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Introduction

OAK forest types make up half of the forest land in West Virginia (Wray 1952). They occur over a wide range of site conditions from rich moist bottomlands and coves to dry infertile ridgetops. Over much of this area the mature stands will be harvested in such a way that new oak stands will be regenerated by natural means. Thus, the reproduction which becomes established following harvesting, as well as the reproduction present on the ground at the time of harvesting, will determine the composition of the next stand.

In order to harvest mature oak stands properly so that desired species will make up the next crop, more information pertaining to basic and applied phases of silviculture is needed. Work of a fundamental nature is now in progress in which the effect of site factors on oak reproduction is being studied. These site factors include soils, topography, stand density, insects, and animals. The results should aid in a better understanding of natural establishment of oak seedlings which will help to improve silvicultural methods used in harvesting stands of the oak types.

The reproduction data have been summarized although not yet related to the measured site factors. Since future work on this project will be built on this evaluation of reproduction, and since the results contain material of interest without relating to site factors, this bulletin will present the evaluation of the reproduction found under oak stands.

Conditions and Methods

Two different sets of plots were studied. One set, permanent plots, was established in an attempt to have plots with both high and low amounts of reproduction. Detailed information on the permanent plots was taken on stand composition, reproduction, yearly seed crops, and site factors, including insect and rodent damage to acorns. The other set, temporary plots, was studied to investigate further the effect of site factors, other than insects and rodents, on amounts and species of re-

production under oak stands. A total of 68 plots were established, 28 permanent and 40 temporary. All permanent plots were located in Preston and Monongalia counties. Temporary plots were studied in these same two counties, as well as in Grant, Greenbrier, Mineral, Morgan, Randolph and Tucker.

The mixed oak stands selected for study were even-aged or sometimes two-storied. All of the stands contained trees large enough to produce considerable amounts of seed, the majority of the trees falling between 60 and 120 years of age. Stands damaged recently by fire, grazing, logging, or any other agent were not used in this study.

An attempt was made to select fully stocked stands, although two areas containing temporary plots were poorly stocked. The amount of sunlight reaching the forest floor of the plots averaged 5.6 per cent, as determined with a photometer of the photoelectric-cell type.

Site quality of the plots varied from poor to excellent. Site indexes ranged from 41 to 83, with an average of 68, after adjusting the different oak species to a red oak base. This average is close to that of 66 reported by Trimble and Weitzman (1956).

Reproduction was tallied using milacre quadrats. A red oak or white oak tree was chosen as the plot center. The reproduction was tallied in four quadrats under the center tree and in four quadrats beyond the crown of the center tree. Thus the reproduction on each plot was tallied from eight milacre quadrats, the most distant being 80 feet from the crown of the central tree.

Reproduction was considered to be less than 0.6 inches d.b.h. and was separated into height classes in the following manner: less than 1 foot, 1.0 to 1.9 feet, 2.0 to 2.9 feet, 3.0 to 3.9 feet, 4.0 to 4.9 feet, 5.0 to 5.9 feet and 6.0 feet and larger.

All woody species were tallied except vines. No distinction was made between seedlings and sprouts. However, nearly all of the regeneration was of seedling origin.

Results

ABUNDANCE OF REPRODUCTION

The reproduction under mixed oak stands is presented on an acre basis in Tables 1, 2, and 3 by species and by height classes. Table 1 presents the results with the permanent and temporary plots combined. Table 2 presents the results of the permanent plots, and Table 3 the results of the temporary plots.

The amount of all reproduction and of oak reproduction may be observed to be high in all three tables. Total reproduction exceeds 30,000

Table 1. Abundance of Reproduction Per Acre on Combined Permanent and Temporary Plots

Species	Height Class (Feet)							
Oak Species	Under 1	1-1.9	2-2.9	3-3.9	4-4.9	5-5.9	Over 6	Total
White Oak	2,496	829	222	68	22	13	0	3,650
Northern Red Oak	1,092	209	24	7	4	7	2	1,345
Chestnut Oak	1,020	136	26	6	2	2	2	1,194
Black Oak	116	31	6	4	2	0	2	161
Scarlet Oak	66	11	0	0	0	0	0	77
Shingle Oak	0	0	4	0	0	0	0	4
Total Oaks	4,790	1,216	282	85	30	22	6	6,431
Other Species								
Red Maple	17,939	239	86	44	16	13	11	18,348
Black Cherry	5,519	575	167	48	4	11	0	6,324
Chestnut Oak	562	270	75	29	16	9	2	963
Serviceberry	629	81	22	13	4	9	4	762
Witch-hazel	360	142	64	26	4	6	15	617
Flowering Dogwood	346	132	50	33	29	7	7	604
Slippery Elm	342	141	53	22	7	7	0	572
Sassafras	312	169	37	7	2	2	0	529
Hickory	299	101	35	4	4	0	6	449
Yellow-poplar	419	6	2	0	4	0	0	431
White Ash	224	68	22	16	7	0	5	342
Maple-leaved Viburnum	195	83	44	9	4	0	0	335
Blackgum	167	77	29	22	2	4	2	303
Black Chokeberry	105	121	57	11	0	0	2	296
Pinxter-flower	173	86	26	6	0	0	2	293
Blue Beech	154	59	29	13	9	11	7	282
Sugar Maple	138	37	18	2	0	0	4	199
Black Birch	160	16	6	0	0	0	6	188
Eastern Hophornbeam	167	4	2	0	0	0	0	173
Blueberry	88	35	4	2	0	0	2	131
Spicebush	59	20	26	16	2	2	2	127
American Chestnut	6	35	26	0	0	0	2	69
Striped Maple	22	20	18	1	4	0	0	68
Fire Cherry	31	13	13	2	0	0	0	59
Arrow-wood	20	11	11	4	0	0	0	46
Hazelnut	4	16	9	6	4	6	0	45
White Pine	39	4	0	0	0	0	0	43
Mountain-laurel	29	11	2	0	0	0	0	42
American Elm	18	7	0	2	4	2	0	33
Cucumbertree	11	7	9	2	0	0	0	29
Black Locust	9	13	4	2	0	0	0	28
American Beech	16	1	0	2	2	0	0	21
Eastern Hemlock	6	2	4	0	0	0	0	12
American Basswood	4	1	2	0	2	0	0	12
Rosebay Rhododendron	6	2	0	0	2	0	0	10
Gooseberry	4	6	0	0	0	0	0	10
Sweet Crab Apple	6	0	0	0	4	0	0	10
Eastern Redbud	0	4	2	2	0	2	0	10
Yellow Birch	6	2	0	0	0	0	0	8
Smooth Alder	2	2	2	0	2	0	0	8
Sourwood	2	0	4	2	0	0	0	8
Virginia Pine	4	2	0	0	0	0	0	6
Blackhaw	0	0	2	0	0	0	0	2
Staghorn Sumac	0	0	0	0	0	0	2	2
Others	2	0	0	0	0	0	4	6
Total - Other Species	28,604	2,627	962	351	138	91	85	32,858
Grand Total - All Species	33,394	3,843	1,244	436	168	113	91	39,289

TABLE 2. ABUNDANCE OF REPRODUCTION PER ACRE ON PERMANENT PLOTS

Species	Height Class (Feet)							
Oak Species	Under 1	1-1.9	2-2.9	3-3.9	4-4.9	5-5.9	Over 6	Total
White Oak	3,616	1,562	500	152	40	22	0	5,892
Northern Red Oak	1,232	282	51	9	4	4	0	1,632
Chestnut Oak	1,808	12	0	0	0	0	0	321
Black Oak	120	53	4	9	0	0	0	186
Scarlet Oak	0	0	9	0	0	0	0	9
Scarlet Oak	4	4	0	0	0	0	0	8
Total Oaks	5,160	1,863	544	170	44	26	0	8,048
Other Species								
Red Maple	24,994	835	89	45	4	13	0	25,480
Black Cherry	7,732	1,062	339	103	4	13	0	9,253
Hawthorn	781	370	116	31	18	0	0	1,316
Slippery Elm	795	286	120	45	18	18	0	1,282
Serviceberry	841	125	40	13	4	9	0	1,035
Yellow-poplar	741	4	0	0	0	0	0	745
Witch-hazel	366	201	80	9	0	9	0	665
Flowering Dogwood	397	147	58	36	22	0	0	660
Hickory	437	147	58	9	9	0	0	660
Sassafras	312	156	22	9	0	0	0	499
Blackgum	228	94	22	22	0	4	4	374
Blue Beech	156	80	18	4	4	0	0	262
Spicebush	116	31	53	31	4	4	4	243
White Ash	112	53	18	18	4	0	0	205
Sugar Maple	107	45	9	4	0	0	0	165
Pinxter-flower	49	80	22	9	0	0	0	160
Fire Cherry	76	31	31	4	0	0	0	142
Maple-leaved Viburnum	94	40	4	0	0	0	0	138
Black Birch	94	18	0	0	0	0	0	112
American Chestnut	4	27	31	0	0	0	0	62
Hazelnut	4	13	4	0	0	0	0	21
American Beech	13	4	0	4	0	0	0	21
Sweet Crab Apple	9	0	0	0	9	0	0	18
Cucumbertree	4	4	9	0	0	0	0	17
Smooth Alder	4	4	4	0	4	0	0	16
Gooseberry	0	13	0	0	0	0	0	13
Blackhaw	0	0	4	0	0	0	0	4
Black Locust	0	4	0	0	0	0	0	4
Rosebay Rhododendron	4	0	0	0	0	0	0	4
Total Other Species	38,173	3,374	1,151	396	104	70	8	43,576
Grand Total - All Species	43,873	5,238	1,695	566	148	96	8	51,624

individuals per acre, and the oak exceeds 5,000. Red maple[1] was by far the most abundant species, followed by black cherry and then white oak, which exceeded both northern red oak and chestnut oak in numbers. The relatively high amount of reproduction under one foot in height is

[1] An index of technical names, arranged alphabetically by common names, may be found in the appendix. Technical names follow: Little, Elbert L. 1953. Check list of native and naturalized trees of the United States. Forest Service. USDA Agricultural Handbook No. 41. 172 pp.

TABLE 3. ABUNDANCE OF REPRODUCTION PER ACRE ON TEMPORARY PLOTS

SPECIES	HEIGHT CLASS (FEET)							
OAK SPECIES	UNDER 1	1-1.9	2-2.9	3-3.9	4-4.9	5-5.9	OVER 6	TOTAL
White Oak	1,713	316	28	9	9	6	0	2,081
Chestnut Oak	1,519	222	44	9	3	3	3	1,803
Northern Red Oak	909	194	19	6	3	9	3	1,143
Black Oak	113	16	6	0	3	0	3	141
Scarlet Oak	109	16	0	0	0	0	0	125
TOTAL OAKS	4,363	764	97	24	18	18	9	5,293
OTHER SPECIES								
Red Maple	13,003	172	84	44	25	12	19	13,359
Black Cherry	3,972	234	47	9	3	9	0	4,274
Hawthorn	409	200	47	28	16	16	3	719
Witch-hazel	356	100	53	37	6	3	25	580
Serviceberry	478	50	9	12	3	9	6	567
Flowering Dogwood	309	122	44	31	34	12	12	564
Sassafras	313	178	47	6	3	3	0	550
Black Chokeberry	178	206	97	19	0	0	0	500
Maple-leaved Viburnum	266	112	72	16	6	0	0	472
White Ash	303	78	25	16	9	0	9	440
Pinxter-flower	259	91	28	3	0	0	3	384
Hickory	203	69	19	0	0	0	9	300
Blue Beech	153	44	37	19	12	19	12	296
Eastern Hophornbeam	284	6	3	0	0	0	0	293
Blackgum	125	66	34	22	3	3	0	253
Black Birch	206	16	9	0	0	0	9	240
Sugar Maple	159	31	25	0	0	0	6	221
Blueberry	150	59	6	3	0	0	0	218
Yellow-poplar	194	6	3	0	6	0	0	209
Striped Maple	38	34	31	6	6	0	0	115
Slippery Elm	25	41	6	6	0	0	0	78
Arrow-wood	34	19	19	6	0	0	0	78
American Chestnut	6	41	22	0	0	0	3	72
Mountain-laurel	50	19	3	0	0	0	0	72
White Pine	66	6	0	0	0	0	0	72
Hazelnut	3	19	12	9	6	9	0	58
American Elm	31	12	0	3	6	3	0	55
Black Locust	16	19	6	3	0	0	0	44
Spicebush	19	12	6	6	0	0	0	43
Cucumbertree	16	9	9	6	0	0	0	40
American Beech	19	3	0	0	3	0	0	25
American Basswood	6	6	3	0	3	0	0	18
Eastern Hemlock	9	3	6	0	0	0	0	18
Eastern Redbud	0	6	3	3	0	3	0	15
Sourwood	3	0	6	3	0	0	0	12
Rosebay Rhododendron	6	3	0	0	3	0	0	12
Yellow Birch	9	3	0	0	0	0	0	12
Virginia Pine	6	3	0	0	0	0	0	9
Gooseberry	6	0	0	0	0	0	0	6
Sweet Crab Apple	3	0	0	0	0	0	0	3
Staghorn Sumac	0	0	0	0	0	0	3	3
Others	3	0	0	0	0	0	6	9
TOTAL - OTHER SPECIES	21,694	2,098	821	316	153	101	125	25,308
GRAND TOTAL - ALL SPECIES	26,057	2,862	918	340	171	119	134	30,601

particularly outstanding. For oaks, more than 65 per cent of the individuals are under one foot in height; and for all species combined, 85 per cent are under one foot in height. The amount of reproduction in the height classes above one foot drops rapidly in number. This indicates that hardwood reproduction becomes established in great numbers under well stocked mixed oak stands, but dies out rapidly within the next few years.

The amount of American chestnut reproduction is of interest. Table 1 shows 69 individuals per acre. The authors examined many of the small American chestnuts and considered them to be of seedling or seedling-sprout origin.

ABUNDANCE OF FIRST YEAR OAKS

Reproduction in the permanent plots was tallied during June and July 1955. First-year oak seedlings were kept separate from older oak reproduction under one foot in height. The acorn crop in 1954 was large in this area. The comparison of first-year oaks with older oaks less than one foot in height, and over one foot in height is presented in Table 4. These data are based on the permanent plots only. The amount of first-year oak seedlings varies from 23.0 to 62.1 per cent of the total amount of oak reproduction.

On plots with good oak reproduction the number of white oaks increased with age and height, whereas the number of red oaks decreased. This suggests that white oak is able to become established and survive more readily than red oaks on many sites. On plots with poor oak reproduction, both red oak and white oak decreased in the older and taller classes, but red oak decreased at a more rapid rate than white oak. This may mean that white oak is persistent in surviving where conditions for oak establishment are poor.

The differences between the plots with good and poor reproduction are, at present, not understood. However, site quality alone is not the factor as the site index averaged nearly the same for both sets of plots.

COMPARISON OF REPRODUCTION UNDER AND BEYOND TREE CROWN

The amount of reproduction beneath the tree crowns and beyond the tree crowns was studied to determine if a difference existed. Reproduction counts were made in each plot using four milacre quadrats beneath a central oak tree, and four milacre quadrats beyond the crown projection of that tree. A comparison was made with oak reproduction under and beyond the central tree crown, and with the reproduction of all other species.

TABLE 1. THE NUMBER OF YEAR-OLD OAK SEEDLINGS COMPARED WITH OLDER OAK SEEDLINGS ON THE 28 PERMANENT PLOTS (14 WITH GOOD OAK REPRODUCTION; 14 WITH POOR OAK REPRODUCTION)

ALL OAK SPECIES

AGE AND HEIGHT	ALL PLOTS		PLOTS WITH GOOD OAK REGENERATION		PLOTS WITH POOR OAK REGENERATION	
	NUMBER PER ACRE	%	NUMBER PER ACRE	%	NUMBER PER ACRE	%
1 year old	2,562	31.8	3,803	28.2	1,321	50.5
More than 1 year old, less than 1 foot tall	2,839	35.3	4,857	36.0	821	31.4
1 foot to 6 feet tall	2,652	32.9	4,830	35.8	473	18.1
Total	8,053	100.0	13,490	100.0	2,615	100.00

WHITE OAK

AGE AND HEIGHT	ALL PLOTS		PLOTS WITH GOOD OAK REGENERATION		PLOTS WITH POOR OAK REGENERATION	
	NUMBER PER ACRE	%	NUMBER PER ACRE	%	NUMBER PER ACRE	%
1 year old	1,451	24.6	2,428	23.0	473	38.2
More than 1 year old, less than 1 foot tall	2,165	36.7	3,893	36.9	437	35.2
1 foot to 6 feet tall	2,277	38.7	4,223	40.1	330	26.6
Total	5,893	100.0	10,544	100.0	1,240	100.0

RED OAK

AGE AND HEIGHT	ALL PLOTS		PLOTS WITH GOOD OAK REGENERATION		PLOTS WITH POOR OAK REGENERATION	
	NUMBER PER ACRE	%	NUMBER PER ACRE	%	NUMBER PER ACRE	%
1 year old	795	48.7	1,071	44.0	518	62.4
More than 1 year old, less than 1 foot tall	558	34.1	893	36.6	223	26.9 10.7
1 foot to 6 feet tall	281	17.2	473	19.4	89	
Total	1,634	100.0	2,437	100.0	830	100.0

Oak reproduction under the crown of the central oak tree averaged 7,041 stems per acre, and beyond the tree crown averaged 5,852 stems per acre. This difference was not significant at the 5 per cent level.

Reproduction of other species, oak excluded, averaged 32,984 stems per acre under the crown of the central tree, and 34,079 stems per acre beyond the crown of the central tree. This difference also was not significant.

It is not surprising that the differences noted above were not significant, since the amount of reproduction between plots varied greatly. As the difference in reproduction under the crown of the central oak tree and beyond the crown is not significant, all plots were used in evaluating the various phases of the reproduction results.

STOCKING (FREQUENCY) OF OAKS

The degree of stocking, or frequency, of the oak reproduction was determined to find out whether the reproduction was evenly distributed over the plots, or was concentrated at various points. Any milacre quadrat which contained one or more oak seedlings was considered to be stocked. Stocking was compared under the central oak tree crowns and beyond them for both permanent and temporary plots.

On the permanent plots, 82.1 per cent of the quadrats under the tree crowns were stocked, whereas 75.0 per cent of the quadrats beyond the tree crowns were stocked. This difference was not significant.

On the temporary plots, 78.3 per cent of the quadrats under the tree crowns were stocked, and 77.6 per cent of the quadrats beyond the crowns were stocked. The difference also was not significant.

Values obtained for percentage of stocking indicate that the oak seedlings are well distributed over the area, and that they are as well distributed beyond the crown of the central oak tree as under its crown.

OAK ABUNDANCE BY AREA

The relatively high abundance of oak reproduction occurring under oak stands has been surprising to the authors. To be sure, most of this is under one-foot high and varies in abundance considerably from plot to plot. The number of oak seedlings per acre based on per cent of the area are presented in Figure 1. These curves may be used to show the percentage of the area having different amounts of oak reproduction. The upper curve is for total number of oaks, and the lower curve excludes the first-year seedlings. By selecting any number of oak seedlings per acre on the abscissa and drawing a line vertically to a curve, then extending the line horizontally from the point where the curve is touched to a point on the y axis, a percentage value is indicated. This value represents the per cent of the area on which that number of oak seedlings or more occur. For example, in Figure 1, 3,000 or more oak seedlings per acre occur on 15.5 per cent of the area. In a like manner the per cent of the area containing any other minimum number of oak seedlings may be determined.

Much variability in amounts of oak reproduction occurred between plots, ranging from a minimum of 125 to a maximum of 55,750 per acre for total oak reproduction, and from 85 to 11,125 per acre when the first-year seedlings are excluded.

The appearance of the areas having different amounts of oak reproduction may be observed in Figures 2, 3, 4, and 5. It is of interest that oak regeneration was not noticeable on the areas of Figures 2 and 3

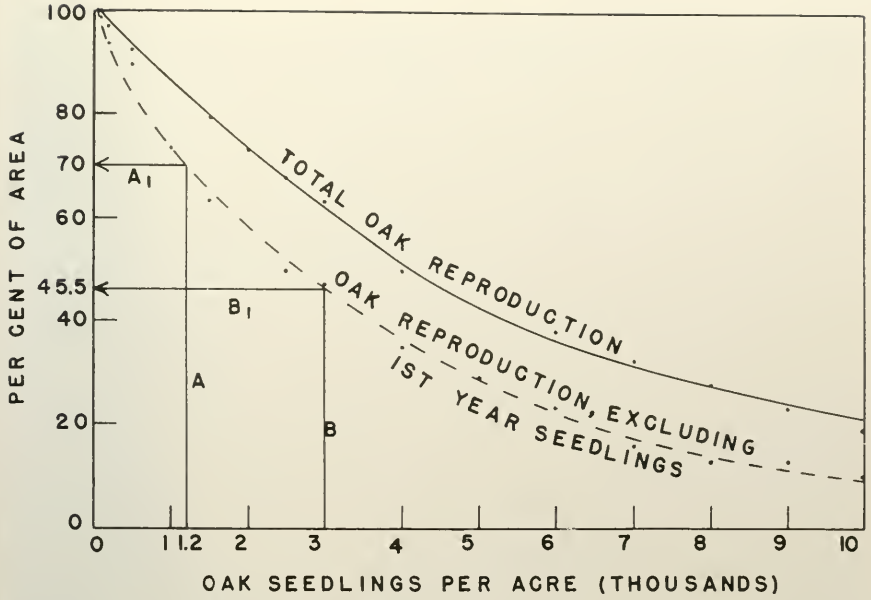

FIGURE 1. Abundance of oak seedlings under mixed oak stand. The curves indicate percentage of area having different amounts of oak reproduction. Each value of the abscissa represents the amount indicated, or more. For example lines A_1 A indicate that 1,200 or more oak seedlings, excluding first-year ones, occur on 70 per cent of the area. Lines B_1 B indicate that 3,000 or more oak seedlings, excluding first-year ones, occur on 45.5 per cent of the area.

until a close examination was made. Figure 2 has only 500 oaks per acre in the reproduction class and Figure 3 has 1,125. These are mainly less than one foot in height.

OAK REPRODUCTION RELATED TO REPRODUCTION OF OTHER SPECIES

An attempt was made to determine the effects of amount of reproduction of species other than oaks on amount of oak regeneration. No clear-cut trend could be observed. However, there did appear to be a slight negative relation between large reproduction of other species and oak reproduction less than one foot tall. Thus high amounts of tall reproduction of other species may have an effect in reducing oak regeneration.

WHITE AND RED OAK REPRODUCTION COMPARED TO WHITE AND RED OAK IN OVERSTORY

The abundance of white oak reproduction was observed to be greater than red oak reproduction on both the permanent and temporary plots

FIGURE 2. A permanent plot with 500 oak seedlings per acre in the reproduction class.

FIGURE 3. A permanent plot with 1,125 oak seedlings per acre in the reproduction class. The seed trap shown is $\frac{1}{4}$ milacre in area and one of a pair maintained under the central oak tree in each permanent plot.

FIGURE 4. A permanent plot having 3,250 oak seedlings per acre. Although ferns were abundant on the plot, they were not dense enough to limit the regeneration of tree species, as a dense fern cover often does.

FIGURE 5. A permanent plot having 55,750 oak seedlings per acre in the reproduction class. This stand had much more oak reproduction than any other area studied. The overstory is mainly of white oak.

(see Tables 2 and 3). As red oak saw timber occurs in greater amounts than white oak saw timber in West Virginia (Wray 1952), a greater amount of red oak reproduction might be expected. Therefore, the amounts of red and white oak regeneration were compared with the amounts of red and white oak in the overstory.

The data from the permanent plots only were used, as complete data on the overstory were not taken on the temporary plots. On these plots 85.0 per cent of the red and white oak reproduction was white oak. Of the number of red and white oak stems in the overstory 6 inches d.b.h. and over, 81.9 per cent were white oak. A similar comparison was made using basal area of the trees in the overstory. Of the red and white oaks, 6 inches d.b.h. and over, the white oaks made up 73.6 per cent. Thus there is a reasonable agreement between the greater amounts of white oak regeneration with the greater number of white oak in the overstory.

To test further the relationship between red and white oak reproduction and red and white oak overstory, ratios between the two species were obtained by plots and the correlation coefficient was used. The results obtained between (a) reproduction and number of stems 6 inches and over and (b) reproduction and basal area of stems 6 inches and over were not significant. Though agreement was found, a close relationship does not exist, indicating that factors other than the amount of white oak in the overstory influence the number of white oak seedlings.

To study further the effectiveness between red and white oaks in producing seedlings, a more limited and detailed test was made. The number of sound acorns collected from the center oak in each permanent plot was determined from the fall collection of 1954. These results were related to the number of new seedlings from the 1 milacre quadrats under each center oak in 1955. These seedlings were all presumed to have originated from the 1954 mast. All values were adjusted to equal crown areas.

It was found that for each 100 red oak seedlings there were 101 white oak seedlings, all seedlings being in their first growing season. However, for each 100 sound red oak acorns collected in the fall of 1954 there were only 20 sound white oak acorns. The equal number of red and white oaks agrees well with the comparison of total red and white oak reproduction to red and white oak in the overstory. However, the white oak acorns were five times as effective as the red oak acorns in producing seedlings.

The reason for the greater effectiveness of the white oak acorns in producing seedlings is not known at present, although work in progress may produce the explanation. It is doubtful if the fall germination of

the white oak proved an advantage over the spring germination of the red oak acorns as spring and early summer moisture were adequate according to results from soil moisture blocks. Possibly the smaller white oak acorns were better covered by the litter and protected to a greater extent from animals than the larger red oak acorns.

The greater amount of white oak reproduction is partly, perhaps largely, due to the greater number of white oaks in the overstory. However, other factors, as yet undetermined, appear to favor the establishment of white oak over red oak.

RED MAPLE REPRODUCTION COMPARED TO RED MAPLE IN OVERSTORY

Red maple was the most abundant species of all the reproduction, making up approximately 50 per cent of the total (note Tables 1, 2 and 3). This seems to be a rather high amount considering that the stands were classified as mixed oak, with oaks the predominant species. The oak reproduction itself made up only about 15 per cent of the total reproduction.

Red maples 6 inches d.b.h. and over in the permanent plots were compared to the total number of trees the same size in order to determine the amount of red maple in the overstory. Red maples made up 15.0 per cent of the total number of stems, or 10.3 per cent of the total basal area. Thus red maple must develop seed in a very prolific manner to produce reproduction so abundantly.

COMPARISON OF NUMBERS OF ACORNS BETWEEN PLOTS WITH HIGH AMOUNTS OF OAK REPRODUCTION AND PLOTS WITH LOW AMOUNTS OF OAK REPRODUCTION

Acorn production was measured on the 14 permanent plots with high amounts of oak reproduction and on the 14 permanent plots with low amounts of oak reproduction in order to find out if a difference in acorn production occurred. A difference, if existing, might in itself explain the reason for a difference in amount of reproduction between the areas of high and low oak reproduction.

Areas chosen for high amounts of oak reproduction showed an average of 13,491 oak seedlings per acre. Areas chosen for low amounts of oak reproduction had about one-fifth as much, or 2,616 oak seedlings per acre.

Acorns were collected bi-weekly during each fall of the 1954-1957 period in two seed traps under each center oak tree of each permanent plot. Such a trap may be seen in Figure 3. Wire screen was placed inside each trap to keep rodents out, however, acorns could pass through

the screen and collect in the bottom of the trap. After each collection the total number of acorns, immature acorns, insect damaged acorns, and sound acorns were determined. Results from each tree were adjusted according to the crown area, determined by its horizontal projection.

A comparison of the acorn production between the plots with high oak reproduction and low oak reproduction is presented in Table 5. Comparison was made of total acorn production and of the amount of sound acorns between the high and low reproduction areas.

It was discovered that little difference in acorn production occurred between plots of high oak reproduction and low oak reproduction. In both total number of acorns and sound acorns these variations were not significant as determined by the t-test.

Thus acorn production was essentially the same on areas having high amounts of oak reproduction and on areas having low amounts of oak reproduction. This means that differences in amounts of oak reproduction are caused by site factors affecting the acorns or seedlings after the acorns have reached the ground. A study of such site factors is underway, but has not been completed.

REPRODUCTION ABUNDANCE BY HEIGHT

The amount of reproduction in the different height classes varied considerably. The greatest amount is under one foot in height, and it drops rapidly with increasing height. For all oaks in Table 1, approximately 75 per cent are under one foot in height, 19 per cent are in the 1.0-1.9-foot height class, and only 1 per cent are in the 2.0-2.9-foot height class. This rapid drop in numbers with increasing height may be observed in Figure 6. As all stands in which the plots were taken had been

TABLE 5. ACORN PRODUCTION ON PLOTS WITH HIGH AND LOW AMOUNTS OF REPRODUCTION (1954-1957)

SPECIES	TOTAL NUMBER ACORNS		SOUND ACORNS	
	HIGH OAK REPRODUCTION PLOTS	LOW OAK REPRODUCTION PLOTS	HIGH OAK REPRODUCTION PLOTS	LOW OAK REPRODUCTION PLOTS
White Oak	958*	1,655	133	279
Red Oak	2,679	2,089	978	776
Total	3,637	3,744	1,111	1,055

* Each value represents the average number of acorns produced per tree for the four-year period after adjusting collection data to crown area.

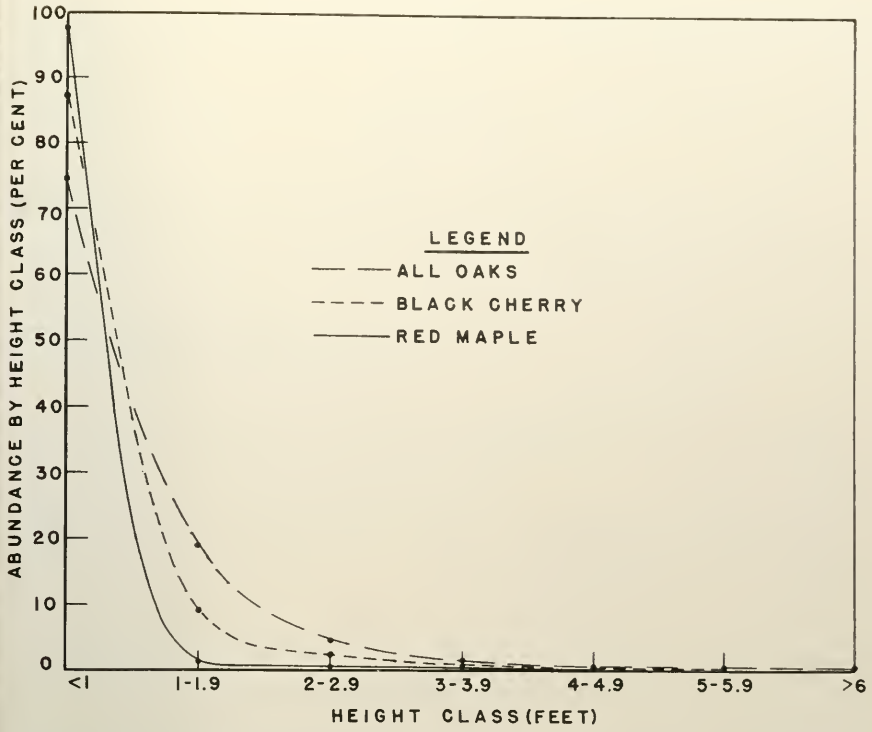

FIGURE 6. Abundance of oak, red maple, and black cherry reproduction by height classes, expressed in per cent. Data from permanent and temporary plots.

undisturbed for several years, this illustrates the ability of oaks, and other species, to live a short time under a forest canopy and then die out. This general trend is evident for all species for which an appreciable number occurred in the sample, regardless of their tolerance rating.

The rapid decrease in number of red maple seedlings with height was unexpected when compared with other species. Red maple is known to be a tolerant species (Baker 1950; Little 1950; Toumey and Korstian 1947; Zon and Graves 1911) and in theory the curve should drop less rapidly than the curve for species of lower tolerance rating. Such a comparison is shown in Figure 6. The red maple is compared with black cherry and the oaks because both are less tolerant than red maple and because both should be high enough in abundance to give reliable results by height class. The curve for red maple may be observed to drop more rapidly than the other curves, indicating a smaller percentage of seedlings in the taller height classes. The first interpretation was that red maple is considerably less tolerant than it is rated. However, the condition of the red maples sampled was considered by the writers and it

was definitely agreed that most of the red maple reproduction (well over 90 per cent) was in its first growing season. This point suggested that the rapid dying out of the red maple might be caused by difficulty in becoming established rather than its tolerance as the term is generally understood.

To test this idea a similar set of curves were drawn, but the height class *under one foot*, which contained the red maples in their first growing season, was omitted. These curves are presented in Figures 7. In this, the red maple curve runs above the curves for black cherry and the oaks in the taller height classes, indicating a higher percentage of red maple living in the taller height classes. In this way the greater tolerance of red maple as compared to black cherry and the oaks is indicated.

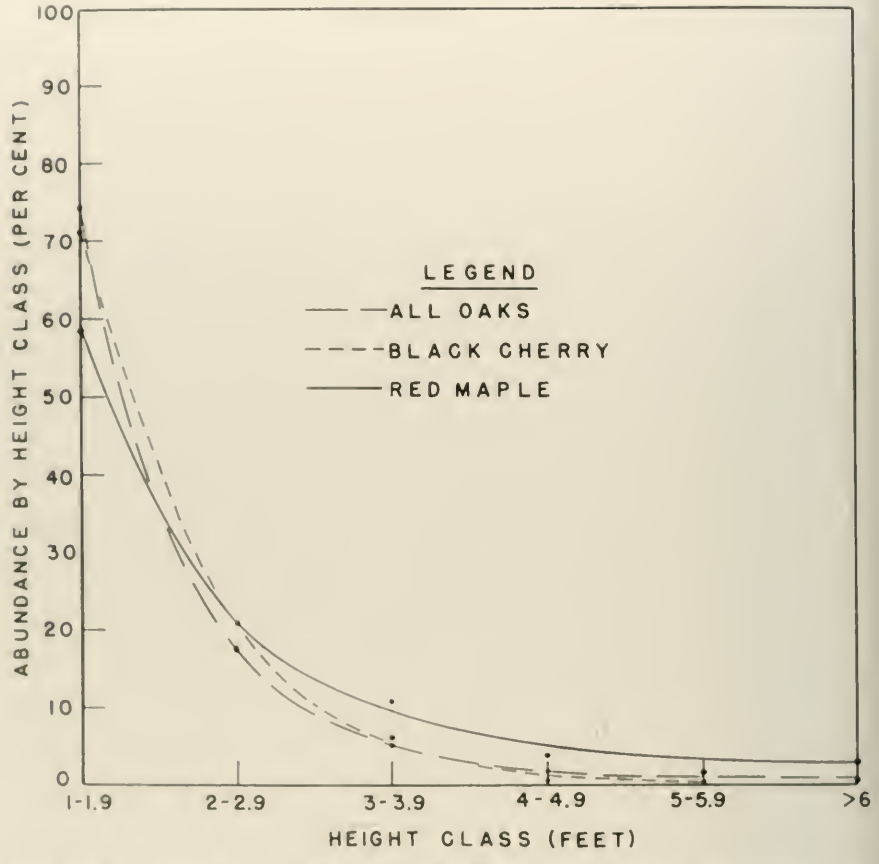

FIGURE 7. Abundance of oak, red maple, and black cherry reproduction by height classes, excluding the smallest class of less than 1 foot, expressed in per cent. Data from permanent and temporary plots.

The inability of red maple to become established successfully seems to account for the relatively low abundance of the species in the taller height classes, rather than to its tolerance rating. The reason for this establishment difficulty is not known; however, the seedlings are small and often quite succulent during the first growing season and may have high mortality during the first winter. Whatever the reason, it is fortunate that red maple has difficulty in establishment. If this were not so, the species would make up a much greater proportion of the final stand than it does today, because it is tolerant, and produces first-year seedlings in such a prolific manner.

Summary and Conclusions

The abundance of reproduction under mixed oak stands was studied on 28 permanent plots and 10 temporary plots. The amount of reproduction under these stands was high. There was an average of approximately 39,000 individuals per acre composed of some 50 different species, and over 6,000 were oaks. The stocking, or frequency, of oak reproduction was high, indicating an even distribution of oak seedlings over the area.

A considerable difference in amount of oak reproduction occurred between areas. Generally, the number was higher than had been expected when this study was initiated, with the majority being less than one foot tall. Excluding the oaks in their first growing season, it was found that one-half of the study areas had 2,500 oak seedlings or more per acre. One plot contained 55,000 oak seedlings per acre.

This abundance of regeneration suggests the possibility of using the one-cut shelterwood silvicultural method, removing the entire overstory in a single removal cut (Hawley and Smith 1954). The number of oak seedlings needed to produce the next stand following harvesting by this method is not known. Various factors enter into the determination, any of which might prohibit the use of this method. These factors include logging damage, size and condition of seedlings present, and death of seedlings due to exposure after the mature stand is cut. The initial growth rate of other species and of oaks must be considered. In spite of these factors, certain selected oak stands may be adequately handled by the one-cut shelterwood method, if logging damage is kept to a minimum.

One-half of the permanent plots were rated high in abundance of oak reproduction, and the other half low. The number of acorns collected during a four-year period was essentially the same on both sets of plots. Thus the difference in amount of oak reproduction appears to be the result of site factors acting on the acorn after falling from the tree, or on the resulting seedling.

The abundance of white oak reproduction exceeded that of the red oak and the relationship between the two was close to that of white oak and red oak in the overstory. For both the reproduction and overstory trees the white oak exceeded the red oak by more than 70 per cent. Thus the greater amount of white oak than red oak appears to result from the greater seed source. However, the red oak, during the period of the study, was a more abundant seed producer than the white oak. By studying the first year oak seedlings in 1955 and the 1954 acorn crop, it was found that for equal numbers of red and white oak acorns, the number of white oak seedlings produced was five times as great as the red oaks. In this instance the white oak acorns were more effective in producing seedlings than the red oak acorns, and this situation is believed to be the usual one. The reason for the difference is not known, but the smaller size of the white oak acorn may allow it to be covered more readily and so protect it from damaging agents.

Most of the seedlings, including the oaks, were found in the smallest height class. Their abundance reduced rapidly with increasing height. This is a normal condition under a forest canopy and is a result of low light intensity and competition.

Red maple seedlings, which were the most abundant under the oak stands, were noted to die out rapidly after the first growing season. This appears to result from a problem of seedling establishment rather than tolerance.

Literature Cited

Baker, Frederick S. 1950. *Principles of Silviculture.* McGraw-Hill Book Co., New York. xii and 414 pp.

Hawley, Ralph C. and David M. Smith. 1954. *The Practice of Silviculture.* John Wiley & Sons, Inc., New York. vii and 525 pp.

Little, Silas, Jr. 1950. *Ecology and Silviculture of Whitecedar and Associated Hardwoods in Southern New Jersey.* Yale Univ. School of Forestry Bul. 56. 101 pp.

Toumey, James W. and Clarence F. Korstian. 1947. *Foundations of Silviculture Upon an Ecological Basis.* John Wiley & Sons, Inc., New York. xxi and 468 pp.

Trimble, George R. and Sidney Weitzman. 1956. "Site Index Studies of Upland Oaks in the Northern Appalachians." *Forest Science* 2:162-173.

Wray, Robert D. 1952. *Forest Statistics for West Virginia.* Northeastern Forest Expt. Sta. Forest Statistics Series: West Virginia No. 1. 48 pp.

Zon, Raphael, and Henry S. Graves. 1911. *Light in Relation to Tree Growth.* U.S.D.A. Forest Service Bul. 92. 59 pp.

APPENDIX

COMMON AND TECHNICAL NAMES OF TREES AND SHRUBS

Common Name	Technical Name
Alder, smooth	*Alnus serrulata* (Ait.) Willd.
Apple, sweet crab	*Malus coronaria* (L.) Mill.
Arrow-wood	*Viburnum recognitum* Fern.
Ash, white	*Fraxinus americana* L.
Basswood, American	*Tilia americana* L.
Beech, American	*Fagus grandifolia* Ehrh.
Beech, blue	*Carpinus caroliniana* Walt.
Blackgum	*Nyssa sylvatica* Marsh.
Blackhaw	*Viburnum prunifolium* L.
Birch, black	*Betula lenta* L.
Birch, yellow	*Betula alleghaniensis* Britton
Blueberry	*Vaccinium* spp.
Cherry, black	*Prunus serotina* Ehrh.
Cherry, fire	*Prunus pensylvanica* L.f.
Chestnut, American	*Castanea dentata* (Marsh.) Borkh.
Chokeberry, black	*Prunus virginia* L.
Cucumbertree	*Magnolia acuminata* L.
Dogwood, flowering	*Cornus florida* L.
Elm, American	*Ulmus americana* L.
Elm, slippery	*Ulmus rubra* Muhl.
Gooseberry	*Ribes* spp.
Hawthorn	*Crataegus* spp.
Hazelnut	*Corylus* spp.
Hemlock, eastern	*Tsuga canadensis* (L.) Carr.
Hickory	*Carya* spp.
Hophornbeam, eastern	*Ostrya virginiana* (Mill.) K. Koch
Locust, black	*Robinia pseudoacacia* L.
Mountain-laurel	*Kalmia latifolia* L.
Maple, red	*Acer rubrum* L.
Maple, striped	*Acer pensylvanicum* L.
Maple, sugar	*Acer saccharum* Marsh.
Oak, black	*Quercus velutina* Lam.
Oak, chestnut	*Quercus prinus* L.
Oak, northern red	*Quercus rubra* L.
Oak, scarlet	*Quercus coccinea* Muenchh.
Oak, shingle	*Quercus imbricaria* Michx.

Oak, white	*Quercus alba* L.
Pine, Virginia	*Pinus virginiana* Mill.
Pine, white	*Pinus strobus* L.
Pinxter-flower	*Rhododendron nudiflorum* (L.) Torr.
Redbud, eastern	*Cercis canadensis* L.
Rhododendron, rosebay	*Rhododendron maximum* L.
Sassafras	*Sassafras albidum* (Nutt.) Nees
Serviceberry	*Amelanchier* spp.
Spicebush	*Lindera benzoin* (L.) Blume
Sourwood	*Oxydendrum arboreum* (L.) DC.
Sumac, staghorn	*Rhus typhina* L.
Viburnum, maple-leaved	*Viburnum acerifolium* L.
Witch-hazel	*Hamamelis virginiana* L.
Yellow-poplar	*Liriodendron tulipifera* L.