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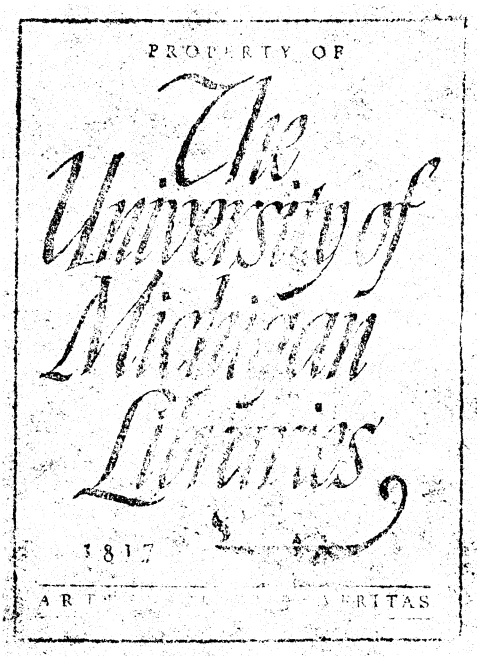

A STUDY OF
SEEDLING REPRODUCTION
IN EBER WHITE WOODS

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By C.S.Coffman, Jr.

March 1937

FOREWORD

This report on the results of a study of seedling reproduction in Eber White Woods is submitted to fulfill partial requirements for a degree of Master of Forestry from the University of Michigan. The work was done under the direction of Professor L.J. Young of the School of Forestry and Conservation to whom I am indebted for the suggestion of the problem, for advice in gathering the data, and in preparing the report.

March 1937

Clifton S. Coffman, Jr.

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A STUDY OF SEEDLING REPRODUCTION IN EBER WHITE WOODS

"A knowledge of natural reproduction is the key to the successful development of forests and to methods of silvicultural management and protection". This statement Toumey (13) qualifies by saying that mere recording of the frequency and abundance of reproduction is of little value unless the reasons for its presence or absence are given. Various lines of research must be carried on over extended periods of time to find the explanation of these reasons. Boerker (2) in 1916 said that while forestry had joined the great industries in developing the investigational side of the business, most of the investigations had been along industrial lines and not along silvicultural lines. That silvicultural research is still not being carried on to any great extent is indicated by the statement appearing in "A National Plan for American Forestry" (Copeland Report), published in 1933, which says: "In the subject of natural reforestation much fundamental work remains to be done, and the problem of carrying established stands through to maturity is, in general, still in a preliminary, empirical stage". Research along silvicultural lines can not be carried to a conclusion in a few years, but must go on, in many cases, through several generations before definite results can be obtained. As yet forestry is in its early stages in America, and this, together with the large supplies of timber available, accounts for the lack of silvicultural research. Such work is now being begun at various forest experiment stations and schools, and

in time much valuable information will be gathered. However, it will probably be many years before definite knowledge on the silvics of the various forest types and species in America is available.

In order to establish definite management plans for forests where natural reproduction is to be relied upon, there must be some exact information as to the response of the particular type to various silvicultural treatments. The primary object of any silvicultural system is the regeneration of the stand with the species desired by the owner. Before the owner can decide upon the system best suited to his forest he must have some knowledge as to the silvical characteristics of the species he wishes to maintain in his stand. Such knowledge must be secured for many types before definite predictions of future stands over wide areas can be made.

This paper will present figures as to the seedling reproduction in a single type operated under one silvicultural system. It will be only a step toward securing of definite knowledge concerning reproduction under the particular conditions. No such study has been made before at Eber White Woods. Consequently, many blunders will probably be made in interpreting the data, and mistakes were undoubtedly made in collecting the data. However, it is hoped that such results as were obtained will be of assistance to others in later investigations.

The objects of this study are as follows: (1) To collect and present data concerning seedling reproduction in Eber White Woods; (2) To account for the occurrence of such reproduction or

for its absence by taking into consideration the silvical characteristics of the various species in connection with the environmental conditions at Eber White. This will be done in a more or less general way. It is believed that the field work was not intensive enough to justify an exhaustive discussion along ecological lines.

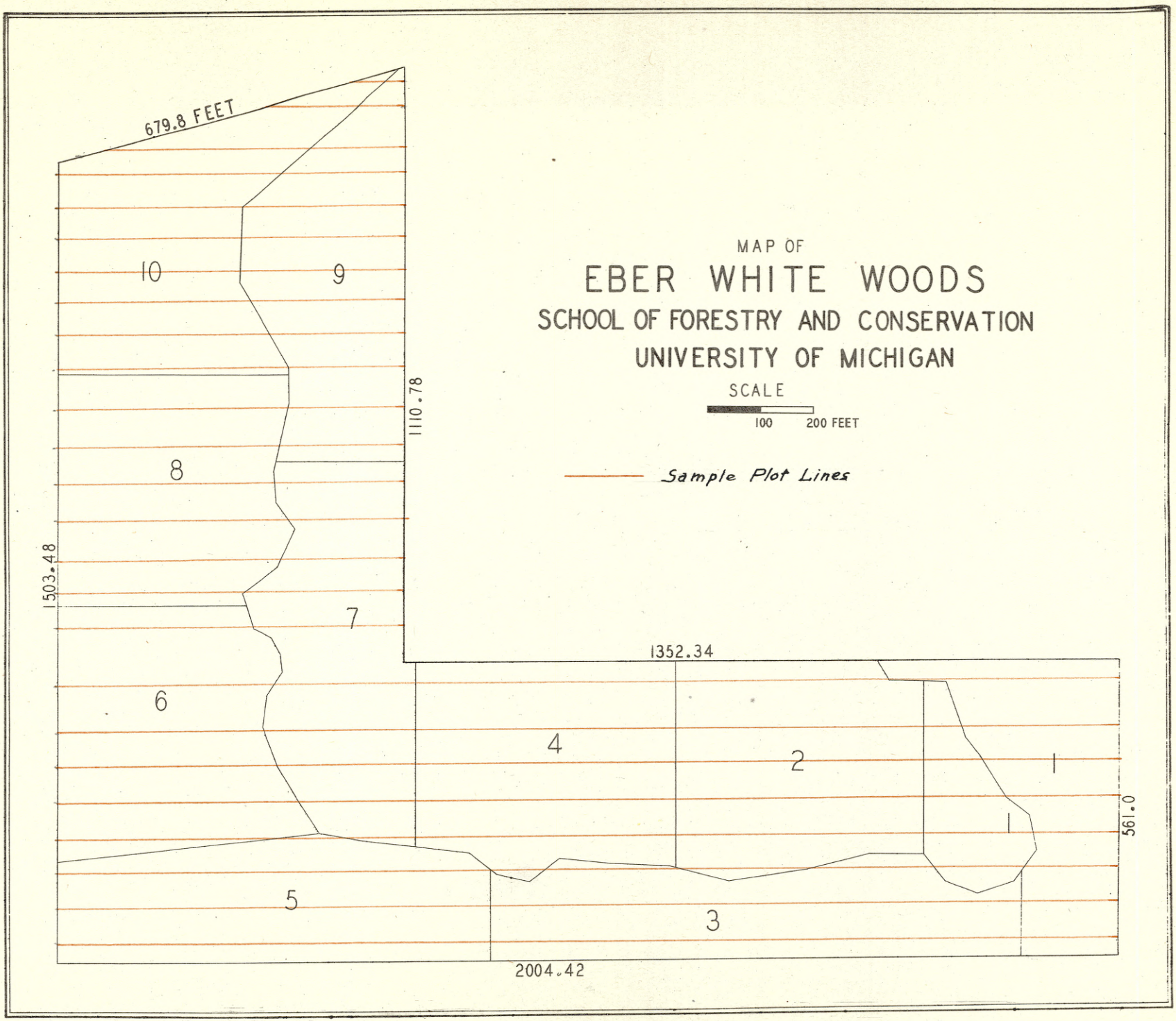
Consideration was given to the formulating of a system for measuring reproduction stocking in mixed hardwood forests, such a system to be applicable over a wide area and suggestive of a definite degree of density and distribution. In the past forest inventories noted reproduction in general terms such as "good", "fair", or "poor", if at all. These terms are usually not defined and the collector of the data is the only one to whom they suggest the actual picture of the conditions on the forest. The need for some system for measuring and expressing degree of reproduction stocking has been recognized by foresters and one such system developed will be given later in this paper. However, since reproduction of larger size than seedlings is of more importance in drawing up plans for the immediate management of forests, it was thought best not to discuss this phase of the subject here.

Description of Eber White Woods

Location: The data for this study was taken on the tract of land belonging to the University of Michigan and known as Eber White Woods. This tract has an area of 41.18 acres and is located in the S.E.$\frac{1}{4}$ of section 30, T.2S., R.6 E., M.P.M., just west of the city limits of Ann Arbor, Michigan. Using the classification given in the U.S. Dept. of Agri. miscellaneous publication number 217, Eber White lies in the northern portion of the central hardwood forest region.

Topography and Soil: The topography of the Woods is fairly regular, being slightly rolling in the southern part, and sloping off rather steeply to the northwest in the northern portion (see map, page 5). The general aspect of the southern part is to the east and northeast. There is a small wet weather stream passing through the northwestern corner of the tract. In the central part of lot 8 there are two small swampy areas which have no tree growth on them. The elevation ranges from about 880 feet to 940 feet. The Woods is surrounded on all sides by open fields.

The entire region around Ann Arbor is a glacial terminal moraine underlain by Coldwater shale and Berea sandstone. Wells in the immediate vicinity show this base rock to be about 250 feet below the surface (11). The soil is Miami silt loam with a little Washtenaw loam found in the swales and creek bottom. The Miami silt loam is described by Veatch, Wheeting, and Bauer (14) as follows: "The cultivated soil consists of the following layers: (1) a gray-brown silt loam to plow depth; (2) a layer of 2 to 6 inches of light gray or grayish-yellow silt loam which is floury or pul-


679.8 FEET
1110.78
1503.48
1352.34
561.0
2004.42
10
9
8
7
6
5
4
3
2
1
1
MAP OF
EBER WHITE WOODS
SCHOOL OF FORESTRY AND CONSERVATION
UNIVERSITY OF MICHIGAN
SCALE
100
200 FEET
Sample Plot Lines

verulent when dry; (3) a layer of 18 to 24 inches of yellowish-brown, firm, more clayey material which is plastic and impervious when moist and jointed and coarsely granular when dry; (4) parent material of massive compact, moderately gritty and stony, but comparatively impervious bluish-gray clay which continues to a depth of several feet. The content of organic matter is not high, but the supply is fairly durable. The average content of moisture is comparatively high as both the subsurface layer and substratum are rather impervious and highly retentive of moisture. In general, the suraface soil of the virgin soil is slightly acid or neutral, the second layer is medium or strongly acid, and acidity decreases with depth, until an alkaline reaction is obtained at a depth ranging from 24 to 36 inches. The organic layers of the virgin soil are very thin, containing undecomposed woody matter". Table I gives the chemical analysis of the Miami silt loam.

TABLE I

Chemical analysis of Miami silt loam, Washtenaw County. #

Horizon	Depth	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	P_2O_5
$A_0 + A_1$	0"-3"	71.4%	10.6%	2.55%	1.54%	0.90%	0.17%
A_2	3"-8"	79.2	10.6	2.80	1.22	0.84	0.07
B	8"-32"	66.8	11.2	3.75	1.00	1.68	0.08
C	48" -	50.5	8.88	2.97	10.9	2,82	0.13

According to the same source (14) the Washtenaw loam "---- occurs in depressions where the soil has been washed in from the slopes. For the most part it represents the finer materials —— clay, silt, and very fine sand —— and contains a high per cent of organic matter. The thickness of the accumulated soil ranges from

Taken from reference (14)

one to ten feet, beneath which are old or fossil soils".

Weather conditions in the region: The climate of the region is characterized by fairly cool winters and mild summers. The mean annual temperature is 47.4 degrees Fahrenheit (see Table II) with an average frost free season from May 2nd to October 13th. The mean annual precipitation is 31.31 inches, including melted snow, and the annual snowfall is about 37 inches. The prevailing winds are westerly (14). Table III shows the yearly and seasonal precipitation for the seven year period 1930-1936.

TABLE II

Normal seasonal and annual temperature and precipitation at Ann Arbor, Michigan. 18? -1930 inclusive. #

Season	Mean Temp.	Mean Ppt.	Mean 1930 Dry year	Mean 1880 Wet year
Winter	24.3	5.77"	5.02"	4.99"
Spring	45.4	8.36"	6.39"	13.89"
Summer	69.3	9.10"	4.62"	17.42"
Fall	50.4	8.08"	5.95"	7.95"
Year	47.4	31.31"	22.01"	44.25"

TABLE III

Yearly and seasonal (April, May, June, July, August) precipitation from 1930 to 1936, Ann Arbor, Michigan. ##

	Year						
Period	1930	1931	1932	1933	1934	1935	1936
Seasonal	9.91"	11.65"	17.73"	14.98"	6.30"	14.47"	8.74"
Yearly	22.01	25.04	37.23	26.50	18.95	26.60	25.04

Particular attention is called to the facts that the seasonal precipitations for 1934 and 1936 are the lowest and that the annual precipitations for every year following 1930, with the exception of 1932, are lower than the mean annual precipitations

Taken from reference (14)
Ann Arbor weather station records.

for all the previous years for which records have been kept.

Composition of the stand: The stand in Eber White Woods belongs to the oak-hickory type of the central hardwood region. Table IV gives the composition of the stand by species. These figures were obtained by averaging the stands on some of the 10 lots in the Woods.

TABLE IV

Composition of the stand in Eber White Woods by species.

Species	% of total B.A. #	% of total stems over 1" D.B.H ##
Oaks (white, red, black)	53.5	10.1
Hickory	17.9	7.0
Basswood	5.6	16.2
Elm	5.5	7.9
Maple (hard)	4.7	8.5
Ash (white)	4.4	14.8
Ironwood	4.0	27.9
Black cherry	0.9	1.4
Others	3.5	6.2
Totals	100.0	100.0

By inspection of the values of this table an idea of the average size, comparatively speaking, of the various species can be obtained. For example, the oaks make up 53.5% of the total basal area but only 10.1% of the total number of trees one inch and over in diameter, while ironwood makes up only 4% of the total basal area but 27.9% of the total number of trees are of this species. This indicates that the average size of the ironwoods is much smaller than that of the oaks.

Since the University obtained the land some conifers have been planted along the southern and western boundaries. A

Based on lots 2,3,5,7,8,9.
Based on lots 2,3,7,8.

heavy border of planted conifers is also found along the road which borders the north side of the Woods.

The tract is comparatively free from underbrush. Some graybark dogwood is found in clumps and is usually scattered along the boundaries of the Woods, although a few isolated clumps are found in the interior. The only ground cover of any significance occurs along the western edge of the Woods and consists of grass. This grass has been here since the acquisition of the property by the University. The grass, together with the prevailing winds, has restricted reproduction except ironwood from coming in. Slash is almost totally absent and the small amount that is present is neither a fire hazard nor an obstacle to reproduction.

History: Eber White Woods was acquired by the University of Michigan in 1915. Previous to that time the area had been culled several times for firewood and sawlogs, but to what extent is unknown. For some time prior to 1915 there had been neither fires nor grazing on the land.

Cutting under the supervision of the Forestry School began in 1917-18. For the purpose of management it was divided into ten lots of approximately equal size, each lot being cut over every five years. The cutting has been on an improvement basis with the object of building up the growing stock. Each cut takes about 10% or less of the basal area of the particular lot. The largest trees, especially oaks, are cut only when they begin to show signs of extreme overmaturity. Due to the proximity of the Woods to the city of Ann Arbor, the esthetic value of the larger trees is considered much higher than their value as wood. With the exception of lot 1 ironwood has been cut heavily. Dead, dying, and diseased trees, regardless of age, are usually removed.

Review of Literature

No literature was found which applied directly to a study of this same general nature. There were numerous articles on various specialized factors of reproduction.

The earliest reference found to the sampling of reproduction stands was that by Haig (8). Speaking of the Northern Rocky Mountain Region, he says that the stocked quadrat method of judging degree of stocking was first used by Lowdermilk in 1921. The stocked quadrat method as here used was based on the assumption that if a given area is divided into squares of such size that one seedling per square will be sufficient to fully stock the area at maturity, then the percentage of squares containing one or more established seedlings, regardless of the number of seedlings per acre, will give the proportion of the area being utilized for tree growth. Due to the patchy character of the western white pine reproduction in which he was working, Lowdermilk decided that the extent of reproduction was influenced more by distribution than by number of seedlings. He used mil-acre plots (6.6 feet by 6.6 feet) in his count.

This same system was used in 1926 in Idaho and Montana on cut over lands. Strips were run at definite intervals, each strip consisting of contiguous mil-acre squares which were recorded as either stocked or non-stocked (8).

In discussing the size of sample square used Haig (8) says that the mil-acre size was first used because of its convenience in computations. This was believed by many foresters to be too small. To determine the proper size of square to use Haig gives

the following procedure: From a yield table for the area under consideration compute the size of square necessary for each tree in a fully stocked mature stand. This size may vary for different regions and species.

It should be noted that this method of judging stocking was used in either clear cut or haevily cut stands of western white pine. The methods used here would not necessarily be applicable to a selectively cut mixed hardwood stand.

Haig (7) gives the prosedure used in another study in the same region. Mil-acre plots were laid out at intervals of $\frac{1}{2}$ to 1 chain along parallel strips 2.5 to 10 chains apart. From data collected from these plots the percentage of area stocked and the average number of seedlings per acre was computed. This survey took a sample of from 0.8% to 1.0% of the total area.

Cowlin (4) describes the stocked quadrat method of sampling Douglas fir reproduction in Washington. A four mil-acre square (13.2 feet by 13.2 feet) was used here. At one chain intervals on the strips squares were taken with the chain mark locating the common corner of four squares. Squares were recorded as being stocked or non-stocked. At ten chain intervals the number of seedlings in each square was recorded. In finding the average number of seedlings per square no one square was allowed more than 11 seedlings regardless of how many more it might have.

In all of the above cases the figures were collected from the mensuration standpoint, with no attempt to give the reasons for the degree of stocking. The treatment of the figures presented in this study will be largely along lines suggested by the above cases.

Literature concerning the effects of environmental factors on reproduction was equally scanty. The most exhaustive study is that by Korstian (9) on oaks. Boerker(2) gives some general findings concerning the growth and earky development of forest trees when planted by man. His conclusions on the effect of habitat factors upon germination all are connected with the finding that soil moisture is the most important factor in germination and any other factors which tend to increase or decrease the moisture affect the germination favorably or unfavorably.

Craib (5) found that in the forest the available soil moisture was greatly increased by the elimination of root competition. In trenched quadrats he found, during dry periods, 2 to 9 times as much moisture available to plants in the first 6 inches of soil as in the untrenched quadrats. Several experiments of this type have been made to show the effect of trenching on the growth of plants. In all instances the trenched plots showed a heavier herbaceous growth as well as more tree seedlings than the untrenched control plots.

References will frequently be made to the above mantioned studies and also to other literature on the silvical characteristics of the various species found in Eber White Woods in the section on the interpretation of the data collected.

Method Used to Collect the Data

Under the circumstances existing at the beginning of this study it was necessary to draw up rather hastily the plan to be followed in the field for collecting the data. The nearness of the snow season allowed no time for a review of the literature on the subject before the field work was started. The size of the sample plots and the per cent of area to be covered were suggested by Professor Young. Otherwise, the plan as used was formulated from knowledge of cruising prosedures obtained in previous courses in Forest Mensuration. The field work was done during the later part of November 1936.

The entire tract of 41.18 acres was considered in deciding upon the distribution of the sample plots. As a mil-acre plot was used, a 1% sample of the area would require approximately 410 plots. With this in mind the distance between the plots necessary to get an even distribution over the entire area was computed. This was done by using the dimensions found on the map of Eber White Woods published by the School of Forestry and Conservation (page 5). It was found that the required number of plots could be secured if parallel east and west lines one chain apart were run, the plots being spaced at one chain intervals along these lines.

Only 406 plots were taken, this being due to several factors. The chief one probably being the fact that pacing instead of a tape was used to maesure the distances. As the field work had to be done alone it was obviously impractical to measure distances in any other way. Since the calculated locations of the lines and

plots were based on the horizontal distances given on the map, the actual locations did not agree exactly with the former, although allowances were made for slopes in pacing.

The direction of the lines was established by the use of a box compass and then tags were placed on trees falling on these lines. After the direction of the lines had been established, the plots were located. The end of each chain marked the center of a mil-acre plot. The first plot on each line was taken ½ a chain from the boundary of the Woods. The borders of the sample plots were determined when seedlings occurred near the borders by the use of a small pole 6.6 feet long.

All seedlings (trees originating from seed and not over 3 feet tall) and all small seedling saplings (trees 3 to 10 feet tall) were tallied by species for each sample plot. Seedling sprouts were usually counted as seedlings. The data concerning the small saplings will be found in condensed form in the Appendix. No discussion will be presented in connection with these tables. No differentiation was made between the various species of oaks or hickories. Dogwood (flowering and graybark) were tallied as present or absent from the plots, the tendency of the dogwood seedlings to occur in groups being the reason for this.

The possibility of treating each lot in the Woods as a unit in collecting the data was not considered until the field work was under way. At the time any change of procedure was thought to be unwise as it was then rather late in the fall. Establishment of some easily visible markings for the boundaries of each lot would have been required and would have further delayed

the work. As things finally turned out a very satisfactory distribution of sample plots in each lot was secured by the method used. The map on page 5 shows the approximate location of each line of plots.

A criticism that might be made of this method is that absolute accuracy was not possible using a box compass and pacing for location of the plots. In my opinion this criticism would be justified if the data had been collected on a much more extensive scale over a wide area. However, in this instance a small area was covered and the sample plots were evenly distributed and fairly close together. As to the per cent of the total area sampled more will be said after the presentation of the data.

Data in Tabular Form

By means of the tables of figures which follow an attempt will be made to show the present situation with regard to seedling reproduction in Eber White Woods. As far as is possible with the knowledge of the silvical characteristics of the various species and of the environmental conditions at Eber White at hand, the reasons for the density and distribution of the reproduction will be given. An effort has been made to reduce the number of tables to a minimum, as well as to make each table as simple as possible. A few tables which might be of interest, but which were not considered essential to the problem will be found in the Appendix along with all data concerning small sapling reproduction.

The 406 sample plots taken represent 0.98% of the total area in the Woods. Table V gives the number of seedlings of each species converted to a per acre basis. From this we see that the number per acre for all species is 2820. Using only the valuable species (all those shown in the table except ironwood) gives 2641 seedlings per acre. Table IX shows that the frequency of occurrence of plots having ten or more seedlings is insignificant. Following Cowlin's (4) suggestion on page 11 and allowing no plot more than ten seedlings gives a per acre stand of 2384 seedlings of valuable species. #

Using the theory of the stocked quadrat method of judging distribution as given on page 10, the percentage of sample plots stocked with the various species and the totals for the individual lots and for the entire tract were computed and the re-

1 Ky. coffeetree and 2 yellow poplar seedlings were not included in these calculations.

sults appear in Table VI. From this we see that 72.1% of all the plots had some seedling reproduction on them. Excluding ironwood

TABLE V

Number of seedlings per acre by species on the various lots in Eber White Woods. November 1936.

Lot	Species								Total	Size of sample
	Ash	Bassw.	Maple	Oak	Hick.	Cherry	Elm	Ironw.		
	Number of seedlings per acre									acres
1	756	244	244	73	24	73	24	73	1510	.041
2	1052	710	1261	53	79	105	0	236	3500	.038
3	1895	500	1578	158	105	316	473	421	5450	.038
4	925	300	1025	75	25	300	0	150	2800	.040
5	775	350	325	0	75	224	0	325	2075	.040
6	2610	395	920	131	79	263	26	394	4820	.038
7	1085	715	972	57	114	342	29	86	3400	.035
8	250	575	625	125	75	200	0	125	1975	.040
9	50	800	0	100	224	275	0	0	1448	.040
10	482	768	178	125	18	125	143	54	1892	.056
Totals	953	541	680	91	89	216	71	179	2820	.406

TABLE VI

Percentage of the sample plots stocked with seedlings of the various species. Eber White Woods, November 1936.

Lot	Species								Total
	Ash	Bassw.	Maple	Oak	Hick.	Cherry	Elm	Ironw.	
	% of sample plots stocked								
1	34.0	19.5	14.6	4.9	2.5	7.3	2.4	7.3	51.2
2	47.3	36.9	36.9	5.3	7.9	7.9	-	18.4	84.2
3	63.1	34.3	31.6	15.7	10.5	15.8	2.6	29.0	89.5
4	40.0	22.4	47.5	7.5	2.5	20.0	-	10.0	77.5
5	32.5	22.4	17.5	-	7.5	15.0	-	17.5	67.5
6	36.9	18.4	44.7	10.5	7.9	21.0	2.6	18.4	81.6
7	40.0	40.0	40.1	5.7	8.6	34.3	2.9	8.6	85.7
8	17.5	45.0	27.6	10.0	5.0	15.0	-	12.5	65.1
9	5.0	35.0	-	10.0	17.5	15.0	-	-	65.1
10	23.2	37.5	5.4	8.9	1.8	12.5	5.4	5.4	64.3
Totals	33.9	31.1	26.6	7.8	7.2	16.4	1.6	12.7	72.1

from the calculations gives 69.7% of the plots stocked. Cowlin (4) states that 70-100% of the plots stocked is considered "good stocking" in the Douglas fir region (speaking of reproduction areas).

Since, in this case, the area has a mature stand on it that is fairly evenly distributed over the entire tract, the reproduction due to shading and root competition might well be expected to be rather patchy. This figure, therefore, represents a very good degree of stocking as far as distribution is concerned. This method of judging reproduction stocking seems to be a very good one for clear cut areas and also for very tolerant species. In the latter instance a slight modification in the per cents might be necessary to allow for root competition. In forests of intolerant species, such as oak, some radical changes should be made to show actual conditions. As oak does not reproduce well under heavy shade the degree of stocking of the older trees would have to be considered and some method for giving this fact recognition in the expression of the distribution devised. For example, where an effort was being made to perpetuate an oak stand by natural seeding through the use of some form of selection cut, it would be inaccurate to express the degree of stocking as an absolute per cent from the results of a cruise of the whole area. Some differentiation would have to be made between heavily cut areas, lightly cut areas, and uncut areas.

As stated before no tally was made of the number of dogwood seedlings. From the original tally sheets it was found that 24.9% of the sample plots had seedling reproduction of this species on them.

Table VII gives the per cent of the total number of seedlings on the various lots by species. This table together with the two preceding it will be referred to frequently in the section of the report which follows.

TABLE VII

Percentage of the total number of seedlings of the different species in Eber White Woods. November 1936.

Lot	Species								Total
	Ash	Bassw.	Maple	Oak	Hick.	Cherry	Elm	Ironw.	
	% of total seedlings								
1	50.0	16.2	16.2	4.8	1.6	4.8	1.6	4.8	100.0
2	30.0	20.3	36.0	1.5	2.3	3.1	-	6.8	100.0
3	34.8	9.2	29.0	2.9	1.9	5.8	8.7	7.7	100.0
4	33.0	10.7	36.6	2.7	0.9	10.7	-	5.4	100.0
5	37.4	16.9	15.7	-	3.6	10.8	-	15.6	100.0
6	54.1	8.2	19.1	2.7	1.6	5.5	0.6	8.2	100.0
7	31.9	21.0	28.6	1.7	3.4	10.0	0.8	2.6	100.0
8	12.6	29.1	31.6	6.4	3.8	10.1	-	6.4	100.0
9	3.4	55.2	-	6.9	15.5	19.0	-	-	100.0
10	25.4	40.5	9.5	6.6	1.0	6.6	7.5	2.9	100.0
Total	33.8	19.2	24.1	3.2	2.8	7.7	2.5	6.4	99.7 #

Discussion

The discussions on the different species will be brief and very general in nature. No definite statements as to reasons for the presence or absence of reproduction can be given, since the study was mainly along quantitative lines with no intensive work done on the ecological aspects of the subject. Suggestions, and the known facts accounting for them, as to the reasons for the situation in regard to each species will be given. An attempt was made to correlate the present stand of seedlings with the stocking on each lot, or with the length of time since the lot was cut over, but in neither instance did such a correlation seem to exist. There does seem to be slight correlation in some cases between the stand of mature trees of a particular species and the number of seedlings of that species on the individual lots. These will be mentioned later.

This discrepancy is due to the omission of 3 seedlings of Ky. coffeetree and yellow poplar from the calculations.

Ash: From the above tables it can be seen that over the entire tract ash is reproducing from seed better than any other species, both as to total number of seedlings and as to distribution (i.e. percentage of sample plots stocked). Before taking up the conditions on the various lots, a general discussion of the reproducing characteristics of ash will be given. Sterrett (12) gives the most complete information along this line. Ash usually seeds freely about every other year, and bears some seed almost every year. Exceptionally heavy crops occur at intervals of from three to five years. The dominant trees produce large quantities of seed. The seed is very light, Sterrett giving 10,000 seeds per pound and Toumey 6,200 per pound, and this, together with its structure, enables it to be carried long distances by the wind. Ash seed is especially exacting in its moisture and seed bed requirements for germination and seedling establishment. Sterrett cites an experiment in which good, sound, untreated seed was planted under favorable conditions . White ash germinated feebly in five months, while blue ash failed to germinate in the first year. A seed bed with a layer of undecomposed leaf litter less than two inches thick, with the humus underneath fairly well decomposed, is sufficient. Reproduction is most common where the soil is protected from the drying influences of sun and wind and where at the same time there is some light which need not be direct. After the first year the seedlings require direct light for best development. However, they are persistent, and will maintain themselves under cover, but in a stunted condition, for five to twenty years.

Ash is the leading seedling reproducer at Eber White

Woods probably because it is one of the heaviest seed producers of the species present. This, taken in connection with the characteristic of the soil in maintaining a fairly high moisture content and the degree of stocking, which is not heavy, thus admitting sufficient light, makes for favorable conditions for seedling reproduction. While it is true that the cutting done so far has not been heavy, the present stocking of the area is not full, the basal area averaging about 80 square feet per acre. The accumulated litter on the forest floor does not exceed two inches in thickness and in many places is thinner than this.

It will be noted that the number of seedlings per acre on the lots is fairly constant with the exception of lots 3, 6, 8, and 9. In the case of lot 3 the larger number is accounted for by the fact that 30 seedlings occurred on two sample squares, and in that of lot 6 by the occurrence of 69 seedlings on two sample squares. This is a good example of the value of the per cent of sample plots stocked in describing the degree of stocking on an area. On lot 6 the ash seedlings may be said to occur on 36.9% of the entire lot (see Table VI), while on lot 2, with only about 40% as many seedlings as lot 6 (see Table V), they are spread over 47.3% of the lot. It may be concluded from this that the 1052 seedlings per acre om lot 2 will be just as effective, if not more so, in restocking this lot with ash as will be the 2610 seedlings per acre on lot 6. In the case of lot 8 the topography and the wind are probably the chief factors in causing the smaller number of seedlings. Here the slopes are steeper than in any lot except 9 and the moisture content of the soil is , therefore, probably lower. The winds being westerly, for the most part, carry a large

proportion of the seeds to the east. To check this assumption a careful analysis was made of the distribution of ash seedlings on lot 7. It was found that 92% of the seedlings here occurred on that portion of the lot lying to the south of a westward extension of the northern boundary of lot 4 (see map, page 5). This indicates that the L-shape of the Woods may be an important factor in the determination of the future stand. The wind goes through the narrower part of the Woods lying to the north of the above mentioned extended line with greater velocity than it does through the much wider part to the south of the line. The almost total absence of ash seedlings from lot 9 is probably due to a combination of the steepness of the topography, the wind, and a lack of seed trees.

The greater part of lot 10 lies in the low ground along the stream bed. 74% of the ash seedlings here were blue ash and the remaining ones white.

Basswood: Basswood next to ash has the widest distribution of any of the species. As regards total number of seedlings, however, it is behind both ash and maple. According to Cheyney (3) basswood seeds prolifically almost every year. The seed is of about the same weight as that of ash. The seeds are attached to a leafy bract, and are scattered by the wind, but not to the extent of ash or maple, as several seeds are on each bract. (See Table VIII). Basswood will grow on white pine soil but does better on richer hardwood soil. The seed can germinate and establish themselves either on bare ground or in deep duff, provided they are given a little protection from the sun. Basswood is very tolerant, being exceeded among hardwoods only by beech, and is of about the same degree of tolerance as maple. Apparently there are some factors

in the environment which favor ash over basswood, since there is about the same number of seed trees of each species. The tolerance of basswood may be the chief of these factors, the open nature of the stand giving ash an advantage.

Sugar maple: Maple is second in total number of seedlings and third in spread of distribution. According to Cheyney (3) maple seeds every two to five years but produces large crops. The seed is light (7,000 seeds per pound) and is widely scattered by the wind. Germination seldom takes place on bare ground but is best on moist leaf litter where there is not too much underbrush. Next to beech, maple is the most tolerant of hardwoods, and the seedlings can endure heavy shade and establish themselves almost anywhere. However, maple does best on deep, rich ground. In speaking of the central hardwood region Westveld (15) says that the white oak-red oak- black oak type of the region is succeeded by types in which sugar maple is more prominent, and that where sugar maple occurs it tends to become more abundant under conservative management, especially in the northern part of the region. From Table IV it can be seen that at present maple makes up about 8.5% of the stand of trees one inch and more in diameter, while Table VII shows 24.1% of the seedlings to be of that species. This indicates that maple is definitely on the increase in this type also. The total absence of maple seedlings, as indicated by the sampling done, from lot 9 is probably due to the lack of seed trees and to the steepness of the slopes which means drier soil. On lot 9 there is only 0.94 square feet of basal area in maple trees over one inch in diameter. Cheyney gives moisture and frost as the controlling factors of maple distribution.

Ash, maple, and basswood make up 77.1% of the total number of seedlings found on the entire tract. To further check the assumption made in the discussion on ash as to the effect of wind in relation to the shape of the Woods on the distribution of a light seeded species lot 7 was analyzed again, using these species. It will be noted from Table VII that compared to ash and maple, basswood is more abundant on the lots of the northern part of the Woods (lots X, 8, 9, and 10) than elsewhere, while this species is less abundant on the southern part of the Woods. The same relation was found to exist between these species on the northern and southern parts of lot 7 (see Table VIII). This would seem to indicate that either basswood seed is not distributed as widely by the wind as is that of the other two species or there are some other factors exerting a strong influence here. It may be that the soil fertility and moisture conditions due to the steeper slopes are such that basswood is better able to reproduce here.

TABLE VIII

Distribution of ash, maple, and basswood seedlings on lot 7.

Species	Total no. seedlings on lot 7	% on northern ½ of lot	% on southern ½ of lot	% of sample plots southern ½
Ash	1085	8	92	48.5
Basswood	715	80	20	48.5
Maple	972	38	62	48.5
Totals	2772	37	63	48.5

Oak: Oak seedling reproduction is not plentiful when compared with ash, maple, and basswood, but the distribution is fairly uniform over the Woods. The average stand per acre for the whole area is 91. This number would insure a good stocking of oak

in the future stand if all survived, but due to slow growth and intolerance many of thses will be crowded out. Oak is not a climax type and, as stated before, will eventually give way to a type dominated by maple and other tolerant species. Intensive management of the proper kind must be practised in order to perpetuate this species by natural methods. Precisely what form this management should take can not be stated here. There are many adverse factors affecting the reproduction of this species and all of them must be considered. Cheyney (3) states that white oak's heavy acorn and comparative intolerance prevent it from being aggressive despite the fact that a good seed crop is produced almost every year. Red oak is also a good seeder and as a seedling can grow in dense shade, but becomes intolerant later. Rodents destroy the greater part of the oak seed. Korstian (9) states that in many cases, particularly when the supply is limited, 90% to 100% of the acorns are destroyed in this way. Insect injury was found by the same writer in 10% of white oak acorns, in 28% of black oak acorns, and in 24% of red oak acorns in the southern Appalachains. He also found that in normally moist white oak acorns moisture comprises 60% to 70% of the dry weight and when the moisture content fell below 25% to 30% there was a marked decrease in viability. Drought is, therefore, likely to seriously damage the germinating ability of the seed. White oak acorns germinate promptly in the fall and, as a result, the seedlings are subject to unfavorable weather. According to Westveld (15) favorable moisture conditions in the seed bed is the most potent factor in the successful germination and survival of oak seedlings. The seeds

should be covered for best results, and the covering of leaf litter which usually falls after the acorns have been shed affords ample protection, according to Korstian.

As to management both Westveld and Korstian state that for successful regeneration from the seed a form of partial cutting is best, as a fairly open site is desirable. In order that enough seed be available with the heavy destruction by rodents and insects, large crops are almost a necessity.

At Eber White Woods the cutting practise together with a small production of acorns probably accounts, to a large extent, for the comparatively small number of oak seedlings. The cutting done so far has not opened the stand up enough to bring about heavy seedling reproduction. The fact that 53% of all sample plots having oak seedlings on them were located within 100 feet of the edge of the Woods implies that the absence of light from the interior of the area may be a hindrance to oak reproduction. Many of the oak trees are beyond the best seed bearing age. During the past few years the dry weather may also have lowered the supply as well as being a detrimental factor in the germination of the seed. A study of the effect of drought on oak forests in Pennsylvania (10) does not, however, indicate that drought has such an effect on reproduction. In four types —— chestnut oak, hemlock, scarlet-black oak, and white pine-chestnut oak-chestnut —— studied, all showed a percentage loss in reproduction after the drought of 1930. The loss, however, was not in white, red, or black oak in any case. Many mature and overmature trees were killed or badly injured and the consequent opening of the stands may have offset

any disadvantage caused by the drought.

Hickory: Hickory reproduction shows about the same density and distribution as does that of oak. As in the case of oak, a heavy seed which is eaten by rodents, and man also, limits regeneration of hickory by natural seeding. Hickory produces a seed crop every two or three years. The seed will germinate and become established even on deep duff, and the young seedlings are very tolerant, being exceeded in this respect only by beech, maple, and basswood (3). A long tap root is developed during early life and at the end of five years the seedlings are usually not more than 15 to 20 inches tall. They will stand suppression for a number of years, recovering if released. On lot 9, where the cutting policy is obviously favoring hickory, it is reproducing itself best. On this lot 36.9% of the total basal area is of hickory.

Black cherry: Cherry seedlings are more abundant than are those of any species except ash, maple, and basswood. While it makes up a very small portion of the mature stand (see Table IV), its fairly large crop of seed produced annually, and the occurrence of enough light in the Woods may account for its relatively high reproducing capacity. Cherry is intolerant and is more likely to occur in breaks in the crown canopy than elsewhere. About half of the seedlings found were on sample plots within two chains of the borders of the Woods. The seed is largely distributed by birds.

Elm: The relatively small amount of elm reproduction may be accounted for by the intolerance of this species (3). The

large number of seedlings per acre on lot 3 is due to the occurremce of 18 seedlings on ome sample plot, which was in a rather large opening in the forest canopy.

Ironwood: As mentioned before an effort is being made to reduce the stand of ironwood in the Woods. Table IV shows that this species makes up a larger per cent of the total stand one inch and above in diameter than any other species. From Table V it can be seen that in the seedling stand it ranks behind ash, maple, basswood, and cherry in number of seedlings. This would seem to indicate that the future stand of this weed tree will be much smaller than the present one. This statement, however, is not necessarily true as sprout reproduction is the chief source of trouble in reducing the stand of ironwood.

General Discussion: Lots 2, 4, 5, and 7 have approximately the same average number of seedlings per acre as the average for the entire area and will not be discussed here. An attempt will be made to account for the divergence from the average of the stands on the other lots. (See Table V).

In the case of lot 1 the lower number of seedlings results from a stand of each species that is lower than the average for the Woods for that species. This latter condition may be due to the location of the lot and to the cutting policy in regard to ironwood. The map on page 5 shows that three sides of lot 1 lie on outside boundaries of the Woods, thus giving a large part of this lot no protection from an adjacent stand. No other lot in the Woods has more than two sides lying on the exterior boundaries and many of them have only one side so located. A heavy stand of

ironwood saplings in this lot also probably discourages reproduction of all species.

Lot 3 has the largest average stand because maple, oak, elm, and ironwood are reproducing here more plentifully than on any other lot. Ash, hickory, and cherry are also reproducing above their average for the whole area. Allowing no one sample plot more than 10 seedlings of all species will reduce the number per acre from 5450 to 4450, which still gives it the largest number when the stands on the other lots are treated in the same way. One possible explanation for so much reproduction here is the fact that the only exterior boundary of this lot faces to the south, the northern and western boundaries being protected by other lots.

Lot 6 has a large stand per acre primarily because of the large number of ash seedlings. Reducing the number per acre as was done in the case of lot 3 gives a stand per acre of 3450 instead of 4820. This brings the lot to near the average in number per acre.

Lots 8, 9, and 10 are all well below the average in number of seedlings per acre. The small number of ash and maple seedlings on these lots is largely responsible for this situation. Possible reasons for fewer seedlings of these species on these lots have been given previously.

The fact that in some instances species are shown by Table V to be absent from different lots does not mean that there are absolutely no seedlings of the particular species present. It does, however, indicate that the probable number occurring is comparatively small.

There seems to be a relation between the total number of seedlings on each lot and the percentage of the sample plots stocked on the corresponding lots. From Table V and Table VI we see that lots 1, 5, 8, 9, and 10 have below the average number of seedlings per acre and also have a percentage of sample plots stocked that is lower than the average percent for the Woods. However, there is not a fixed relation which can be assigned a definite value.

Statistical Discussion

A short discussion along statistical lines will be presented here, the objects of which will be to form a basis for comparison of results with a later study of the same sort, should one be made, and to indicate what degree of accuracy was possible with the size of sample used.

The tabulation of the data as it appears in Table IX was used in computing the results given below. The average number of seedlings per plot is 2.64. The plots with more than 10 seedlings are of such limited occurrence that it was thought best to find an average on the same basis as was used in computing the average number of seedlings per acre on page 29——namely, to count all plots having over 10 seedlings as having not the actual number, but 10. On such a basis the average number per plot is 2.38.

TABLE IX

Frequency distribution of number of seedlings per sample plot, Eber White Woods. November 1936.

No. of seedlings per plot	No. of plots	No. of seedlings total	No. of seedlings per plot	No. of plots	No. of seedlings total
0	123	0	11	1	11
1	78	78	12	3	36
2	44	88	13	1	13
3	54	162	14	1	14
4	37	148	15	1	15
5	23	115	16	1	16
6	9	54	20	1	20
7	11	77	26	1	26
8	10	80	31	1	31
9	4	36	42	1	42
10	1	10	Totals	406	1072 ##

Based on material taken from Belyea (1) and Gavett (6).
Ironwood not included.

As a measure of the dispersion of the number of seedlings occurring on the individual plots about these means the standard deviations were computed. In the first case it was found to be 3.908 and in the second 2.59.

Statistical methods can be used to find the number of plots necessary to obtain, within certain limits, a predetermined degree of accuracy. A degree of accuracy of 10% with chances of its occurrence being 21 to 1 will be used. This means that the chances will be 21 to 1 that any other sample of same size, and of the same degree of distribution (i.e. standard deviation), taken from the same area will have an average number of seedlings per plot within 10% of the average of the first sample. The calculation of the required number of plots is as follows:

Maximum allowable error: $2.38 \times 10\% = .238$

Standard error (21 to 1): $\frac{.238}{2} = .119$

Let X - number of plots required.

$$X = \left(\frac{\text{standard deviation}}{\text{standard error}}\right)^2 = \left(\frac{2.59}{.119}\right)^2 = (21.76)^2$$

$= 473.5$ or 474 plots.

An index of the precision of the work done can be calculated as follows:

$$\text{Computed standard error} = \frac{\text{standard deviation}}{\sqrt{\text{no. of plots taken}}}$$

$$= \frac{2.59}{\sqrt{406}} = \frac{2.59}{20.146} = .1285$$

Maximum error here: $.1285 \times 2 = .257$

$$\% \text{ of accuracy} = \frac{.257 \times 100}{2.38} = 10.8\%$$

This per cent of accuracy indicates that the average number of seedlings per plot of any other sample of the same size should,21 out of 22 times, fall somewhere between 2.142 and 2.618.

Summary

1. In both total number of seedlings and distribution white ash leads all other species at Eber White Woods. Sugar maple and basswood rank next.

2. Ash, maple, and basswood make up 77.1% of all seedlings in the Woods.

3. The fact that the mature stand is not fully stocked (80 sq. ft. of basal area per acre) probably accounts for ash reproduction being more plentiful than that of the more tolerant maple and basswood.

4. The percentage of sample plots stocked with one or more seedlings is 72.1%. Omitting ironwood from this calculation gives 69.7%. (See Table VI)

5. The average stand per acre of all seedlings based on a sample of 0.98% of the total area is 2820. (See Table V)

6. Other species than ash, maple, and basswood represented in the reproduction are black cherry, ironwood, oak, hickory, elm, yellow poplar, and Kentucky coffeetree in that order.

7. The present stand in terms of basal area is predominantly oak with hickory as the chief associate. The present stand in number of stems one inch and over in diameter is predominantly ironwood with basswood, ash, and oak as the chief associates. These facts, together with the findings of the seedling study, indicate that the oaks and hickories are being succeeded by the more tolerant species.

8. The distribution of the seedlings in the various lots indicates that the shape of the Woods (see map, page 5) in rela-

tion to the prevailing westerly winds may have some effect on the scattering of seeds. The noticeably smaller number of ash and maple seedlings in the northern part of the Woods which has its long dimension at a right angle to the direction of the wind in contrast to the number in the southern part which has its long dimension parallel to the direction of the wind is the underlying reson for this assumption. (See page 24). It is probable that much of the seed of these species is blown out of the northern portion of the Woods.

9. The sampling upon which the above data is based was done by taking mil-acre plots spaced at intervals of one chain on parallel east and west lines one chain apart. Using statistical calculations it may be said that the average number of seedlings per plot obtained from this sampling is within 10.8% of the true mean for the area with a probability of 21 to 1.

Scientific Names of Trees Discussed

Ash, white	*Fraxinus americana*
Ash, blue	*Fraxinus quadrangulata*
Basswood	*Tilia americana*
Cherry, black	*Prunus serotina*
Dogwood, flowering	*Cornus florida*
Elm	*Ulmus americana*
Hickory	*Carya* sp.
Ironwood	*Ostrya virginiana*
Kentucky coffeetree	*Gymnocladus dioicus*
Maple, sugar	*Acer saccharum*
Oak, white	*Quercus alba*
Oak, red	*Quercus borealis maxima*
Oak, black	*Quercus velutina*
Poplar, yellow	*Liriodendron tulipifera*

Taken from Sargent's "Manual of the Trees of North America".

APPENDIX

TABLE I

Actual number of seedlings counted on the sample plots. Eber White Woods. November 1936.

Lot Number	Species								
	Ash	Bassw.	Maple	Oak	Hick.	Cherry	Elm	Ironw.	Total
	Number of seedlings								
1	31	10	10	3	1	3	1	3	62
2	40	27	48	2	3	4	0	9	133
3	72	19	60	6	4	12	18	16	207
4	37	12	41	3	1	12	0	6	112
5	31	14	13	0	3	9	0	13	83
6	99	15	35	5	3	10	1	15	183
7	38	25	34	2	4	12	1	3	119
8	10	23	25	5	3	8	0	5	79
9	2	32	0	4	9	11	0	0	58
10	27	43	10	7	1	7	8	3	106
Totals	387	220	276	37	32	88	29	73	1142 #

TABLE II

Number of small saplings per acre by species on the various lots in Eber White Woods. November 1936.

Lot	Species								Total	Size of sample AC acres
	Ash	Bassw.	Maple	Oak	Hick.	Cherry	Elm	Ironw.		
	Number of saplings per acre									
1	146	73	219	49	24	49	0	122	683	.041
2	158	263	316	26	26	26	0	105	920	.038
3	605	79	105	52	52	52	210	421	1578	.038
4	550	75	150	0	50	25	0	75	925	.040
5	300	100	75	25	25	25	25	300	875	.040
6	210	105	184	26	52	79	0	1290	1945	.038
7	400	200	171	28	28	171	57	372	1428	.035
8	250	150	150	0	25	100	0	900	1575	.040
9	150	550	0	100	125	75	25	25	1050	.040
10	304	465	0	89	178	107	0	160	1300	.056
Totals	305	216	130	42	64	71	29	364	1220	.406

1 Ky. coffeetree and 2 yellow poplars not included.

TABLE III

Percentage of the total number of saplings of the different species in Eber White Woods. November 1936.

Lot	Species								Total
	Ash	Bassw.	Maple	Oak	Hick.	Cherry	Elm	Ironw.	
	% of total saplings								
1	21.4	10.7	32.1	7.2	3.6	7.2	0	17.8	100.0
2	17.1	28.6	34.2	2.9	2.9	2.9	0	11.4	100.0
3	38.4	5.0	6.7	3.3	3.3	3.3	13.3	26.7	100.0
4	59.5	8.1	16.2	0	5.4	2.7	0	8.1	100.0
5	34.2	11.4	8.6	2.9	2.9	2.9	2.9	34.2	100.0
6	10.8	5.4	9.5	1.3	2.7	4.1	0	66.2	100.0
7	28.0	14.0	12.0	2.0	2.0	12.0	4.0	26.0	100.0
8	15.9	9.5	9.5	0	1.6	6.3	0	57.2	100.0
9	14.3	52.5	0	9.4	11.9	7.1	2.4	2.4	100.0
10	23.3	35.6	0	6.9	13.7	8.2	0	12.3	100.0
Totals	25.0	17.7	10.7	3.4	5.2	5.8	2.4	29.8	100.0

TABLE IV

Percentage of the sample plots stocked with saplings of the various species. Eber White Woods. November 1936.

Lot	Species								Total
	Ash	Bassw.	Maple	Oak	Hick.	Cherry	Elm	Ironw.	
	% of sample plots stocked								
1.	12.2	4.9	12.2	2.4	2.4	4.9	0	9.8	39.0
2	15.8	13.1	18.4	2.6	2.6	2.6	0	10.5	47.4
3	34.2	7.9	7.9	5.3	5.3	5.3	2.6	15.8	57.8
4	35.0	5.0	15.0	0	5.0	2.5	0	7.5	52.5
5	22.5	10.0	5.0	2.5	2.5	2.5	2.5	17.5	47.5
6	10.5	7.9	15.8	2.6	2.6	5.3	0	55.2	68.5
7	22.8	17.1	14.3	2.9	2.9	14.3	5.7	37.2	80.0
8	17.5	12.5	12.5	0	2.5	7.5	0	32.3	55.0
9	12.5	42.5	0	7.5	10.0	7.5	2.5	2.5	57.5
10	16.0	32.2	0	7.1	16.0	10.7	0	14.3	66.1
Totals	19.7	16.0	9.6	3.4	5.7	6.2	1.2	18.9	57.1

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