Notes Upon the Rate of Tree Growth in Glacial Soils in Northern Indiana.

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The clearing of certain small timber areas near Lafayette in January and February, 1906, gave an exceptional opportunity for studying the rate of growth of certain native species of trees. The species occurring in sufficient number to warrant deductions were the white oak, red oak and black walnut. Of the red oak forty-nine trees were examined; of the white oak, sixty, and of the black walnut, thirty-two. It was assumed that the annual rings gave a fair indication of the age, despite the occasional formation of two rings in a single year, or the apparent suppression of an annual ring because of exceptionally unfavorable conditions, which were recognized as possible contingencies. In the forms examined neither of these conditions were indicated, the growth in each case having apparently proceeded in an orderly and orthodox fashion.

The measurements are the averages of the longest and shortest diameters and were taken inside of the bark. Both the measurements and the counting of the rings were made by four groups of students, insistence being placed upon accuracy. In cases of discrepancy a recount or remeasurement, or in some cases both, was directed. The tables, therefore, may be considered as exceptionally accurate, each specimen having been independently studied by four groups working on different days.

The oaks, with but few exceptions, occurred on the highest levels, just northwest of Purdue University. The general surface is rolling, with a southeastern exposure, more or less interrupted by ravines formed by small streams. Approximately the topographical conditions were the same.

The soil in the area under consideration is relatively thin. It consists of a few inches of humus made up of the usual forest material; a few inches (8-12) of a loam soil more or less alluvial in character, followed by perhaps a foot of fairly heavy clay. Underlying this is the glacial drift, extending downward from one hundred and ten to one hundred and twenty feet to the bed of the river. The drift in this region is mainly sand and

gravel, with a few thin seams of light clay at various levels. Throughout the area from which the oaks were cut, the soil overlying the drift material ranges from eight to twenty-three inches in thickness. So far as the physical and chemical composition of the soil is concerned we have practically identical conditions over the entire area.

The black walnut was cut for the most part in an area lying in the second river terrace, where, in addition to the forest humus, there occurs from three to five feet of alluvial soil before the clay is struck. The clay also in this area is perhaps twice as thick as in the former case. The terrace has an eastern exposure, while the curves of the river protect the particular tract in question from the north winds, but leave it open to winds from the south. Upon the west it is protected by the escarpment of the upper terrace. The area covers but a few acres and evidently furnishes as uniform conditions as can be found in nature. The two tracts present, however, fairly distinct conditions, a fact which should be borne in mind in any comparison of the rate of growth.

The measurements of the different species are given in tabular form as furnishing in the main the data for the deductions drawn later in this paper. Possible occasional errors may occur in the computation of percentages in spite of the fact that the figures have been reviewed three times.

From the tables it is shown that in the area indicated and under the conditions outlined the average yearly increase in white oak, based upon sixty specimens, was .1995 of an inch; of red oak, based upon forty-nine specimens, was .22674 of an inch; of black walnut, based upon thirty-two specimens, was .27712 of an inch.

A number of interesting inferences seem plain.

1. There is a wide range in the growth rate in trees of the same species, even when growing under the same conditions. Thus the range in white oak is from .095 to .328 of an inch; in red oak, from .134 to .515 of an inch; in black walnut, from .195 to .358 of an inch. Such wide range under conditions so nearly identical must be referred to individual idiosyncracies, probably referable in most cases to the vigor of the acorn, to the character of the tree from which the acorn was derived, to inherited growth tendencies or similar causes. An examination of the table of trees of similar age in respect to their diameters will show clearly this "personal equation" of the tree. For example, in Table II, numbers 38 to 45, inclusive.

TABLE I. QUERCUS ALBA.

Serial Number.	Inches Diameter.	No. of An. Rings.	Average Yearly Increase.
1	32	200	.160
2	11	68	.162
3	11	74	.149
4	16	76	.210
5	22	78	.282
6	13	66	.196
7	19	60	.317
8	17	74	.230
9	15.5	74	.209
10	17	76	.223
11	17	79	.215
12	17	77	.220
13	16.5	74	.223
14	15	75	.200
15	13	77	.170
16	12.5	75	.166
17	15	77	.195
18	15.5	77	.201
19	13.5	78	.173
20	21.5	80	.269
21	16	79	.202
22	20	77	.260
23	13	77	.169
24	19	77	.247
25	19	75	.253
26	47	303	.155
27	9	63	.143
28	12	73	.164
29	16	78	.205
30	17	89	.191
31	15	78	.192
32	24	252	.095
33	12	75	.160
34	12	75	.160
35	50	243	.206
36	28	185	.151
37	28	180	.155
38	31	222	.140
39	26	232	.112
40	30	230	.130
41	18.5	72	.257
42	18.5	77	.240
43	25	76	.328
44	14	73	.191
45	13.5	77	.175
46	20	77	.261
47	16	79	.202
48	20.5	81	.253
49	13.5	76	.177
50	15.5	78	.200
51	14.5	73	.200
52	13	76	.171
53	13	76	.171
54	17	75	.226
55	41	208	.197
56	15.5	80	.194
57	17	76	.223
58	17	79	.215
59	17.5	78	.223
60	16.5	78	.211

TABLE II. QUERCUS RUBRA.

Serial Number.	Inches Diameter.	No. of An. Rings.	Average Yearly Increase.
1	20	76	.263
2	15	78	.192
3	14	77	.182
4	15	77	.193
5	14.5	75	.193
6	24	77	.311
7	22	78	.282
8	22	83	.265
9	20	82	.244
10	19	82	.231
11	16.5	82	.201
12	15	82	.183
13	17	82	.207
14	15	82	.183
15	9.5	76	.125
16	15	80	.187
17	23	73	.315
18	14.5	77	.188
19	12	87	.138
20	15.5	115	.134
21	14.5	76	.190
22	15.5	90	.172
23	13.5	78	.173
24	13	71	.183
25	11.5	74	.155
26	15	63	.238
27	14.5	76	.190
28	16	73	.219
29	22.5	81	.277
30	16	70	.228
31	14.5	72	.201
32	24	88	.272
33	20	64	.312
34	22	79	.278
35	20	71	.281
36	22	71	.310
37	33	64	.515
38	22	82	.268
39	18.5	82	.225
40	20	82	.243
41	19	82	.231
42	15	82	.182
43	17	82	.207
44	15	82	.182
45	16.5	82	.201
46	13.5	61	.221
47	11	60	.183
48	23	73	.315
49	18.5	82	.225

TABLE III. JUGLANS NIGRA.

Serial Number.	Inches Diameter.	No. of An. Rings.	Average Yearly Increase.
1	25	82	.305
2	14	64	.219
3	15	77	.195
4	19	73	.260
5	18	67	.270
6	21	81	.260
7	19	58	.327
8	20	64	.312
9	18	76	.237
10	20	74	.270
11	14	52	.270
12	15.5	68	.228
13	21.5	64	.336
14	21	72	.291
15	22.5	71	.317
16	20	66	.303
17	24	67	.358
18	15	45	.333
19	22.5	88	.255
20	18	74	.243
21	19	76	.250
22	20	70	.285
23	20	78	.256
24	24	80	.300
25	17	63	.270
26	16	60	.266
27	23	74	.311
28	23	80	.287
29	22	77	.285
30	22	83	.265
31	19	79	.240
32	20	75	.266

are of the same age and grew on a gentle northward-facing slope in an area of less than an acre, yet the diameters range from 15 to 22 inches.

2. Conclusions as to the rate of growth of various species, which fail to take into account individual variations are manifestly misleading. This variation may reach as much as 25 to 30 per cent. above or below the average growth rate. Incidentally it gives strong emphasis to the necessity of great care in the selection of seeds for cultural work—since a careful selection may increase the wood crop to the extent of 25 per cent. beyond the average.

3. The growth rate in the area examined was exceedingly slow, especially in the case of the oaks. In a report of W. F. Fox, Superintendent of State Forests, New York, it is stated that a vigorous three-inch white oak sapling would, under favorable conditions, at the end of twenty years at-

tain a diameter of eleven inches, or make a net gain of eight inches. This would give an average yearly increase of .4 of an inch, which is considerably greater than the highest yearly increase in any of the sixty specimens examined, or .328 of an inch. Mr. Fox also states that a three-inch red oak sapling would, in twenty years, attain a diameter of thirteen inches, thus making a net gain of ten inches. This gives a yearly rate of .5 of an inch, or more than double the average yearly rate (.22674 of an inch) of the forty-nine specimens examined. It is true that specimen 37 shows an average yearly growth of .515 of an inch, but the next is .336 of an inch and only six out of the forty-nine show an average yearly growth in excess of .3 of an inch. An examination of a number of white and red oak logs at local mills confirms the conclusion that the growth rate in the area studied is exceedingly slow.

It is probable that the cause of this slow growth is to be found in relatively thin soil underlaid by the hundred or more feet of drift. The sand and gravel of the drift constitute a natural filter which rapidly carries the soil water to lower levels. The thin soil and the stratum of clay can not hold sufficient water to carry the trees through our long summer drought and at the same time furnish a large amount of material for growth. Observation of the trees of the Purdue campus furnishes confirmation of this view. The soil conditions of the campus are practically the same as in the area studied. The older trees of the campus were set out between 1875 and 1880, and were largely maples and elms along the driveways, other forms being scattered through the grounds. The maples and elms are in sufficient numbers to justify a few generalizations. The trees show an early period of rapid growth, a period of slow growth and finally a practical cessation of growth. During this latter period the trees begin to show all the signs of what might be called senility. In the early years, the roots not having penetrated deeply, find sufficient available moisture in the thin soil to provide for the maintenance of the tree and its normal growth. A little later, the deeper penetrating roots reaching the drift find but little water, so little, indeed, that under the most favorable conditions provision can be made for only a slight growth. Still later the increasing demands of the tree can not be satisfied and it begins to age, and we have the case of elms and maples completing their life cycle in twenty-five or thirty years, attaining in the meantime a diameter of from ten to fifteen inches. The duration of life upon the campus is much less that in forest conditions, be-

cause of the absence of the forest floor and of its work in the conservation of moisture and the enrichment of the soil.

4. It may be concluded that the most important factor in the growth of trees is *soil moisture*. A confirmation of this may be found in the conditions existing in areas of maximum development in number and size. According to Sargent, the hardwoods of the United States find their maximum development in numbers and size in the lower stretches of the Wabash Valley. In other words, in a region in which the soil possesses a rich water content.

In any forecasts as to the results of reforestation, or as to the rate of tree growth in any given locality the supreme factor to be considered is the constancy of the water content of the soil.

5. In the case of the oaks an examination of the table will show a period of rapid growth, a period of slower growth and finally a period of scarcely appreciable increase. In the case of the walnut the growth is much more uniform throughout the life of the tree. These are conditions that would be expected if conclusion three is at all correct.

6. It is probable that red and white oak in regions such as the one studied have reached their full size at from eighty to a hundred years, after which they begin to deteriorate. The few large forms introduced in the table are from the lowest river terrace and were introduced for purposes of comparison.

7. The growth habit of the tree seems to control more largely than external factors of growth. In a group of trees closely grouped the majority may show an exceptionally rapid growth in a given year, while one or two show but a small increase. That this might be due to insect defoliation or other causes is of course possible, but an examination of the growth through a series of years show a habit of slow growth as compared with other individuals, whatever may be the external conditions. On the other hand, individuals showing a habit of rapid growth are easily recognized. No observable differences in the proportion of spring and summer wood, in texture, in color or in any gross characters are to be observed in these differing forms. Some individuals of each species are rapid growers and some are slow growers, whatever may be the origin of the habit. It was impossible to determine whether or not this habit could be determined by external features, as the trunks had been sent to the saw mill before the area was found.

8. The conditions of the area described are fairly typical and apply

to a large part of the glaciated region of northern and northwestern Indiana. Of course the immediate valleys and terraces of rivers and streams furnish special conditions which must be considered as exceptional. It is probable that any extended study of the rate of growth of the species discussed in the region indicated will show results but slightly varying from those given above.

9. It is probable that under soil conditions such as those described, larger forms than those found today but rarely occurred. A careful examination over wide areas for old stumps of the virgin forest, showed that all of the large forms were found in alluvial soils and never by any chance in the thin-soiled uplands.

These studies are being extended to include many of our native species and arrangements have been made to increase the number of forms studied of the species discussed in this paper.

The exact knowledge of the rate of growth of various species under differing conditions is a matter of vital importance from the viewpoint of wood-lot forestry. It is scarcely less far reaching in its application and of scarcely less economic significance than a knowledge of forest utilization. If the conclusions here presented are warranted by the date very self-evident practical application necessarily follow. These, however, are not included in the scope of this paper, but will be presented later.