Observations on the Girth-increase of Trees in the Royal Botanic Garden, Edinburgh, for Twenty Years, 1878-1897.

BY

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PART I.—DECIDUOUS TREES.

THE late Sir Robert Christison, when nearly four score years of age, began in 1875 a series of girth-measurements of trees on scientific principles in order to ascertain their annual girth-increase, and was, I believe, the first to do so. The observations for the first three years were initiatory upon a few trees only, but in 1878 systematic observations were begun on a much larger number. In a series of papers read to the Botanical Society of Edinburgh in 1878, 1879, 1880, and 1881, he explained his methods, gave the results of his observations, and showed the practical uses to which such observations could be put. One of these,—the rather elaborate computation of the age of trees from a series of girth-measurements in a particular tree and in others of the same species at different sizes,—has been superseded by the process of extracting borings on which the annual rings can be counted, and for practical purposes the same ready method is applicable in determining the present rate of growth of a stem; but for this purpose it is necessary to take the average of several borings in the circumference of the tree, and girth-measurements probably yield more precise results in determining, not only annual increments, but more particularly the finer rates for months or even shorter periods. It must always be remembered, however, that such measurements show

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simply the increase in girth, and cannot discriminate between the amount due to deposit of wood on the one hand, or to changes in the bark or cambium on the other. In this respect borings have the advantage, but as to the bark I may state generally that except in very old trees there seems to be little loss in mass, or even by gradual attrition—so little as to be inappreciable in a single year. Thus, even in old rough-barked trees, my painted distinguishing numbers often show little trace of wearing in ten or twelve years, although distorted and rendered illegible from the gradual widening and splitting of the bark. Notable exceptions among the species are the true Plane tree and the Yew, whose tendency to shed their bark is so manifest.

Sir Robert Christison at first aimed at no finer division of his tape than tenths of an inch, and confined himself to annual observations, but very soon, with practice and improved tapes, he measured to the twentieth of an inch and took monthly observations. Since his death in 1882, I have continued to measure his original trees, but as many of them, even from the first, were old or prematurely old, it was evidently desirable to experiment on younger specimens, not only because the results would be probably more reliable, but in order to ascertain the increments of the species over a greater range of age. Accordingly, in 1887, I selected some thirty-five young deciduous trees, from six to twenty inches in girth, chiefly situated in the South and East shelter belts of the Arboretum, and a similar number of young Pinaceæ in the Botanic Garden, taking two of each species when possible, so that in case of one failing the other might preserve the continuity of observations in the species. With the exception of a few that were cut down from death or degeneracy, all of this second set were observed annually till the end of the period, and monthly from 1887 to 1891. The deciduous specimens generally throve well, considering that they had been put in without preparation of the naturally poor sandy soil, before the Arboretum was handed over to the authorities of the Garden, but they were almost all transplanted after 1891, and thus the continuity of observations was interrupted. The Pinaceæ, again, throve so badly as greatly to mar the value of the results in them.

To compensate for this interruption in the deciduous group, I selected in 1892 a fresh set of twenty young trees, each of a different species, almost all growing in the North and West borders of the Arboretum, subject to the same objection of want of preparation of the ground before planting as the former set, but favoured by a rather better soil. Once more, however, the continuity of observation was interrupted, in 1896, by a close pruning of branches and roots, in preparation for transplantation, which at once reduced the aggregate girth-increase by nearly one-half. As to the Evergreens, discouraged as I was by the comparative failure of the first set, I made no effort to increase their number, although the observations on the original set were continued.

The introduction of Chesterman's steel tapes insured an accuracy of measurement unattainable in the original experiments, and enabled me to initiate new inquiries, such as the determination, within narrow limits, of the seasonal beginning of girth-increase in the different species, the weekly rate of growth, the relation of girth-increase to the development of the leaves and twigs, &c.; and the various results were communicated to the Royal Society of Edinburgh in 1883, and to the Botanical Society in 1887, '88, '89, and '92. In the present Report I shall confine myself to the annual and monthly results,—and in the deciduous trees only,—bringing them down to 1897, which completes a period of twenty years. The observations for 1892–97, both annually and monthly, and the annual observations of the original set for the second decade, which have not yet been published, will be given in detail, but only the general results for the first decade are reproduced from my former papers. In these papers were incorporated observations made on trees at Craigiehall, near Cramond, but these have long been discontinued, and the results will only be incidentally used here. Thus, the present Paper becomes peculiarly a record of the life-history, as indicated by girth-increase, of a considerable number of deciduous trees in the Botanic Garden and Arboretum, over periods of from six to twenty years.

Doubts have been expressed as to the possibility of measuring the girth of trees to the twentieth of an inch with accuracy, and unquestionably in stems of great size, and in all stems of irregular

form or with very rough bark, an error of the twentieth or even the tenth of an inch may be caused by the slightest shifting of the tape. But such trees should be rejected, at least for fine or frequent observation, and if we select young cylindrical stems with smooth bark, or even when it is rough, provided the roughness be regular and free from excrescences, it is possible, by adopting careful methods, and with practice, to attain a wonderful degree of accuracy. I have frequently checked an observation on such trees by repeating it three times, using a fine millimetre tape, and found a variation of not so much as half a millimetre. The method adopted by me is fully explained under the next head.

GENERAL EXPLANATIONS.

1. METHOD OF TAKING OBSERVATIONS.—The measured point, generally five feet above ground, is marked in white paint by several short horizontal lines round the stem. A short perpendicular line at one of them that occupies the most prominent position marks the spot where the measurement begins.

Chesterman's steel tapes are used, one, graduated to twentieths of an inch, for ordinary observations, and another, of more slender make, graduated to millimetres, for finer work. In both, the ordinary ring is replaced by a square, slightly wider than the tape, and included in the graduation.

In small stems the tape is held in position at the fixed starting point with the nail of the forefinger of the left hand, and the tape is passed round the stem with the right hand, and brought fairly over the square, which can be accurately done, as the square is wider than the tape. The amount is then read off at the outer edge of the square. For larger stems the process is the same, except that, to allow the observer to go round the tree, the square is kept in place by a "brog," which must be removed, the square being kept in position with the nail of the forefinger, in order that the measurement may be read off accurately.

2. THE GIRTH OF A TREE usually signifies its circumference at five feet from the ground, or, in a short stem, at its narrowest point. But five feet was the height aimed at for observation whenever it was practicable.

3. HEIGHT OF MEASUREMENTS.—When trees were too young to be measured at five feet, a convenient point was chosen two or three feet from the ground, and as the trees grew and became fit, the point was raised to the five-feet level. I do not think the results were in any way invalidated by this necessary compromise.

4. SUMMING-UP OF TABLES.—The entries in the Tables of increments due to years in which trees were temporarily ineligible, from the effects of transplantation or pruning, are printed in *italics*, and such entries are not included in the summing of the lines and columns.

5. SCALE USED FOR MEASUREMENTS.—All measurements are in inches and decimal parts of an inch unless otherwise stated.

I. ANNUAL RESULTS.

Following the plan formerly adopted, I take first the results for the species separately, and then the collective results. To preserve the convenience of division into decennial and quinquennial periods, I have omitted from the Tables the first year's observations on the second set of trees, but they will be available in the text, and will be fully given in the monthly division of the subject.

The chief results derived from the annual observations are—

1. The annual rate of girth-increase in the species at different ages ;

2. The seasonal range in the species separately ; and

3. The same in the aggregate.

The seasonal variations ought to be considered in connection with meteorology, but an inquiry of this kind is complicated by the variety of influences that come into play, such as the ripening of the wood, the formation of the buds, low temperatures of the air or earth, the protective or destructive effects of snow, sudden thawing, excessively low temperature, excess or defect of rain or humidity, &c., besides the effects of position in sheltering or exposing different trees to these weather influences. To have done justice to all these points would have taken far more time than I had at my command. I have been content therefore to

deal only with instances in which the cause of a marked depression was not far to seek. None such occurred in the second decade, but the first was signalised at the outset by an unprecedented series of three most unfavourable seasons, chiefly owing to exceedingly low winter temperatures, which reduced the aggregate increment by nearly one-half, and affected some trees for years afterwards, if not permanently. The disastrous effects on girth-increase of these seasons have been described in former papers by my father* and myself,† and will be only incidentally mentioned now.

A. General History of the Species Separately.

In place of taking the species in scientific sequence, it was deemed preferable to deal with them in the order of the reliability of the observations, whether depending on the larger number of observations, or on the better thriving of the species in the soil of the Garden. A certain preference has also been given to the importance of the species as forest trees.

Each Table is drawn up so as to show—

(1) The following results in the original adult or old trees of 1878:—*a.* The average increase in girth for the first decade for each tree under observation. *b.* The annual increase in detail for the second decade. *c.* Its total amounts and its average annual rate. *d.* The girth of each tree at the end of the decade in 1897.

(2) The same details, as far as they go, in the second decade for the younger trees selected in 1887 and 1892, given at the foot of the Tables.

* *On the Exact Measurement of Trees*, Part 4. Trans. Bot. Soc. Ed., 1880.

† *Op. cit.*, 1880-89, p. 397. The Depression in Girth-Increase of 1879, 1880, and 1881; *et passim.*

FAGUS SYLVATICA.

No. in List.	Av. Annual Rate, 1st Decade.	Annual Increments.										Total.	Ann. Rate.	Girth, Oct. 1897.
		1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
7	1·03	·75	·80	·95	·90	1·20	1·10	·85	·60	·90	·80	8·85	·88	89·60
8	0·99	·80	·95	·95	·90	·90	·90	·90	·90	1.10	·90	9·20	·92	79·50
14	0·48	·40	·35	·20	·25	·30	·25	·45	·30	·25	·30	3·05	·30	83·70
38	0·43	·30	·25	·25	·25	·40	·25	·45	·25	·40	·25	3·05	·30	67·75
		2·25	2·35	2·35	2·30	2·80	2·50	2·75	2·05	2·65	2·25			
97	..	1·15	1·30	1·50	1·30	Died after Transplantation.						5·25	1·31	15·55
98	..	1·00	1·10	1·45	1·35	1·55	Do.					6·45	1·29	14·55
20	..	..	..	..	..	..	1·70	1·45	·20	*·60**	*·55*	4·35	1·45	20·95

* See Explanation of Figures, page 44.

I have placed this species first, because the Beech here, as in Scotland at large, thrives better perhaps than any other of our forest trees.

The two first in the Table, handsome and healthy looking trees, stand free in the low ground where the original Botanic Garden bordered the former Horticultural Garden. Reckoning in round numbers, they have increased in girth, No. 7 from six feet to seven and a half feet, No. 8 from five feet to six and a half feet, in twenty years, and the annual rate in each has been ·95. But the rates in the first decade were 1·03 and ·99, and in the second ·88 and ·92 respectively, showing an appreciable decline, which, however, was not steady, for if we take the total increments for the two trees in quinquennial periods they come out—9·70, 10·35, 8·95, 8·95. The inferiority of the first to the second quinquennial period is explicable by the depressing effect of the low temperatures in 1879, 1880, and 1881, which, although they affected this species less than any other, still left their mark upon it for three years. Thus, the united increase of Nos. 7, 8 was 2·40 in 1878 and only 1·75, 1·55, and 1·75 in the three following years. The marked decline in the third quinquennium from 10·35 to 8·95 cannot be explained unless on the theory that the trees had passed the maximum of their growing power, but the rate underwent no further fall in the fourth quinquennium.

The *annual range* in these two trees differed remarkably. In No. 7 it was ·60 to 1·20, in No. 8 ·80 to 1·20. But the extremes do not show the difference sufficiently. If we take, for example, the seven years 1889-95, the range in No. 7 was ·60 to 1·20, and in No. 8 only ·90 to ·95. It is difficult to understand this difference in two trees of much the same size, growing at the same rate, and within fifteen yards of each other, unless it may be due to No. 7 standing quite free, whereas No. 8, although not pressed upon, has trees and shrubs near it, and is more closely sheltered.

Nos. 14, 38 were much the same size respectively as Nos. 7 and 8 when they were all first measured in 1878, but have fallen behind in the race, their rates in the first decade having been only ·48 and ·36, and in the second being reduced in both to 0·30, the average for the twenty years being 0·39 and 0·36, or considerably less than half that of Nos. 7 and 8. This may be accounted for by their position, on the South of Inverleith House, on a high site and probably in inferior soil. They are tall and handsome enough, but have not the fine heads of the other two. The variations in their history have been much the same as in Nos. 7 and 8, the results for their quinquennial periods being 4·80, 4·55, 3·10, 3·25, showing the same fall as in the other two in the third period, not progressing in the fourth.

The *annual range* in No. 14 was ·25 to ·65, and in No. 38 ·15 to ·60.

Taking the four trees together, the range in the first decade was considerably greater than in the second, owing to the disturbing influence of the low temperatures in 1879, 1880, and 1881. In the first decade it was 1·95 to 3·60 and in the second it was only 2·05 to 2·80.

The career of the young beeches, Nos. 97 and 98, was unfortunately soon cut short by death after transplantation, and that of No. 20 temporarily interfered with by pruning, but the *average annual rate* of the three, 1·34, was considerably above that of the best of the older trees. Their *range* in the twelve available records was 1·00 to 1·70.

[TABLE.

QUERCUS ROBUR.

No. in List.	Girth at first.	Annual Increments.										Total Incr.	Ann. Av.	Girth at last.
		1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
1	5·50	·40	·40	·65	·75	·70	·45	·50	*·10*	*·15*	·60	4·45	·56	10·15
2	8·00	·20	·30	·65	·80	·90	·90	·50	·45	*·5*	*·10*	4·70	·59	11·70
70	7·95	·50	·75	·95	1·05	1·20	1·00	·75	1·05	·80	dead.	8·05	·89	13·90
72	6·40	·20	·40	·80	·55	1·15	1·05	1·00	·40	·60	do.	6·15	·68	11·55
10	11·60	..	..	..	..	..	·75	·65	·35	*·20*	*·25*	1·75	·58	13·85

The native Oak does not show to much advantage in the Edinburgh district, and the specimen put under observation in the Garden in the first decade, and that only from 1880 (not in the Table), was a short-stemmed spreading tree, on the west slope from Inverleith House, that had lost many branches and become misshapen. It was by a long way the patriarch of the oaks in the Garden, having attained the respectable girth of eight feet. It increased in nineteen years from 95 to 99 inches in girth, or at the annual rate of ·22, more than, from its appearance, I should have expected, but it is not desirable to give the details, as from the small increments and the rough bark they are not reliable.

The four young trees Nos. 1, 2, 70, and 72, placed under observation in 1888, and No. 10, begun in 1893, yielded annual rates varying from ·56 to ·89, the average of the whole being ·66; but if we leave out the three first years when they were very young, and the last three, when those that were still eligible had, for some unknown reason, begun to fail, the average rises to ·84, and the annual rate of No. 70, the quickest grower, in its six best years, 1890–95, was exactly one inch.

The best of those is probably a poor rate compared with what might be expected in young oaks under more favourable circumstances, for even near Edinburgh, at Craigiehall, a tree, ten feet in girth at the beginning of the first decade, yielded a rate of 0·69 for ten years.

The aggregate increases of the four first on the list for the seven available years 1888–94 were 1·30, 1·85, 3·05, 3·15, 3·95,

3·40, 2·75. These figures probably represent a natural rise from extreme youth in the first two years to an equilibrium for the next four years, but there seems to have been a depression in the seventh year, followed by the death of two of the trees.

The *range* is very high, as might be expected from the erratic history, and cannot be regarded as normal. Even in No. 70 it was ·50 to 1·20, or taking the six steadiest years ·75 to 1·20.

OTHER SPECIES OF QUERCUS.

QUERCUS CONFERTA.

No. in List.	Annual Av., 1st Decade.	Annual Increments.										Total.	Ann. Av.	Girth at last.
		1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
40	1·65	1·05	1·20	1·35	1·25	1·70	1·80	*·90*	*1·30*	*·50*	*·60*	8·35	1·39	51·80
54	1·70	1·30	1·75	2·05	1·50	1·75	2·30	*1·05*	*1·25*	*·65*	*·0*	10·65	1·77	43·35
55	1·57	1·30	1·55	1·65	1·30	1·70	2·10	*·75*	*1·25*	*·65*	*·5*	9·60	1·60	39·05
		3·65	4·50	5·05	4·05	5·15	6·20	*2·70*	*3·80*	*1·80*	*·65*			

The Hungary Oak is much more at home in the Botanic Garden than its native cousin, at least in early youth; indeed, with the exception of the Willow, it has proved the quickest growing species of all that were under observation. Unfortunately for my purposes, owing to a liberal pruning to promote upward growth, the results became unavailable for the last four years of the second decade, but in the first decade the rates of the three trees were 1·65, 1·70, and 1·57, and in the third quinquennium with the one available year of the fourth they were 1·39, 1·77, and 1·60, the respective girths attained being four feet four inches, three feet seven inches, and three feet three inches. Of the 44 recorded measurements not one fell to an inch, the lowest being 1·05, while two inches and upwards was reached five times, the highest being 2·30. The great and progressive depression caused by pruning has been such that, while in 1893 the aggregate increase was 6·20, in 1897, four years afterwards, it was only ·65, yet the trees look healthy and well clothed, with the exception of No. 40, which for a year or two before the pruning had looked rather scraggy.

The aggregate annual increments for fourteen years were 3·60, 5·15, 5·25, 5·40, 5·05, 4·85, 4·65, 5·30, 3·65, 4·50, 5·05, 4·05, 5·15, 6·20. They were generally therefore pretty steady, but two marked depressions occurred. The first, in the year of the first record, 1880, when the fall, to 3·60, was probably due to the severe previous winter; the second, 3·65, was in 1888, from some unknown cause. The highest record, 6·20, was in 1893, the year before the changes produced by pruning.

The range in the trees individually was from 1·05 to 1·85 in No. 40, 1·10 to 2·30 in No. 54, and 1·10 to 2·10 in No. 55, but excluding the two years of marked depression the figures are 1·20 to 1·85, 1·60 to 2·30, and 1·20 to 2·10.

QUERCUS CERRIS.

No. in List.	Annual Av., 1st Decade.	Annual Increments.										Total.	Ann. Av.	Girth at last.
		1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
43	·57	·50	·30	·70	·60	·70	·65	·60	·50	·70	·55	5·80	·58	53·50
63	..	·70	·45	·65	·50	·70	·85	·70	·55	·80	·60	6·50	·65	67·15
15	..	..	..	..	..	..	·70	·65	·70	·65	·65	3·35	·67	10·00
		1·20	·75	1·35	1·10	1·40	2·20	1·95	1·75	2·15	1·80			

The Turkish Oak, although it grows at a much less rate than the last, is another species that thrives much better in the Garden than the native tree, and that to a considerable size; indeed, there are few handsomer trees than No. 63 growing free in the centre of the Garden, and now upwards of five feet and a half in girth. The other tree, No. 43, is also tall and handsome, but, although only four and a half feet in girth, is growing at a somewhat slower rate than No. 63, perhaps because it is in the East border and has not the freedom of its brother. The rate of No. 43 in the first decade was ·57, and in the second it was even a trifle higher. No. 63 in the first quinquennium of the second decade had a rate of 0·60, and in the second 0·70, so that it seems to be increasing rather than diminishing in vigour. The very young No. 15, in the North border of the Arboretum, measuring only six and a half inches in girth, when put under observation

in 1893, had much the same rate, ·67, in the second quinquennium of the second decade.

In the aggregate returns the only traceable depression was in 1889, when the two trees then available grew only ·75. Deducting this year, the growth was pretty steady, the extremes in the last five years, when all three were available, being 1·80 and 2·20.

The *range* of No. 43 for the two decades was ·30 to ·70, but removing two depressed years,—1881, when the tree suffered from the low temperatures of the winter, and 1889,—the range was only ·50 to ·70. With deduction of 1889, that of No. 63 in the second decade was also ·50 to ·70, and that of No. 15 in the fourth quinquennium was only ·65 to ·70.

The species appears to thrive even better in the vicinity of Edinburgh. Thus, a fine specimen at Craigiehall, when nearly seven feet in girth in 1890, had been growing at the rate of ·89 for eleven years; and a very fine healthy tree at Cramond House, measured by Sir Robert Christison in 1878, girthed no less than 12 feet 8 inches at the narrowest part of the stem, five feet above ground.

QUERCUS PALUSTRIS.*

* Erroneously called *Q. rubra* in former papers, from a mistake in the label on the tree.

No. in List.	Annual Av., 1st Decade.	Annual Increments.										Total.	Ann. Av.	Girth at last.
		1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
44	·45	·40	·30	·50	·35	·45	·40	·55	·40	·35	·25	3·95	·39	39·20

This species does not seem to do so well; at least the largest in the Garden, No. 44, now only three and a quarter feet in girth, grew at the low rates in the first decade of ·45 and in the second of ·39. It was noted since 1880 as having a shabby look, with many dead twigs.

QUERCUS RUBRA.

No. in List.	Annual Av., 1st Decade.	Annual Increments.										Total.	Ann. Av.	Girth at last.
		1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
61	..	..	..	·90	1·00	1·15	1·50	1·75	·55	·50	·35	5·90	1·18	12·35

This American Oak, on the other hand, seems to excel the native species in its rate. At least the young No. 61, after fully recovering from transplantation, averaged 1·18 for five years, when it became temporarily ineligible from re-transplantation.

QUERCUS ILEX.

No. in List.	Annual Av., 1st Decade.	Annual Increments.										Total.	Ann. Av.	Girth at last.
		1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
45	·28	·45	·40	·60	·55	·55	·70	·15	·20	·0	·	3·65	·36	47·55
46	·23	·40	·40	·45	·30	·25	·45	·15	·25	·25	·5	2·95	·29	34·05
16	..	·55	·80	·85	·50	·60	·65	·15	·25	·45	·35	5·15	·51	9·85

In my paper of 1888 it is remarked that no species suffered more from the three severeseasons than the Evergreen Oak. The largest in the Garden, upwards of six feet in girth, lost two years' growth of twigs, recovered its foliage slowly and imperfectly, some large limbs requiring to be cut off, and has quite lost its handsome, shapely form. Nos. 45, 46 did not suffer so badly, but their girth-increase was reduced to a mere nothing in 1880 and 1881. Afterwards they rallied somewhat till 1894, when they suddenly failed and almost ceased to grow. No. 45 seems now to be dying. It is remarkable that the infant specimen, No. 16, in the oak grove of the Arboretum, suffered a serious diminution in girth-increase in the same year, so that it would seem that all three had been then subjected to some common evil influence. The rate of No. 16 in the first quinquennium was no less than ·66, although it was a mere infant, girthing only 4·65 inches at fifteen inches above ground, when measured at the beginning of the period. In the first year of the second quinquennium it maintained this average, but in 1894 the rate fell to ·15, and there has been no full recovery since, so that the rate for the second quinquennium has been only ·37, or little more than half that of the first. At the same time, the tree has never looked ill, and it is now a remarkably thriving and vigorous looking specimen.

ACER PSEUDOPLATANUS.

No. in List.	Annual Rate, 1st Decade.	Annual Increments.										Total.	Ann. Av.	Girth at last.
		1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
13	0·26	·25	·20	·25	·30	·30	·25	·25	·30	·10	·25	2·45	·24	136·50
28	·35	·20	·20	·30	·10	· 5	·25	·15	·15	·35	·15	2·20	·22	64·25
71	..	·85	1·05	1·40	1·20	1·40	1·30	1·30	1·00	1·00	*·0*	10·50	1·17	19·90
74	..	·70	1·10	1·55	1·40	1·55	1·40	1·45	1·55	*·15*	*·30*	10·70	1·34	19·25
67	..	..	..	·50	·40	·65	·75	·95	·70	1·05	·85	5·85	·73	11·40
16	..	..	..	..	..	·20	1·40	1·20	..	*·15*	*·5*	3·80	1·27	16·10

The Sycamore grows fairly well near Edinburgh, although it is rarely seen in the city gardens, and the largest trees in the Arboretum are of this species. Trees at several ages were tested. No. 67, only about a foot in girth in 1897, had grown at the rate of ·73 for eight years; Nos. 16, 71, and 74, girthing one foot four to one foot eight inches in 1897, had grown, the first for three, the second for nine, and the third for eight years, at the rates of 1·26, 1·17, and 1·34, or on an average 1·26. These younger trees were only under observation in the second decade.

No. 28, now five feet four inches in girth, was chosen in 1878 as a handsome and thriving tree in a plantation belt opposite the Palm House, but, although it continued to look well, its rate all along has been surprisingly low, only ·35 in the first decade and ·22 in the second, or not much above a quarter of an inch annually for twenty years.

The veteran, No. 13, chosen by Sir Robert in 1878, perhaps because it was the largest tree of any kind in the Garden, although even then past its best, is still presentable, and girths nearly eleven and a half feet. Its rough and scaling bark renders it unreliable for single years, but the average rate for the first decade was ·26 and for the second ·24, showing no very perceptible decline, and scarcely less, on the whole, than that of No. 28, which has just half its girth.

The range of No. 67, the youngest specimen, was great, ·50 to 1·05, but that is, no doubt, because it was only growing out of

infancy. Deducting the year 1888, which appears to have been unusually unfavourable to Nos. 71 and 74, the range of these two and of No. 16 in eighteen records was moderate, 1·00 to 1·55.

ACER CAMPESTRIS.

This young Maple, No. 12, at the N.-W. corner of the Arboretum, has only been under observation since 1892, and its increments have been 1·60, 1·30, 0·85, 1·55, 1·00, and ·90, giving an average of 1·20, the girth being now twenty inches. Since 1896 the tree has not looked so healthy as at first, possibly the result of pruning, although it was not excessive. The increase has been very erratic, and the range, ·85 to 1·60, is high for so short a period.

ŒSCULUS HIPPOCASTANUM.

No. in List.	Annual Av. 1st Decade.	Annual Increments.										Total.	Ann. Av.	Girth at last.
		1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
9	·33	·35	·5	·10	00	·25	·10	·25	·25	·30	·00	1·65	·16	53·75
73	..	·70	1·10	·90	·80	·85	·90	·75	·60	*·25*	*·60*	6·60	·82	11·85
80	..	1·05	1·35	1·30	1·15	*·10*	*·40*	*·55*	1·25	1·25	·95	8·30	1·19	15·45
4	..	..	..	..	..	1·35	1·40	1·05	1·05	*·75*	*·60*	4·85	1·21	19·00

No. 9, the only Horse Chestnut observed in the first decade, was somewhat crowded, but had a fair head of foliage, and was four feet in girth. In 1878 the girth-increase was 0·70, but it suffered a decided fall from the very low temperatures of the next two winters, only to rally again to 0·70 in 1881. Next year, from some cause that affected the species universally near Edinburgh, the foliage withered in May, but it revived next year, and has been dense and healthy ever since. Nevertheless, the average increase for the six years following 1882 was only 0·17, and for the next ten 0·16. In twenty years it has increased only five inches. Is the singular fact of apparent healthiness and vigour, along with an extremely low rate, the prolonged effect of the disease of 1882? Or may it be due to the over-

topping of it by a neighbouring tree, although this cause could not have operated at first? Of the two very young trees, Nos. 73, 80, growing near each other in the South border of the Arboretum, the first has proved inferior to the second, although of the same age, the rate of No. 73 having been ·81 and of No. 80 1·19. That of No. 4, a somewhat older tree in the North border, was 1·21, when its career was interrupted by pruning, as that of the other two had been by transplantation.

The range was moderate in them all, ·60 to 1·10 in No. 73; ·95 to 1·35 in No. 80; and 1·05 to 1·40 in No. 4.

ULMUS MONTANA.*

* Erroneously named U. campestris in my former paper.

No. in List.	Annual Increments.										Total.	Annual Av.	Girth at last.
	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
93	1·75	1·80	1·75	1·50	1·30	1·70	1·60	2·05	1·75	1·35	16·55	1·65	30·75
94	1·15	1·75	1·50	1·30	*·10*	*·30*	*·80*	1·55	1·60	1 20	10·05	1·43	22·30
	2·90	3·55	3·25	2·80	..	..	..	3·60	3·35	2·55	..	..	..

In the Edinburgh city gardens the Wych Elm resists the deleterious influences of town life better than any other species. In the Botanic Garden there is no specimen of considerable size, and thus it happened that Sir Robert did not experiment on the species, and I have no records in the first decade. In the second the two healthy young trees, Nos. 93, 94, in the Arboretum have done remarkably well, the former yielding an annual rate of 1·65 for ten years, the latter 1·43 for seven years, the other three years of its decade having been employed in making up the loss sustained by transplantation. Not one of the seventeen records falls to one inch.

The *range* has been moderate, 1·30 to 2·05 in No. 93 and 1·15 to 1·75 in No. 94, and there has been no marked depression, although both trees were almost at their lowest rate in 1897, the united increments being 2·55. The best year was 1895, with 3·60, being an average of 1·80, but several other years were nearly as good.

ULMUS CAMPESTRIS.

This great ornament of the South-west of England makes but a poor show in Scotland, where it is scarcely recognisable as the same tree. Two tall, lanky, but well-clothed specimens in the Botanic Garden, however, girth 58 and 59 inches. A quite young one was selected in the Arboretum in 1892, when it girthed 9·60 inches. The increases for the next four years were only ·75, ·60, ·55, and ·50, yielding a rate little over half an inch, and as it had a very shabby appearance it was cut down.

TILIA EUROPŒA.

No. in List.	Annual Av., 1st Decade.	Annual Increments.										Total.	Ann. Av.	Girth at last.
		1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
2	·30	·00	·50	·40	·25	·20	·40	·30	·00	·30	·35	2·75	·27	81·50
18	·35	·30	·15	·55	·15	·45	·65	·45	·10	·40	·00	3·20	·32	49·40
69	..	·60	·85	·75	·55	1·00	·90	·70	·70	·85	*·00*	6·90	·77	12·60
85	..	·50	60	·65	·45	·75	·70	·55	·50	·60	*·05*	5·30	·59	11·45
		1·40	2·10	2·35	1·40	2·40	2·65	2·05	1·30	2·15	..			
3	..					1·35	1·45	1·25	·90	*·60*	*·50*	4·55	1·24	19·90

The fine spreading Lime, No. 2, stands free in the centre of the Botanic Garden, and is one of its best trees. It increased in the first decade at the rate of ·30 and in the second ·27, a slow progress; but it looks healthy, and is approaching seven feet in girth.

No. 18, although only four feet in girth, has nearly as poor a rate. Possibly it has been permanently checked by the low temperatures in the winter of 1879, as it fell in that year to ·40 from ·70 in 1878, and in the two following years was only ·15 and ·25. Although it may have been somewhat crowded formerly it has not been so when under observation, and it is now a well-formed, healthy-looking tree, so that its continued low rate is somewhat mysterious. It has recently, 1899, been transplanted a short distance, and now stands quite free.

The rates of the quite young Nos. 69, 85 are only ·77 and ·59, and seem poor compared with those of most other forest trees in the Garden, but No. 3, not much older, averaged 1·24 in four years, so that the conduct of Nos. 69, 85 may be exceptional.

In the species there seem to have been years of depression in 1888, 1891, and 1895.

The range in the young trees was not excessive, ·55 to 1·00, ·50 to ·75, and ·90 to 1·35.

FRAXINUS EXCELSIOR.

No in List.	Annual Increments.										Total.	Annual Av.	Girth at last.
	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
23	·85	1·15	·90	·80	*·30*	*·25*	1·05	1·40	1·0	*·20*	7·35	1·05	14·70
75	·45	·60	·45	·65	·65	·65	·60	*·5*	*·25*	·50	4·55	·57	9·40
2	..	..	..	..	1·30	1·10	1·20	1·25	*·65*	*·45*	4·85	1·21	18·25

This species was not observed in the first decade. In the second the two very young trees, Nos. 23, 75, of nearly the same girth, and growing in the same circumstances in the South border of the Arboretum, fared so differently that No. 23, with an average of 1·05, grew at nearly twice the rate of No. 75. Both were transplanted during the decade, No. 23 twice. No. 2, a somewhat older tree in the West border, had a rather better rate than No. 23, or 1·21. The ranges were moderate, ·85 to 1·40, ·45 to ·65, and 1·10 to 1·30.

FRAXINUS ORNUS.

This flowering Ash, a graft on a two-foot stool of the common Ash, and a transplant from the older Garden of 1822, was a handsome and flourishing tree about six and a quarter feet in girth in 1878, and grew at the rate of ·41 in the first decade. It still looks fairly well, but girth-increase almost ceased in the second decade, the total being less than an inch. The girth in 1897 was 80·30, and that of the stool at its narrowest 107·50.

CASTANEA VESCA.

No. in List.	Annual Rate, 1st Decade.	Annual Increments.										Total.	Ann. Av.	Girth at last.
		1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
4	·94	·60	·75	1·00	·60	·90	·90	·40	·80	·45	·55	6·95	·69	87·20

This rather handsome tree grew at the rate of nearly an inch annually in the first decade, and was little affected by the low temperatures of 1879, 1880, and 1881. In the third quinquennium, however, the rate fell to ·77, and in the fourth to ·62, so that the tree seems to be past its best. It still looks well, and has reached the respectable girth of seven feet three inches.

The range in the first decade, ·75 to 1·10, was slight, but the decline in the second has raised it to ·45 to 1·10 in the whole period of twenty years.

JUGLANS REGIA.

No. in List.	Annual Rate, 1st Decade.	Annual Increments.										Total.	Ann. Av.	Girth at last.
		1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
12	·13	·05	·00	·15	·00	·50	·25	·25	·15	·15	·10	1·40	·14	136·50

As the Walnut is rare in the Edinburgh district, it is somewhat surprising to see so large a specimen in a situation so little favourable to tree longevity as the Arboretum, and where it has been so much exposed to the west winds. It has a short stem, eleven feet four inches in girth at the narrowest, a foot above ground, which has only increased an inch or two in twenty years. The two chief limbs girth upwards of eight and five feet. The only annual measurements kept up were on the latter, and it has increased, very irregularly, only two and a half inches in twenty years. Very probably the girth-increase was permanently checked by the low temperatures of 1880, as in the previous year it increased ·40 and in 1878 ·50, almost as much as in the following eighteen years. In some years it produces an abundance of fruit, which, however, never reaches anything like maturity. The

soil of the Garden seems rather favourable to the walnut, as a very handsome specimen, four feet nine inches in girth, recently transplanted, promises to do well.

SALIX SP.

No. in List.	Annual Rate, 1st Decade.	Annual Increments										Total.	Ann. Av.	Girth at last.
		1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
19	...	·90	1·80	1·65	1·65	2·40	2·80	2·65	4·00	3·00	2·40	23·25	2·32	26·25

This Willow, on the South side of the pond, but on dry ground, was measured in its infancy at three feet above ground, the point being raised to five feet when practicable. It was at first only an inch and a half in girth, and is now about two feet at the five-feet mark, having grown twenty-three inches in ten years, at the rate of 1·68 in the first quinquennium, and 2·97, or all but three inches, in the second. The increases of four inches in 1895 and three in 1896 are quite unequalled in other species in all my twenty years' observations.

POPULUS FASTIGIATA.

No. in List.	Annual Rate, 1st Decade.	Annual Increments.										Total.	Ann. Av.	Girth at last.
		1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
76	...	·75	1·75	1·35	·75	1·45	·00	·50	·95	dying	...	7·00	1·17	15·05
87	...	·80	1·35	1·00	·45	·80	dead	...	...	...	...	4·40	·88	12·65
9	...	...	...	...	...	1·25	1·35	1·05	1·30	·80	·65	4·95	1·24	15·10

Three of this species were under observation in the second decade, but the careers of Nos. 76 and 87 have been ended by transplantation followed by death, and that of No. 9 by transplantation threatening death. The average rate in the few available years was 1·18 in No. 76, and 1·24 in No. 9, and if we deduct the years 1891 and 1892 from No. 87, when it was evidently failing, its rate would be 1·05, or not much less than in the others.

ALNUS GLUTINOSA.

No. in List.	Annual Rate, 1st Decade.	Annual Increments.										Total.	Ann. Av.	Girth at last.
		1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
88	...	·85	1·20	·60	·70	·65	·70	·50	·75	*·10*	*·05*	5·95	·74	14·20
7	...	...	...	...	...	·85	·80	·60	·75	*·30*	*·15*	3·00	·75	11·85

The results in this species are also not very satisfactory. No. 88 at first looked well, and in 1889 had an increase of 1·20, but fell off in appearance thereafter, with an increase never rising above ·75 in the six next years. It was then transplanted. No. 7 has never looked vigorous. The annual averages of the two, ·74 and ·75, are almost identical, but cannot be regarded as representative of normal growth.

BETULA ALBA.

No. in List.	Annual Rate, 1st Decade.	Annual Increments.										Total.	Ann. Av.	Girth at last.
		1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
1	·07	·05	·00	·20	·05	·05	·10	·10	·05	·15	·00	0·75	·07	56·80
78	...	·80	1·35	1·10	·95	1·45	1·30	1·25	trans	pl'd &	died	8·20	1·17	19·55
82	...	·70	·90	1·10	·80	1·40	cut	down	...	...	...	4·90	·98	26·65
17	...	...	...	...	...	1·70	1·80	1·60	1·35	*·50*	*·30*	6·45	1·61	20·20

The only Birch measured in the first decade, No. 1, was a transplant from the former Garden in 1822, and was for long a chief ornament of the present one. Previously to 1878 it had been measured for three years, and had an annual rate of ·41, but in that year it dropped to ·25, and possibly the tree was past its prime. Then came the three winters so disastrous to girth-increase in general, when many twigs died, the girth-increase almost ceased, and at the end of the decade not half of the long weeping branches remained. In the second decade there was no rally of girth-increase, which in twenty years has only amounted to an inch and a half, but there has been little further degeneration in appearance, and the tree, now nearly five feet in

girth, still retains something of its original beauty. The cause of its falling off has been ascertained by recent borings to be a fungoid disease in the stem. A Birch of the same size at Craigiehall in the first decade grew for eight years at the annual rate of nearly half an inch.

The two younger Birches, Nos. 78, 82, yielded rates of 1·17 and ·98 for seven and five years respectively, the ranges being ·80 to 1·45 and ·70 to 1·40. But No. 17, about the same age, showed the much better average of 1·61 for the four available years of its career.

CARPINUS BETULUS.

No. in List.	Annual Rate, 1st Decade.	Annual Increments.										Total.	Ann. Av.	Girth at last.
		1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
33	·41	·25	·40	·45	·30	·45	·55	·35	·30	·50	·25	3·80	·38	52·40
81	...	·80	1·00	·65	·55	·45	*·00*	*·35*	·65	·85	·70	5·65	·71	11·90
86	...	·40	·70	·60	·70	·75	·80	·65	1·00	*·15*	*·00*	5·60	·70	11·30

No. 33, a tall, erect, and handsome tree in 1878, above three and a half feet in girth, grew at the rate of ·41 in the first decade and in the second at the somewhat less rate of ·38, always rather falling off in condition. It is now four feet four inches in girth. The annual rate of the two much younger Hornbeams, Nos. 81, 86, selected for the second decade in the South border of the Arboretum, was ·70 and ·71. Their growth was erratic, as shown by the range, which in the former was ·45 to 1·00 and in the latter ·40 to 1·00.

LIRIODENDRON TULIPIFERA.

No. in List.	Annual Rate, 1st Decade.	Annual Increments.										Total.	Ann. Av.	Girth at last.
		1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
6	·60	·35	·40	·80	·50	·65	·40	·75	·35	·40	·25	4·85	·48	86·55

This short-stemmed but handsome spreading tree seems to have been a quick grower up to a girth of about six feet, at the

narrowest part, four feet two inches above ground, as Sir Robert Christison ascertained its rate to have been 1·20 for the three years before the first decade, and in the first year of that decade it grew 1·00. It then encountered the three hard winters, in the two first of which the rate fell to ·40 and ·30, and it never afterwards rallied to above ·80; the average rate in the first decade being ·60 and in the second ·48. Notwithstanding this progressive decrease, the tree is still handsome and healthy looking, with a girth of above seven feet at four feet above ground, and nearly ten feet at the base.

ROBINIA PSEUDACACIA.

No. in List.	Annual Rate, 1st Decade.	Annual Increments.										Total.	Ann. Av.	Girth at last.
		1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
14	...	...	...	...	...	·60	·75	·85	1·40	1·05	·95	5·60	·93	11·90

This very young tree is thriving well in the North border of the Arboretum. It was but slightly pruned in 1895, so I have included the two following years' results. The rate, compared with other infant trees, seems good, as it is barely a foot in girth, and has increased nearly at the rate of an inch a year for six years. The growth was progressive, from ·60 to 1·40 for four years, but has declined to ·95 in the next two years.

CRATÆGUS OXYACANTHA.

No. in List.	Annual Rate, 1st Decade.	Annual Increments.										Total.	Ann. Av.	Girth at last.
		1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
16	·55	·60	·65	·65	·45	·50	·65	·35	*·05*	*·10*	*·05*	3·85	·55	47·55
19	...	1·05	1·65	·95	1·00	1·20	·45	·50	·85	*·10*	*·20*	7·65	·96	10·40
11	...	...	...	...	...	1·00	1·10	·85	1·10	*·20*	*·25*	4·05	1·01	14·45

The handsome Hawthorn, No. 16, at the East walk of the Garden, grew at the rate of a little above half an inch in the first decade, and attained a girth of above three and a half feet.

In the first seven years of the second decade its rate continued precisely the same ; but in 1895 its roots were cut round about to prepare it for transplantation. It then almost ceased to grow till 1899, when it was transplanted to the Arboretum. It now girths all but four feet, and promises to do well in its new quarters.

The rates of the two quite young trees, Nos. 19 and 11, in the second decade, for eight and four years respectively, have been ·96 and 1·01, or about one inch each. The increase in No. 19, the one observed for the longest period, has been erratic, as proved by the extreme range of ·45 to 1·20 in eight years.

CYTISUS LABURNUM.

No. in List.	Annual Rate, 1st Decade.	Annual Increments.										Total.	Ann. Av.	Girth at last.
		1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
21	...	·75	1·00	·85	·90	·70	1·05	·75	*·15*	*·35*	·85	6·85	·86	13·30
1	...	...	...	...	...	·85	·55	·85	·45	*·30*	*·35*	2·70	·67	11·80

The results in these young Laburnums, still only about a foot in girth, have been ·86 and ·67, or an average of about three-quarters of an inch. The range in the one longest tested, No. 21, has been moderate, ·75 to 1·05.

PYRUS COMMUNIS.

No. in List.	Annual Rate, 1st Decade.	Annual Increments.										Total.	Ann. Av.	Girth at last.
		1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
8	...	...	...	...	...	·95	·90	·65	·70	*·25*	*·10*	3·20	·80	14·70

The rate of this young Pear tree, in the West border of the Arboretum, was ·80 for four years, when it was healthy-looking, but the increase almost ceased from excessive pruning, which threatens the life of the tree.

PYRUS AUCUPARIA.

No. in List.	Annual Rate, 1st Decade.	Annual Increments.										Total.	Ann. Av.	Girth at last.
		1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
77	...	·80	·40	·75	·55	·75	·60	·55	*·5*	*·35*	·70	5·10	·64	12·45
79	...	·75	1·05	1·10	·90	*·20*	*·45*	·80	·80	·90	·85	7·15	·89	14·70
13	...	...	...	...	...	·85	·90	·75	·70	*·10*	*·00*	3·20	·80	16·50

The rate of No. 77 was only ·60, kept down perhaps by the very sandy soil where it grew, in the South border of the Arboretum, as No. 79, in the East border, had the considerably better rate of ·89. It was somewhat less, only ·80, in No. 13, favourably situated in the West border, but it has been under observation for only four available years. The ranges of all three, ·40 to ·70, ·75 to 1·10, and ·70 to ·90, have been moderate.

PRUNUS PADUS.

No. in List.	Annual Rate, 1st Decade.	Annual Increments.										Total.	Ann. Av.	Girth at last.
		1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.			
18	...	·65	·90	·80	·70	·70	1·00	·60	*·00*	·75	·70	6·80	·76	11·20
22	...	1·20	1·45	1·35	1·35	*·15*	*·80*	1·05	1·55	1·35	1·10	10·40	1·30	17·20
5	...	...	...	...	...	2·00	1·90	1·60	1·70	*1·10*	*1·00*	7·20	1·80	21·65

These two trees, growing apparently under much the same conditions in the South border of the Arboretum, before being transplanted, have fared very differently, the rate of No. 18 being only ·76, while that of No. 22 was 1·30. The range in both was comparatively small, ·60 to 1·00 and 1·05 to 1·55. But No. 5, South of the Arboretum Lodge, proved greatly superior to these, with an average of 1·80 for four years, and the small range of 1·60 to 2·00. It is thus one of the few trees of any species that has grown as much as two inches in a single year.

B. Annual Rate and Range of Girth-increase in Deciduous Trees at Different Ages.

The rate of girth-increase in trees must evidently be affected by various conditions of locality, such as soil, shelter, crowding or the reverse, the effects of which cannot always be easily eliminated. But another condition of no little influence is age, for there is a natural rise in the annual increase from infancy through youth, and a subsequent decline, the limits of which in the different species have not been, perhaps cannot be, determined. To get rid in some degree of this last cause, I have divided my trees in Tables I. to V. under five categories, according to their size. Usually only the quickest growers have been given, as being more likely to be representative of the normal characteristics of the species than such as proved comparative failures. Some have been under observation for a period sufficiently long to appear in more than one of the categories.

Leaving the Tables mainly to tell their own tale, attention may be directed to a few of the chief points in each of the categories.

ANNUAL RATE AND RANGE OF INCREASE IN GIRTH IN DECIDUOUS TREES.

TABLE I.—Under 15 inches in Girth at the end of the Observations.

No. in List.	Species.	Girth at last Observation.	Annual Rate.	Least Increase in a Year.	Greatest Increase in a Year.	Number of Years.
96	Salix	12·70	2·06	1·65	2·80	five.
94	Ulmus montana	15·00	1·45	1·15	1·75	three.
22	Prunus Padus	13·15	1·30	1·15	1·45	five.
98	Fagus sylvatica	14·55	1·29	1·00	1·55	five.
16	Acer Pseudoplatanus ...	15·	1·27	1·20	1·40	three.
9	Populus fastigiata	13·65	1·24	1·05	1·35	four.
76	Do.	14·15	1·17	·75	1·75	five.
61	Quercus rubra	10·95	1·18	·90	1·50	five.
23	Fraxinus excelsior	14·50	1·07	·85	1·40	five.
78	Betula alba	14·50	1·05	·95	1·35	five.
11	Crataegus Oxyacantha ...	14·00	1·01	·85	1·10	four.
19	Do. ...	10·10	·96	·45	1·65	eight.
14	Robinia Pseudacacia ...	11·90	·93	·60	1·40	six.
70	Quercus robur	13·90	·89	·50	1·20	nine.
79	Pyrus Aucuparia	14·05	·89	·75	1·10	eight.
21	Cytisus Laburnum	13·30	·86	·70	1·05	eight.
8	Pyrus communis	14·35	·80	·65	·95	four.
69	Tilia europœa	12·60	·77	·60	1·00	nine.
7	Alnus glutinosa	11·40	·75	·60	·85	four.
88	Do.	14·05	·74	·50	1·20	eight.
81	Carpinus Betulus	11·90	·71	·45	1·00	eight.
86	Do.	11·15	·70	·40	1·00	eight.
16	Quercus Ilex	8·60	·63	·45	·85	seven.

TABLE II.—Between 15 inches and 2 feet in Girth.

No. in List.	Species.	Girth at last Observation.	Annual Rate.	Least Increase in a Year.	Greatest Increase in a Year.	Number of Years.
96	Salix	23·85	3·21	2·65	4·00	three.
5	Prunus Padus	21·65	1·80	1·60	2·00	four.
93	Ulmus montana	19·55	1·70	1·50	1·80	four.
17	Betula alba	19·40	1·61	1·35	1·80	four.
54	Quercus conferta	24·50	1·61	1·10	1·90	five.
55	Do.	21·40	1·58	1·10	1·80	five.
20	Fagus sylvatica	19·80	1·45	1·20	1·70	three.
74	Acer Pseudoplatanus ...	18·80	1·47	1·40	1·55	five.
3	Tilia europœa	18·80	1·24	·90	1·45	four.
2	Fraxinus excelsior	17·15	1·21	1·10	1·30	four.
4	Œsculus Hippocastanum ...	17·65	1·21	1·05	1·40	four.
12	Acer campestris	19·75	1·20	·85	1·60	six.

TABLE III.—Between 2½ feet and about 5 feet in Girth.

54	Quercus conferta	·36	1·86	1·30	2·05	six.
40	Do.	·36	1·69	1·05	1·80	six.
55	Do.	·36	1·60	1·30	2·10	six.
93	Ulmus montana	·31	1·71	1·35	2·05	three.
43	Quercus Cerris	·53	·57	·35	·65	twenty.
16	Cratægus Oxyacantha ...	·48	·55	·10	·80	twenty.
33	Carpinus Betulus	·52	·40	·10	·55	twenty.
18	Tilia europœa	·46	·35	·15	·70	ten.
28	Acer Pseudoplatanus ...	·62	·35	·15	·50	ten.
9	Œsculus Hippocastanum ...	·52	·32	·05	·75	ten.

TABLE IV.—Old Trees, from about 6 feet to 7½ feet in Girth.
Decade 1878-87.

No. in List.	Species.	Girth at last Observation.	Annual Rate.	Least Increase in a Year.	Greatest Increase in a Year.	Number of Years.
7	Fagus sylvatica	·82	1·03	·65	1·20	ten.
8	Do.	·70	·99	·90	1·20	ten.
4	Castanea vesca	·80	·94	·75	1·10	ten.
6	Liriodendron tulipiferum ...	·82	·60	·30	1·00	ten.
3	Fraxinus Ornus	·80	·41	·20	·75	ten.
2	Tilia europœa	·78	·30	·00	·65	ten.

TABLE V.—Decade 1888-97.

7	Fagus sylvatica	·90	·85	·60	1·20	ten.
8	Do.	·80	·92	·80	1·10	ten.
4	Castanea vesca	·87	·69	·40	1·00	ten.
6	Liriodendron tulipiferum ...	·86	·48	·25	·80	ten.
2	Tilia europœa	·81	·27	·00	·50	ten.

TABLE VI.—Rates of Old Trees at Craigiehall, Cramond, for comparison.

10	Quercus Cerris	·80	·92	·70	1·25	eight.
20	Fagus sylvatica	1·43	·81	·60	·95	eight.
16	Quercus robur	1·27	·69	·45	1·00	eight.
5	Betula alba	·60	·45	·40	·55	eight.
6	Fraxinus excelsior	1·44	·37	·25	·70	ten.
7	Acer Pseudoplatanus ...	1·30	·40	·20	·55	ten.

I. TREES UNDER 15 INCHES IN GIRTH.

Annual rate.—These infant trees have been under observation for from three to eight years. Fully one-half of the twenty-three trees and of the nineteen species had an annual rate of an inch or upwards, the Willow being *facile princeps* with a rate of two inches for five years, when it grew in girth from three to thirteen inches. The Wych Elm follows with

nearly an inch and a half for three years; then come the Cherry, Beech, Sycamore, and Poplar with about an inch and a quarter, and the American Oak, Ash, Birch, and Hawthorn with about an inch. At the other end of the scale are Alder and Hornbeam with three-fourths of an inch, Robinia, British Oak, Rowan, Laburnum, Pear, and Lime being slightly better than that.

Annual range.—Naturally this tends to be greatest in the trees that were longest under observation; but even confining ourselves to the seventeen which had from five to nine years' records the range is not great. In ten the maximum was less, sometimes much less, than double the minimum; in six it was only rather more than double; and in only one was it extreme, being three and a half times greater than the minimum. This was the Hawthorn, No. 19, a very infantile specimen, and in the slightly older No. 11 the range was quite slight.

Maximum single year's increase.—Only three of the twenty-three trees failed to attain one inch of increase in one or more years; these were the Pear, with 95; Alder, No. 7, with 85; and Evergreen Oak, with 85. But another Alder, No. 88, attained 1·20. The highest results were—Willow 2·80, Wych Elm 1·75, Poplar 1·75, Hawthorn 1·65.

II. TREES BETWEEN 15 INCHES AND TWO FEET IN GIRTH.

Annual rate.—Of the twelve trees, belonging to eleven species, admissible to this category, eight have already figured in the infantile period. The Willow reappears with the very high rate of 3·21 for three years. The Cherry now takes second place with 1·80, and Wych Elm follows with 1·70; but the Birch, and the two new comers of *Quercus conferta*, are also above an inch and a half, and *Acer campestris*, at the bottom of the list, averages, along with Lime, Ash, and Horse Chestnut, about an inch and a quarter.

Annual range.—This is much less than in the infantile period. In no tree is the maximum double the minimum; generally it is considerably less, and only in *Acer campestris* does it come perilously near as much.

Maximum single year's increase.—Willow again far and away heads the list with no less than four inches in a single year. Cherry is the only other that attains even two inches, although

one Hungary Oak comes near it with 1·90; the other Hungary Oak, with the Wych Elm and Birch, attain fully an inch and three-quarters, and the Ash, at the bottom of the list, reached an inch and a quarter.

III. Trees between Two and a Half and Five Feet in Girth.

Annual rate.— Few of the species and none of the actual trees of the first or Infant Table are to be found in this category, which includes ten trees, three being Hungary Oaks. They head the list, one of them with 1·86, but it is fair to state that they are younger than most of the others; the Wych Elm is well up with 1·71; but the next best, a Turkey Oak, has only ·57, and the others dwindle down to ·32, the rate for ten years of a Horse Chestnut.

Annual range.—This was moderate in the three Hungary Oaks, the Wych Elm, and Turkey Oak, the maximum being less than double the minimum; but it was very great in Hawthorn, Hornbeam, Lime, Sycamore, and Horse Chestnut, the proportion being as ·50 to ·15 in Sycamore, the best of them, and as ·05 to ·75 in Horse Chestnut, the worst; a proof, I think, that these trees, healthy though they look, had passed their prime of growing power when only from four to five feet in girth.

Maximum single year's increase.—The three specimens of Hungary Oak are conspicuous with 2·10, 2·05, and 1·80, and the Wych Elm also mounted a trifle above two inches; but Hawthorn, Lime, and Horse Chestnut do not attain more than about three-quarters of an inch, Turkey Oak somewhat less, Sycamore and Hornbeam only half an inch.

IV. Trees from about Six to Seven and a Half Feet in Girth.

Our list is now reduced to six trees, none of which appeared in the former categories. As they were observed for twenty years they may conveniently be divided into two decades.

Annual rate.—The two Beeches, which attained respectively nearly seven and nearly six feet in girth in the first decade, and seven feet and a half and six feet and a half in the second, are at the head, with a rate of 1·03 and ·99 in the decade 1878–87,

and ·88 and ·92 in the decade 1888–97. This shows a considerable falling off in the second period, although the trees seem as vigorous and healthy as ever. The Spanish Chestnut, with ·94 and ·69, shows the same tendency, as do the Tulip tree, with ·60 and ·48, and in a less degree the remarkably handsome Lime, nearly seven feet in girth, with ·30 and ·27. As to the flowering Ash, although its rate was ·40 in the first decade, it almost ceased to increase in the second, while showing little degeneracy in its general aspect.

Annual range.—This was slight in the Beech No. 8 and the Spanish Chestnut, at least in its first decade; moderate, the maximum being somewhat less than double the minimum, in Beech No. 7; large in the Tulip tree and flowering Ash; and extreme in the Lime, ·00 to ·65.

Maximum single year's increase.—Beech No. 7 attained 1·20 in both decades, and No. 8 the same in the first decade and 1·10 in the second; Spanish Chestnut reached 1·10 in the first and 1·00 in the second; Tulip tree 1·00 in the first and ·80 in the second; and Lime ·65 in the first and ·50 in the second.

C. Comparison with Trees in the Neighbourhood of Edinburgh.

The rates, particularly of the older trees in the Botanic Garden, by no means represent the capacity for increase in trees of the same or even of greater size in the Edinburgh district, when more favourably situated as to soil.

Even the handsome Beeches Nos. 7, 8, with a rate of ·85 and ·92, when six and a half and seven and a half feet in girth respectively, were nearly equalled by a specimen twelve feet in girth, with a rate of ·81 for eight years, at Craigiehall; and the wonderful tree at Newbattle, nineteen feet in girth, shows what is possible at so great a size, by having increased at the annual rate of about half an inch for fifteen years.

The largest British Oak in the Garden is much of a wreck, although only eight feet in girth, and has been increasing for twenty years at about the annual rate of only a quarter of an inch; but one at Craigiehall kept up a rate of nearly three-quarters of an inch for eight years, although at the considerably greater girth of ten and a half feet.

A fine Turkey Oak in the Garden, four and a half feet in

girth, had a rate of ·57, while one at Craigiehall, six and a half feet in girth, gave a rate of ·92 for eight years, and a very vigorous specimen at Cramond, nearly thirteen feet in girth when measured in 1878, must certainly have been a rapid grower.

The handsome Sycamore, No. 28, five feet in girth, with the unaccountably low rate of ·35, is not much above the ·22 of the largest Sycamore, eleven feet in girth, in the Garden; and a Craigiehall tree, nearly as large, excelled it with a rate of ·40 for ten years.

The finest Birch in the Garden ceased to increase when a few inches short of five feet in girth, while a slightly larger specimen at Craigiehall continued to grow at the rate of nearly half an inch for eight years.

D. Aggregate Annual Results.

The results in the aggregate are chiefly interesting as showing, in the first place, the effects upon girth-increase of good or bad seasons; and, secondly, any tendency there may be towards alteration in the rate from increasing age in the trees. This inquiry must be confined to the group of adult and aged trees, as in them alone has the period of observation, amounting in most of them to twenty years, been sufficient to yield reliable results. As the two kinds of results just specified are concurrent it will be easier to study them together than separately, and it will be advantageous to take first the species which seem to be still growing with undiminished vigour, as far as external appearance goes, and subsequently those that may be suspected of having decidedly passed their prime. The first set includes Beech, Hungary Oak, and Turkey Oak, of each of which from two to four specimens were under observation. These will be dealt with separately. The second set contains nine species, mostly illustrated by only one specimen, and may be taken in mass.

The first decade of observations, 1878–1887, was remarkable for three successive most unfavourable seasons, 1879, 1880, and 1881. In all three the winters were marked by exceedingly low temperatures, and in 1879 the growing months were remarkably cold and sunless. Fortunately the measurements in most of the species began in the previous year, and thus we can appreciate the extraordinary immediate loss in the aggregate girth-increase

and the prolonged effects on some of the trees, all of which is fully detailed in former papers.* Suffice it to say here that in 1880, the worst year for the deciduous trees, their aggregate girth-increase was only half what it was in 1878, and that, while the Deciduous group reached their minimum of increase in 1880, the second of the three severe seasons, rallying very decidedly in 1881, the Pinaceæ continued to fall off in that season and did not rally till 1882.

The second decade shows no such startling results, and the other seasonal fluctuations, considerable though they be, are probably only such as may be ordinarily expected in a climate so variable as ours ; but they are interesting as showing that the species were not all implicated in the same seasons of depression. The effects of increasing age seem to be pretty clearly indicated also.

FAGUS SYLVATICA.

AGGREGATE GIRTH-INCREASE IN FOUR BEECHES FOR TWENTY YEARS.

First Decade, ...	1878.	1879.	1880.	1881.	1882.	1883.	1884.	1885.	1886.	1887.
Increase, ...	3·60	2·85	1·95	2·75	3·35	2·90	3·45	2·85	3·10	2·60
Second Decade, ...	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.
Increase, ...	2·25	2·35	2·35	2·30	2·80	2·50	2·75	2·05	2·65	2·25

These four Beeches girthed, in round numbers, five and a half, six and a half, seven, and seven and a half feet in 1897, and showed no outward sign of diminished vigour. The Table shows, however, that they never quite regained the standard of 3·60 in 1878, the year preceding the three severe seasons, although twice, in 1882 and 1884, they very nearly did so. Their minimum, 1·95, occurred in the second bad season, and severe as the fall may seem, it was less than in any of the other deciduous species. The rally to 2·75 in 1881 and to 3·35 in 1882 was so complete that evidently no permanent injury had been done, and the subsequent gradual though fluctuating

* "The Influence of the Unfavourable Season of 1879 on the Growth of Trees." By Sir R. Christison, Bart., Tr. Bot. Soc. Ed., 1880.

"The Growth of Wood in 1880." By Sir R. Christison. *Op. cit.*, 1881.

"The Depression in Girth Increase of Trees in 1879, 1880, 1881." Dr. D. Christison. *Op. cit.*, 1888-89, p.

decrease in girth-increase is probably due to increasing age. In the second decade the maximum, 2·80, compares unfavourably with the 3·60 before the bad years, and 3·45 after them, of the first decade. The range in the first decade, 1·95 to 3·60, is great owing to the severe winters; in the second it is remarkably small, 2·05 to 2·80. That the Beeches were subject to minor depressions, in common with other species, in 1883, 1885, 1887, and 1895 is evident, but I have not been able to inquire into their causes.

QUERCUS CERRIS.

AGGREGATE GIRTH-INCREASE IN TWO TURKEY OAKS FOR EIGHTEEN YEARS.

	1878.	1879.	1880.	1881.	1882.	1883.	1884	1885.	1886.	1887.
First Decade, ...	..	..	1·05	1·85	1·55	1·45	1·55	1·50	1·45	1·45
	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.
Second Decade, ...	1·20	·75	1·35	1·10	1·40	1·50	1·30	1·05	1·50	1·15

Unfortunately these Turkey Oaks only came under observation in the third year of the first decade, but the decided rally from 1·05 in that year to 1·85 in the next indicates that they shared in the general depression of the time. It is somewhat remarkable that they never again approached the standard of 1881 nearer than 1·55. The only other startling event in their career was the great fall in 1889 to the minimum, ·75, due apparently to some cause specially affecting the species, as few others showed any sign of depression then. On the whole, there has been a falling off in the amount of girth-increase with time, but not to a marked degree.

The range was 1·05 to 1·85 in the first decade, and ·75 to 1·50 in the second.

QUERCUS CONFERTA.

AGGREGATE GIRTH-INCREASE OF THREE HUNGARY OAKS FOR FOURTEEN YEARS.

1878.	1879.	1880.	1881.	1882.	1883.	1884.	1885.	1886.	1887.
..	..	3·60	5·15	5·25	5·40	5·05	4·8	4·65	5 30
1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.
3·65	4·50	5·05	4·05	5·15	6·00	..	..	..	..

The Hungary Oaks only came under observation in the same year as their Turkish cousins, but, like them, a rise from 3·60 in 1880 to 5·15 in 1881 indicates a marked depression during the severe winters of 1879 and 1880. They then went on steadily till 1888, a year of pretty general depression, when they descended nearly to the level of 1880. Another severe fall, to 4·05, occurred in the generally unfavourable year of 1891, but an immediate recovery took place, and in 1893 they reached their maximum of 6·00. A severe pruning, to promote upward growth, has been successful in that object, but has reduced their girth-increase to a mere trifle for six years. Previously it is plain that, on the whole, their girth-increase had been increasing, due probably to their being adolescents and not adults.

The range in the first decade was from 3·60 to 5·40, and in the second from 3·65 to 6·00.

AGGREGATE INCREASE IN GIRTH FOR TWENTY YEARS OF NINE OTHER SPECIES OF INFERIOR OR DECLINING VIGOUR.

	1878.	1879.	1880.	1881.	1882.	1883.	1884.	1885.	1886.	1887.
First Decade.										
Tilia europœa (2)	1·20	·55	·15	·90	·95	·55	·70	·65	·50	·40
Castanea vesca	1·10	·90	·85	1·10	·90	1·00	1·00	·85	1·0	·75
Liriodendron tulipifera ..	1·00	·40	·30	·65	·60	·45	·65	·55	·7	·65
Acer Pseudoplatanus ..	·50	·20	·15	·30	·40	·45	·55	·40	·35	·20
Œsculus Hippocastanum	·75	·50	·35	·70	·10	·30	·20	·05	·20	·20
Carpinus Betula	·40	·35	·10	·55	·5	·45	·55	·40	·30	·50
Quercus rubra	·50	·40	·30	·50	·40	·40	·45	·55	·45	·55
Juglans regia	·50	·40	·00	·00	·10	·10	·15	·00	·15	·15
Betula alba	·25	·05	·05	·10	·10	00	·10	·00	·10	·00
Total	6·20	3·75	2·25	4·80	4·15	3·70	4·35	3·45	3·80	3·40
Second Decade.										
	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.
Tilia europœa	·30	·65	·95	·40	·65	1·05	·80	·10	·70	·35
Castanea vesca	·60	·75	1·00	·60	·90	·90	·40	·80	·45	·8
Liriodendron tulipifera ..	·35	·40	·80	·50	·65	·40	·75	·35	·40	·25
Acer Pseudoplatanus ..	·20	·20	·30	·10	·35	·25	·15	·15	·35	·15
Œsculus Hippocastanum	·35	·10	·05	·00	·25	·10	·25	·25	·30	·00
Carpinus Betula	·25	·40	·45	·30	·45	·55	·35	·30	·50	·25
Quercus rubra	·40	·30	·50	·35	·45	·40	·55	·40	·35	·25
Juglans regia	·05	·00	·15	·00	·30	·25	·25	·15	·15	·10
Betula alba	·05	·00	·20	·05	·05	·10	·10	·05	·15	·00
Total	2·55	2·75	4·45	2·30	4·05	4·00	3·60	2·55	3·35	2·20

The progressive though fluctuating degeneracy in this group is very marked. From the standard of 6·20 in 1878 the fall in 1880, the second severe season, was to 2·25, and the rally in 1881 was only to 4·80, an amount which they never again quite reached. Their average for the last five years was little above 3·00, or one-half the standard of 1878. It is probable, therefore,

that the severe seasons of 1879 and 1880 produced, besides an immediate severe depression, a permanent effect, by accelerating, or it may be in some cases inducing, the falling off in girth increase to be looked for in trees either beyond their prime or in weak health ; and this took place in the majority without any apparent degeneracy in the foliage. In the two Limes and the Sycamore it has always been fine, and the same may be said, in a somewhat less degree, of the Spanish Chestnut, Tulip Tree, and Hornbeam. The conduct of the Horse Chestnut was peculiar. It probably rallied completely in 1881 from the previous severe seasons, but in 1882 fell a victim to some disease that withered the foliage early in summer of nearly all the Sycamores near Edinburgh, and, although subsequently the foliage was always healthy and dense, the girth-increase for fifteen years has been very slight, and in some seasons there has been none at all. Permanent injury to girth-increase, if it existed at all, is least traceable in the Hornbeam and American Oak. In the Walnut and Birch the degeneracy both in appearance and girth-increase is distinct.

E. Variety in the Incidence of Years of Depression on the Different Species.

This is perhaps most simply shown by the following statement:—Of the nine species in twenty years, 4 were affected in 1879, 8 in 1880, 1 each in 1881, 1882, and 1883, 2 in 1885, 2 in 1887, 3 in 1888 and 1889, 5 in 1891, 2 in 1894, 4 in 1895, 1 in 1896, and 8 in 1897.

F. Capacity of Girth-increase as shown in Favourable Years.

To show the growth accomplished by trees of the different species under favourable circumstances I have drawn up Table VII. From this it appears that *Salix* stands, in a most marked degree, at the head with an average increase of practically three inches, and a maximum increase in a single year of four inches, the average girth being nineteen inches. In the four best consecutive years it grew fully a foot in all. No other tree comes up to this, but *Quercus conferta* comes next with an average for five consecutive years of above an inch and three-quarters, and *Ulmus montana* is third, with a little below that amount, the

TABLE VII.—Average Annual Increase in Girth in the five best consecutive years (Column A), and in the best single year (B), in Trees of different species at different sizes ; (C) gives the Girth at the middle of the five years' period.

No.	Species.	Average for five best consecutive years.	Best Single Record.	Girth in inches.	No.	Species.	Average for five best consecutive years.	Best Single Record.	Girth in inches.
	Under one foot in girth.	A	B	C		One to two feet in girth —*continued.*	A		C
19	Salix sp.	1·68	2·40	6	12	Acer campestris	1·20	1·60	16
22	Prunus Padus	1·34	1·45	11	19	Cratægus Oxyacantha ..	1·17	1·65	14
9	Populus fastigiata	1·24	1·35	11	70	Quercus robur	1·01	1·20	13
61	Quercus rubra	1·18	1·50	9	69	Tilia europœa	·83	1·00	13
80	Œsculus Hippocastanum ..	1·17	1·35	10	8	Pyrus communis	·80	·95	13
14	Robinia Pseudacacia ..	1·00	1·40	9	79	Pyrus Aucuparia	·80	·95	15
79	Pyrus Aucuparia	·95	1·10	10		Two to four feet in girth.			
23	Fraxinus excelsior	·91	1·15	10	54	Quercus conferta	1·87	2·30	40
21	Cytisus Laburnum	·90	1·05	11	93	Ulmus montana	1·69	2·05	27
67	Acer Pseudoplatanus ..	·86	1·05	9	40	Quercus conferta	1·46	1·80	47
88	Alnus glutinosa	·80	1·20	11	16	Cratægus Oxyacantha ..	·58	·65	41
86	Carpinus Betulus	·78	1·00	9	45	Quercus Ilex	·56	·70	45
16	Quercus Ilex	·68	·85	7	41	Carpinus Betulus	·49	·55	47
15	Quercus Cerris . ..	·67	·70	8		From four to six feet in girth.			
6	Ulmus campestris . ..	·60	·75	11	63	Quercus Cerris	·70	·85	65
	One to two feet in girth.				41	Carpinus Betulus	·43	·55	51
19	Salix sp.	2·97	4·00	19		From six to seven feet in girth.			
55	Quercus conferta	1·71	1·80	19					
93	Ulmus montana	1·62	1·80	16	7	Fagus sylvatica	1·15	1·20	77
74	Acer Pseudoplatanus ..	1·47	1·55	16	7	The same tree	1·00	1·20	84
20	Fagus sylvatica	1·45	1·70	19	4	Castanea vesca	·97	1·10	73
22	Prunus Padus	1·26	1·55	15	4	The same tree	·83	1·00	83
3	Tilia europœa	1·24	1·45	17	6	Liriodendron tulipifera ..	·63	·80	84
78	Betula alba	1·23	1·45	15	2	Tilia europœa	·39	·65	76
4	Œsculus Hippocastanum ..	1·21	1·40	15	2	The same tree	·35	·40	80
2	Fraxinus excelsior	1·21	1·30	16					

respective best single years yielding 2·30 and 2·05. Their average girths were forty and twenty-seven inches.

It would be tedious to speak of all the trees in detail ; suffice

it to say that the following thirteen additional species attained an annual average of an inch to an inch and a half in their best consecutive five years :—*Acer Pseudoplatanus*, *Fagus sylvatica*, *Prunus Padus*, *Populus fastigiata*, *Tilia europæa*, *Betula alba*, *Œsculus Hippocastanum*, *Fraxinus excelsior*, *Acer campestris*, *Quercus rubra*, *Cratægus Oxyacantha*, *Quercus robur*, *Robinia Pseudacacia*. These are arranged in order, *Acer Pseudoplatanus* at the head with an average of all but an inch and a half, and *Robinia* at the foot with exactly one inch ; but it must be remembered that the comparison is not quite fair, as the ages of the trees were very different.

Species that appear to thrive in the Garden but yield comparatively low rates are *Carpinus Betulus*, *Pyrus communis*, *Pyrus Aucuparia*, and *Quercus Cerris*.

II. MONTHLY RESULTS.

The trees adopted at various periods for monthly measurements were selected from those observed annually, and the reasons for choosing and abandoning successive sets, already given in the Introduction, apply with even greater force now than in the First Part of our subject.

Monthly measurements were commenced tentatively by Sir Robert Christison in 1880 upon five deciduous and six evergreen trees, but the tape he used was too coarse to yield very reliable results. In 1882 I added about thirty-five deciduous examples, and took monthly measurements of the whole, in the growing season, till 1887. The early results, down to 1882, were included in a Paper to the Royal Society of Edinburgh in 1883,* and the whole results were communicated to the Botanical Society in 1887.†

But the objections, already explained, to observations upon old and large trees induced me to abandon this set in 1887 and take up the fresh set ‡ of about thirty-five young trees, used

* "Observations on the Annual and Monthly Growth of Wood in Deciduous and Evergreen Trees." By the late Sir Robert Christison, Bart., and Dr. Christison. Trans. Royal Society of Edinburgh, 1883, pp. 45, 66.

† "On the Monthly Increase in the Girth of Trees at the R. Botanic Garden and at Craigiehall, near Edinburgh," by David Christison, M.D. Trans. Bot. Soc. Ed., 1887.

‡ "Observations on the Increase in Girth of Young Trees in the Royal Botanic Garden, Edinburgh, for five years ending 1891," by David Christison, M.D., President. Trans. Bot. Soc. Ed., 1892.

also for annual observations, selecting as far as possible such as had smooth bark and regularly cylindrical stems. These having become ineligible as a connected set in 1892—although some of them became available afterwards, as they recovered at various dates from transplantation—were replaced by the final young set of twenty trees, available from 1892 to 1895, but then disabled for my purpose by a severe pruning.

The plan followed in dealing with the monthly observations is to give *in extenso* the results for the set of 1892–95, not hitherto published, to compare these with the results yielded by the other young set of 1887–91, and to make use of the original set of older trees, 1882–87, only incidentally.

In considering the records of 1892-95, I shall first try to give the aggregate results, and then describe the conduct of each species separately, inquiring at the same time how far the results may agree with those obtained from other young trees observed in 1887-91, in so far as the same species happen to have been examined in both these periods.

In the first place, however, it is well to state that neither the number of trees of each species, nor the length of time during which they have been under observation, is sufficient to warrant the deduction of precise conclusions or definite laws. At first sight, indeed, it might seem that three specimens of a species, of similar ages, growing in the same locality, and under observation, two of them from 1887 to 1891, and the other from 1892 to 1895, should yield true averages, but that this is not so is proved by the occasional quite contradictory conduct of a tree in one year as compared with the other three or four years, or what is still more striking, by the contradictory conduct of one tree during the whole four or five years of observation, when compared with the other two trees. Neither is it always easy to account for this erratic conduct, although among probable reasons may be suggested—temporary unhealthiness, not, it may be, betrayed by the appearance of the tree; individuality of character, as when we see two trees of the same species, and equally vigorous, of which one invariably comes into leaf much earlier than the other; difference of age, which, even when slight, has, I suspect, considerable influence in early youth; difference of position, which even within narrow limits may place trees under very

different conditions of soil, exposure, etc.; unsuitability of the species to the climate or soil; the complicated effects of weather affecting species or individual trees in different ways. But notwithstanding all this, the results in some species agree quite as remarkably as in others they disagree, and while greater confidence must be placed in the former, some idea may be formed, on a careful consideration, of the general tendencies in the latter also.

A. Aggregate Results.

A. For the Months Separately.

The chief points to which attention will be directed under this head are—the aggregate increase in girth of the twenty trees due to each month in succession in each year and over the whole period; the proportion or percentage of seasonal increase due to each month in each year and on the average; the species that yield the largest and smallest proportions of seasonal increase in each month; and the largest individual scores or records in a single year that may have happened in any species in each month.

APRIL.

Aggregate Results, 20 Trees.	1892.	1893.	1894.	1895.	Average.
Total increase, ...	0·15	1·15	1·30	0·50	0·77
Percentage of seasonal increase, ...	0·6	4·7	6·0	2·4	3·4
Number with no increase, ...	17	7	3	11	9·5

The average annual increase for April amounts to only three-quarters of an inch, somewhat less than for September, at the other end of the season, and, as might be expected from our variable springs, the range, ·15 to 1·30 in amount and 0·6 to 6·0 in percentage, is very great.

The number of trees that yielded no increase in April in one or more seasons was large, the annual average default being about one half of the whole, but the proportion of the default varied as much in the different years as from 3 to 17.

Species with the Largest Proportional Increase in April.	1892.	1893.	1894.	1895.	Total.	Average.	Seasonal p.c.
Quercus robur, ...	...	10	10	5	·25	·06	9·4
,, Cerris, ...	...	10	5	5	·20	·05	7·3
Fraxinus excelsior, ...	5	10	10	10	·35	·09	7·2
Betula alba, ...	...	15	15	5	·35	·09	5·4
Robinia Pseudacacia, ...	5	5	5	...	·15	·04	5·2
Quercus rubra, ...	...	10	10	5	·25	·06	5·0
Species with the Smallest Proportional Increase.							
Œsculus Hippocastanum, ...	...	...	...	...	...	...	...
Tilia europœa, ...	...	...	5	...	5	·01	1·0
Populus fastigiata, ...	...	...	5	...	5	·01	1·0
Acer Pseudoplatanus, ...	...	...	5	...	5	·01	1·2
Fagus sylvatica, ...	...	...	5	...	5	·01	1·2

Large individual scores were scarcely to be expected. *Salix* alone reached a quarter of an inch once, and did not exceed it, and ·15, the next best score, was only recorded three times, once in *Salix* and twice in *Betula*.

MAY.

Aggregate Results, 20 Trees.	1892.	1893.	1894.	1895.	Average.
Total increase, ...	2·75	4·70	2·55	2·95	2·24
Percentage of seasonal increase, ...	11·3	19·0	11·8	14·3	14·1

The average annual increase is two inches and a quarter, or about three times greater than in April, and the range, though not so excessive as in that month, is still high. A total absence of increase was only recorded twice, but in sixty-two of the eighty observations the amount did not reach a quarter of an inch, and in thirteen it was only ·05.

SPECIES WITH THE LARGEST PROPORTIONAL INCREASE IN MAY.	1892.	1893.	1894.	1895.	Total.	Average.	Seasonal p.c.
Betula alba, ...	·30	·50	·35	·25	1·40	·35	21·7
Fraxinus excelsior, ...	·20	·30	·20	·25	·95	·24	19·5
Prunus Padus, ...	·25	·50	·30	·25	1·30	·32	18·0
Salix sp., ...	·35	·45	·30	·50	1·60	·40	14·5
SPECIES WITH THE SMALLEST PROPORTIONAL INCREASE.							
Robinia Pseudacacia, ...	5	5	5	10	·25	·06	9·6
Cratægus Oxyacantha, ...	10	15	5	10	·40	·10	10·2
Ulmus campestris, ...	5	10	5	5	·25	·06	10·4

Several species besides those in the Table showed a *capacity* for May growth by having an occasional good score. *Acer Pseudoplatanus* once had ·35, *Fagus* and *Tilia* 30, and *Pyrus communis* 25. *Betula*, *Prunus*, and *Salix* alone reached half an inch, once each, and none of them exceeded it.

JUNE.

Aggregate Results, 20 Trees.	1892.	1893.	1894.	1895.	Average.
Total increase, ...	8·05	7·05	5·80	5·80	6·67
Percentage of seasonal increase, ...	33·4	28·5	26·7	28·0	29·1

The average annual increase for June is six inches and three-quarters, or three times that of May, and the range is considerably less than in that month. There was no record so low as ·05, and only three of ·10. Of the eighty records, fifty-three were above a quarter of an inch, and of these seventeen were half an inch or more.

Species with the Largest Proportional Increase in June.	1892.	1893.	1894.	1895.	Total.	Aver-ge.	Seasonal p.c.
Acer Pseudoplatanus, ...	·55	·50	·50	·15	1·70	·42	40·3
Tilia europœa, ...	·65	·55	·50	·25	1·95	·49	39·4
Fraxinus excelsior, ...	·55	·45	·40	·45	1·85	·46	38·1
Species with the Smallest Proportional Increase.							
Robinia Pseudacacia, ...	·10	·15	·10	·25	·60	·15	15·9
Salix sp., ...	·80	·60	·40	·95	2·75	·69	20·0

In June growth becomes well established, and the annual variations are much less than in the earlier months. The differences in the proportional increase of the species appear to be mainly due to normal differences in the distribution of girth-increase over the growing season in the different species. For example, the increase is much more evenly spread over the months in *Salix* than in *Acer*, so that the proportion of increase due to June is much less in the former. The highest single score was very nearly one inch in 1895 by *Salix*.

JULY.

Aggregate Results, 20 Trees.	1892.	1893.	1894.	1895.	Average.
Total increase, ...	7·60	6·65	7·15	5·35	6·69
Percentage of seasonal increase, ...	31·5	27·0	33·0	26·0	29·4

The average annual increase is six inches and three-quarters, or the same as in June, and the range is similarly moderate. The records fall as low as ·10 five times, and of these two were ·05, all in 1895, when, as appears from the Table, there was a great general depression in July.

SPECIES WITH THE LARGEST PROPORTIONAL INCREASE IN JULY.	1892.	1893.	1894.	1895.	Total.	Average.	Seasonal p.c.
Populus fastigiata, ...	·55	·50	·40	·40	1·85	·48	37·5
Cytisus Laburnum, ...	·25	·15	·35	·10	·85	·21	34·2
Pyrus Aucuparia, ...	·15	·25	·30	·20	·90	·22	34·0
Tilia europœa, ...	·40	·45	·45	·30	1·60	·40	32·4
Œsculus Hippocastanum, ...	·45	·40	·40	·30	1·55	·39	32·0
SPECIES WITH THE SMALLEST PROPORTIONAL INCREASE.							
Betula alba, ...	·40	·40	·40	·30	1·50	·37	23·3
Robinia Pseudacacia, ...	·25	·35	·20	·15	·95	·24	24·6
Salix sp., ...	·65	·65	·70	·85	2·85	·71	25·0

In July the variation in the comparative seasonal percentage of the species attains a decided minimum, being only from 23·3 to 37·5, whereas in June, the next steadiest month, it is 15·9 to 40·3. In July, in no less than eight species the seasonal p.c. lies between 30 and 32.

Half an inch or upwards was attained in all four years by *Salix* and *Prunus*, in two years by *Populus*, and in one year by *Fagus*, *Quercus rubra*, and *Acer campestris*. The highest single score was ·85 by *Salix*. Forty-seven other records are between a quarter and half an inch, so that only twenty of the eighty records fell below a quarter of an inch.

AUGUST.

Aggregate Results, 20 Trees.	1892.	1893.	1894.	1895.	Average.
Total increase, ...	4·90	4·35	3·80	4·20	4·31
Percentage of seasonal increase, ...	20·3	17·6	17·5	20·3	18·9

The annual average increase is four inches and a half, about two-thirds that of June or July and double that of May, and the

range is small. There was no increase on three occasions, and it fell to ·05 ten times, and to ·10 twelve times.

Species with the Largest Proportional Increase in August.	1892.	1893.	1894.	1895.	Total.	Average.	Seasonal p.c.
Robinia Pseudacacia, ...	20	25	25	45	1·15	·39	34·2
Quercus rubra,...	No ob.	25	30	50	1·05	·35	26·3
Salix sp., ...	45	75	75	95	2·90	·72	25·8
Populus fastigiata, ...	30	25	35	30	1·20	·30	24·0
Species with the Smallest Proportional Increase.							
Fraxinus excelsior, ...	15	...	5	10	·30	·07	6·2
Acer Pseudoplatanus, ...	5	20	10	5	·50	·12	9·7
Tilia europœa, ...	15	10	5	20	·40	·10	10·1
Quercus robur,...	15	10	5	...	·30	·07	11·7

The variation in the seasonal proportion of the species in August, 6·2 to 34·2, is very great compared with June or July, and even exceeds that of May. An increase of half an inch is only attained four times, of which *Salix* claims three, *Quercus rubra* being the other successful candidate. There were twenty-eight records between a quarter and half an inch, The maximum record, ·95, or nearly an inch, was by *Salix*.

SEPTEMBER.

Aggregate Results, 20 Trees.	1892.	1893.	1894.	1895.	Average.
Total increase, ...	·70	·80	1·10	1·85	1·11
Percentage of seasonal increase, ...	2·9	3·2	5·0	9·0	5·
Number with no increase, ...	10	9	6	8	8·2

The average annual increase of September, the last month of the growing season, is a little more than an inch, only a quarter

of an inch above that of April, the first month of the season, and only a fourth that of August. The range is greatly less than in April, but much greater than in May. The number of records of no increase amounted to nearly one-half of the whole, and was not much less than in April.

SPECIES WITH THE LARGEST PROPORTIONAL INCREASE IN SEPTEMBER.	1892.	1893.	1894.	1895.	Total.	Average.	Seasonal p.c.
Salix sp., ...	20	15	25	70	1·30	·32	10·7
Robinia Pseudacacia, ...	...	10	15	30	·55	·14	10·5
Fagus sylvatica, ...	...	10	5	15	·30	·07	6·9
Betula alba, ...	5	10	5	15	·35	·09	5·4
SPECIES WITH THE SMALLEST PROPORTIONAL INCREASE.							
Quercus robur,...	...	...	...	...	...	...	...
,, rubra,...	...	...	...	...	...	...	...
Fraxinus excelsior, ...	...	...	...	...	...	...	...
Populus fastigiata, ...	5	...	...	...	5	·01	1·0
Pyrus Aucuparia, ...	...	...	5	...	5	·01	1·5

Salix alone reaches half an inch, and that only once, but with the phenomenal score of ·70. *Robinia* follows with ·30, which is perhaps still more remarkable, as its total annual increase is only about a third of that of *Salix*. No other species scored higher than ·15.

B. FOR THE MONTHS IN GROUPS.

1. *Two periods of three months each.*—As stated in my previous paper, the division of the growing season into two periods of three months each, although the only practicable one with observations at monthly intervals, does not imply that the periods of actual growth are equal in the two divisions. Unquestionably there is a great variety both in the normal beginning and normal ending of seasonal girth-increase in the different species, but

as the beginnings and endings are very gradual it would be perhaps impossible to define their precise limits by girth measurements. On the whole, however, a division into a first half-season consisting of April, May, and June, and a second comprising July, August, and September, besides being very convenient, is probably fair enough.

It appears from the little Table annexed that in three of the years 1892 to 1895 the half-seasonal results were remarkably uniform, being nearly as 45 to 55 in favour of the second half, but that in 1893 the proportion was slightly in favour of the first half, thus reducing the four years' averages to 47, 53, in round numbers.

	1st Half Season.	2nd Half Season.
1892, ...	45·3	54·7
1893, ...	52·2	47·8
1894, ...	44·5	55·5
1895, ...	44·7	55·3
Average, ...	46·7	53·3

The young trees observed in 1887–91 yielded a somewhat greater superiority for the second half-season, the figures being 44, 56. This is no great difference, but when a comparison is made with the adult and aged trees of 1882–87 the superiority of the second half in them is much more marked, the figures being 35, 65, proportions which are very little affected, as I find, by limiting the comparison to the species which are represented in both sets of trees. Thus, the result arrived at in 1891—that adult and old trees have a greater tendency than young ones to throw their main girth-increase into the second half-season—is amply confirmed by the more recent observations.

The variation or range of the half-seasons would have been almost *nil* but for the exceptional year 1893; even with it the figures are only 44 to 52 for the first half and 48 to 55 for the second, in round numbers.

2. *Three periods of two months each.*—Dividing the growing season into equal first, middle, and last periods, it comes out that the girth-increase in the first was less than in the last on the average, though not in the year 1893, but that both, as a matter of course, were much below the middle, in which nearly three-fifths of the whole seasonal increase took place, whereas the first period claimed only a sixth and the last one quarter of the whole.

	First.	Middle.	Last.
1892, ...	11·9	64·9	23·2
1893, ...	23·7	55·5	20·8
1894, ...	17·8	59·7	22·5
1895, ...	16·7	54·0	29·3
Average, ...	17·5	58·5	24·0

The annual variation or range was much greater in the first period than in the others, being in the proportion of two to one, whereas in the last it was as three to two, and in the middle period as six to five. The excessive variation of the first period is no doubt due to the great irregularity in the arrival of spring in our climate. In the two midsummer months growth is well established, and therefore is much steadier. In the two autumn months the girth-increase begins to die away, and therefore again becomes more irregular, but probably it is less affected by climatic variations than in the spring months, and hence its range is less.

3. *Six periods of one month each.*—The Table of monthly percentages shows that the first and second months are exceeded by the last and second last months respectively, but only on an

Percentage of Monthly Girth Increase in Twenty Young Deciduous Trees for Four Years, 1892-1895.

	April.	May.	June.	July.	August.	Sept.
1892, - -	0·6	11·3	33·4	31·5	20·3	2·9
1893, - -	4·7	19·0	28·5	27·0	17·6	3·2
1894, - -	6·0	11·8	26·7	33·0	17·5	5·0
1895, - -	2·4	14·3	28·0	26·0	20·3	9·0
Average,	3·4	14·1	29·2	29·4	18·9	5·0
AVERAGE OF THIRTY YOUNG DECIDUOUS TREES FOR FIVE YEARS, 1887-1891.						
	1·5	12	31	30	20·5	5·0

average, as in the four years April twice exceeded September, and May once exceeded August. The proportions of June and July are almost identical, and of course greatly exceed those of the other months, even August. When compared with the trees of 1887–91 as shown in the Table there is a close correspondence, the only great difference being in the April proportion, the month in which disproportion is almost inevitable. Stated roundly, April claims $\frac{1}{30}$ of the annual girth-increase, May $\frac{1}{8}$, June and July not far from $\frac{1}{3}$ each, August $\frac{1}{5}$, and September $\frac{1}{20}$.

As to the variation or range in the months, it is, as might be expected, extreme in April, the amount of increase being nearly twelve times greater in the best year than in the worst, whereas even in September the best is only three times greater than the worst. May follows next in the ratio of less than two to one, while in June, July, and August the variation is comparatively trifling.

4. *Order of precedence of the months in the amount of girth-increase.*—The sequence in the case of the young trees of 1892-95 is as follows:—July 23·4 p.c., June 29·2, August 18·9, May 14·1, September 5, April 3·4. This differs but little from the results in the thirty young trees of 1887–91, for, although the positions of June and July are reversed, the difference between the two months in both sets of observations is very trifling. The sequence and proportions for 1887–91 are:—June 31, July 30, August 20·5, May 12, September 5, April 1·5.

B. Results in the Species Individually.

In treating the Second Part of this Division of my subject, a tabular view of the results, followed by remarks, is given for each species. Each Table is constructed so as to show, first, the amount and p.c. for each month and for the half-seasons in the single tree of the set 1892-95. The corresponding p.c. for the other sets are then given. The last column gives the girth of the trees at the end of the observations upon them. The remarks that follow bear chiefly upon the proportions of the half-seasonal increase, and of the monthly increase. Finally, the highest record for each month is given, to show the capacity of growth of each species in each month under the most favourable circumstances.

The detailed records for the sets of 1884-87 and 1888-91, formerly published, could not be reproduced here without unduly swelling the bulk of this Paper, but many quotations from them occur in the text.

No. 20.—Fagus sylvatica.

Year.	Apr.	May.	June.	July.	Aug.	Sept.	1st Half Season.	2nd Half Season.	Girth in Inches at the end of the Observations.
1893.	...	30	50	45	35	10	80	90	...
1894.	5	15	50	40	25	5	70	70	...
1895.	...	10	35	30	30	15	45	75	...
Total,	5	55	135	115	90	30	195	235	17
P.C. -	1·2	13·0	31·3	26·7	20·9	6·9	45·5	54·5	...
Two Young Beeches, 1888-91.									
P.C. -	0·5	8·0	32	34	23	2·5	40·5	59·5	13, 15
Four Adults, 1884-87.									
P.C. -	4·1	8·2	25·6	31·4	24·8	5·9	37·9	62·1	64, 70, 80, 81
Five Adult and Aged (Craigiehall), 1884-87.									
P.C. -	1·7	10·3	27·6	38·3	18·1	4·0	39·6	60·4	138, 121, 101, 78, 66

The half-yearly results in No. 20 show a sufficiently well marked preponderance of the second half, although it is less evident than in the other groups given in the Table, whether of young or old trees.

The monthly amounts and proportions indicate that the species is rather late in beginning to grow, and that the increase is comparatively small in the first two months. The four adults of 1884-87, indeed, have a fair proportion in April, but in May it is correspondingly small. In No. 20 June yields the highest increase, but it is not much above July. In the other sets it is the reverse, but the superiority of July is well marked only in the old trees. The united percentage of June and July is 58 in No. 20; 66, 57, and 66 in the other sets. On the whole the species continued to increase in girth well on to the end of the season.

The highest records in each month of No. 20 were 5 in April, 30 in May, 50 in June, 45 in July, 35 in August, and 15 in September. Taking in the three sets of older observation published in my former Papers, the figures are but little raised except in July. The highest there are April 15, May 30, June 55, July 60, August 40, and September 15.

No. 10.—QUERCUS ROBUR.

Year.	Apr.	May.	June	July.	Aug.	Sept.	1st Half Season.	2nd Half Season.	Girth in Inches at end of Observations.
1892.	...	15	30	30	15	...	45	45	...
1893.	10	15	20	20	10	...	45	30	...
1894.	10	10	20	20	5	...	40	25	...
1895.	5	10	15	5	0	...	30	5	...
Total,	25	50	85	75	30	...	160	105	13
P.C. -	9·4	18·8	32·1	28	11·7	...	60·3	39·7	...
FOUR YOUNG OAKS, 1887-91.									
P.C. -	1·5	15·5	17·5	40	21	4·5	34·5	65·5	11, 10, 8, 8
OLD OAK (CRAIGIEHALL), 1884-87.									
P.C. -	7	24	7	41	21	...	38	62	80

The results for the half-seasons in No. 10 are completely at variance with those for the other four young trees and for the old oak at Craigiehall. The incidence of the half-seasonal growths is greatly in favour of the first half in No. 10, and as much in favour of the second half in the others. No. 10, also, in place of agreeing with the young trees in having a very small April growth and a substantial September growth, corresponds with the old tree in having a large April proportion and no increase in September at all.

The difference may be partly explained by the manifestly increasing and abnormal deficit in No. 10 in the second half-season, which in the fourth year fell almost to zero. The uniformity in the records of the other four young trees tends to prove that their results are normal on the whole. Of the eighteen observations thirteen yield a great preponderance in the second half; in two the half-seasons are equal; and the three in which the first preponderates all happened in one year, and appear therefore to be due to a special failure, analogous to that of No. 10,

although in the latter the failure continued from season to season.

On the whole, therefore, it seems probable that the normal conduct of the very young British Oak is to throw its growth mainly into the second half of the season.

None of the Oaks yield remarkably large individual scores. The highest records in young and old are—April, 10; May, 30; June, 30; July, 40; August, 40; September, 10. So that there is not a single instance in any month of half an inch increase.

NO. 15.—QUERCUS CERRIS.

Year.	Apr.	May.	June.	July.	Aug.	Sept.	1st Half Season.	2nd Half Season.	Girth in Inches at end of Observations.
1892.	...	10	25	25	15	...	35	40	...
1893.	10	10	25	15	10	...	45	25	...
1894.	5	5	10	30	5	5	20	40	...
1895.	5	10	15	20	15	5	30	40	...
1896.	5	30	10	20	5	...	45	25	...
1897.	5	10	15	20	15	...	30	35	...
Total,	30	75	100	130	65	10	205	205	...
P.C. -	7·3	18·3	24·4	31·7	15·8	2·5	50	50	10
TWO WELL-GROWN TREES, 1884-87, 1887-91.									
P.C. -	2	24	14	34	20	6	40	60	63, 43

Although the half-season growths are exactly equal in No 15 on an average, they vary exceedingly from year to year; sometimes the first half greatly predominates, but in other years it is the reverse. This is probably due to youth, as in the two well-grown trees, one of which was at Craigiehall, the predominance of the second half-season is quite pronounced in every record.

The discrepancies between the young No. 15 and the two well-grown trees are not so great as between the young No. 10

and the other examples of *Quercus robur*, but they are great enough. They appear to be chiefly due to an almost invariable and remarkable deficiency in June in the older trees, whereby the amount is actually much less than in May. But for this strange anomaly the half-seasons would be about equal, as in No. 15. Another difference is that the percentage of April is greater, and of September less, in the young tree than in the older ones.

The highest individual records, including the three trees, were 10 in April, 20 in May, 25 in June, 30 in July, 30 in August, and 15 in April.

NO. 18.—QUERCUS RUBRA.

Year.	Apr.	May.	June.	July.	Aug.	Sept.	1st Half Season.	2nd Half Season.	Girth in Inches at last Observation.
1890.	...	10	20	40	15	5	30	60	...
1891.	...	10	15	45	25	5	25	75	...
1892.	...	10	30	50	25	...	40	75	...
1893.	10	20	45	45	30	...	75	75	...
1894.	10	15	25	35	50	...	50	85	...
Total,	20	65	135	215	145	10	220	370	11
P.C. -	3·4	11·0	22·8	36·5	24·6	1·7	37·2	62·8	...

The half-season results show a great preponderance in favour of the last, and this happened in every year of the five but one, when they were equal. The April proportion is small, but if the observations had been confined to the first three years it would have been nil, showing the necessity of a large number of years to give a fair average in the weak months of April and September, in which last month the percentage is even less. The proportion for August is high, higher than for June, and July is decidedly the best month. The record of 50 in August 1894 is very remarkable. It is very large for that month in any tree, and is the maximum of its year.

The highest individual records for each month were—for April 10, May 20, June 45, July 50, August 50, September 5.

THE GENUS QUERCUS.

Five species of *Quercus*, comprising ten young and four adult trees, have been under observation at various periods, two of which — *Q. conferta* and *Q. Ilex*—have been dealt with in my Paper of 1892. Taking the whole, the following have showed a decided preference for the second half-season :—

Quercus robur—four young trees	35	65
,, ,, —one adult tree	38	62
,, conferta—three young trees	39	61
,, Cerris—two adult trees	40	60
,, rubra—one young tree	37	63
,, Ilex—one young tree	25	75

On the other hand, of an apparently exceptional character were—

Quercus Cerris—one very young tree...	50	50
,, robur—one young tree, 1892-95	60	40

In the first of these the result may be due to extreme youth, and we have already given reasons why the results in the second may be abnormal.

Q. conferta is the most reliable species, as the three trees were vigorous, quick growers, and behaved with great uniformity. In it, therefore, the superiority of the second half-season is well made out, and this is the more remarkable as its April growth was steadier and larger than in any other kind of Oak or any other species under observation. In the other species of Oaks, indeed, the April increase was very small.

Apparently exceptional points in the genus are the low rate of June-increase in a large proportion of the trees, but most marked in the two adult examples of *Q. Cerris* and the old Craigie-hall tree, and the large percentage of August-increase in *Q.*

rubra. As to the first point, the following remarks occur in a previous Paper :—*

" I have made a separate study of this genus, as there seems to be a tendency in it to early vigour, followed by a period of slower growth. This is seen most unequivocally in the three Turkey Oaks, in all of which the June percentage is much exceeded by that of May on the one side and July on the other,

No.		April.	May.	June.	July.
63	Q. Cerris .	...	28	17	31
43	,, .	2	20	11	37
10*	,, .	3	22	6·5	35
	Average .	1·5	23	11·5	34
40	Q. conferta .	8	6·5	20	35·5
54	,, .	9	9	29·5	34
55	,, .	9	13	22·5	34
	Average	8·7	9·5	26	34·5

* At Craigiehall.

No.		April.	May.	June.	July.
72	Q. robur .	2	20·5	22·5	39
12	,, .	7	24	7	41
2	,, .	...	20·5	13	43·5
70	,, .	2·5	12·5	16	38
1	,, .	...	11	18	42
	Average .	2·3	17·7	15·8	40·7
44	Q. palustris	10	18	16	41
61	Q. rubra .	2	15	20	39

the general average of the three for from four to five years being 23 for May, 11·5, or exactly half, for June, and 34 for July. In the three Hungary Oaks, the most vigorous growers in early spring of all my deciduous trees, the same tendency is shown, but at an earlier stage and in a considerably less degree, the general proportions being 8·7 for May and 9·5 for June. The general average of the five British Oaks is 17·7 for May and 15·3 for June, in strong contrast with the proportions for thirty trees in mass, which are 12 for May and 31 for June. In *Q. palustris*, not a reliable specimen, however, June is slightly below May. In *Q. rubra* there is no actual inferiority, yet the tendency to it is probably shown by its May increase being one-third above that of the general average of trees, and the June increase one-third below it.

* Trans. and Proc. Bot. Soc., Ed., March 1892, p. 314.

NO. 4.—ŒSCULUS HIPPOCASTANUM.

Year.	Apr.	May.	June.	July.	Aug.	Sept.	1st Half Season.	2nd Half Season.	Girth in Inches at last Observation.
1892.	...	10	45	45	35	...	55	80	...
1893.	...	20	45	40	30	5	65	75	...
1894.	...	20	20	40	15	10	40	65	...
1895.	...	10	30	30	30	5	40	65	...
Total,	...	60	1·40	1·55	1·10	20	200	285	...
P.C. -	...	12·3	29·0	32·0	22·7	4·0	41·3	58·7	18
TWO YOUNG TREES, 1887-91.									
P.C. -	...	9·0	31·0	34·5	22	3·5	40	60	11, 13.

No. 4 is in agreement with the two trees of the earlier period, not only in the general particulars, but in details and degree. The second half-season predominates, there is no increase in April and little in September, July is the best month, and the percentage for August is high. The best individual records in the three trees are 20 in May, 50 in June, 45 in July, 35 in August, and 10 in September.

NO. 16.—ACER PSEUDOPLATANUS.

Year.	Apr.	May.	June.	July.	Aug.	Sept.	1st Half Season.	2nd Half Season.	Girth in Inches at last Observation.
1892.	...	10	55	35	5	5	65	45	...
1893.	...	35	50	30	20	5	85	55	...
1894.	5	5	50	45	10	5	60	60	...
Total,*	5	50	155	110	35	15	210	160	...
P.C. -	1·3	13·5	41·9	30	9·4	3·9	56·7	43·3	16
THREE YOUNG TREES, 1887-91.									
P.C. -	0·5	13	42·5	30	13	1	56	44	15, 14, 8

* I have omitted 1895, as in that year the increase suddenly fell off to less than half an inch, indicative of some abnormal condltion.

The correspondence between the single tree of the recent period and the three earlier ones is even more marked than in the last species (Horse Chestnut). Indeed, it is almost precise in every particular, with the trifling exception that the increase is more equally diffused over August and September in No. 16 than in the others. There is an appreciable though not excessive preponderance of the first half-season, due to the unusually large proportion of 42 per cent. of the increase being in June. 72 per cent. of the increase takes place in the two months June and July. The Sycamore is the first among forest trees to be in full foliage in the Edinburgh district, yet the girth-increase is slow to start, and is slight in May. It makes amends, however, by rushing on quickly in June. The best single records per month are 5 in April, 35 in May, 60 in June, 50 in July, 35 in August, and 5 in September.

NO. 12.—ACER CAMPESTRIS.

Year.	Apr.	May.	June.	July.	Aug.	Sept.	1st Half Season.	2nd Half Season.	Girth in Inches at last Observation.
1892.	5	20	35	55	45	5	60	105	...
1893.	10	20	30	35	30	5	60	70	...
1894.	5	10	40	35	10	5	55	50	...
1895.	...	...	20	10	5	...	20	15	...
1896.	...	15	30	40	15	...	45	55	...
1897.	...	10	25	25	30	...	35	55	...
Total,	20	75	180	200	135	15	275	350	...
P.C. -	3·2	12	28·8	32	21·6	2·4	44	56	19

The conduct of No. 12 has been most erratic. Starting in 1892 with the very large increase of 1·65, of which three-fifths were due to the last half-season, it fell off, in that half only, the next two years, till in the third the first half was slightly in excess. In the fourth year the foliage looked very sickly and some twigs

died, the increase falling to 35. In the next two years the tree revived, the increase rising to about an inch annually, still far below 1892, but with the second half-season again in excess. It seems probable, therefore, that this is the rule. The highest single records were—April 10, May 20, June 40, July 55, August 45, September 5.

I have been able to give seven years' results, as this tree was only very slightly pruned in 1896. It is the only one of the species that I have observed.

NO. 2.—FRAXINUS EXCELSIOR.

Year.	Apr.	May.	June.	July.	Aug.	Sept.	1st Half Season.	2nd Half Season.	Girth in Inches at last Observation.
1892.	5	20	55	35	15	...	80	50	...
1893.	10	30	45	25	...	..	85	25	...
1894.	10	20	40	45	5	...	70	50	...
1895.	10	25	45	35	10	...	80	45	...
Total,	35	95	185	140	30	...	315	170	...
P.C. -	7·2	19·5	38·1	29	6·2	...	64·8	35·2	17
TWO YOUNG ASHES, 1887-91.									
P.C. -	2	23·8	43·5	21·2	8·5	1	69·3	30·7	8, 10

The single Ash, No. 2, agrees in the main with the two younger trees of 1887-91. In both the second half-season is greatly inferior to the first, and June is by far the best month. The chief difference is the greater April growth of No. 2, but taking April and May together the proportions are almost identical.

No. 2 furnishes all the highest single scores, 10 in April, 30 in May, 55 in June, 45 in July, 15 in August, the annual increase having been much greater than in the other two, which were comparatively in their infancy.

NO. 3.—TILIA EUROPŒA.

Year.	Apr.	May.	June.	July.	Aug.	Sept.	1st Half Season.	2nd Half Season.	Girth in Inches at last Observation.
1892.	...	10	65	40	15	5	75	60	...
1893.	...	30	55	45	10	5	85	60	...
1894.	5	15	50	45	5	5	70	55	...
1895.	...	10	25	30	20	5	35	55	...
Total,	5	65	195	160	50	20	265	230	...
P.C. -	1·0	13·1	39·4	32·4	10·1	4·0	53·5	46·5	19
TWO YOUNG LIMES, 1887-91.									
P.C. -	...	13·5	53·5	24·5	5·5	3	67·	33·	10, 10
ONE ADULT LIME, 1884-91.									
P.C. -	...	3	32·5	55	6·5	3	35·5	64·5	46

The results in the three sets are very contradictory in the months of June and July. The two young trees of 1887–91 raised more than half their annual increase in June, whereas the adult of 1884–91 performed the same feat in July. In No. 3 July was inferior to June, but not so remarkably as in the other two young trees. The result of all this is that the young trees agree in throwing the largest share of their growth into the first half-season, but in No. 3 the excess is slight, while in the others it is very great. On the other hand, the second half-season is greatly in excess in the adult tree. The latter, however, although healthy in appearance, grew at the rate of only about a quarter of an inch annually, so that the results are untrustworthy. The two young Limes were also slow growers, and it is probable that No. 3 gives the most reliable results. They all agree in the smallness of the increase in the first and last two months. 72 per cent. of the annual increase took place in June and July in No. 3, 77 per cent. in the other two young trees,

and 87 per cent. in the adult. The highest single records all took place in No. 2, and were 5 in April, 30 in May, 65 in June, 45 in July, 20 in August, and 5 in September.

ULMUS MONTANA.

No Wych Elm was under monthly observation in 1892–95, but I give the results in two thriving specimens for 1888–91 :—

NO. 93, 94.—ULMUS MONTANA.

No.	Apr.	May.	June.	July.	Aug.	Sept.	1st Half Season.	2nd Half Season.	Girth in Inches at last Observation.
93.	10	105	200	180	150	35	315	365	19·55
94.	15	85	205	135	95	30	305	260	16·35
Total,	25	195	405	315	245	65	620	625	...
PERCENTAGE.									
93.	1·5	15	30	26·5	22	5	46·5	53·5	...
94.	2·5	15	36·5	24	17	5	54	46	...
	2	15	32·5	25·5	20	5	49·5	50·5	...

The general result is that the two half-seasons are nearly equal. But taking details, No. 93, the more vigorous grower, although 94 is little inferior to it, has a slight preference for the second half-season, while 94 has a somewhat greater preference for the first half. The difference is somewhat greater than it would otherwise have been owing to the peculiar results in 1888, when the increase in the two trees was nearly equal in the first half, while in the second half that of 93 was just double that of 94.

June was decidedly the best month in both ; the proportions of May and August were fair, but those of April and September rather insignificant.

The highest individual records were 5 in April, 30 in May, 65 in June, 50 in July, 50 in August, and 15 in September.

ULMUS CAMPESTRIS.

Year.	Apr.	May.	June.	July.	Aug.	Sept.	1st Half Season.	2nd Half Season.	Girth in Inches at last Observation.
1892.	...	5	25	20	25	...	30	45	...
1893.	5	10	20	25	...	...	35	25	...
1894.	5	5	15	15	5	10	25	30	...
1895.	...	5	20	10	10	5	25	25	...
Total,	10	25	80	70	40	15	115	125	...
P.C. -	4·2	10·4	33·3	29·2	16·6	6·3	47·9	52·1	12

This species does not attain perfection in Scotland, as is indicated by the low rate of increase, only from half to three-quarters of an inch annually in this specimen. The half-seasons are nearly equal, and June is the best month, but in no month is there a better single record than a quarter of an inch.

SALIX SP.

Year.	Apr.	May.	June.	July.	Aug.	Sept.	1st Half Season.	2nd Half Season.	Girth in Inches at last Observation.
1892.	...	35	80	65	45	20	115	130	...
1893.	15	45	60	65	75	15	120	155	...
1894.	25	30	40	70	75	25	95	170	...
1895.	5	50	95	85	95	70	150	250	. .
1896.	25	55	55	75	65	25	135	165	...
1897.	...	35	15	70	90	30	50	190	...
Total,	70	250	345	430	445	185	665	1060	...
P.C. -	4·0	14·5	20	25	25·8	10·7	38·5	61·5	23
THE SAME TREE WHEN YOUNGER, 1888-91.									
P.C. -	1·0	13·5	22·5	26·5	26·5	10	·37	63	8

Although only one Willow was under observation, the results are probably among the most reliable of all, from the large increments all through the nine years. The tree also has been steadily under observation for the long period of nine years, which enables a comparison to be made between three years of infancy and six of youth, observations having been begun when it was a mere wand, an inch and a half in girth, and continued till it measured two feet. It will be seen from the Table that there is scarcely any difference in the monthly percentages between the earlier and later stage, a larger proportion for April in the later stage being alone noticeable. The second half-season preponderates in the large proportion of above three to two. No single month has the mastery, July and August being equal, and June not much behind them. September is unusually high, and thus the increase is more equably distributed over the growing season than in any other species.

Very high individual scores are numerous. Three times, once in June and twice in August, the tree nearly accomplished a score of an inch, but perhaps the record of nearly three-quarters of an inch in September of 1895 is more remarkable. The highest records for each month are:—April, 25; May, 55; June, 95; July, 85; August, 95; September, 70.

NO. 9.—POPULUS FASTIGIATA.

Year.	Apr.	May.	June.	July.	Aug.	Sept.	1st Half Season.	2nd Half Season.	Girth in Inches at last Observation.
1892.	...	10	25	55	30	5	35	90	...
1893.	...	15	45	50	25	...	60	75	...
1894.	5	10	15	40	35	...	30	75	...
1895.	...	15	45	40	30	...	60	70	...
Total,	5	50	130	185	120	5	185	370	...
P.C. -	1·0	10·1	26·4	37·5	24	1·0	37·5	62·5	14
TWO YOUNG TREES, 1887-91.									
P.C. -	1	8	20·5	34·5	33	3	29·5	70·5	14, 12

There is a substantial agreement in the main facts between No. 9 and the two of the earlier period, all of much the same age. The main increase is thrown into the second half-season very decidedly in No. 9, but still more so in the others, and July is the best month, but only to a trifling degree above August in the latter. Indeed, the percentage of 33 in August with them is almost unprecedentedly high; *Robinia* alone slightly exceeds it, and no other species comes near it.

The best individual records are April 5, May 20, June 55, July 65, August 50, September 10.

NO. 7.—ALNUS GLUTINOSA.

Year.	Apr.	May.	June.	July.	Aug.	Sept.	1st Half Season.	2nd Half Season.	Girth in Inches at last Observation.
1892.	...	10	30	20	20	5	40	45	...
1893.	5	15	15	30	15	...	35	45	...
1894.	...	...	15	25	20	...	15	45	...
1895.	5	15	15	20	15	...	35	35	...
Total,	10	40	75	95	70	5	125	170	...
P.C.	3·4	13·5	25·3	32·2	24·0	1·6	42·2	57·8	11
ONE YOUNG TREE, 1887-91.									
P.C.	1	11	38	33	16	1	50	50	14

This species is not satisfactorily made out. No. 7 gives a decided superiority to the second half-season, while the half-seasons are equal in the other tree. Both, but particularly the latter, were erratic in their conduct, and it is not safe to draw any conclusions as to the monthly distribution of the species.

The highest records were April 5, May 20, June 45, July 40 August 25, September 5.

NO. 17.—BETULA ALBA.

Year.	Apr.	May.	June.	July.	Aug.	Sept.	1st Half Season.	2nd Half Season.	Girth in Inches at last Observation.
1892.	...	30	50	40	45	5	80	90	...
1893.	15	50	35	40	30	10	100	80	...
1894.	15	35	40	40	25	5	90	70	...
1895.	5	25	30	30	30	15	60	75	...
Total,	35	140	155	150	130	35	330	315	...
P.C.	5·4	21·7	24·0	23·3	20·2	5·4	51·1	48·9	20
TWO YOUNG TREES, 1887-91.									
P.C.	1·5	15	32·5	27·5	19	4·5	49	51	25, 14

No. 17 agrees closely with the other two in the half-season proportions, which are nearly equal. The chief difference in details is that the increase of the first half-season was more equably distributed in No. 17 than the others. The former was much quicker in growth, so that all the highest scores occur in its records. They are April 15, May 50, June 50, July 40, August 45, September 15.

A much larger Birch, at Craigiehall, five feet in girth, and growing at the rate of half an inch yearly, gave quite different and altogether anomalous results. During the six years' observations it had no increase whatever in April and May, the only instance in any tree of any kind I ever met with. Consequently the proportion of the first half-season, confined to the single month of June, was only 27 p.c. With all this the tree seemed quite healthy.

NO. 11.—CRATÆGUS OXYACANTHA.

Year.	Apr.	May.	June.	July.	Aug.	Sept.	1st Half Season.	2nd Half Season.	Girth in Inches at last Observation.
1892.	....	10	35	30	20	5	45	55	...
1893.	5	15	35	25	25	5	55	55	...
1894.	5	5	30	25	15	5	40	45	...
1895.	...	10	30	30	15	15	40	60	...
Total,	10	40	130	110	75	30	180	215	...
P.C.	2·5	10·0	33·0	27·9	19·0	7·6	45·5	54·5	14
ONE YOUNG TREE, 1887-91.									
P.C.	4·5	9·5	28	22	24·5	11·5	42	58	15

The two agree in giving a slight or moderate predominance to the second half-season and in the monthly details, except that the distribution is more equable in the earlier example, in which the increase is remarkably large at the end of the growing season, the amount for August being greater than in July, and that for September almost unprecedentedly high.

The highest scores are April 15, May 15, June 40, July 35 August 45, September 25.

NO. 1.—CYTISUS LABURNUM.

Year.	Apr.	May.	June.	July.	Aug.	Sept.	1st Half Season.	2nd Half Season.	Girth in Inches at last Observation.
1892.	...	10	20	25	30	...	30	55	...
1893.	...	10	20	15	10	...	30	25	...
1894.	5	5	20	35	10	5	30	50	...
1895.	...	10	20	10	5	...	30	15	...
Total,	5	35	80	85	55	5	120	145	...
P.C.	1·9	13·2	30·2	32·0	20·8	1·9	45·3	54·7	11
A YOUNG TREE, 1887-91.									
P.C.	7	14·5	24·5	25·5	20	8·5	46	54	9

The half-yearly results in No. 1 in its two years of greatest increase are much in favour of the second period, but the reverse is true of the two less prosperous years, the general result being still in favour of the second period. These results are confirmed by the other tree in every particular. The erratic conduct in both has been too great to establish a law. The only marked difference in the two trees is the more general distribution of the increase in the earlier tree, the percentage for April and September being unusually high.

The highest individual scores are April 10, May 15, June 35, July 35, August 30, September 10.

PYRUS AUCUPARIA.

Year.	Apr.	May.	June.	July.	Aug.	Sept.	1st Half Season.	2nd Half Season.	Girth in Inches at last Observation.
1892.	...	5	35	30	15	...	40	45	...
1893.	5	20	35	25	5	...	60	30	...
1894.	5	5	20	30	10	5	30	45	...
1895.	...	10	15	20	15	...	25	35	...
Total,	10	40	105	105	45	5	155	155	...
P.C.	3·1	12·9	34	34	14·5	1·5	50	50	14
TWO YOUNG TREES.									
P.C.	1·5	5·5	29·3	37	20	6·7	36·3	63·7	15, 9

The conduct of all three trees was erratic, except the quickest grower of the two earlier ones, which always threw the mass of its growth into the second half-season, the percentages being 28 and 72. The highest individual scores were—April, 5; May, 20; June, 35; July, 45; August, 30; September, 10.

PYRUS COMMUNIS.

Year.	Apr.	May.	June.	July.	Aug.	Sept.	1st Half Season.	2nd Half Season.	Girth in Inches at last Observation.
1892.	...	10	40	15	20	10	50	45	...
1893.	...	25	20	25	15	5	45	45	...
1894.	...	10	20	25	10	...	30	35	...
1895.	5	5	25	20	5	10	35	35	...
	5	50	105	85	50	25	160	160	14
	1·6	15·6	32·8	26·9	15·6	7·5	50	50	...

The rate of increase seems low, but I have no other specimen for comparison, and, as it has steadily decreased annually, the tree may not be in a normal condition. As it stands, the half-seasons are exactly equal. June is the best month, and the September proportion is above average. The best single scores are—April, 5; May, 25; June, 40; July, 25; August, 20; September, 10.

NO. 5.—PRUNUS PADUS.

Year.	Apr.	May.	June.	July.	Aug.	Sept.	1st Half Season.	2nd Half Season.	Girth in Inches at last Observation.
1892.	5	25	60	65	40	5	90	110	...
1893.	10	50	40	50	35	5	100	90	...
1894.	5	30	50	50	20	5	85	75	...
1895.	5	25	50	55	30	5	80	90	...
Total,	25	130	200	220	125	20	355	365	...
P.C. -	3·5	18·0	27·8	30·6	17·4	2·7	49·3	50·7	20
ONE YOUNG TREE, 1887-91.									
P.C. -	2	8	36	32	18	4	46	54	13

The half-season proportions agree fairly well in these two trees, in giving a slight preference to the second. In the general distribution they differ in the higher percentage of No. 5 in the beginning of the season, and in its preferring July, while the other chooses June. No. 5 was much the more vigorous of the two, having the high average annual increase of an inch and three-quarters. The highest scores are all from it, except for September. They are—April, 10; May, 50; June, 60; July 65; August, 40; September, 15.

NO. 14.—ROBINIA PSEUDACACIA.

Year.	Apr.	May.	June.	July.	Aug.	Sept.	1st Half Season.	2nd Half Season.	Girth in Inches at last Observation.
1892.	5	5	10	20	20	...	20	40	...
1893.	5	5	15	15	25	10	25	50	...
1894.	5	5	10	25	25	15	20	65	...
1895.	...	20	25	35	45	30	45	110	...
1896.	10	15	15	30	30	...	40	60	...
1897.	5	5	15	15	50	5	25	70	...
Total,	30	55	90	140	195	60	175	395	...
P.C. -	5·2	9·6	15·9	24·6	34·2	10·5	30·7	69·3	12

The most remarkable fact about this stranger from a warmer clime is the general distribution over the six months, combined with a great excess of energy in the last half of the season. In one year the increase for September was no less than ·30; its percentage for that month, 10·5, is high; and as to August, it takes the premier place among the months with 34·2 per cent., and it is the only month with an individual score of half an inch.

I have no other tree of the species to compare it with, but another foreigner—a much older tree, however—has a similar but even more extreme record. This is *Liriodendron tulipiferum*, a handsome specimen, nearly seven feet in girth in 1887, when its four years' record closed. I give the monthly proportions for the two trees :—

	Apr.	May.	June.	July.	Aug.	Sept.	1st Half Season.	2nd Half Season.
Robinia Pseudacacia ...	5·2	9·6	15·9	24·6	34·2	10·5	30·7	69·3
Liriodendron tulipiferum	2	4	4	34	43	13	10	90

C. General Conclusions from the Monthly History of the Species.

In considering some of the conclusions that may be drawn from the history of the species, it is necessary to adopt three categories according to the degree of reliability in the results obtained in the different species. The first includes the species of the period 1891–94 (in which only one example of each was observed) that yielded results in conformity with those obtained from one or more trees of their own species under observation in 1887–91. The second comprises the species in which the results for the two periods are at variance, or are otherwise invalidated. The third contains the species of which only one tree has been under observation.

The chief points to which attention will be directed are the comparative tendency in the different species to early or late increase in girth during the growing season, and the comparatively wide or limited distribution of the girth-increase over the growing season in the different species.

1. Species in which the resnlts for 1892-95 and for 1887-91 are in substantial agreement.

In this category the results are naturally the most reliable, and may be held to establish fairly well the characteristics of the species included, in regard to the points under consideration.

(a.) **The comparative tendencies of the species towards early or late increase in girth during the season of growth** are shown in the Table which gives the percentage of girth-increase due to each month in the trees of 1887–91 and of 1892–95 combined, the arrangement being in the order of greatest tendency to increase in the latter half of the season.

[TABLE.

	Apr.	May.	June.	July.	Aug.	Sept.	1st Half Season.	2nd Half Season.
Populus fastigiata, ...	1	9	23·5	36	28·5	2	33·5	66·5
Quercus conferta, ...	9	9·5	20·5	34·5	23	3·5	39	61
Œsculus Hippocastanum,	0	11	30	33	22	4	41	59
Fagus sylvatica,... ...	1	10·5	31·5	30·5	22	4·5	43	57
Cratægus Oxyacantha,...	3·5	9·5	30·5	25	22	9·5	43·5	56·5
Prunus Padus, ...	3	13	32	31	18	3	48	52
Betula alba, ...	3·5	18	28	25·5	20	5	49·5	50·5
Ulmus montana, ...	2	15	32·5	25·5	20	5	49·5	50·5
Fraxinus excelsior, ...	4·5	22·5	40·5	25	7	0·5	67·5	32·5

On referring back to the history of the species, where the averages for both periods, 1892-95 and 1887-91, are given, it will be seen that in *Œsculus*, *Acer*, and *Betula* these averages are almost identical as regards the half-seasons, and that in general there is a close approximation even in the monthly averages. In *Fagus*, *Fraxinus*, *Populus*, *Cratægus*, and *Prunus* the differences in the two periods are greater, but it is only a question of degree, the general tendencies being similar. *Quercus conferta* is included, although no example was under observation in either of the above periods, because the three trees of 1884-87 yielded such large and steady results, all in harmony with each other, that the laws of girth-increase are probably as well established in it as in any other species. The specimen of *Ulmus montana* observed in the last period proved an utter failure, but as the two of 1887-91 were very fine trees, I give the average as being probably reliable enough, although there were some considerable disagreements in details.

The general result is that in *Populus*, *Quercus*, and *Œsculus* the difference in favour of the second half-season is large; in *Fagus* and *Cratægus* it is comparatively small; in *Ulmus*, *Prunus*, and *Betula* there is an equality, or nearly so; and in *Fraxinus* the advantage is largely on the side of the first half-season. Taking the extremes, the proportions are as 2 to 1 in favour of the second half-season in *Populus*, and the same in favour of the first half-season in *Fraxinus*.

(b.) The distribution of the girth-increase over the growing season shows considerable variety in the Table, but it is difficult to indicate it systematically. One way is to set the three best consecutive months against the other three. The three best are June, July, and August, except in *Fraxinus*, which prefers May, June, and July. The percentages then are as follows :—

	Three Best Consecutive Months.	The Other Three Months.
Populus fastigiata, ...	88 p.c.	12 p.c.
Fraxinus excelsior, ...	88	12
Œsculus Hippocastanum, ...	85	15
Fagus sylvatica,...	84	16
Prunus Padus, ...	81	19
Quercus conferta, ...	78	22
Ulmus montana, ...	78	22
Cratægus Oxyacantha,... ...	77·5	22·5
Betula alba, ...	73·5	26·5

But this chiefly shows that certain species accomplish a considerably greater part of their increase in the three chief months than others, and therefore have presumably a less general spread over the whole period, and the comparative wideness of the spread is better seen if we take the percentages in each species due to the months of April and September united, or at the beginning and end of the season. The order is thus :—*Cratægus* 13 per cent., *Quercus* 12·5, *Betula* 8·5, *Ulmus* 7, *Prunus* 6, *Fagus* 5·5, *Fraxinus* 5, *Œsculus* 4, *Populus* 3. The result is but slightly to change the order as obtained by the first process, and to show that on the whole the seasonal distribution is widest in *Cratægus*, *Quercus conferta*, and *Betula*, and is most limited in *Fraxinus*, *Œsculus*, and *Populus*. A further examination proves that the limitation to a comparatively small increase is at both ends of the season in *Populus*, at the beginning of the season in *Œsculus* and *Fagus*, and at its end in *Fraxinus*.

To put the case in another way, it may be said in a rough way that increase in girth was going on with comparative vigour for five months in *Quercus conferta* and *Cratægus*, for four months in *Fagus*, *Œsculus*, *Prunus*, *Ulmus*, and *Betula*, and for only three in *Populus*, *Acer*, and *Fraxinus*.

(c.) **Progress of girth-increase from month to month.**—Usually there is a progressive rise from the minimum in April to a maximum either in June or July, from which the fall to September is also progressive. Sometimes the actual minimum is in September instead of April. The only exception to this progressive rise and fall is in *Quercus conferta*, in which the percentages for April and May are equal, and the observation is quite reliable, as the amounts are substantial and consistent throughout. Of course it results from what has gone before that the rise and fall are quicker or more abrupt in some species than in others.

(d.) **Highest and lowest average percentages in each month, and the species to which they were due.**—The highest for April was 9 per cent. of the annual increase in *Quercus conferta*; for May, 22·5 in *Fraxinus*; June, 42 in *Acer*; July, 36 in *Populus*; August, 28·5 in *Populus*; September, 9·5 in *Cratægus*. The lowest for April was 0·0 in *Acer*; for May, 9 or 9·5 in *Quercus conferta*, *Populus*, and *Cratægus*; June, 23·5 in *Populus*; July, 25 or 25·5 in *Fraxinus*, *Betula*, and *Cratægus*; August, 7 in *Fraxinus*; September, 0·5 in *Fraxinus*.

2. Species in which the results for 1892-95 are at variance with those for 1887-91, or which are otherwise untrustworthy.

The reasons for regarding as more or less questionable the results in this class have been already given in the history of the five species which it includes, and need not be repeated.

(a.) Comparative tendencies towards early or late increase in girth.—Taking the results for what they are worth, the first five species in the Table seem to have a decided preference for the last half of the season, while the sixth is in favour of the first half.

	Apr.	May.	June.	July.	Aug.	Sept.	1st Half Season.	2nd Half Season.
Quercus robur, ...	1·5	15·5	17·5	40	21	4·5	34·5	65·5
Carpinus Betulus, ...	2	8	29·5	27·5	26	7	39·5	60·5
Pyrus Aucuparia, ...	2	9·5	31·5	35·5	17·5	4	43	57
Alnus glutinosa,... ...	2	12·5	32	32·5	20	1	46·5	53·5
Cytisus Laburnum, ...	5	14	27	28·5	20·5	5	46	54
Tilia europœa, ...	1	13	46·5	28·5	8	3	60·5	39·5

With regard to *Quercus robur*, for the reasons given in its history I have rejected the tree of 1891–95 and adopted the average of the four young Oaks of 1887–91, as being much more likely to be truly representative. As the defaulter has been transplanted to properly prepared ground, it will be interesting to see whether it will now fall into line with the others.* The erratic conduct of the representatives of *Pyrus*, *Alnus*, and *Cytisus* defies explanation, and there was nothing for it but to take their combined averages for both periods. In *Tilia* the difference is rather of degree than kind, but is so extreme as to shut it out from the reliable list. It is probable enough, however, that the united average, which I have given, is fairly representative. *Carpinus* was not observed in 1892–95, but the two young trees of 1887–91 did not agree well, and were in total disagreement with an old tree.

(b.) **The distribution of the girth-increase over the growing season** seems to be most extended and equable in *Cytisus Laburnum*, and confined within the narrowest limits in *Tilia europœa*, in which three-fourths of the whole took place in two months.

(c.) **Progress of girth-increase from month to month.**—In none of these species, except *Quercus robur*—and that in a less degree—was there a check in the rise and fall such as was noticed in *Quercus conferta* of the previous set. In three of them the movement was of an average kind, but in *Quercus robur* a very marked rise in July, and in *Tilia* a still more marked rise in June, were noticeable.

(d.) **Highest and lowest scores in each month.**—The highest for April was 5 p.c. of the annual increase in *Cytisus*; May, 15·5 in *Quercus*; June, 46·5 in *Tilia*; July, 40 in *Quercus*; August, 21 in *Quercus*; September, 7 in *Carpinus*. The lowest for April was 1 in *Tilia*; May, 9·5 in *Pyrus*; June, 17·5 in *Quercus*; July, 28·5 in *Cytisus* and *Tilia*; August, 8 in *Tilia*; September, 1 in *Alnus*.

3. Species in which only one young tree has been under observation.

As we have no means of checking the results in these species

* October 1899. I find that it has done so in this the first available year since transplantation, the increase having been ·35 in the first half-season, and ·70 in the second.

by comparison, all that can be done is to give the results in the same tabular form as in the other two classes, and although there is a considerable variety in their reliability it does not seem to be practicable to divide them into categories in that respect, and it will be sufficient to point out the species which appear to be most worthy of confidence, as we go along.

	Apr.	May.	June.	July.	Aug.	Sept.	1st Half Season.	2nd Half Season.
Robinia Pseudacacia, ...	5	9·5	16	25	34	10·5	30·5	69·5
Quercus rubra, ...	3·5	11	22·5	36·5	25	1·5	37	63
Salix sp., ...	2·5	14	21	26	26·5	10	37·5	62·5
Acer campestris, ...	3	12	29	32	21·5	2·5	44	56
Ulmus campestris, ...	4	10·5	33·5	29	17	6	48	52
Quercus Cerris, ...	7·5	18	24·5	31·5	16	2·5	50	50
Pyrus communis, ...	1·5	15·5	33	27	15·5	7·5	50	50

The *Robinia*, always in good condition, growing consistently, and under observation for six years, may be considered reliable for so very young a tree. It threw no less than 70 p.c. of its increase into the latter half of the growing season, surpassing in this proportion all my other trees, save *Liriodendron tulipiferum*, another native of sunnier climes, in which the proportion rose to 90 p.c., but which does not appear in the Table, as it is an old tree.

If results in any single tree may be relied on as representative of its species, our *Salix* may make the claim, owing to its large increments and the regularity and consistency of its conduct during the long period of nine years.

Quercus rubra and Q. Cerris are not quite so favourably situated, as although they are fine, healthy trees, growing at good rates, they were somewhat erratic in conduct, due perhaps to extreme youth. *Q. Cerris* also disagrees with the two adult and very fine trees that were under observation in the earlier period.

Ulmus campestris and *Acer campestris* are species that can scarcely be said to thrive in Scotland, and the example of *Pyrus*

communis is under suspicion in regard to health, as its increase diminished year by year in place of increasing as it ought to have done in so young a tree; but taking the first year, when the increase was all but an inch, the distribution in the half-seasons was nearly the same as in the total period of four years.

As to the distribution in the four most reliable species, it may be pointed out that it is well spread over the season in all of them. Even in *Robinia*, which shows such a decided preference for the end of the season, the increase began in April in five years out of six. In *Salix* the spread is more equable over five months than in any other species under my observation, and although the proportion for April, the remaining month, is small, it is quite appreciable.

The highest records for the months are—for April, 7·5 in *Quercus Cerris*; for May, 18 in *Q. Cerris*; for June, 33·5 and 33 in *Ulmus* and *Pyrus*; for July, 36·5 in *Q. rubra*; for August, 34 in *Robinia*; and for September, 10·5 and 10 in *Robinia* and *Salix*. The lowest—in April, 1·5 in *Pyrus*; May, 9·5 in *Robinia*; June, 16 in *Robinia*; July, 25 in *Robinia*; August, 15·5 and 16 in *Pyrus* and *Q. Cerris*; September, 1·5 in *Q. rubra*.

D. Bi-Monthly percentage of Increase in the Single Trees of Twenty Species, 1891-95.

The last form in which I show the comparative proportions of the monthly increase in girth of the different species is in bi-monthly periods for the twenty single trees of the set 1891–95, Table VIII. As previously explained, some of these trees are less reliable than others, but I give the whole for what they are worth. A few of the chief results may be pointed out.

In the first, or April-May period, a proportion of 20 p.c. and upwards, or one-fifth of the seasonal growth, was attained by five species, while in nine species it was below 15 p.c. The highest proportion was in *Quercus robur*, 28 p.c., and the lowest in *Populus fastigiata*, 12 p.c.

In the middle, or June-July period, eleven, or a little above the half of the species, attained a proportion of above 60 p.c. of the seasonal growth, and in three the proportion was below 50 p.c. The highest proportion was 72 p.c. in *Acer Pseudoplatanus*, and the lowest, 40 p.c., in *Robinia Pseudacacia*.

In the last, or August-September period, nine species, or nearly one-half, attained a proportion of 25 p.c., or one-fourth of the seasonal growth, and in four it was under 15 p.c. The highest proportion was 45 p.c. in *Robinia*, and the lowest 6 p.c., in *Fraxinus excelsior*.

TABLE VIII.

BI-MONTHLY P.C. OF GIRTH-INCREASE IN SINGLE TREES OF TWENTY SPECIES, 1891-95, ARRANGED IN THE ORDER OF AMOUNT.

	First Two Months.		Middle Two Months.		Last Two Months.
Quercus robur	28·2	Acer Pseudop.	71·9	Robinia	45·0
Betula alba	27·1	Tilia	71·8	Salix	36·5
Fraxinus excelsior	26·7	Pyrus Auc.	68·0	Fagus	27·8
Quercus Cerris	25·6	Fraxinus	67·1	Œsculus	26·7
Prunus Padus	21·5	Populus	63·9	Cratægus	26·6
Salix sp.	18·5	Ulmus	62·5	Quercus rubra	26·1
Pyrus communis	17·2	Cytisus	62·2	Alnus	25·6
Alnus glutinosa	16·9	Œsculus	61·0	Betula	25·6
Pyrus Aucuparia	16·0	Cratægus	60·9	Populus	25·0
Acer campestris	15·2	Acer camp.	60·8	Acer camp.	24·0
Cytisus Laburnum	15·1	Quercus rob.	60·1	Pyrus com.	23·1
Robinia Pseud-acacia	14·8	Pyrus com.	59·7	Ulmus	22·9
Acer Pseudoplatanus	14·8	Prunus	58·4	Cytisus	22·7
Ulmus campestris	14·6	Fagus	58·0	Prunus	20·1
Quercus rubra	14·4	Alnus	57·5	Quercus Cerris	18·3
Fagus sylvatica	14.2	Quercus rub.	57·3	Pyrus Auc.	16·0
Tilia europœa	14·1	,, Cerris	56·1	Tilia	14·1
Cratægus Oxy-acantha	12·5	Betula	47·3	Acer Pseudop.	13·3
Œsculus Hippocas-tanum	12·3	Salix	45·0	Quercus rob.	11·7
Populus fastigiata	11·1	Robinia	40·5	Fraxinus	6·2

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