Regional Spread of Moisture in the Wood of Trees. III.

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With Plates CLXXX–CXC.

I. Deciduous-Leaved Trees during the Period late Autumn to Early Spring (Contd.).

An earlier paper* summarised the results of experiments on the moisture content of the wood of newly felled trees of *Acer Pseudoplatanus* at various times during the leafless period. Up to that time only two species of true heart-wood trees had been examined, viz. *Ulmus montana* and *Quercus cerris*. From the one specimen of each that had then been examined it was possible to say† merely that the results obtained were comparable with those for *Acer* and to suggest that in all probability true heart-wood trees would be found to be similar to *Acer* in their behaviour as regards moisture-spread throughout the entire leafless period.

Subsequently a series of trees of *Ulmus* was examined in exactly the same way as that of *Acer*, the months of felling being October, November, January and March. The general results were exactly as predicted. Moisture storage takes place in the heart-wood in the end of the year and this moisture travels outwards as the season progresses. Slight differences of detail when compared with *Acer* were observed but these in no way affected the general results and in the present state of our knowledge I

* Notes Roy. Bot. Gard. Edin., vol. xi. No. LI. p. 1 (1918); for second paper see ibid, vol. xii. No. LIX. p. 187 (1920).

† Notes Roy. Bot. Gard. Edin. vol. xi. No. LI. p. 13 (1918).

[Notes, R.B.G., Edin., No. LXVI, January 1923.]

had decided to limit the *Ulmus* experiments to elucidation of the one broad principle. It is unnecessary to supply the graphs for *Ulmus* as these are in general but repetition of those for *Acer*.

It may be interesting to record one small experiment which although not carried out by a method ensuring absolute accuracy, yet gave rather unexpected results which might be regarded as suggestive of future lines of investigation.

In the case of one of the trees the annual rings were so broad that I decided to split the ring roughly into Spring and Summer wood and to examine these two separately. The result was that the Summer wood contained on an average about 10% more moisture than the Spring wood. This tree was then in the centre-storage condition. Unfortunately no equally broad rings were present in any of the other trees but some were just broad enough to allow of their being split and the result was that the Spring wood showed a decidedly higher moisture-percentage than the Summer wood. Apparently then when the moisture is stored in the centre of the trunk the Summer wood has the higher percentage but when the moisture is moving outwards the Spring wood has the higher. In recording this small experiment I am well aware of the fact that the methods employed do not give results from which satisfactory conclusions can be drawn. No account has been taken, for example, of the difference in specific gravity between the earlier and the later formed wood of the year. In spite of this I think the results may be worthy of record.*

II. Deciduous-Leaved Trees during the Leaf-bearing Period.

From the condition of the last graph published† to the summer condition with, as I presumed, a large central comparatively dry area, the transition would seem easy. It was legitimate to imagine the large percentage of moisture just inside the cambium in March as very rich in sugar and as ready to be drafted to the cambium at its own level or higher up. The exhaustion of this store, rapid owing to the tree's spring growth activities, would result in the summer condition as presumed. The process is however no such simple one.

This paper is a continuation of that already published‡ and gives the results obtained from the following trees of *Acer Pseudoplatanus* :—

1. Tree felled entire on the morning of 23rd April 1918. At this time the buds were just open and a few leaves here and there were showing. Growth had not yet begun on the trunk but the

* Notes on decidous Coniferae will be found under Coniferae.
† Notes Roy. Bot. Gard. Edin., vol. xi. No. LI. Pl. CLIX (1918).
‡ Notes Roy. Bot. Gard. Edin., vol. xi. No. LI. p. 1 (1918).

cambium throughout was decidedly swollen and "bark" was easily separable. Growth had begun on two year old twigs where a row of spring vessels was fully formed.

This tree was not a satisfactory specimen as it showed very slow diameter growth compared with neighbouring trees of the same age and subsequently in chipping up the cuts it was observed that the pith was discoloured all through the bole and well up into the crown and also that in the centre of the lowermost cut a small area of wood was discoloured. The unexpected results obtained might have been due to this diseased condition and it was resolved to examine another tree which appeared quite healthy.

2. Tree felled entire on the morning of 7th May 1918, when practically all the buds were open but only a few leaves here and there were expanded, i.e. this tree was almost in the same condition as the April one as regards its buds. The results obtained confirmed those of the April tree.

3. Tree felled entire on the morning of 14th May 1918 when the first leaves were all just fully expanded.

4. Tree felled entire on the morning of 20th August 1918.

These four trees represent two phases—distinct in the tree's activities and very distinct in the results :—

a. Bud opening and expanding phase as represented by the April and May trees.

b. Full leaf condition as represented by the August tree.

These two fall to be treated separately.

a. April and May.

As already indicated the results obtained from these trees were quite unexpected. Buds from the March tree opened three days* after felling. Yet owing to a prolonged cold spell I had to wait from 23rd March to 23rd April before a tree showing the opening bud condition was available. This interval was so long that results which I here refer to from the April tree as representing the bud-opening condition may in reality be the state of affairs in a tree with the buds just ready to burst, i.e. the moisture distribution as published for the March tree† may not be the final stage in the closed bud condition. Further experiments alone can settle this point. But however that may be we can still discuss the March and April results as *a* closed-bud condition and *the* bud-opening condition respectively.

The most striking result obtained from this series is the position in the lowermost cuts of the area of maximum moisture content in the case of the April and the first May trees (Plates CLXXXII–CLXXXIII). Here we find the moisture heaped up

* Notes Roy. Bot. Gard. Edin., xi. No. LI. p. 9 (1918).
† Notes Roy. Bot. Gard. Edin., xi. No. LI. Pl. CLIX (1918).

towards the centre—exactly the reverse of the March condition and further in the first May tree we have in the bottom cut a return of the three-wave graph. In short, comparison of the graphs of the bottom cuts for the first May tree (Pl. CLXXXIII) and the January tree (Pl. CLVII) shows that they are practically identical. Nor does the similarity of the results obtained from these two trees end here. There is a general resemblance throughout all the results as plotted for these two trees.

Again, the second May tree shows results (Pl. CLXXXIV) comparable with those of the March tree (Pl. CLIX) but on a much smaller scale. Here there is once more the maximum moisture percentage almost on the outside, though that maximum is very much smaller than in March. Since then the first May tree resembles so closely the January tree in its moisture distribution and the second May tree is comparable with the March tree, one may legitimately ask whether in the interval April-May (?March-May) the moisture does not go through the same movements on a reduced scale and at greatly accelerated speed as in the longer interval October-March.

Again in the second May tree (Pl. CLXXXIV) there is in the uppermost two cuts a decided increase in moisture percentage towards the outside. This increased percentage is correlated with the fact that here growth has now commenced.

The time relationship of bud-opening and the commencement of diameter increase is not the same for all trees. In the trees of *Acer Pseudoplatanus* examined growth began at the twigs when the buds were still closed, extended back along the branches to the trunk and reached a little way down the trunk only after the leaves were fully expanded. This was not the case in a specimen of *Quercus pedunculata* felled in May when only at the top of the tree a few male inflorescences were showing and when not a single leaf was to be seen on the tree. Here a row of new spring vessels was already formed throughout the bole. In *Acer Pseudoplanatus* new wood was formed on the trunk only after leaf-expansion; in *Quercus pedunculata* new wood was present throughout the trunk before the buds had burst.

b. Full-Leaf Condition, August (Pl. CLXXXV).

Interpretation here presents practically no difficulty. The transpiration current is represented by the higher percentages in the youngest wood and throughout most of the tree the whole central area has an almost uniform percentage averaging but slightly over 60. Probably in a tree of uniform growth the graph, excluding the transpiration current, would be a straight line.*

* For deciduous Coniferae see under Coniferae.

These results and their bearing on the tree-felling period are referred to under Coniferae.

III. Evergreen Broad-Leaved Trees (Plates CLXXXVI-CLXXXVII).

The experiments proposed on evergreen broad-leaved trees were unfortunately interrupted and of the series of *Ilex Aquifolium* selected for examination only two trees were felled, one on 5th December 1918 and the second on 15th February 1919. From an examination and comparison of the graphs of the moisture-distribution of these two trees, however, one may conclude :—

1. That in the Holly moisture is stored in the centre. This is shown in the graph of bottom cut of the December tree (Plate CLXXXVI) where moisture is stored in the heart-wood.

2. That later in the season the moisture spreads from the centre as shown by the low moisture-percentage of the heart-wood in February (Plate CLXXXVII).

3. That the movement is much slower than in the case of *Acer* or *Ulmus* and also that the storage is apparently on a much smaller scale as evidenced by the lower range of percentages.

IV. Coniferae (Plates CLXXXI, CLXXXVIII-CLXXXIX).

Amongst the Conifers the deciduous and evergreen habit apparently makes no difference with regard to moisture-spread, but there is a very great difference between the resinous and non-resinous genera.

Of the resinous trees, species of *Pinus, Larix, Chamaecyparis* and *Cedrus* have been examined and in no case is there storage of moisture in the heart-wood.* The impregnation of the walls with resin renders the passage of moisture from the sap-wood to the heart-wood impossible. Hence we have in these resinous trees throughout the year a condition approximating to the August *Acer,* i.e. in mature trees a large dry heart-wood area surrounded by the narrow wet zone of sap-wood.

A typical moisture distribution graph for a resinous Conifer is given on Plate CLXXXVIII (*Chamaecyparis pisifera,* felled 22nd Oct. 1918). The sap-wood gives very high percentages and there is a very sudden drop on entering the heart-wood.

* F. M. Oliphant (apud Sir Hugh Stewart in Trans. Roy. Bot. Scot. Arb. Soc. vol. xxxv. p. 67) suggests that a comparison may be drawn between the regional moisture contents of *Picea sitchensis* and *Acer Pseudoplatanus.* So far as my observations have gone one cannot compare the moisture distribution in the groups to which these two species belong. Of the several examples of resinous conifers examined at different seasons none with central storage comparable with that of *Acer* has been found. There has been here and there a slight rise in moisture-percentage towards or at the centre of the heart-wood but so slight and at times so inconstant as to appear negligible when compared with the central storage condition of *Acer.*

This fact shows quite conclusively that moisture distribution is not the determining factor in the selection of the optimum felling period. For, granted that winter is the period for resinous conifer felling, then the season in broad-leaved trees with a similar moisture distribution is that of the full-leaf condition.

As stated in the earlier paper* other factors must be considered before a decision on the optimum-felling season can be given. But in the meantime the results from the *Acer* tree suggest a method of felling when the tree is in full leaf which might at least be given a trial. The present practice is to cut off all branches almost immediately after the tree is felled. Instead of this let a tree be felled say in August and let the branches be left on until the leaves have flagged and are no longer transpiring. The result would be that the leaves would transpire the bulk of the water in the younger wood and we would have a trunk with, in the case of *Acer,* an almost uniform 60% of moisture throughout.

Non-resinous Conifers have been represented in the experiments by *Taxus,* and in *Taxus* there are two points to be noted.

There is here storage of moisture in the heart-wood. In this respect *Taxus* behaves as the broad-leaved trees, or I should say apparently so because the experiments were interrupted before the summer condition was examined. The winter condition, however, is on the same lines as that of the broad-leaved trees.

In *Taxus* there was noted a peculiarity not present in any of the other trees examined. In the cross section of the newly felled tree, three distinct areas can be recognised—central heart-wood, sap-wood on periphery, and separating these two areas a narrow zone of very pale wood (Plate CLXXXI). A very superficial examination sufficed to show that this narrow pale zone was much drier than either the heart-wood or the sap-wood and the final drying of the chips served but to emphasize the difference.

The position of this dry pale-coloured zone immediately external to the heart-wood suggested that it was some intermediate stage or the primary stage of the conversion of the sap-wood into heart-wood. To test the validity of this conclusion reagents were employed to find out the distribution of tannin in this zone and in the neighbouring heart-wood and sap-wood.

Five tannin tests were used :—Osmic Acid + Hydrochloric Acid; Ammonium molybdate in Ammonium chloride solution; Ferric chloride in Ether; Potassium dichromate; and Ammonium chloride.

Heart-wood responded readily to the various tests as also did the half of the white zone next to the heart-wood, but the white zone gave no reaction in the part next to the sap-wood. These

* Notes Roy. Bot. Gard. Edin., vol. xi. No. LI. p. 12.

tests showing the distribution of the tannin served to confirm the supposition that this white zone is sap-wood in process of conversion into heart-wood by the extraction of moisture of imbibition followed by impregnation of the walls with tannin.

Further, microscopic sections showed that the tannin is actually in the walls of the tracheids, that there is no trace of tannin in the medullary ray cells and that the medullary ray cells are living in the white band. Thus a means of communication is still open through the medullary rays from sap-wood to heart-wood even supposing the impregnation of the tracheid walls with tannin were to act as resin in preventing diffusion through the walls.

Plate CLXXXIX gives the moisture distribution in *Taxus baccata* in November, showing the high moisture-percentage of the sap-wood, the sudden dip owing to the low moisture-percentage of the white band and the rise in percentage on entering the heart-wood.

The coloured plate (CLXXXI) is a reproduction of a painting made from the newly felled wood of this tree to show the conspicuous white band separating the heart-wood and sap-wood.

V. Wind as an Agent in Moisture-Spread (Plate CXC).

That wind is a very effective agent in the raising of the sap in trees is a well-known fact but in the accompanying graph the results of a gale are shown to be not only sap-raising; there is in addition a disturbing of the sap-distribution equilibrium.

The tree examined was a specimen of *Populus trichocarpa* which was blown down during a severe gale on the early morning of 1st March 1918. The results probably do not give the maximum effects of the gale as, not suspecting any such disturbance of the moisture distribution, I treated the tree in an exactly similar way to that adopted for the other trees examined, i.e. by determining the moisture-distribution in strips from north to south and east to west through the centre. Fortunately, however, the gale was from only slightly east of north so that the maximum results shown in the graph are those from north to south.

Without attempting a physical explanation of the results I would simply draw attention to the increasing percentage in the youngest wood as we ascend the tree on the side on which the gale was blowing, to the decreasing percentage in the youngest wood on the side away from the gale, and to the great contrast in the percentages of these two sides.

It must be borne in mind that in such a tree as *Populus trichocarpa* with its elasticity we would find a maximum moisture disturbance. In less flexible trees such as *Quercus* or *Platanus* the result of a gale would probably be very much smaller.

One other point must be noted. The graphs show a comparatively high moisture-percentage in the centre of the trunk. How far this is a result of the gale I cannot say as the whole series of experiments on moisture-spread was interrupted before another *Populus* could be examined to elucidate this point.

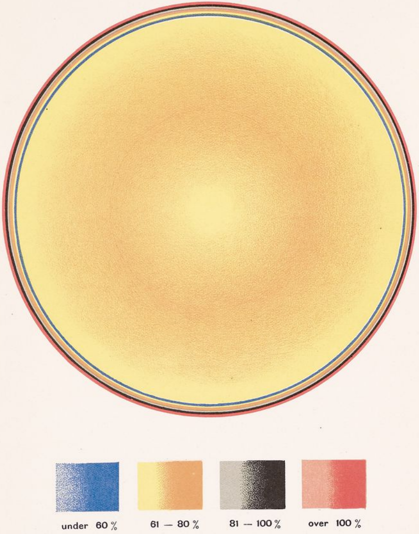
The absence of a graph for the bottom cut in the N–S direction is explained by the fact that the tree was not quite sound on the north side at the point selected for the cut.

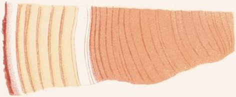
For the material on which the previous and present papers are based I am indebted to the late Sir I. B. Balfour. Not for the material alone, but also for his encouragement throughout the lengthy and laborious experiments and for his friendly advice and criticism I wish now to express my sincere gratitude. Mr R. L. Harrow, F.R.H.S., Head Gardener, Royal Botanic Garden, as before, arranged and saw to the carrying out of the details of the felling operations in a very satisfactory way. For the original painting of the wood of *Taxus* I am indebted to Miss L. Snelling.

LIST OF PLATES* (CLXXX-CXC).

Illustrating Professor Craib's Paper on Moisture-Spread.

* For explanation of methods adopted in these plates see previous paper published in Notes Roy. Bot. Gard. Edin., vol. xi. No. LI.


under 60 %
61 — 80 %
81 — 100 %
over 100 %



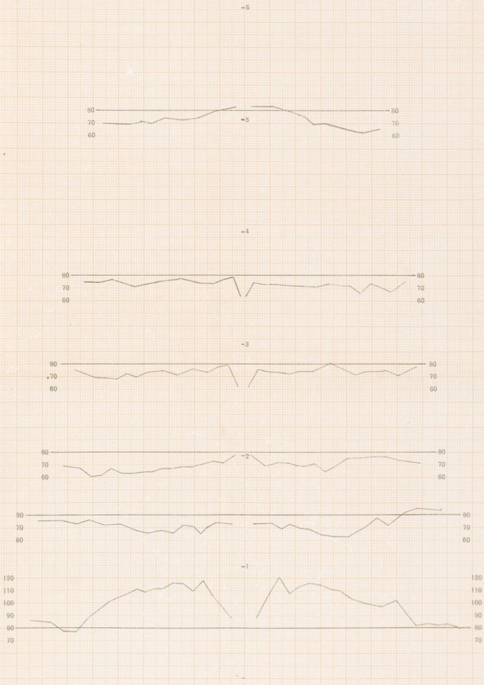


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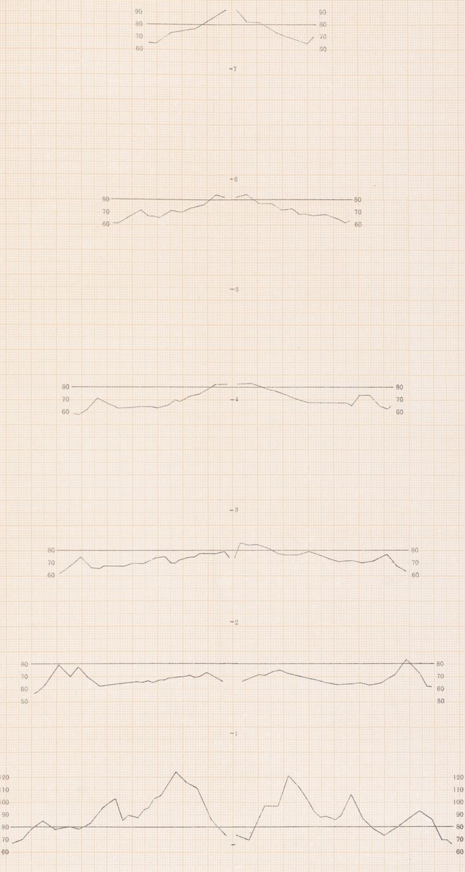
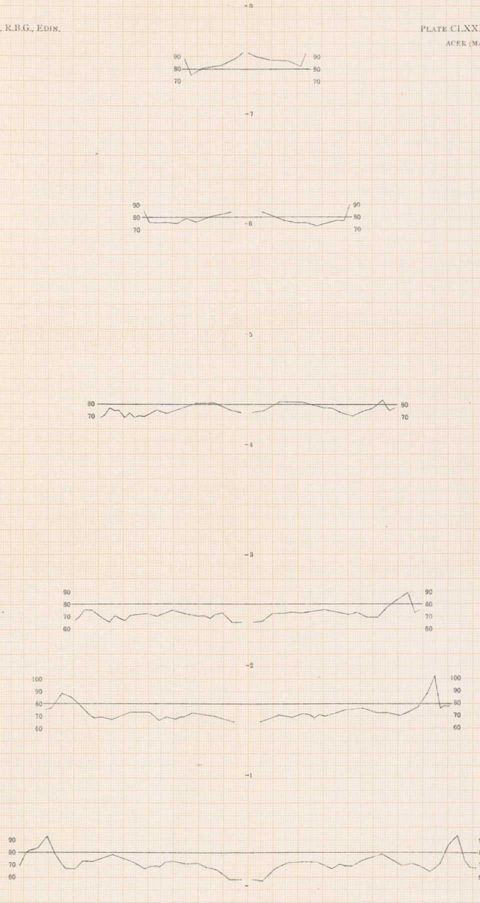
PLATE CLXXXIII.
ACER (MAY 1)



Acer (May 2)



ACER (Aug.)

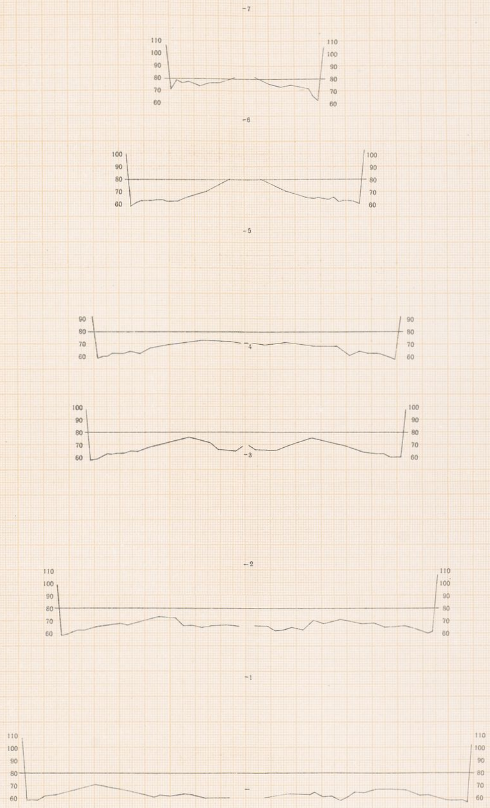

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PLATE CLXXXVI.

ILEX (DEC.)

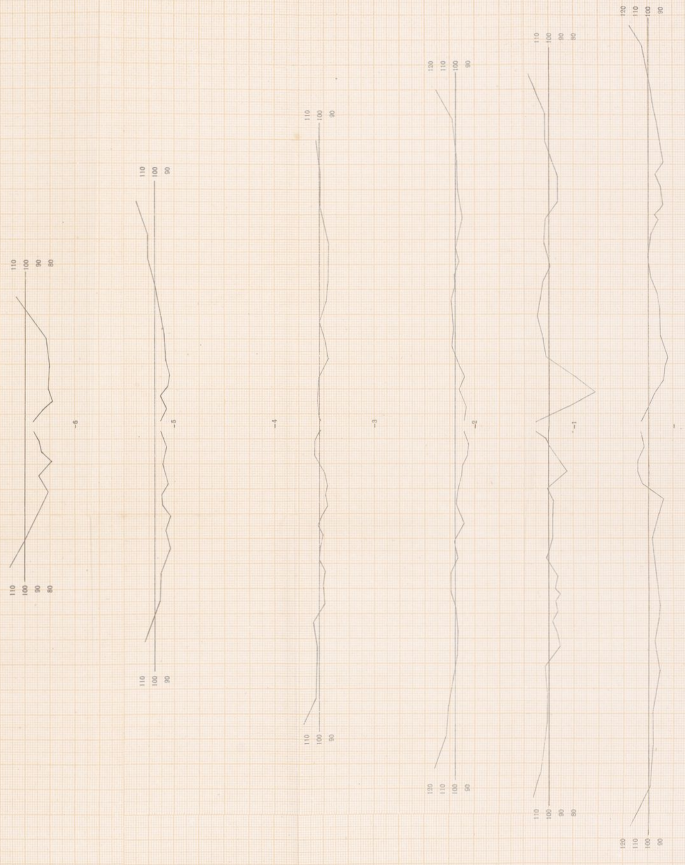
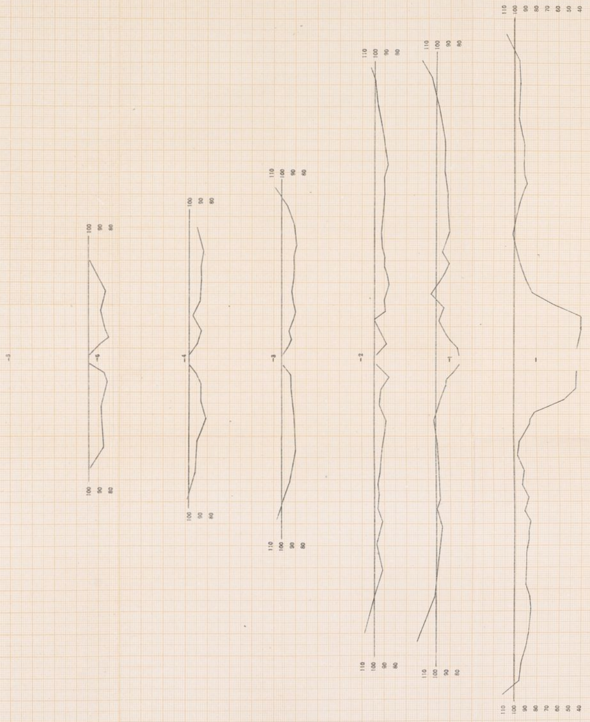


PLATE CLXXXVII.

ILEX (FEB.)



CHAMAECYPARIS

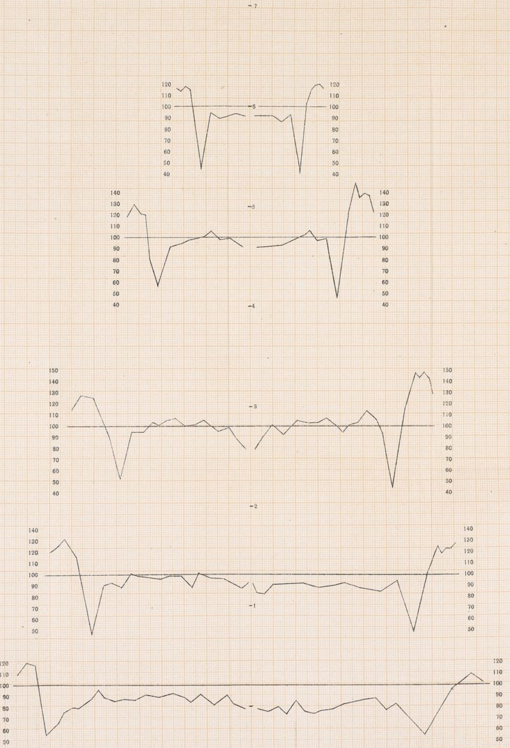

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PLATE CXC.

POPULUS