided development of the

root system characteristic of this form, there is some danger from windthrow. (See Figure 7.) On the basis of height growth they rank next to sprouts.

Multiple seedling sprouts closely resemble seedling sprouts in their growth rate, but the increased number of stems directly increases the danger of decay. The original fusion with the old root system of the previous generation may be complete, but the reduction in the number of stems which usually follows through competition again permits the entrance of decay. When only two stems develop from the old root system, this form may equal the single seedling sprout in vitality and become just as valuable a component of the future stand. (See Figure 14.)

Sprouts offer the greatest chance for the transmittal of decay from the parent stump and roots, and therefore are the least desirable. Sprouts will give a maximum production of material in the shortest period. The prevalence of decay in this class of timber, however, renders it extremely undesirable from an economic standpoint. In a sprout stand, growth culminates in about forty years, and from then on deterioration progresses.

As a general rule the seedlings and seedling sprouts (single and multiple) can be considered desirable elements in the future stand.

Relative Value of Advance Growth as Compared with Younger Reproduction

The evidence at hand indicates that the great majority of dominant, free stems, both of the advance growth and of the younger reproduction, are of promising character. The small percentage not of promising character owe their condition more to their source of origin (growth form) than to their time of origin (advance growth or reproduction arising subsequent to the final cutting).

Height growth of younger reproduction of seedling sprout and sprout origin is much faster than the height growth made, since the final cutting, by the advance growth. (Compare Tables 22 and 23.) This will have the effect of at least partly overcoming the initial advantage in total height held by the advance growth, and will result ultimately in producing a uniform stand in which stems of advance growth cannot be distinguished by appearance alone from younger reproduction. Even the present larger classes of advance growth will be incorporated into the general crown level. Already many individuals of the younger reproduction are taller than many individuals of the advance growth. As time passes the fast growing seedling sprouts and sprouts in the younger reproduction will decrease

their growth rate. Eventually (after the initial period) younger reproduction cannot be distinguished from advance growth by rate of height growth.

It is remarkable how small a percentage of the stenlS in the advance gro\vth are of such poor character as to make them undesirable. Even the flat-topped trees, forming less than 6 per cent of the oaks, have the power of recovery and exhibit the same growth rate as the well-formed and abnormally-spreading crowns. Flat-topped oaks are usually not so crooked as to lessen their ultimate lumber value. The trees classed as abnormally-spreading will improve in form as the stand closes. Most of these abnormally-spreading trees are of sprout origin. Red maple furnishes more examples of badly deformed flat-topped and abnormally-spreading trees than do the other species.

The conclusion reached is that whether a stem belongs to the advance growth or to the younger reproduction is immaterial in determining its value as a component in the future stand. Growth forms and species are of far higher significance.

CONCLUSIONS ON THE BASIS OF SITE

Final conclusions can now be formulated for each of the three sites.

Site I.

The stand on Site I at the present time is fully stocked with 1100 oak and 3000 other hardwood stems of the better growth forms, free and well-formed, included among the 16,000 individuals on each acre. (See pages 25 to 30.)

The area now occupied by the free, well-formed seedling and seedling sprout oaks of all five species is only 20 per cent of the total. (See Table II.) This may be expected to increase to 50 per cent of the total area by the time the stand is fifty years of age. The remaining area \vill be occupied by ,well-farmed" free seedlIngs and seedling sprouts of other hardwood.s, 15percent,and by sprouts and poorly forIned stems of other growth forms, 35 per cent.

Wooclyshfubs will disappear entirely as part of the main stand. Most of the other hardwood stems, due to their slower growth rate, become overtopped by the oaks and lose a large share of the area held in the reproduction stage. Other, hardwoods which appear ina dominant position in the future stand',will be principally of good species, such as tUlip tree, ash, basswood, and black birch.

Many of the .sprouts, both oak and other species, cannot be classed as

wholly undesirable elements in the future stand. While rot will enter earlier in the sprouts than in stems of other growth forms, yet, when grown on a sixty to eighty-year rotation, many sprouts will be sound. As the length of rotation increases, rot in the sprouts increases and the relative value of this growth form becomes less and less.

Table 24 gives for each of the three sites the percentages of the area occupied by different classes of stems in the future stand. The figures in this table are estimated from general observation checked by measurements taken in a few individual stands.

TABLE 24

SHOWING PERCENTAGE OF AREA ON EACH SITE OCCUPIED BY WELL-FORMED, FREE SEEDLINGS, AND SEEDLING SPROUTS OF OAK, AND BY OTHER CLASSES OF STEMS IN STANDS MORE THAN FIFTY YEARS OF AGE

	Site I	*Site II*	*Site III*
	Percentage of total area		
Oaks, well-formed, free seedlings and seedling sprouts	50	55	55
Other Hardwoods, well-formed, free seedlings and seedling sprouts	15	10	5
Sprouts, all species, and poorly formed seedlings and seedling sprouts	35	35	40
Woody Shrubs	0	0	0
Total	100	100	100

Site II.

The reproduction on Site II forms a fully stocked stand with oaks making up 46 per cent of the number of stems. (See Table 5.) Out of 12,000 stems on the average acre, 1100 are free, well-formed seedling or seedling sprout oaks and 1000 are other hardwoods of similar character. (See pages 31 to 34.) In the reproduction stage, this class of oaks occupied 35 per cent of the area, and other hardwoods 25 per cent. (See Table 11.)

The figures in Table 24 indicate what may be expected in the future stand. It is seen that 55 per cent of the area will be taken by the free, well-formed seedling and seedling sprout oaks; 10 per cent by other hard-

woods; and the remaining 35 per cent by sprouts and poorly formed stems., On both Sites I and II the oaks in the future stand will be a varying mixture of all five species, with chestnut oak increasing on Site II.

Site III.

Fifty-nine per cent of the reproduction on Site III is composed of oak. Out of 5000 stems per acre, 1100 are free, well-formed seedling and seedling sprout oaks, while only 5% are other hardwoods of similar character. (Seepages 34 to 37.)

It is interesting to note that in the reproduction stage the number per acre of free, well-fanned seedling and seedling sprout oaks is the same on all three sites, while the number of other hardwoods of similar character decreases from 3000 to 500 per acre in passing from Site I to Site III.

The 1100 oak stems occupy 35 per cent of the area in the reproduction stage, and the 500 other hardwood stems 20 per cent. Only 10 per cent is covered by woody shrubs. Sprouts and poorly formed seedlings and seedling sprouts have possession of 35 per cent of the area.

In the future stand the woody shrubs disappear from the main canopy; free, well-formed seedling and seedling sprout oaks increase to 55 per cent of the area; other hardwoods of similar character drop to 5 per cent; and sprouts and poorly formed seedlings and seedling sprouts spread out to cover 40 per cent of the area. A large share of the oak area in the future stand on Site III will be occupied by chestnut oak. The other hardwoods in a dominant position will be of species less desirable than the oaks on this poor site.

All Sites.

Summed up for all sites, the future stand will be fully stocked, even-aged, with at least one-half the area occupied by oak of the better growth forms, principally seedling sprouts. The remaining one-half of the area, although in possession of other species than oak, or of sprouts and poorly formed individuals of all species, will contain many individuals of equal value with the oak of better growth forms.

The distribution of the different species and growth forms in the future stand should be approximately uniform over the area, with the exception of chestnut oak on the poorer sites. A general mixture of the oaks, with a small percentage of such hardwoods as hickory, hard maple, red maple, ash, black birch, tulip tree, and basswood, will be characteristic. There is reason to believe that red maple, which in the reproduction stage is a strong com-

petitor of the oaks, will show a decided decrease in growth rate during middle age and occupy in the mature stand an intermediate or codominant position in the crown canopy.

Stems both of advance growth and of younger reproduction will be intermixed in the mature stand and will only with difficulty be distinguished. The differences in initial height existing, just subsequent to the final cutting, between advance growth of various ages and the younger reproduction, instead of being disadvantageous may be of benefit, in allowing earlier and more marked differentiation into crown classes, and in preventing in the sapling stage too even and hence too severe a competition between individuals.

TREATMENT ADVISED TO IMPROVE THE FUTURE STAND

The treatment advised for the advance growth during the early period following the final cutting may appear largely negative. Investigation of the height growth and character of the advance growth has shown that the great majority of the stems are of promising character. It would be a mistake, expensive financially and silviculturally, to cut back to the ground or otherwise remove the advance growth as a whole. Instead, the advance growth should be protected, so far as is practicable, during the logging operations which remove the old stand.

There are certain individual stems whose removal in the reproduction stage would result in improving the composition and quality of the future stand. It is evident from the preceding pages that these undesirable stems must belong to one of three classes:

Flat-topped individuals so deformed as to have no future possibilities.

Dominant stems of inferior species overtopping oak or other desirable species.

Dominant individuals of the sprout growth form.

Individuals in the last two of these classes may be either younger reproduction or advance growth. The operation here needed falls within the scope of a cleaning,[9] since it removes dominant trees in a young stand to free more desirable stems of the same age as those cut.

The making of a cleaning should be deferred until three to five years after the final cutting. This enables the stems which will be freed to reach such a height that when freed they thereafter can remain in a dominant position. In some instances it may be necessary to make a second cleaning;

[9] HAWLEY, R. C.: *Practice of Silviculture*, 1921, p. 144.

this will require less cutting than the first. Each cleaning involves an expense amounting to the cost of from one-fourth to one day's work per acre.

The question is an open one, whether or not in mixed hardwood stands such cultural operations as cleanings are too intensive for present-day practice. An independent answer must be sought in each individual case. In general an investment for cleanings appears justified in many instances. Insufficient knowledge as to the future yields to be expected from hardwood stands prevents for the present a more definite statement.

To accomplish nearly the same result in the end there is another method of treating young hardwood stands, which does not involve an investment of money in a cleaning operation. The stand can be allowed to grow on untouched until of cordwood size. As soon as a partial cutting for cordwood can be made profitably—that is, when the material removed will at least pay for the expense of the operation—the stand should receive an improvement cutting.[10] At this time the stand usually will be between twenty-five and thirty-five years of age.

The improvement cutting is in reality a delayed cleaning. Not all of the undesirable stems can be removed at the first operation. The principle may have to be followed in several successive cuttings made at intervals of five to twelve years before the area is brought entirely under control of the more valuable stems.

As stated on page 48, many oak sprouts reach ages of sixty to eighty years without being seriously injured by butt rot. Hence on rotations of this length these sound sprouts are not undesirable elements in the stand. Recognition of this fact should influence the marking in the first improvement cuttings. The more dangerous elements—namely, dominant trees of inferior species and badly deformed individuals of any species—should be taken out before the sprouts as such are discriminated against.

Table 24 indicates that from 50 to 55 per cent of the area in mature stands will be occupied by well-formed seedling or seedling sprout oaks. By means of two to three improvement cuttings, it should be possible to produce stands of practically pure seedling or seedling sprout oak.

This result is predicated upon the possibility of selling cordwood of small size. Where such utilization is practicable, the method of improvement cuttings is preferable to a cleaning. In many cases cordwood of small size cannot be profitably handled and improvement cuttings between the twenty-fifth and fiftieth years are impracticable. Under such conditions,

[10] HAWLEY, R. C.: *Practice of Silviculture*, 1921, p. 192.

if a stand of pure seedling and seedling sprout oak is wanted, a cleaning should be made three to five years after the final cutting.

In conclusion, this study finds that advance growth arising as a result of thinnings and shelterwood cuttings requires no special treatment different from that needed for the purpose of improving the composition and quality of the average upland mixed hardwood stand. This treatment resolves into the making of either cleanings or improvement cuttings. The latter, since they require no direct cash outlay, are preferable wherever small cordwood is salable.

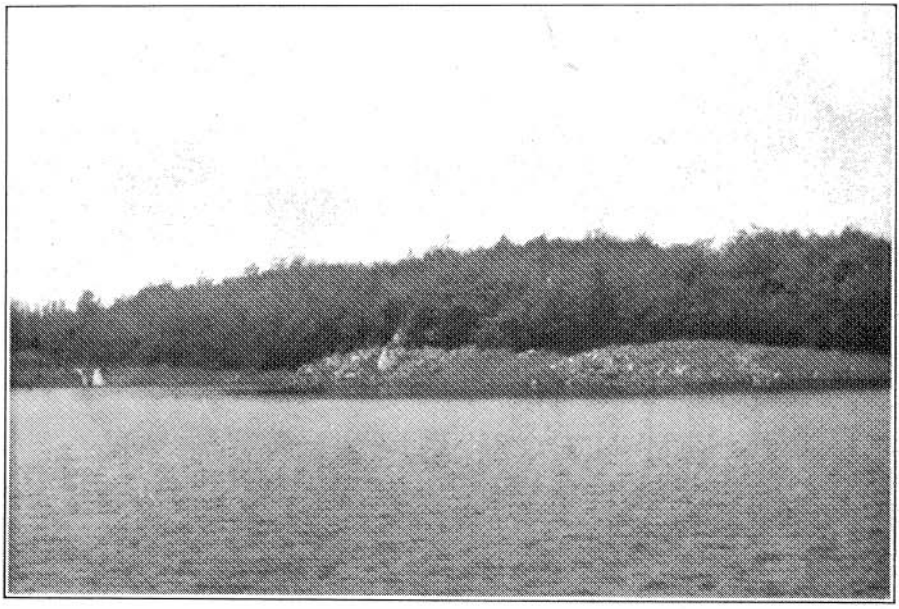

Fig. 1. General view of a representative portion of the area intensively studied. Trees range in age from 1 to 22 years, and in height from 2 to 28 feet.

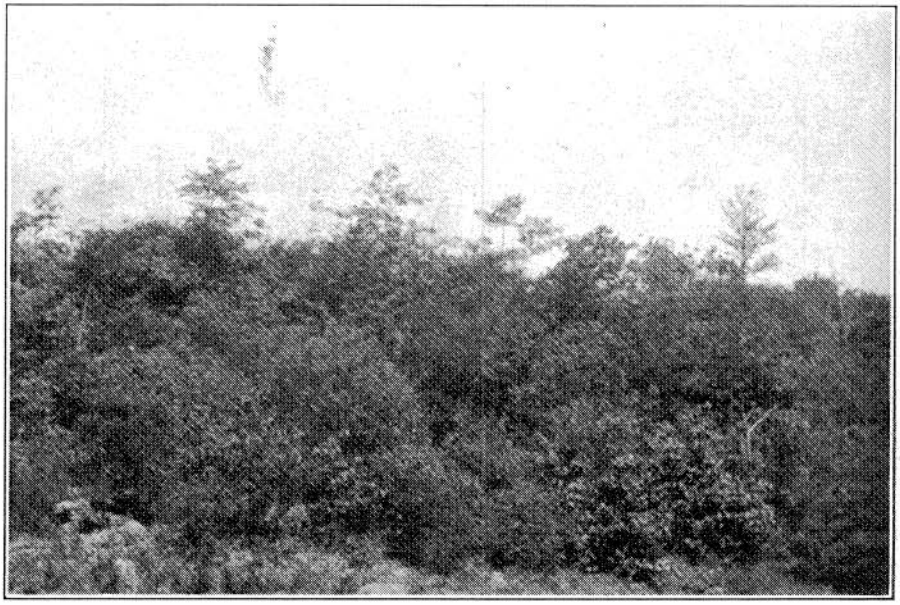

Fig. 2. Part of the same area shown in .Fig. 1. The taller trees are advance growth. Younger reproduction and advance growth are intermixed in the lnedium and lower height classes.

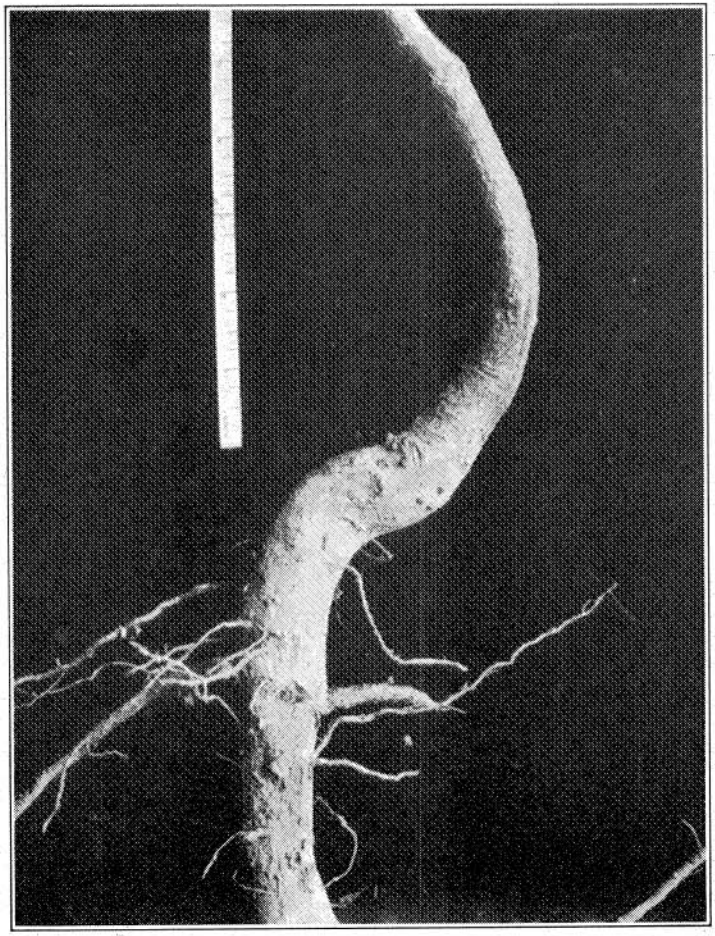

Fig. 3. Red oak seedling showing clusters of dormant buds near the root collar.

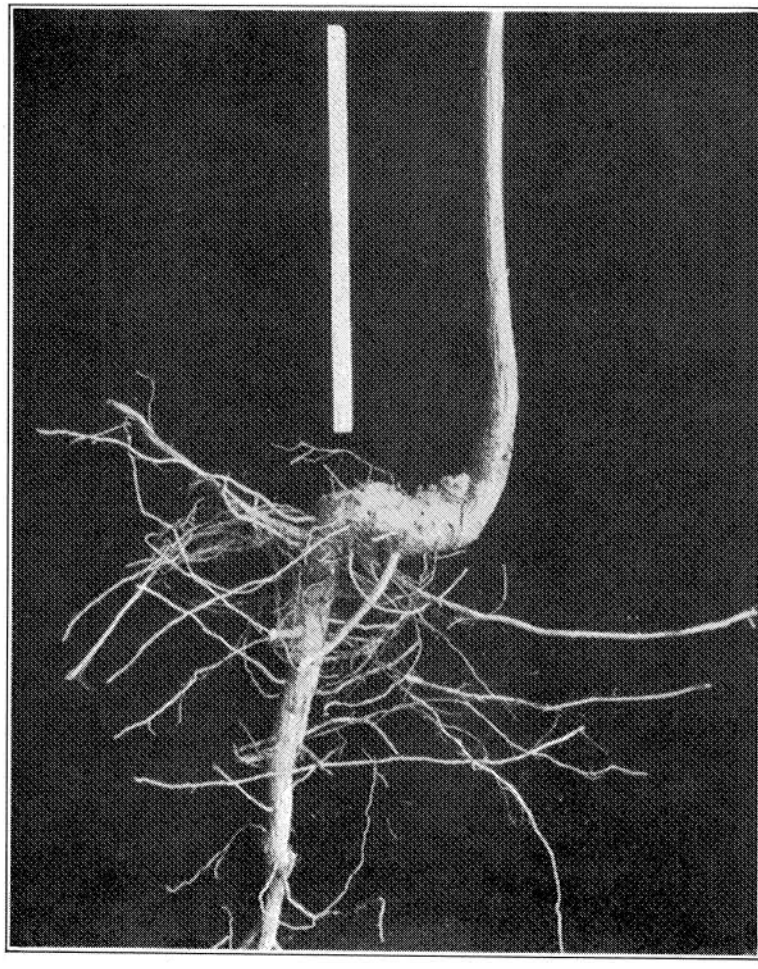

Fig. 4. Red oak single seedling sprout showing stub of previous generation and abrupt curve in taproot.

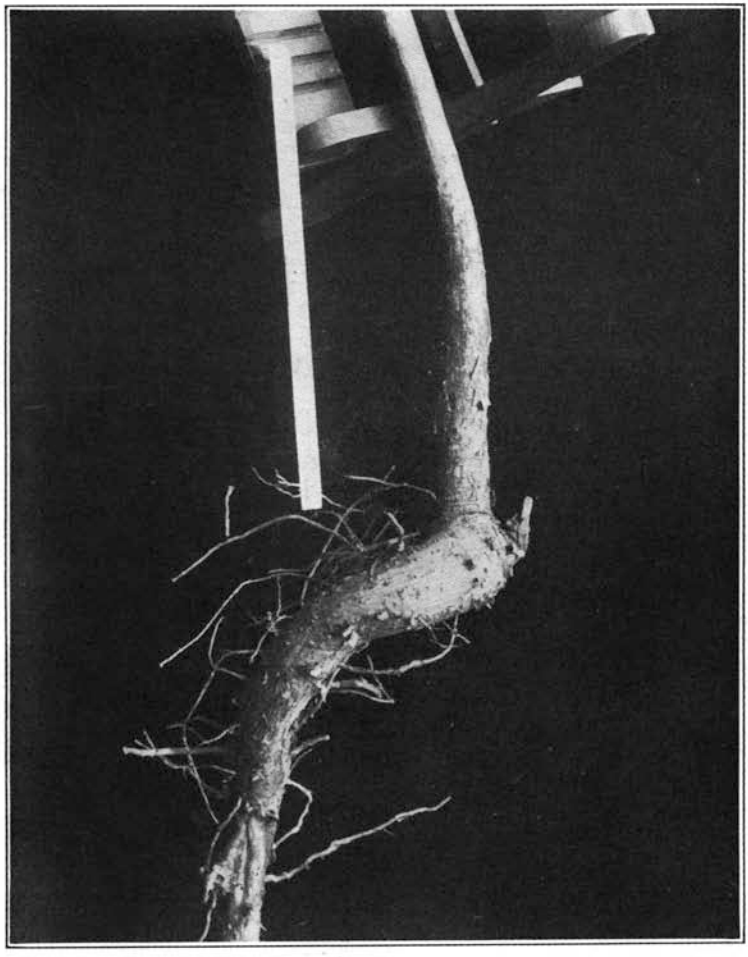

Fig. 5. Red oak single seedling sprout showing variation in the point of origin of new stem. Compare with Fig. 4, where new stem started on the outer side of old stub.

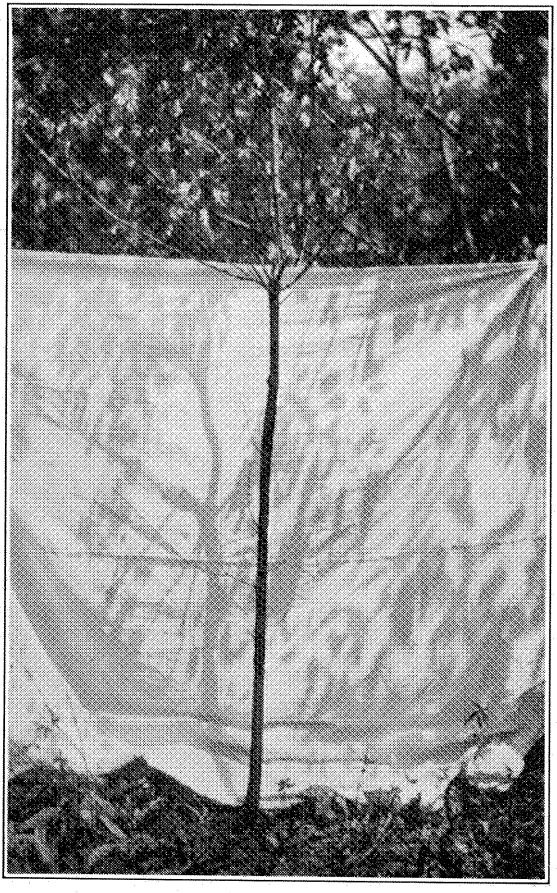

Fig. 6. Red oak single seedling sprout 4 years old and 9.5 feet in height. This tree grew 4.5 feet in height during the first year.

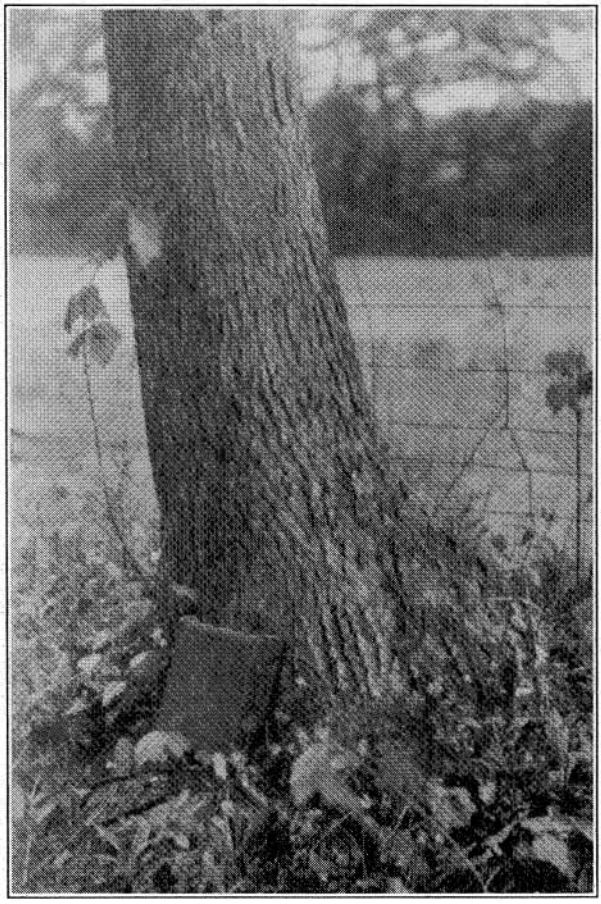

Fig. 7. Mature oak single seedling sprout showing the characteristic swollen base and curve at one side, and the straight sweep of the stem on the opposite side of the trunk.

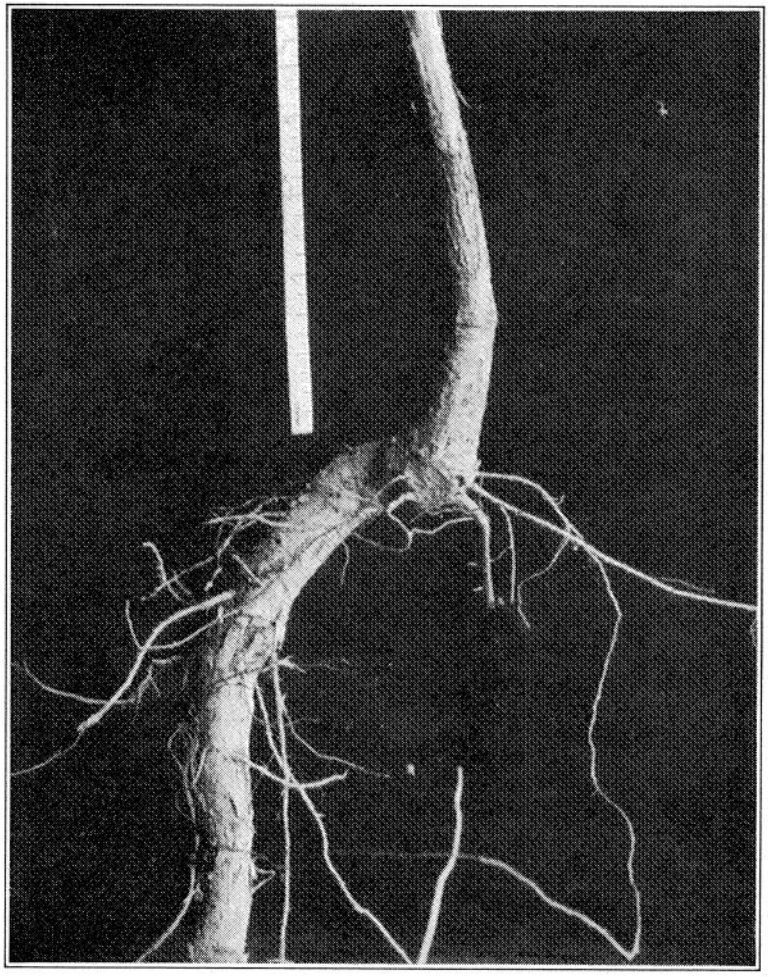

Fig. 8. Red oak seedling showing the first year·s growth and the. slight curve in the taproot, as compared to the abrupt curve characteristic of seedling sprouts. (See Figs. 4 and I I.) Lateral roots are seen developing close to the base of the stem. In seedling sprouts these develop lower down on the taproot. (See Figs. 4 and 10.)

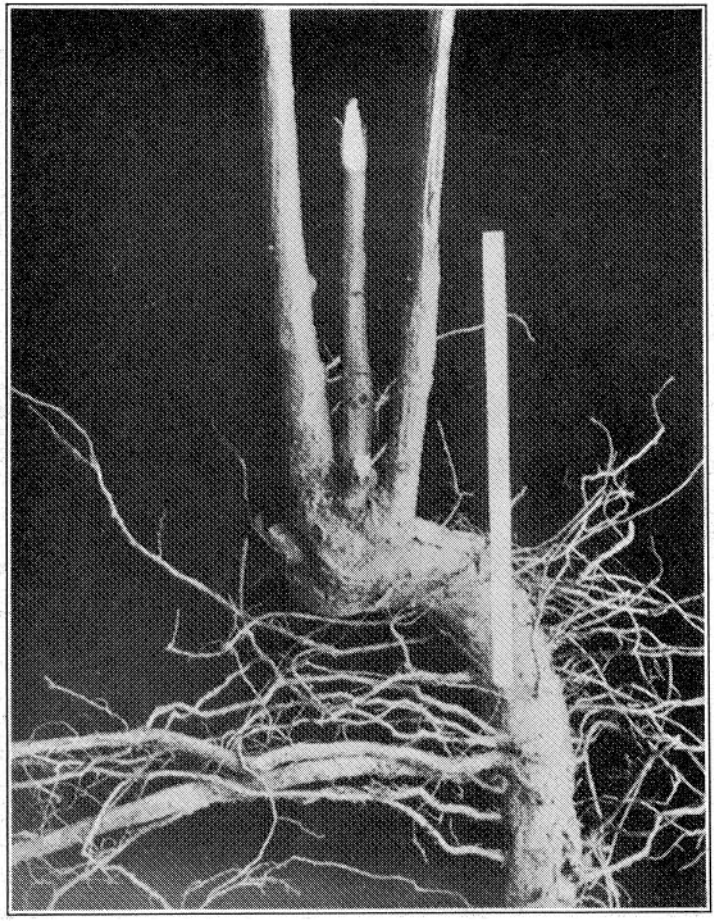

Fig. 9. Multiple seedling sprout showing the characteristic development of more than one stem. The stub of the original seedling which had been cut still remains. Several sprouts developed but competition has reduced the number to two. Note large lateral roots developing from point well below the root collar. (Compare with Fig. 8.)

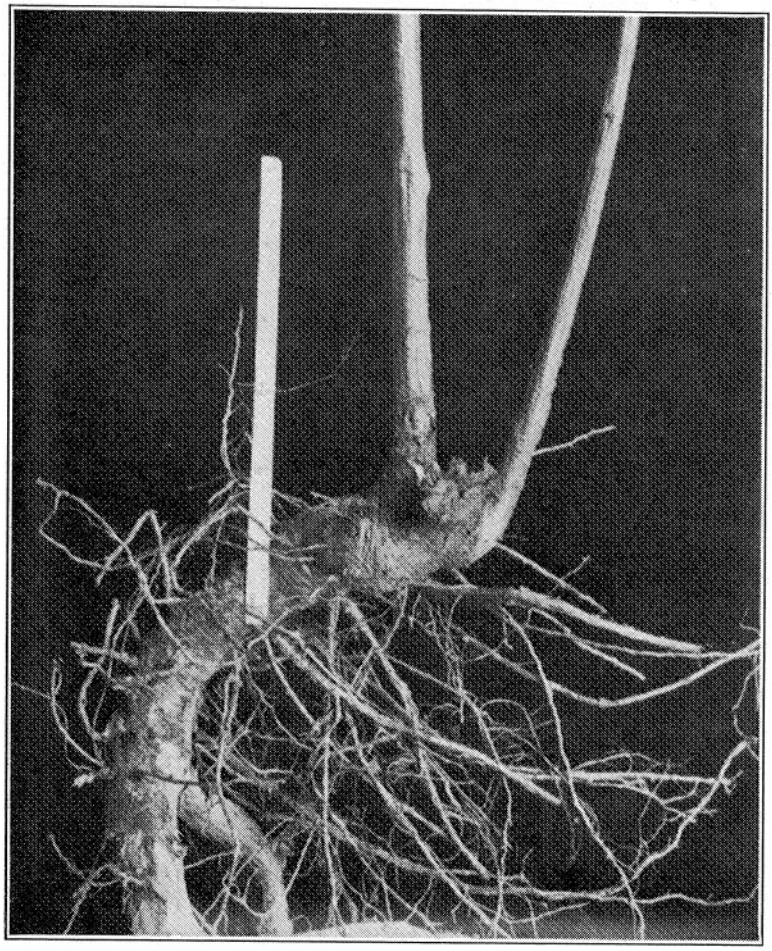

Fig. 10. Usual form of multiple seedling sprout with one stem slightly larger in dialneter than the other.

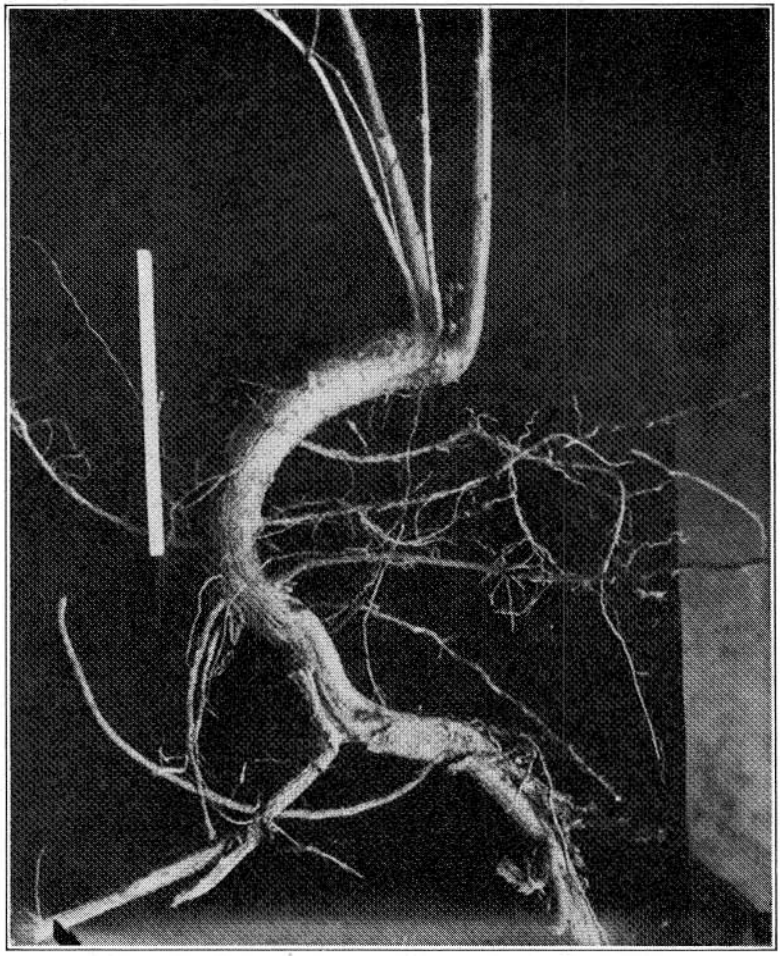

Fig. 11. Red oak multiple seedling sprout with two generations of sprouts. The larger stems are each 4 years of age, the dead stems showed 7 growth rings, and the root 14 rings. The tree lived under the previous stand for 3 years as a seedling and 7 years as a multiple seedling sprout, and then developed the present generation of stems. The root is not decayed but was damaged when it was removed from the soil.

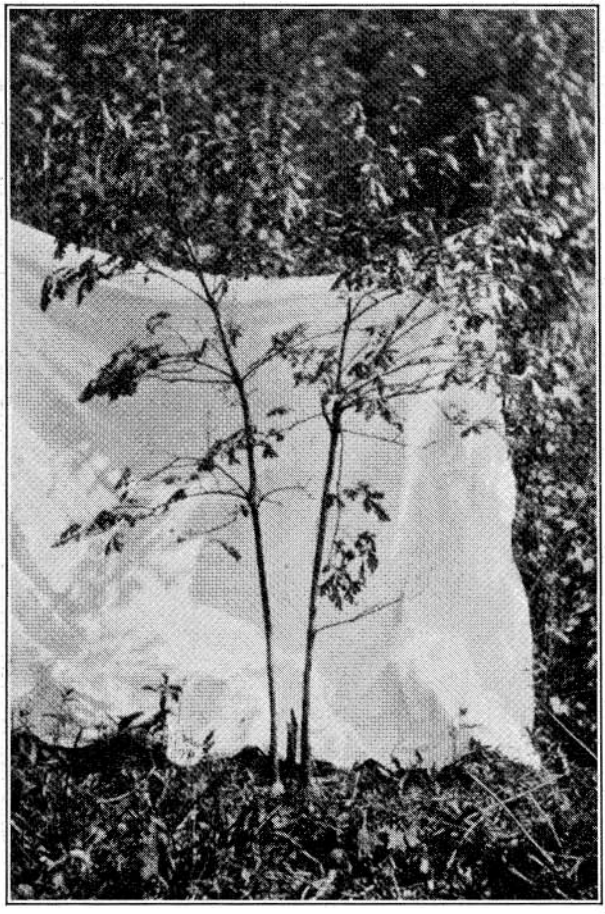

Fig. 12. White oak multiple seedling sprout 4 years old and 6 feet high.

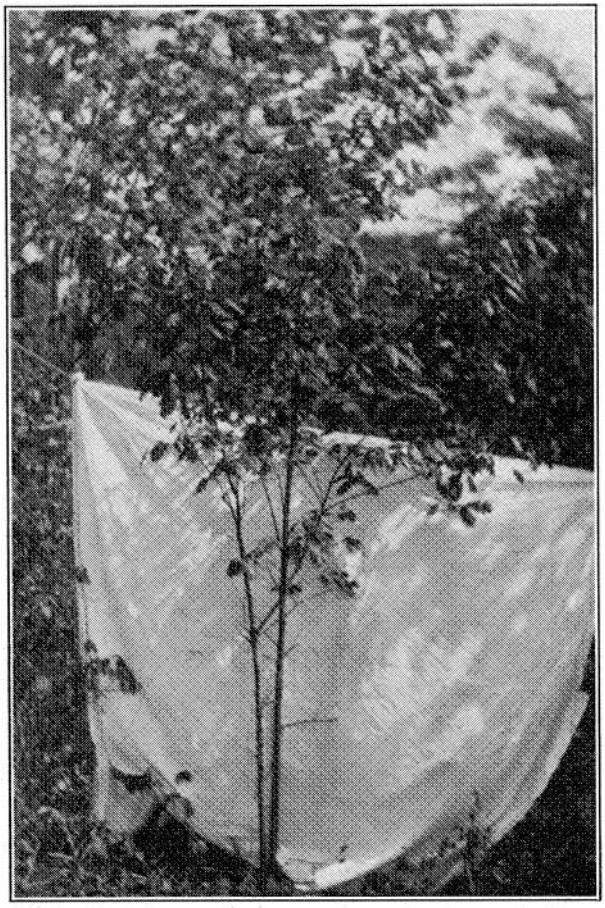

Fig. 13. Red oak multiple seedling sprout 4 years old. The large stem was 8.2 feet in height, the other 7 feet. A difference in the height of the stems is characteristic of this gro'wth form.

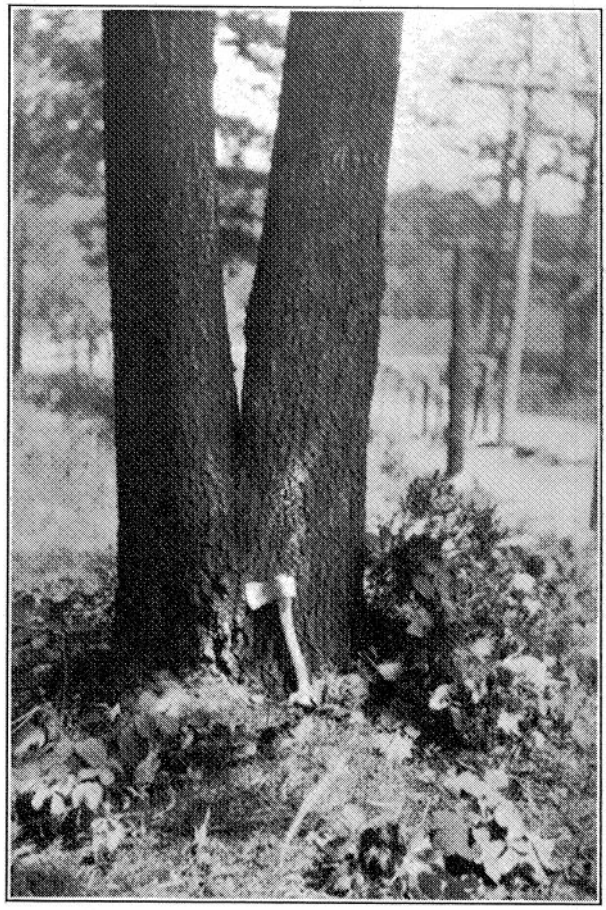

Fig. 14. IVlature lllultiple seedling sprout.

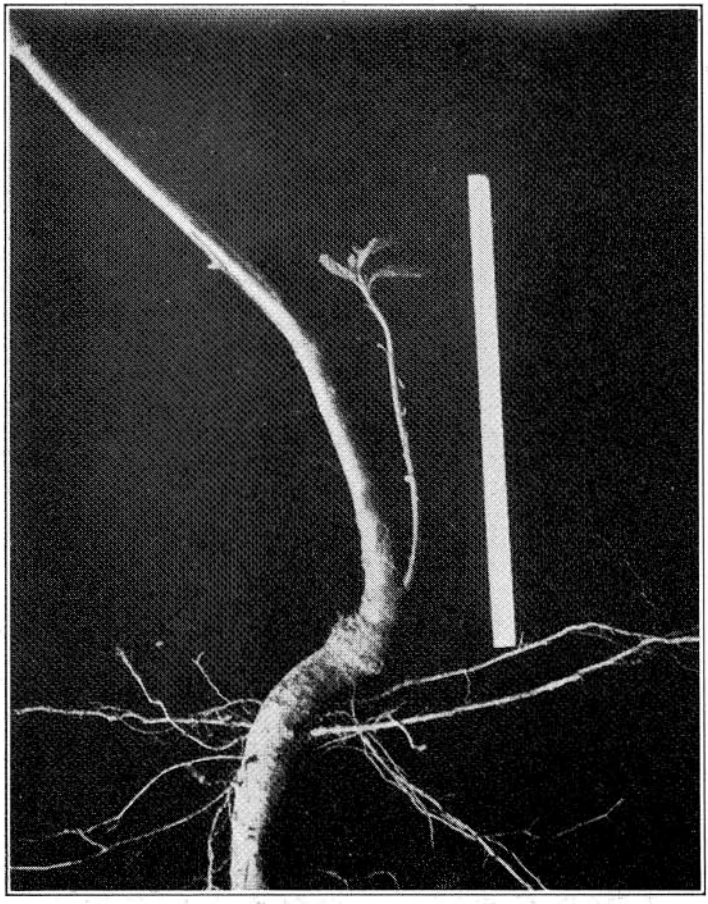

Fig. 15. Chestnut oak seedling 4 years of age. The young sprout is 3 weeks old. This is an excellent illustration of an early stage in the transformation of a seedling into a seedling sprout. The stem of the seedling was damaged by rodents and the young sprout has developed as a reaction to this injury.

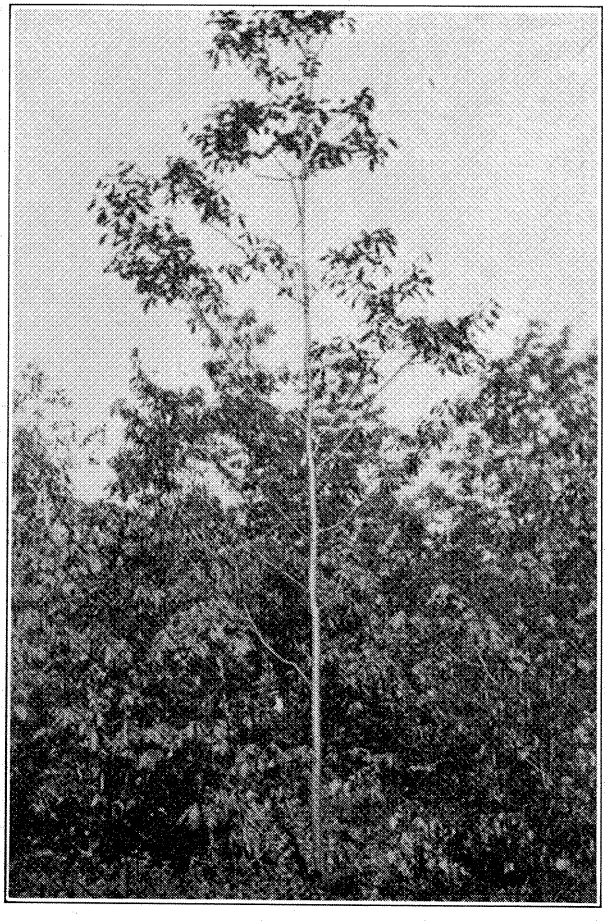

Fig. 16. Typical example of advance growth showing the well-formed crown and straight stem characteristic of this class of reproduction. This is a single seedling sprout 22 years old, 24 feet in height, and 5.2 inches D. B. H.

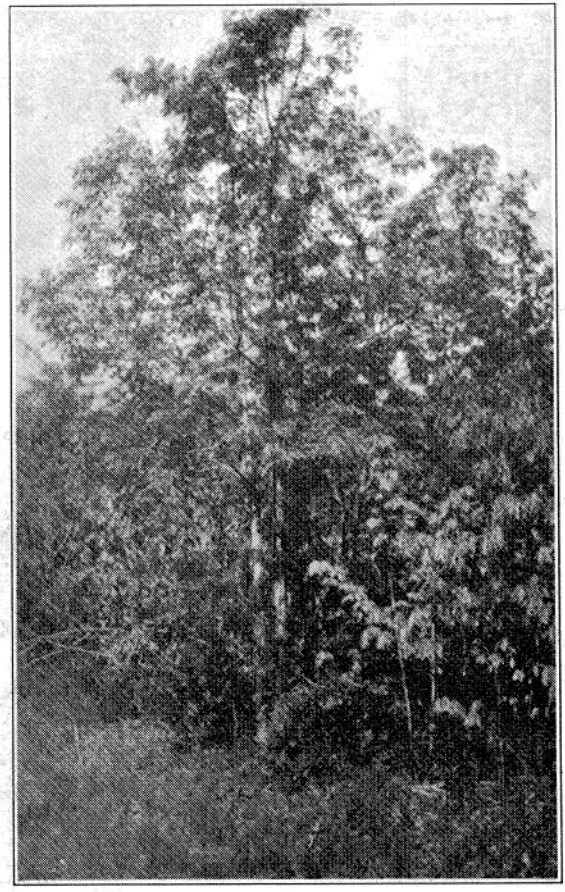

Fig. 17. White oak multiple seedling sprout of advance growth. Note healthy appearance of crown and stems.

End of Document