Transpiration of Evergreen Trees in Winter.

By

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With Plate XVIII.

I. Introductory.

It is well known, from the researches of previous investigators, that evergreen trees in temperate climates can transpire even in the midst of winter. But as no such investigations have been undertaken with regard to plants indigenous to Japan, it has seemed desirable that efforts should be made to ascertain certain numerical values relating to the absorption of water by the roots of such plants and the evaporation of it from their leaves, during winter.

Almost all the investigations with regard to transpiration, made up to the present time, by an enormous number of authors[1]

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[1] A fuller account with regard to transpiration is to be found in Burgerstein's excellent work, "Materialien zu einer Monographie betreffend die Erscheinungen der Transpiration der Pflanzen." I, 1887; II, 1889.

have been confined to the vegetating season. That evergreen trees are constantly supplied with water even in winter, was first observed by **Hales**,[1] and then by **Duhamel**[2]. **Treviranus**[3], in his "Physiologie der Gewächse," says "In Ansehung der Jahreszeiten ist sie (Transpiration) unter gleichen Umständen im Frühjahre und Sommer am stärksten: im Herbste nimmt sie sehr ab und im Winter bemerkt man keine mehr." In the year 1860, **T. Hartig**[4] made some experiments on transpiration with *Picea*, a meter high, in milder winter, and found that the plant gave off from about 100 to 125 grams of water a day ($^1/_{10}$-$^1/_4$ Pfund); but as he gave neither the area nor weight of the transpiring part, we are unable to calculate the actual intensity of transpiration. Afterward **Burgerstein**[5] pointed out in 1875, the relation of transpiration to lower temperatures and ascertained that transpiration of cut-branches of *Taxus baccata* was found to occur even in temperatures below zero. According to the results obtained by the latter botanist, *Taxus baccata* transpired in an hour at –2°C., 0.288 per cent. and even at –10.7°C., 0.019 per cent. of its fresh weight. A similar experiment was made by **Wiesner** and **Pacher**[6] with leafless cut-branches of *Aesculus*. In branches either one or three years old, the loss of water at a temperature of –13°C. could still be observed.

The above instances sufficiently prove that although the

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[1] **Hales**, Statik der Gewächse 1748, p. 29.

[2] **Duhamel**, De l'exploitation des bois 1764, Bd. I, p. 337.

[3] **Treviranus**, Physiologie der Gewächse 1835, Bd. I, p. 488.

[4] **T. Hartig**, Ueber die Bewegung des Saftes in den Holzpflanzen. Bot. Ztg., Bd. XIX, 1861, p. 17; and Lehrbuch für Förster 1877, 11 Aufl., Bd. I, p. 252.

[5] **Burgerstein**, Ueber die Transpiration von Taxuszweigen bei niederen Temperaturen. Oesterr. Bot. Zeitschr., Bd. XXV, 1875.

[6] **Wiesner** und **Pacher**, Ueber die Transpiration entlaubter Zweige und des Stammes der Rosskastanie. Oesterr. Bot. Zeitschr., Bd. XXV, 1875.

lower temperature affects the plant in diminishing the evaporation of water, it has but little influence in wholly stopping it.

That the amount of transpiration greatly depends upon the temperature of the soil in which the plant grows, was first clearly shown by the well-known experiment of Sachs[1]. He observed that some herbaceous pot-plants, e.g. *Cucurbita*, *Nicotiana*, &c., wither when the soil full of moisture was exposed to a temperature of 2–4°C., and he attributed this to the deficiency of the absorption of water. It must, however, not be concluded that, from the above experiments, the absorbing activity of the root of many plants in temperatures near the freezing point, or even below it, is completely destroyed: on the contrary, in several species of plants the root or even the cut-branches can absorb water considerably, as Kosaroff[2] has recently shown.

The most interesting fact that the diminution of transpiration of evergreen trees in winter has a close relation to the closure of the stomata in that season, can be seen from the results of the investigations made by several authors. Stahl, who laid stress especially upon this point, says: "Bei unseren immergrünen Straüchern und Baümen, deren Existenz ohne den Spaltenschluss gar nicht möglich wäre, tritt derselbe schon frühzeitig im Herbste ein."[3] He has proved this fact by his "Kobaltprobe"[4]; and has shown that in some winter-green trees, for example, *Hedera Helix*, ten days were required to make the stomata reopen in a hot chamber.

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[1] Sachs, Das Erfrieren bei Temperaturen über 0°. Bot. Ztg., Bd. XVIII, 1860, p. 124. Compare Sachs, Text Book of Botany 1882, 2nd Ed., p. 734.

[2] Kosaroff, Einfluss verschiedener äusseren Factoren auf die Wasseraufnahme der Pflanzen. Inaug. Disst. Leipzig. 1897.

[3] Stahl, Einige Versuche über Transpiration und Assimilation. Bot. Ztg., Bd. LXX, 1894, p. 126.

[4] l. c., p. 118.

Subsequently, Lidforss[1] found that the guard-cells of the stomata on the leaves of some winter-green plants which he examined, were free of starch during winter, and that this absence of starch rendered the stomata incapable of performing their normal function.

Although I have not made an extensive study of this point, that is to say, to the extent of examining in each given case whether the stomata were surely closed or not, I have reason to conclude, so far as my observations extend, that many of our indigenous evergreen trees, unlike those of Germany above referred to, have their stomata more or less open even in the midst of winter. This condition may probably be considered as one of the chief causes which make the amount of the winter transpiration of our evergreen trees considerable.

II. Method.

The amount of water transpired by plants may be determined in various ways: first, by weighing the plants themselves at definite intervals; secondly, by condensing the vapour which is given off from the plants and measuring its volume; thirdly, by measuring the increase of the weight of some hygroscopic substances, like calcium chloride, by which the vapour derived from the plant is absorbed; and fourthly, by measuring the amount of water absorbed from the root or cut-surface. Of these four methods, only the first and the last were adopted in my investigations.

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[1] Lidforss, Zur Physiologie und Biologie der Wintergrünen Flora. Bot. Centlbl., Bd. LXVIII, 1896, p. 35.

A.—*Method of determining the amount of water transpired by plants, by weighing.* The first method, recommended by many investigators as being the most accurate for experiments in which, of course, rooted plants must be employed, was fully discussed by Burgerstein[1]. A number of evergreen trees, 40–60 cm. high, were selected for my experiments and planted last September in pots, measuring 15 cm. in diameter and 12 cm. in height. These pots in which the plants grew were enclosed within metallic cases of exactly the same form and size, and having bisected covers. For cementing the covers hermetically, I used tin-foil and a mixture of beeswax and olive oil. Through the covers a hole for supplying water was made which, however, was closed air-tight during the experiments. The whole weight of each pot, including the plant and the cover, amounted to about 2 kgr., when the soil contained in it was saturated with water, and I knew by calculation that about one third of the whole weight represented the quantity of water contained in the soil. By this method, I was able to make a rough estimate of the amount of water contained in the soil at different times during the experiments.

Since the activity of the root is weakened in a closed soil owing to the deficiency of the air supply[2], experiments of long duration must be avoided. During the experiments I opened the hole in the cover several times, in order to supply water and also to renew the air.

B.—*Method of measuring the amount of water transpired by plants, by absorption.* The apparatus which I employed for measuring absorption was a slight modification of the potometer

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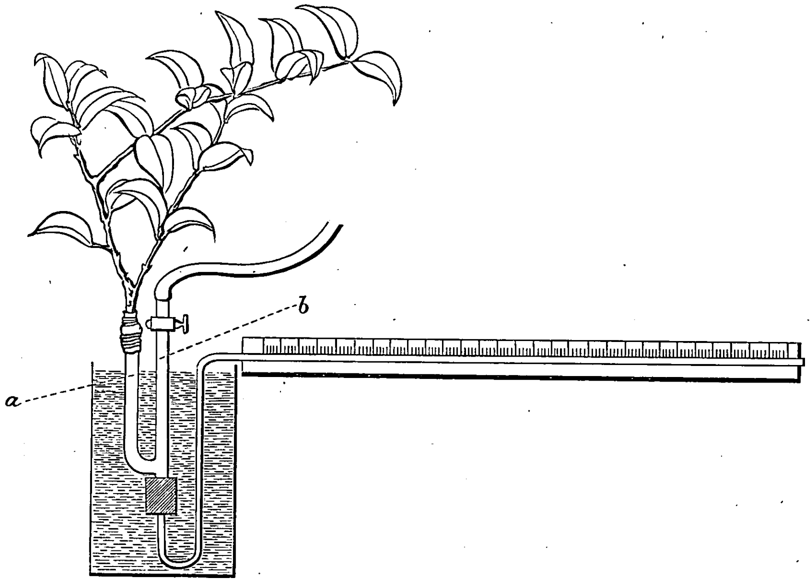
[1] Burgerstein, Materialien zu einer Monographie betreffend die Erscheinungen der Transpiration der Pflanzen 1889, II, p. 5.

[2] Sachs, Vorlesungen über Pflanzenphysiologie 1882, p. 307.

designed by MacDougal[1]. One arm (Fig. 1 *a*) of a T-shaped glass tube was bent parallel to the other arm (*b*); at the end of the former the branch was inserted, fitted with a rubber tube and bound with wire for safety. From one end of the latter arm, water was supplied by means of a stopcock, from the reservoir, while the other end of the same arm was connected with the capillary tube which had an even inner diameter of nearly one millimeter. After the apparatus was filled with water, taking care not to leave any air bubbles in it, the loss of water absorbed by the cut-surface and transpired from the surface of the leaves was indicated by the diminution of the column of water in the capillary tube. The volume of the T-tube must not be too large, since, if that be the case, a change of temperature gives rise to a change of the volume of water which will consequently

Fig. 1.



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[1] MacDougal, A convenient potometer. Bot. Gazette, Vol. XXIV, 1897, p. 110.

cause an error in reading the water column. To prevent a violent change of the temperature of the water in the tube, the whole apparatus was immersed in a glass vessel filled with water, and the experiments were always commenced after a lapse of time sufficient to equalize the temperature both inside and outside the tube. By this means, I equated the temperature in the glass vessel and in the tube. The details obtained by this method will be given in the description of each special experiment.

The amount of transpiration was reduced, for the sake of comparison with different kinds of plants, to the area of leaves in □ dm., and also to their fresh weight and dry weight in 100 grams. For measuring the area of leaves, I employed the usual method of weighing pieces of paper cut in the same forms as the leaves, the weight of the unit area being previously ascertained.

III. The Climate of Middle Japan.

Before describing the details of my experiments, it will be worth while to give a brief account of the climate of middle Japan (Hondo) in which my observations were made. Since the climate of this island is greatly influenced by the ocean, it has a wide range and is rather inequable; as a whole it is mild and highly favourable to a luxuriance of vegetation.

Temperature. The mean temperatures during the winter in Tokyo[1] are 5.1°C. in December, 2.7°C. in January and 3.5°C. in February; the average temperature being, therefore, 3.8°C. In January, the maximum is 15°C.; while the minimum is –6.5°C.

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[1] Calendar for 1899 published by the Imperial University of Tokyo.

For the sake of comparison with certain localities in Europe, the names of the following cities with their respective mean temperatures in January are given, thus[1]:—

Berlin	0.1°C.	Modena	1.3°C.
Munich	-2.6 „	Florence	5.2 „
Vienna	-1.2 „	Rome	6.7 „
Triest	4.7 „	Milan	0.5 „

Hence the northern part of Italy is, in respect of temperature, comparable with middle Japan.

Humidity. Japan is comparatively wet during the winter, especially in the coastal regions, thus the relative humidity of the latter is[2] :—

	Dec.	Jan.	Feb.
Southern coast............	73%	69%	79%
Eastern coast	73 „	77 „	76 „

and also the relative humidity in Tokyo[3] is :—

December........................	65%
January	65 „
February	67 „

That the humidity in Japan is not so slight as to be injurious to plants, as is the case during the dry season in tropical regions can also be ascertained by the following value of the rainfall and the number of rainy days in Tokyo[4]:—

	Dec.	Jan.	Feb.
Rainfall	47.3 mm.	51.5 mm.	77.8 mm.
Rainy days	6.2	6.7	9.2

and in Tokyo, the amount of rain throughout the year is 1463 mm.

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[1] Hann, Handbuch der Klimatologie. Bd. III, 1897.

[2] Koide, Climatology of Japan (in Japanese), 1898, p. 295.

[3] Calendar for 1899 l. c.

[4] l. c.

Temperature of the soil. The temperature of the soil is to be considered one of the most important factors affecting vegetation. The number of days, when the minimum temperature of the earth's surface sinks below 0°C., is larger than that when the temperature of the air falls below 0°C.; thus the former is 91–121 days, while the latter 61–79 days.

It is obvious that in winter an herbaceous plant rooted in shallow soil in the open ground, can not supply itself with a sufficient quantity of water for transpiration and the whole of it is destroyed, as we see in so-called annual plants; but with regard to evergreen trees this is not the case, since their roots go deep into the soil where the temperature is not so low as to hinder the absorption of water. Thus the Central Meteorological Observatory gives the following observations[1]:—

Temperature of earth's surface.	Dec.	Jan.	Feb.
Mean	3.22°C.	3.60°C.	4.08°C.
Minimum	1.17 „	1.37 „	1.35 „
Maximum	7.51 „	8.24 „	9.59 „
Temperature in soil.			
m.			
0.05 deep	3.64 „	4.00 „	4.33 „
0.1 „	4.29 „	4.26 „	4.48 „
0.2 „	5.44 „	4.80 „	4.84 „
0.3 „	6.45 „	5.18 „	5.07 „
0.6 „	9.52 „	7.51 „	6.80 „

The warmer temperature, greater abundance of rainfall and higher humidity during winter months in middle Japan, in comparison with the countries of central Europe,—Germany, for example—, lead us to anticipate that transpiration goes on much more actively in the former than in the latter. In this respect the northern part of Italy is perhaps in harmony with middle Japan.

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[1] Annual Report 1897.

IV. Evergreen Trees of Japan.

The evergreen trees of Japan are numerous and luxuriant ; most of them being indigenous. Several kinds of *Quercus* and Lauraceæ, which form thick woods in southern Japan, are also found in the vicinity of Tokyo, where they attain a considerable height. *Pasania* (*Quercus*) *cuspidata* is one of the commonest evergreen trees more than 10 meters in height, and has densely foliate branches. Besides, we have *Illicium Anisatum*, *Michelia compressa* (Magnoliaceæ); *Pittosporum Tobira* (Pittosporaceæ) ; *Photinia glabra*, *Eriobotrya japonica*, *Rhaphiolepis japonica* (Rosaceæ) ; some kinds of *Citrus*, *Skimmia japonica* (Rutaceæ) ; *Daphniphyllum macropodum* (Euphorbiaceæ) ; *Ilex latifolia*, *I. integra*, *I. crenata* (Aquifoliaceæ); *Euonymus japonica* (Celastraceæ); *Thea japonica*, *T. Sasanqua*, *T. sinensis*, *Ternstrœmia japonica*, *Eurya ochnacea*, *E. japonica* (Theaceæ) ; *Daphne kiusiana* (Thymelæaceæ) ; *Fatsia japonica*, *Hedera Helix var. colchica* (Araliaceæ) ; *Aucuba japonica* (Cornaceæ) ; *Ardisia japonica* (Myrsinaceæ) ; *Ligustrum japonicum*, *Osmanthus Aquifolium*, *O. fragrans* (Oleaceæ) ; and so forth. Most of them are shrubs or small trees, and in the vicinity of Tokyo are generally found in a state of cultivation.

Species of Coniferæ are also abundant. *Pinus Thunbergii*, *P. densiflora*; *Cryptomeria japonica;* *Chamæcyparis obtusa*, and *Cephalotaxus drupacea* have the widest distribution throughout Japan, extending from the southern to the northern parts. *Podocarpus Nageia*, *P. macrophylla* ; *Sciadopitys verticillata* ; *Juniperus rigida* and *J. sinensis* are commonly found in the southern part ; and *Abies firma* ; *Thujopsis dolabrata* ; *Thuja orientalis* ; *Torreya* *nucifera*; *Pinus parviflora*; *Abies Veitchii*; *Picea bicolor, P. hondoensis*; *Larix leptolepis*; *Abies Mariesii, A. sachalinensis*; *Picea ajanensis, P. Glehnii*, etc., are found in the more northern part. Mayr[1] counted 14 groups with 30 species of Coniferæ (Nadelholz) in all Japan, which shows their abundance.

The leaves of these foliage trees are, with the exception of Araliaceæ, generally lanceolate and of a smaller size, with an entire or slightly serrated margin and a thick, hard and leathery texture. Almost all of them are hairless and have a glossy upper surface owing to the presence of a thick cuticular layer. As to their anatomical structures both cuticula and epidermal walls are tolerably well developed; pallisade tissue generally consists of two (*Quercus glauca, Ternstrœmia japonica*, etc.) or three (*Thea japonica, Pittosporum Tobira, Daphniphyllum macropodum*, etc.) layers of cells compactly arranged. Intercellular spaces are diminished as is usually the case in xerophilous leaves; while, the deep depression of the stomata in the epidermis is not to be found in the leaves of our evergreen trees. On the whole, it seems that our indigenous evergreen trees, in contradistinction to those in dry tropical or alpine regions, are less protected against transpiration.

For my experiments, I selected, from among numerous species of trees belonging to different families, especially those whose anatomical structures differed the most widely. Experiments with cut-branches were made with materials found in the Botanical Garden. The species of plants used in my experiments were the following:—

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[1] Mayr, Monographie der Abietineen des Japanischen Reiches 1890.

Coniferæ—*Cryptomeria japonica* Don.
Pinus Thunbergii Parl.
Podocarpus sinensis Wall.
,, *macrophylla* Don.
Torreya nucifera Sieb. et Zucc.
Chamœcyparis obtusa Sieb. et Zucc.
Fagaceæ—*Quercus glauca* Thunb.
Pasania cuspidata Oerst.
Magnoliaceæ—*Illicium Anisatum* L.
Berberidaceæ.—*Nandina domestica* Thunb.
Lauraceæ—*Cinnamomum Loureirii* Nees.
Pittosporaceæ—*Pittosporum Tobira* Ait.
Rosaceæ—*Eriobotrya japonica* Lindl.
Photinia glabra Thunb.
Aquifoliaceæ—*Ilex crenata* Thunb.
Euphorbiaceæ—*Daphniphyllum macropodum* Miq.
Theaceæ—*Ternstorœmia japonica* Thunb.
Thea japonica Nois.
,, *Sasanqua* Nois.
Araliaceæ—*Fatsia japonica* Decne. et Planch.
Cornaceæ—*Aucuba japonica* Thunb.
Oleaceæ—*Ligustrum japonicum* Thunb.
Rubiaceæ—*Gardenia florida* L.
Compositæ—*Ligularia Kœmpferi* Sieb. et Zucc.*
Liliaceæ—*Aspidistra elatior* Bl.*
Filices—*Gymnogramme japonica* Desv.*

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* Herbaceous plants.

V. Transpiration under Direct Insolation.

For this experiment I used the pots prepared as has been described above (p. 317). The pots were exposed all day to direct sunlight on a stand in front of the laboratory. To keep them free from rain, a glass roof was employed only during nights or rainy days, while in fine weather it was always put aside from morning till evening. Each pot was weighed once a day (4–5 p.m.), but I omitted the weighing several times, since the loss of water was too insignificant and the balance which I used was not sufficiently accurate under 0.5 gram.

In the beginning of each series of experiments a sufficient amount of water was supplied to make the whole weight nearly 2 kilograms, at which weight the content of water might roughly be equalized in each pot. The weighing began at the end of December and lasted to the end of March, and in order to get a correct comparison at different times during the winter I noted, as far as possible, only the results of experiments in transpiration obtained on fine days, thereby omitting those obtained on rainy or cloudy days.

The materials employed were limited to the following fourteen species of plants, of which five species were conifers, and the others, foliage trees. Their characters and ages were as follows :—

Name of plants.	Age.	Number of leaves.	Area of leaves.	Fresh weight of leaves.	Dry weight of leaves.
			□ dm.	gr.	gr.
Cryptomeria japonica	3	—	—	73.925	35.145
Pinus Thunbergii	5	1422	—	106.547	38.815
Podocarpus sinensis	6	670	—	113.405	49.970
Torreya nucifera	7?	2340	—	39.065	14.890
Chamæcyparis obtusa	5	—	—	37.732	18.000
Quercus glauca	3	27	5.552	12.579	6.030
Pittosporum Tobira[1]	8	124	11.430	35.770	13.710
Illicium Anisatum	6	93	15.028	46.374	23.770
Ternstrœmia japonica[2]	4	72	6.656	22.289	8.634
Thea japonica	8	89	16.412	49.880	34.575
Eriobotrya japonica	8	36	9.306	30.141	14.490
Photinia glabra	5	184	11.400	30.738	14.325
Fatsia japonica	3	7	10.820	44.174	12.785
Daphniphyllum macropodum.	5	36	14.644	35.770	14.900

All the materials remained healthy during the experiments, only a few leaves having fallen off in the case of *Pittosporum* and *Ternstrœmia.*

With these materials daily measurements have shown that the amount of transpiration of each species decreased day after day until it attained a minimum value at the end of January[3] (conf. Table III), as had been expected; it increased together with the rise of temperature, and at the end of March, it be-

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[1] At the beginning of the experiment, the number of leaves was 143; area 12.610; fresh weight 39.05; dry weight 14.97.

[2] At the beginning of the experiment, the number of leaves was 76; area 6.982; fresh weight 23.191; dry weight 9.00.

[3] Table IV shows the actual minimum transpiration, but as this observation was made in bad weather it can not be considered to be normal.

came about 3–6 times greater than at the end of January; thus the average values of daily transpiration during January 17th–24th and March 21st–23rd (see Tables III and VIII) were:—

	Daily transpiration per □dm. in gr. End of January.	End of March.
Quercus glauca	0.901	6.063
Pittosporum Tobira	0.506	2.012
Illicium Anisatum	0.462	1.974
Ternstrœmia japonica	0.328	1.802
Thea japonica	0.331	0.934
Eribotrya japonica	0.476	2.006
Photinia glabra	0.395	1.140
Fatsia japonica	0.495	2.464
Daphniphyllum macropodum	0.434	1.251

As shown in the foregoing table, the minimum average value of transpiration lies between 0.328 (i.e. *Ternstrœmia*) and 0.506 gram (i.e. *Pittosporum*) per □ dm. a day in the above nine species, with the single exception of *Quercus* (0.901). Of all the eight tables (Table I–VIII) we see that *Quercus* represents the maximum in the amount of transpiration, while *Ternstrœmia* shows, for the most part, the minimum. Other plants behaved themselves differently during different periods of the experiments. For the sake of comparison, therefore, I summed up the whole amount of transpiration in each case, from the beginning to the end of the experiments, and then reduced this to the unit area of leaves, as represented in the following table:—

Names of Plants.	Total amount of Transpiration during experiments.	Reduced to the unit area of leaves □dm.
Quercus	345.0 gr.	62.1 gr.
Pittosporum	402.5 ,,	32.9 ,,
Illicium	413.0 ,,	27.5 ,,

Names of Plants.	Total amount of Transpiration during experiments.	Reduced to the unit area of leaves □ dm.
Ternstrœmia	142.0 gr.	20.4 gr.
Thea	365.0 ,,	22.2 ,,
Eriobotrya	336.5 ,,	36.2 ,,
Photinia	327.5 ,,	28.7 ,,
Fatsia	386.0 ,,	35.7 ,,
Daphniphyllum	386.5 ,,	26.4 ,,

If these are arranged, according to the value of their amounts, in a descending order, they stand in the following succession:— *Quercus*, *Eriobotrya*, *Fatsia*, *Pittosporum*, *Photinia*, *Illicium*, *Daphniphyllum*, *Thea* and *Ternstrœmia*.

Mode of transpiration. When we compare the intensity of transpiration of different kinds of plants, we see that their differences are smaller when the plants are in the period of their minimum transpiration, that is, at the end of January in the case of my experiments. If we take, for example, the amount of transpiration in the case of *Ternstrœmia* as a unit, the relative amounts in the other plants might stand as follows (conf. Table III):—

Quercus	2.75
Pittosporum	1.54
Illicium	1.40
Ternstrœmia	1.00
Thea	1.00
Eriobotrya	1.45
Photinia	1.20
Fatsia	1.50
Daphniphyllum	1.32

Thus, with the exception of *Quercus*, practically none exceeds one and a half times.

It is probable, though I have not made any accurate observations respecting it, that stomatal transpiration is, in this period at least, greatly checked; but that a hermetic closure of the stomata does exist in these plants, as observed by Stahl[1] and Lidforss[2] in most winter-green leaves, is doubtful judging from the results of the cobalt-test.

If, on the other hand, we compare the transpiration in each plant observed in March, we obtain the following arrangement (conf. Table VIII) :—

Quercus	3.92
Pittosporum	2.15
Illicium	2.11
Ternstrœmia	1.93
Thea	1.00
Eriobotrya	2.14
Photinia	1.22
Fatsia	2.63
Daphniphyllum	1.34

Here the differences between them are greater, and the ratio ranges between 1 and 2.63 (*Quercus* being excepted). It may thus be seen that, in the coldest part of winter, the transpiration in various evergreen trees becomes approximate in amount, but diverges widely as the environment becomes favourable to transpiration. The explanation of this phenomenon is not easily found, since the factors which act upon plants are complex; but it is obvious that their influence varies with different species.

This variability of transpiration becomes more apparent when the change of transpiration of each individual is traced

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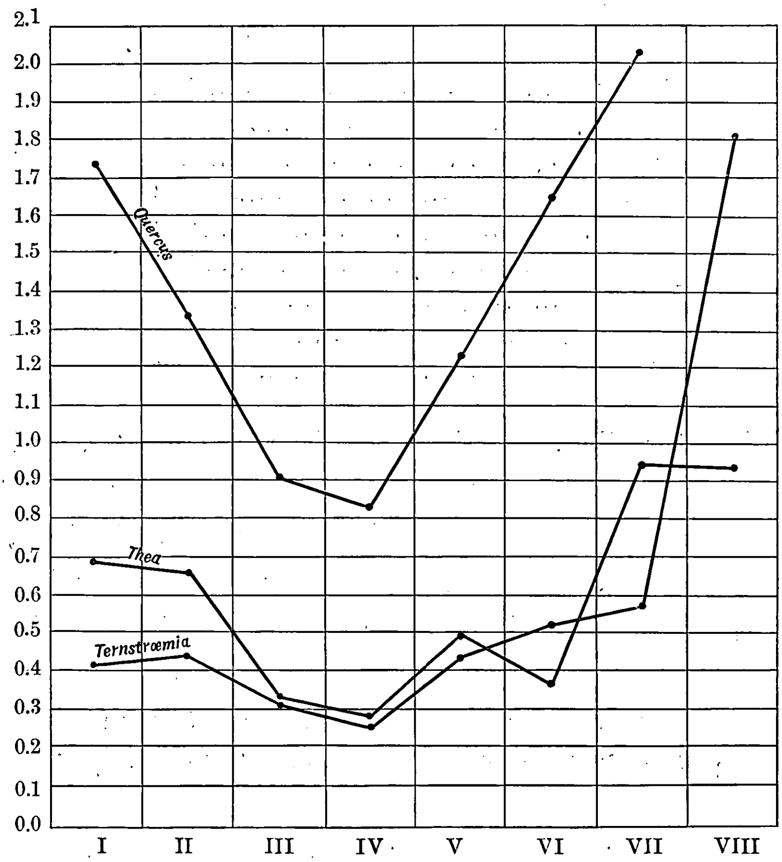
1) Stahl, l.c.
2) Lidforss, l.c.

through the different periods of time. To cite a few examples; *Thea* transpired 0.6956 gram per □ dm. per day at the beginning (conf. Table I), 0.331 at the minimal period[1] (conf. Table III), and 0.934 at the end of the experiment (conf. Table VIII). Their relation is, therefore, 2.1 : 1 : 2.8. In *Ternstrœmia* the amount of transpiration was 0.419 at the beginning, 0.328 at the minimal period and 1.802 at the end, so that their ratio

Fig. 2.



Curves of transpiration in *Quercus, Ternstrœmia* and *Thea.* In the ordinate the amount of transpiration and in the abscissa the periods of observation are denoted. I–VIII show the number of Tables.

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[1] i. e. the period of minimum transpiration.

is 1.3 : 1 : 5.5. The increase of transpiration at the end of experiment was far greater than that in the former plant. In *Quercus*, the variation at the three periods was even greater, viz., 1.9 : 1 : 4.1 (see Fig. 2).

From these few examples, it is obvious enough that the action of low temperature and other factors did not equally affect the different species ; that is, in one plant the transpiration was accelerated, while in the other plants, it was not. As will be seen in the curves (Fig. 2), the amount of transpiration in *Ternstrœmia* at VIII suddenly increases, in spite of the fact that the difference in other periods had been slight. In *Thea*, the amounts of transpiration at different periods were somewhat different from those of *Ternstrœmia*. Especially the increase of the transpiration at VIII is not remarkable in comparison with the other species.

Relation of the anatomical character of leaves upon transpiration. As the plants employed in my experiments had no peculiar anatomical difference, they did not show much difference from one anothor in the amount of water transpired. It is well known that the mode of passing the winter varies with different kinds of plants ; some close their stomata, while others excrete tannin on the epidermis, by which they protect themselves from excessive transpiration. Although I did not attempt to find out the exact relation between transpiration and the anatomical character of the leaves, still I was able to examine in the plants under observation, the number of the stomata[1] and the character of the epidermal wall, which seem to play an important part in causing the difference of the amount of water transpired.

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[1] Since the leaves of the given plants were used for another purpose, I was not able to ascertain the exact number of their stomata. I depend therefore for my data on the determinations given by Prof. S. Ikeno (Bot. Magazine, Tokyo, Vol. VIII, 1894, p. 231).

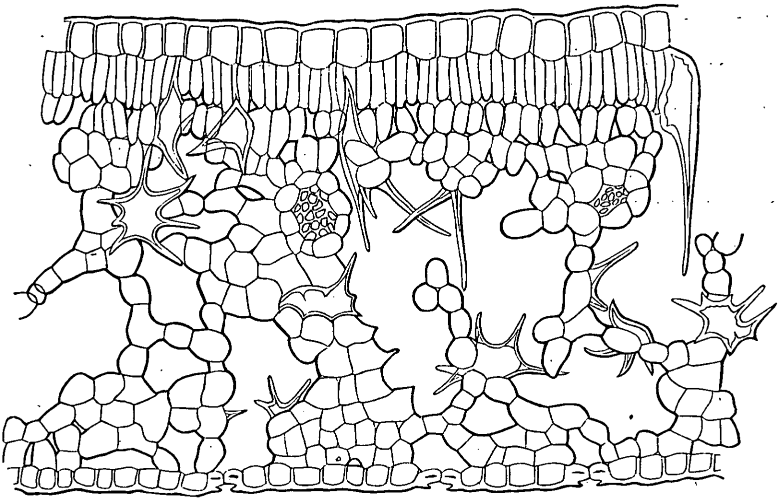
In *Quercus* and *Fatsia,* the epidermal wall is very thin, in fact the thinnest among the plants employed in my experiments, having the upper wall 5 μ in thickness and the lower wall about half as thick. The fact that the greatest amount of water was transpired by *Quercus* can no doubt be attributed to this peculiarity of the wall, as well as to the large number of stomata (the largest number among my plants reaching 557 per □ mm.). The last mentioned number is very remarkable if we make comparison with other plants, for example with *Fatsia,* which has only 182 per □ mm.

The epidermal walls in *Photinia, Daphniphyllum* and *Illicium* have nearly the same thickness, viz. from 8 to 6.5 μ in the upper, and from 6.5 to 6 μ in the lower sides. In the first two plants, we have just the same number of stomata, viz., 300 per □ mm ; while in the latter a smaller number, viz., 218 per □ mm., but with greater dimension. As the variation in the anatomical characters of these plants is slight, so the amount of water transpired by them differs only a little (see Tables I–VIII).

The remaining plants have rather thick epidermal walls ; thus in *Pittosporum,* the thickness is 14 μ in those of the upper side, and 9 μ in the lower ; in *Ternstrœmia* 10 μ in the upper, and 10–5 μ in in the lower ; and in *Thea* 10–5.5 μ in the upper, and 10–4 μ in the lower. In spite of the well developed epidermis in *Pittosporum,* we observe that the amount of transpiration is far greater than in the case of *Photinia, Illicium* and *Fatsia,* all of which have thinner cell-walls. This difference is most probably due to the larger number of stomata in the first named plant.

A seemingly exceptional case is observed in *Ternstrœmia,* where in spite of the tolerably large size of the stomata and the abundance of the intercellular spaces (Fig. 3), the amount of transpiration is very small, even less than that of *Pittosporum* which has smaller stomata and narrower intercellular spaces, although the number of the former is somewhat greater. This may probably be due to the checking of stomatal transpiration in winter, as may be seen by comparing the amount of transpiration at the end of March (vide Table VIII), when the amount suddenly increases, owing to the recovery of the function of the stomata.

Fig. 3.



Cross-section of a leaf of *Ternstrœmia japonica* showing the large intercellular spaces. × 97.

The amount of transpiration in *Thea* is a little greater than in *Ternstrœmia*, but less than in all the other plants which I examined. Here, we see that all parts of the epidermal wall are thickened, the intercellular spaces become smaller, and the number of stomata amounts only to 293 per □ mm.; all these characteristics point to the fact that this plant has well developed protection against transpiration in winter. Moreover, in *Thea* the increase of transpiration was not parallel with the increase of temperature, as is shown by the curve in Fig. 2. My experiment with cobalt paper gave the following results for interpretation of this feebler transpiration :—On February 21st some leaves taken from a pot-plant of *Thea* were unable to redden the paper even after half an hour's exposure to direct sunlight, while at the same time *Aucuba*, *Pittosporum*, *Photinia*, *Ligustrum* and *Daphne odora* all gave positive reactions, indicating open stomata. On April 23rd, the same experiment with *Thea* was repeated without obtaining any positive sign of stomatal transpiration. This limited value of transpiration may be attributed to a loss of function by the stomata, caused by the formation of thyloses (Thyllen) under the guard cells, to which Schwendener[1] first called attention, and of which I myself was able to find evidences in the leaves of *Thea*. The measurement of the epidermis and stomata are given as follows :—

Names of plants.	Thickness of the outer-wall of epidermis.		Number and dimensions of stomata.[2]		
	On the upper side of the leaves.	On the lower side of the leaves.	Number in 1 □mm.	Length.	Breadth.
Quercus glauca	5^{μ}	2.5^{μ}	557	22^{μ}	15^{μ}
Fatsia japonica	5	2.5	182	24	18
Photinia glabra	8	6.5	300	21	18
Illicium Anisatum	6.5	6.5	218	39	19
Daphniphyllum macropodum...	8	6	300	24	18
Ternstrœmia japonica..........	10	10–5	317	36	30
Pittosporum Tobira..............	14	9	337	21	12
Thea japonica.....................	10–5.5	10–4	293	27	15
Eriobotrya japonica	13	5	260	24	18

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[1] Schwendener, Gesammelte Abhandlungen Bd. I, 1898, p. 62.

[2] From Ikeno, l.c., excepting *Quercus*.

The intensity of transpiration in winter, as the results of my experiments show, seems to be so great as to indicate that the movement of water, or the corresponding activity of the root in absorbing water, still exists, even in winter, in a considerable degree; and this fact becomes more obvious when we consider, on the one hand, the climate of Japan, and, on the other, the abundance of evergreen trees and also the general structures of their leaves (vide Chapter III and IV).

Comparison of transpiration between conifers and other evergreen trees. It was Höhnel who first compared the intensity of transpiration of conifers with that of foliage trees. By repeated investigations, he found that the intensity of transpiration of both kinds of plants stood at 1 : 6.[1] I attempted to find out the difference of transpiration between conifers and other evergreen trees in Japan, and for this purpose parallel experiments with both kinds of plants were carried on during my investigations, the numerical data of which are given in Tables I–VIII.

As the results of the above experiments, we found that the difference between them was very slight; thus if we reduce the respective value shown in Tables III and VIII, for instance, to the fresh weight, and even to the dry weight, of the transpiring parts, and take its average in five species of conifers on one hand, and in nine species of other evergreen trees on the other, the relative amount of transpiration in them is roughly 1 : 2 or 1 : 1.5.

Thus in Tables III, and VIII we find that the average amount of transpiration are as follows:—

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[1] Höhnel, Weitere Untersuchungen über die Transpirationsgrösse der forstlichen Holzgewächse.—"Referat" in Just, Bot. Jahresbericht, Bd. VIII. 1, 1880, p. 241.

	Reduced from Table III.		Reduced from Table VIII.	
	Per cent. of fresh weight.	Per cent. of dry weight.	Per cent. of fresh weight.	Per cent. of dry weight.
Cnifers	8.18	19.72	39.16	93.9
Foliage evergreen trees	16.58	37.74	64.65	150.18
Ratio	1:2.02	1:1.91	1:1.65	1:1.6

Although this slight difference exists in winter, there can be little doubt that in other seasons it would be greater, since, as we have explained in the foregoing paragraph (cf. *mode of transpiration*), the difference of transpiration in different plants is least during the cold winter but increases more and more when the outer conditions become more favourable.

The feebler transpiration in conifers can be easily understood when we examine closely their anatomical characters; the contrivances for protecting transpiration are highly developed especially in this class of plants. Their structures are characterized by the smallness of the transpiring surface, by the lignified cell-layer with its thick wall underlying the epidermis, by the deep depression of the stomata in the epidermis, and by the cuticular layer which attains a considerable thickness, etc.[1] Thus we see that in conifers, the development of xerophilous characters is perfect, while in other evergreen trees it is less so, and this anatomical difference chiefly causes the difference in the mode of transpiration in both kinds of plants.

VI. Transpiration under Diffused Light.

In order to understand the process of transpiration exhibited in successive short intervals, the method of absorption has been

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[1] Compare Thomas, Zur vergleichenden Anatomie der Coniferen-Laubblätter. Jahrb. f. wiss. Bot., Bd. IV, 1866, p. 23.

preferred here for ascertaining the amount of water transpired from cut-branches. A consideration of the relation between absorption and transpiration ought not to be neglected, when, as in the present instance, we use this method. While the outer conditions are constant, the relation between these functions also remains the same, but any violent change in the former at once modifies the latter; as is shown by the experiments of many investigators.[1] Eberdt[2] has also shown that the excess of absorption occurs at night, while on the other hand, the excess of transpiration is observed in the daytime as the obvious result of the change of outer conditions, such as temperature and humidity, to which the plant is exposed during both day and night. To make the amounts of both absorption and transpiration approximately equal, the external conditions, which effect these functions, must be kept constant, and in this case only can the amount of absorption be regarded as an indication of the amount of transpiration.

A remarkable fact, not overlooked in my investigations, is that the absorption by cut-branches behaves differently from that of a rooted-plant. As the cut-branches are, strictly speaking, dying parts of the plant, not only is their absorbing power gradually weakened thereby, but also the filtrating activity of the cut-surface of the branches sometimes becomes weaker in consequence of the varying conditions to which they are subjected.[3] It is requisite, therefore, that the experiments should be made with

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[1] Burgerstein, Materialien. II, p. 55.

[2] Eberdt, Die Transpiration der Pflanzen und ihre Abhängigkeit von äusseren Bedingungen 1889.

[3] Pfeffer, Pflanzenphysiologie 1897, 2 Aufl. Bd. I, p. 209.

fresh cut-branches.[1] Moreover in the case of cut-branches we meet with the existence of negative pressure, which may sometimes produce great errors in the measurement of transpiration. Certain plants, for instance, *Daphniphyllum macropodum*, when cut off at 12.50 p.m. and observed at 1 p.m. and in each succeeding interval of 10 minutes, the following lengths of the column of water in the capillary tube were found to have been absorbed, under a constant temperature:—

226, 144, 120, 106, 102, 103, 89, 89, 88, 89, 88, 87, 85, 85, 82, 79, 79, 78, 79, 79, and so forth.

In *Pasania cuspidata* taken at 8.50 a.m., I observed at 9 a.m. and every succeeding 10 minutes, as follows:—

47, 38, 31.5, 28.5, 26, 23.5, 23.5, 22, 22, 22, 21, 20.5, 20, 19.5, 18, 19, 20, and so on.

The greater amount of absorption at the beginning of the experiments shows that the water is taken up by the plant in consequence of the existence of negative pressure, rather than merely to supply the loss of water effected by transpiration at that time.

To avoid, as much as possible, such disturbing conditions, the experiments were carried on in a room where the temperature and humidity were kept nearly constant; and the experiments were commenced two hours after the cut-branches had been placed in the room, when the negative pressure had nearly ceased and at the same time the branches had become somewhat accustomed to the conditions in the room. With regard to the preparation of the branch, a part of the required plant, the

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[1] A gradual diminution of absorption of water by cut-branches has been pointed out by Sachs. (Flora, 1856). F. Darwin and W. Phillips have noted the precautions to be observed while using the potometer in their paper "On the Transpiration-Stream in Cut-Branches" (Proceed. of the Cambridge Philos. Society, Vol. V, Pt. V, 1885, p. 330).

cut-surface of which had been immediately immersed in water, was at first brought into the room and then a shoot vigorous enough for the experiment was cut off from it under water.[1]

With these precautions, I measured the intensity of transpiration in some twenty kinds of plants, including, besides foliage trees, a conifer, a monocotyledon and also a fern; and the results are given together as follows, denoting the quantity of water transpired from our evergreen trees in winter (Table IX experiment 1–20)[2]:—

	per □ dm. per hour. mgr.
Gymnogramme japonica	96.86
Quercus glauca	95.66
Thea Sasanqua	81.55
Ligularia Kœmpferi	71.71
Daphniphyllum macropodum	63.72
Thea japonica	62.24
Eriobotrya japonica	59.15
Fatsia japonica	55.79
Pittosporum Tobira	55.36
Aucuba japonica	54.64
Gardenia florida	53.54
Podocarpus macrophylla	52.57
Nandina domestica	46.02
Pasania cuspidata	41.30
Cinnamomum Loureirii	40.95
Photinia glabra	32.53
Ligustrum japonicum	31.53
Ternstrœmia japonica	30.56
Ilex crenata	24.62
Aspidistra elatior	6.48

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[1] Precautions for using cut-branches are given by Burgerstein, Materialien. II, p. 7.

[2] The temperature and humidity were not constant in the different experiments; the temperature varying from 11.5 to 7.4°C. in air, and from 12.6 to 6.4°C. in water. As to the details, reference should be made to that section in which the experimental data are treated of (Table IX).

Thus, among twenty kinds of plants, the intensity of transpiration did not exceed 0.1 gram per □ dm. per hour in diffused light. The greatest activity of transpiration was attained by *Gymnogramme japonica,* a species of fern ; it has thin herbaceous leaves, whose anatomical structure is characterized by the pallisade consisting of cells loosely arranged in one layer, and also by having an imperfectly developed cuticula. This fern, which grows in sheltered places, sheds its leaves in winter when it is found in open tracts. In such a slightly xerophilous plant, it is natural for us to expect a considerable loss of water. On the other hand, we see the least amount of transpiration in *Aspidistra elatior,* a monocotyledonous plant, whose cuticula is very thick, the mesophyll consisting almost entirely of compactly arranged parenchyma. *Between these two extremes of transpiration stand the typical evergreen trees, which emit, on an average,* 53 *mgr. of water per* □ *dm. per hour.* Among these evergreen trees again, the maximum amount is attained in *Quercus glauca,* while the minimum amount is found in *Ilex crenata.*

We see in our experiments, that the relative amount of transpiration in pot-plants on one hand, and in cut-branches on the other, do not correspond with each other, as for instance, the amount transpired by the cut-branches of *Thea japonica* was greater than that of *Pittosporum* ; while in the case of potted plants, the former was surpassed by the latter. This diversity in the amount of water transpired in the two different cases is partly due to the difference of conditions (temperature, humidity, light &c.) under which the experiments were made ; but chiefly to the methods of the experiments, for in one case the entire plant was used, while in the other only a part was employed. Moreover the difference between individual plants, and also between different parts of the same plant is an important factor causing a great diversity of results in a given experiment; as we see in the researches of Kröber[1] who found, for instance, that the difference in the amount of transpiration between any two branches taken from the same plant was sometimes greater than the difference between two branches taken from two different plants of the same species. A difference between different plants was observed by me in *Thea japonica*: some individuals of this plant which I examined either in pot or in garden showed closure of stomata after the "Kobaltprobe," while others had the apertures completely opened at the same time.

It is, already, well known that a considerable amount of water is given off even in a temperature near 0°C. I witnessed the same fact in the cut-branches of a few evergreen trees. Thus for example (Table IX experiment 21–27):—

	The amount of transpiration per □ dm. per hour. mgr.
Thea japonica	25.71
Ternstrœmia japonica	24.84
Daphniphyllum macropodum	22.87
,, ,,	21.07
Pittosporum Tobira	19.99
Aucuba japonica	13.60
,, ,,	13.69
Pasania glabra	9.90
Average amount	18.96

Comparing these results with those of the preceding experiments (expt. 1–20), we see that the effect of low temperature upon transpiration seems to vary according to the nature of the plants. Thus in *Aucuba japonica*, the intensity of transpiration

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[1] Kröber, Ist die Transpirationsgrösse der Pflanze ein Maasstab für ihre Anbaufähigkeit? Landwirtsch. Versuchst., Bd. XXIV, 1895, p. 503.

in the latter cases (expts. 22 and 26) is reduced to one fourth of that in former case (expt. 1), and in *Daphniphyllum macropodum* as well as in *Pittosporum Tobira*, to one third; while *Ternstrœmia japonica* transpires very sluggishly without showing any noticiable difference during the experiments in both high and low temperatures. This slight variation in the quantity of transpiration of *Ternstrœmia japonica* under such condition of temperature was *ceteris paribus* a noteworthy phenomenon during these experiments; thus again, the amount of transpiration, under air temperature of 9.2–9.°C. and water temperature of 9.2–9.6°C. in December was 30.56 mgr. per □ dm. per hour, while at the lower temperature, both of air and water, of 2.6–2.8 and 1.5°C., 24.84 mgr. of water was given off. The cause of this slight difference becomes evident when we consider the presence or absence of stomatal transpiration.

Lastly let us describe here, for the sake of comparison, some experiments made, in the midst of summer, in a room under diffused daylight. At that time the weather was very wet and almost rainy, the relative humidity indicated being 80–90%, or even more. *Helianthus tuberosus* with 56 leaves, standing in a glass vessel filled with water, transpired 2.511 grams per □ dm. in the interval between 12 m. and 6 p.m. on the 25th of August, and 3.349 grams per □ dm. between 6.20 a.m. and 5.20 p.m. on the next day. The amount of water transpired by the space of a square decimeter of the leaves in an hour was, therefore, 0.418 gr., in the first, and 0.304 gr., in the second experiment. Thus with the typical evergreen leaves observed in the cold winter on the one hand (at a temperature near 0°C.,—Table IX experiment 21–27) and with the typical summergreen leaves observed in the midst of summer on the other hand, the relative difference of transpiration between two series of observations was great, and can be indicated at about 1 : 20.

Recently, Kosaroff in his dissertation, quoted above, has experimentally shown that rooted plants as well as cut-branches can absorb water even under 0°C.; and also that in the stem of trees water can pass through when a portion of the stem is cooled below 0°C. My experiment has been carried on with the view of ascertaining the mode of absorption of water by plants when they are exposed to extreme cold. Such conditions commonly occur in plants on cold winter morning when the leaves are sometimes frozen stiff. As is well known, the absorption of water by cut-branches, in ordinary air temperature, is greatest at first in consequence of the negative pressure of gas, and gradually diminishes as the pressure comes to an equilibrium. However, when the branches were cut off on a cold winter morning and were brought into the room, a quite different phenomenon was found to occur; the power of absorption was at first very weak but after a short time, it suddenly increased and then sank gradually until it became constant in each succeeding interval. As it appeared to me that this fact might have a close connection with the process of transpiration on a cold morning, I endeavoured to examine it more closely.

In the middle of last winter I cut off some shoots and immediately measured the amount of water absorbed by them in a room in which a nearly constant temperature above 0°C. was maintained. In *Daphniphyllum macropodum* and *Aucuba japonica*, the alteration of the absorbing power was remarkable. In the former plant (see Table X) 8 mm. of water column was absorbed during the first hour, but after one hour 245 mm. was absorbed in only 10 minutes (compare Curve X in Plate XVIII). In the latter plant, the absorption of water in the first 10 minutes was 5 mm. but after about one hour it reached the maximum of 50 mm. (vide Table XII and Curve XII).

This mode of absorption depends not only upon either the temperature of the open air or that of the room, but also varies according to the nature of the plants used in the experiments. In a branch of *Thea japonica,* cut off on a very cold morning and brought into a room, in which the temperature stood at 1.8°C., and 1.0°C. in air and water respectively, I could not observe any increase of the power of absorption, but, on the contrary, when the cutting surface was made, the power was most vigorous at first which we often observe to be the case in an ordinary temperature. In *Aucuba japonica* (vide Tables XII and XIII) and *Ternstrœmia japonica* (vide Table XIV), a retardation of the absorption was indicated even at a little higher temperature.

In order to reach the maximum degree of absorption, more than one hour after the branch was brought in the room, seemed to be necessary in my experiments; thus, in *Daphniphyllum,* it was reached in one case after two and a half hours, and in another after two hours and forty minutes; in *Aucuba* the interval was in one instance one hour and twenty minutes and in another nearly two hours; in *Pasania glabra,* one hour and twenty minutes; and in *Ternstrœmia,* only forty minutes (compare Table X-XV and Plate XVIII).

This rapid absorption of water during the first few hours is due not to the suddenrise of transpiration, but to the restoration of the absorping power itself. This may take place in the following way:—Exposure of the plants during the night to a cold temperature many degrees below 0°C. rendered the absorption of water more difficult. Owing to the deficiency of water the plant lost their turgidity of tissue and consequently became wilted. As the temperature after daybreak gradually increased and reached about 0°C. or above, the absorption of water became gradually easier, until after about an hour, it attained its maximum. When a sufficient quantity of water was thus taken up, the rate of absorption became slower and constant, and the wilted branches gradually resumed their normal position and stood perfectly erect.

VII Summary.

The results of my investigations may be briefly summarized as follows:—

1. The evergreen trees indigenous to Japan used in my experiments transpired in winter in Tokyo, an average quantity of, at least, 0.48 gr. per □ dm. per day (with the exception of conifers), or 16.58 gr. per 100 grams of fresh weight in foliage trees, and 8.18 gr. in conifers per day.

2. In the southern part of our country where the climate is milder (the mean temperature at Nagasaki in January being 5.°C.), the intensity of transpiration would undoubtedly be greater. But the contrary is no doubt the case in the northern part, especially in the island of Yezo, where the winter is severe (the mean temperature at Sapporo in January being -6.3°C.), and the plants must protect themselves from a great loss of water; and perhaps we may in their case expect the same occurrence of a minimum transpiration, as has been observed, for example, in Germany.

3. Not only is the transpiration continued in winter in Tokyo, but also the assimilation, as Miyake[1] has recently shown, takes place without intermission in winter, though it is much feebler than in summer; and the non-cessation of these principal physiological functions in winter would naturally lead us to conclude that the abundance of evergreen trees in Japan is chiefly due to the favourable climate.

4. The time of minimum transpiration agrees with that of the minimum temperature, and occurs at the end of January.

5. The difference in the amount of transpiration in different species of evergreen trees becomes smallest at the time of minimum transpiration; and a change in the external conditions, especially in temperature, does not necessarily produce a corresponding change in transpiration in different species.

6. In average cases the amount of water transpired by foliage evergreen trees, is one and a half or two times greater than that transpired by conifers if we reduce the amount either to the fresh weight or to the dry weight of the transpiring part.

7. In diffused light at a temperature of ca. 10°C., the average transpiration of many evergreen trees amounts to 53 mgr. per □ dm. per hour.

The present work was undertaken, at the suggestion of Prof. M. Miyoshi, during the academic year of 1898-1899, and, under his direction, I was able to carry on a large number of experiments. To both Prof. J. Matsumura and Prof. M.

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[1] Bot. Centlbl. Bd. LXXX, 1899, p. 172.

Miyoshi I wish to offer my heartiest thanks for their kind advice during the progress of my work in the laboratory of the Botanical Institute belonging to the College of Science. I am also indebted to Mr. K. Nakamura, Director of the Central Meteorological Observatory in Tokyo, for his kind permission to use the climatological tables made in the Observatory there, and to all other friends who have kindly assisted me in various ways.

July 1899.

ERRATA.

Page 327, line 1, *for* 3-6 times, *read* 3-5 times.
" " " 6, *for* 6.063, *read* 3.661.

EXPERIMENTAL DATA.

I. Transpiration by Direct Insolation of Pot-Plants.

With regard to the temperature and relative humidity which are referred to in the following experiments, I adopted the observations made by the Central Meteorological Observatory of Tokyo, which is situated at a distance of one and a half miles from our laboratory. Both places are almost similar not only in position but also environment, and the hourly observation shows that the air temperature in both places are nearly the same, as will be seen from the following comparison.

Sept. 27th.	At Bot. Gard.	At Obs.
3 p.m.	23°C.	23.6°C.
4	22.5	22.4
28th.		
10 a.m.	21.5	21.5
11	22.75	22.3
12	23.5	22.8
1 p.m.	23.5	23.9
2	23.5	24.6
3	23.0	23.5
4	21.75	21.8
5	20.0	20.2

Sept. 29th.	At Bot. Gard.	At Obs.
10 p.m.	16.2	16.4
11	16.2	16.3
12 a.m.	16.2	16.3
1 p.m.	16.25	16.3
2	16.5	16.5
3	15.75	15.9
30th.		
7 a.m.	17.5	17.8
8	20+	20.1
9	21.5	21.8
10	23.5	23.4
11	24.75	24.1

In the column representing the total amount of transpiration in the following tables, I have given the total daily transpiration; and in the column of average of daily amount of transpiration, the mean value for each day. In the succeeding three columns, I have given the value of transpiration, calculated from the average of the daily amount of transpiration and reduced to the area, fresh weight and dry weight, of the transpiring parts respectively. The amounts were expressed all in gram.

TABLE I (December 28, 1898–January 4, 1899).*

Weighing was made at the beginning and at the end; during the interval the glass cover was not removed. The weather was fine throughout the day.

Names of plants.	Total amount of transpiration.	Average of daily amount of transpiration.	Transpiration during 24 hours.		
			per □ dm. of surface.	per 100 gr. of fresh weight.	per 100 gr. of dry weight.
Cryptomeria	95.0	13.571	—	18.4	38.6
Pinus	91.5	13.071	—	12.3	33.7
Podocarpus	65.5	9.357	—	8.3	18.7
Torreya	58.0	8.285	—	21.2	55.6
Chamæcyparis	39.0	5.571	—	14.8	30.9
Quercus	68.0	9.714	1.742	77.2	161.1
Pittosporum	73.5	10.500	0.833	26.9	70.1
Illicium	81.0	11.570	0.769	24.9	48.7
Ternstrœmia	20.5	2.928	0.419	12.6	32.5
Thea	80.0	11.418	0.6956	22.9	35.9
Eriobotrya	64.5	9.210	0.990	30.3	63.6
Photinia	70.5	10.071	0.883	32.4	70.3
Fatsia	67.0	9.571	0.885	21.7	74.8
Daphniphyllum	38.0	11.714	0.800	32.8	78.6

		29th	30th	31st	1st	2nd	3rd	4th.
* Temperature	Mean	6.0	5.2	3.7	2.9	3.3	5.7	5.0
	Maximum	11.7	9.1	9.3	10.8	9.5	10.6	11.4
	Minimum	1.9	1.8	-1.1	-2.2	0.4	1.3	-0.6
Relatitve humidity		71.9	41.3	47.7	66.7	72.2	68.2	71.8

TABLE II (January 4-11).

During daytime the glass cover was put aside and the weighing was made every evening at 4 p.m. The weather was every fine throughout the day.

Names of plants.	Daily amount of transpiration.								Total amount of transpiration.	Average of daily amount of transpiration.	Transpiration during 24 hours.		
	Date.	4–5	6	7	8	9	10	11			per □ dm. of surface.	per 100 gr. of fresh weight.	per 100 gr. of dry weight.
	Temp. Mea.	4.2	3.1	3.0	3.3	3.5	5.5	5.7					
	Temp. Max.	10.7	7.8	8.9	12.4	9.9	11.9	10.9					
	Temp. Min.	-1.0	-1.5	-1.2	-1.5	-3.0	2.0	1.5					
	Humid.	63.4	49.2	57.9	65.6	71.3	65.5	58.4					
Cryptomeria ……		11.5	8.5	9.0	8.5	6.5	9.0	12.0	65.0	9.286	—	12.6	26.4
Pinus …………		10.0	5.5	6.5	3.5	3.5	4.5	6.5	40.0	5.714	—	5.4	14.7
Podocarpus ……		10.0	8.5	7.0	8.0	5.0	7.0	10.0	55.5	7.929	—	7.0	15.9
Torreya …………		8.5	7.5	5.5	6.0	5.5	5.5	8.0	46.5	6.642	—	17.0	44.6
Chamæcyparis …		7.0	4.5	5.0	3.5	3.5	3.5	6.0	33.0	4.714	—	12.5	26.2
Quercus…………		8.0	8.5	8.0	5.5	5.0	6.0	11.0	52.0	7.429	1.34	59.1	123.2
Pittosporum ……		8.5	11.5	7.5	7.0	6.0	8.0	16.0	64.5	9.214	0.731	23.6	61.6
Illicium…………		9.0	12.0	8.5	8.0	6.5	8.5	11.0	63.5	9.071	0.604	19.6	38.2
Ternstrœmia ……		4.0	2.5	3.0	3.5	3.0	2.0	3.5	21.5	3.071	0.440	13.2	34.1
Thea ……………		14.0	15.5	12.0	9.5	5.5	8.0	11.5	76.0	10.857	0.662	21.8	31.4
Eribotrya ………		8.0	8.0	7.0	3.0	3.5	7.0	10.0	46.5	6.643	0.714	22.3	45.8
Photinia ………		8.0	8.0	6.0	6.5	4.0	7.0	11.5	51.0	7.286	0.639	23.7	50.9
Fatsia …………		9.5	8.5	8.5	6.0	3.0	8.5	9.5	53.5	7.643	0.701	17.3	59.8
Daphniphyllum…		12.0	8.0	8.0	6.5	6.0	7.5	8.0	56.0	8.000	0.546	22.4	53.7

TABLE III (January 17–24).

During daytime the glass cover was removed and the weighings were made every day at 4 p.m. The weather was very fine throughout the day.

Names of plants.	Daily amount of transpiration.								Total amount of transpiration.	Average of daily amount of transpiration.	Transpiration during 24 hours.		
	Date.	17-18	19	20	21	22	23	24			per □ dm. of surface.	per 100 gr. of fresh weight.	per 100 gr. of dry weight.
	Temp. Mea.	2.9	2.5	2.8	1.4	1.9	0.7	3.1					
	Temp. Max.	8.9	10.5	7.7	6.3	8,9	8.9	7.5					
	Temp. Min.	-3.3	-4.2	-1.8	-2.6	-3.1	-5.9	-0.8					
	Humid.	39.2	56.6	61.5	48.8	47.7	74.2	72.3					
Cryptomeria		10.0	7.5	7.5	7.0	9.0	5.5	4.5	51.0	7.286	—	9.9	20.7
Pinus...............		10.0	6.0	10.5	11.0	5.5	3.0	4.0	50.0	7.143	—	6.7	18.4
Podocarpus		5.5	7.0	5.5	4.0	7.5	3.5	2.0	35.0	5.000	—	4.4	10.0
Torreya		9.0	5.5	5.5	6.5	7.0	4.0	2.5	40.0	5.714	—	14.6	38.4
Chamœcyparis ...		2.0	3.0	2.0	2.0	2.0	1.0	2.0	14.0	2.000	—	5.3	11.1
Quercus		5.5	4.0	6.5	5.0	7.5	2.5	4.0	35.0	5.000	0.901	39.7	82.9
Pittosporum		6.0	7.5	6.5	7.5	6.0	4.5	2.5	40.5	5.786	0.506	14.8	38.7
Illicium		9.0	6.0	8.5	8.0	7.0	6.5	3.5	48.5	6.929	0.462	14.9	28.1
Ternstrœmia		2.0	2.5	2.5	2.5	3.5†	1.5	1.5	16.0	2.286	0.328	9.8	27.7
Thea		6.0	3.5	6.5	6.5	7.5	5.0	3.0	38.0	5.429	0.331	10.9	15.7
Eriobotrya.........		5.5	4.0	5.5	5.5	5.5	2.0	3.0	31.0	4.429	0.476	14.7	30.6
Photinia		4.5	5.5	5.0	6.0	4.5	4.0	2.0	31.5	4.500	0.395	14.6	31.4
Fatsia		7.5	7.0	5.0	5.5	5.5	4.0	3.0	37.5	5.357	0.495	12.1	41.9
Daphniphyllum...		6.5	6.5	6.5	7.5	8.0	6.0	3.5	44.5	6.357	0.434	17.7	42.7

† A leaf had fallen off.

TABLE IV (January 24–28).

Between the preceding night and the forenoon of the 25th there was a snow fall; the 28th was cloudy, but all the other days were fine. The glass cover was removed during the daytime. Weighings were made at 4 p.m. every day.

Names of plants.	Daily amount of transpiration.					Total amount of transpiration.	Average of daily amount of transpiration.	Transpiration during 24 hours.		
	Date.	24–25	26	27	28			per □ dm. of surface.	per 100 gr. of fresh weight.	per 100 gr. of dry weight.
	Temp. Mea.	0.8	1.5	2.9	1.7					
	Temp. Max.	5.5	7.5	9.8	4.9					
	Temp. Min.	-1.7	-2.4	-4.	-2.5					
	Humid.	85.9	55.3	54.7	74.7					
Cryptomeria		6.0	7.0	8.0	3.5	24.5	6.125	—	8.3	17.4
Pinus		6.5	7.5	3.5	3.0	20.5	5.125	—	4.8	13.2
Podocarpus		3.0	4.5	6.0	2.5	16.0	4.000	—	3.5	8.0
Torreya		2.5	7.0	5.5	2.5	17.5	4.375	—	11.2	29.4
Chamœcyparis ...		2.0	1.0	1.5	0.5	5.0	1.250	—	3.3	6.9
Quercus............		3.5	5.5	5.5	4.0	18.5	4.613	0.832	36.7	76.5
Pittosporum		3.5	6.0	6.0	2.5	18.0	4.500	0.357	11.5	30.0
Illicium...........		3.5	7.0	7.0	2.0	19.5	4.845	0.322	10.4	20.4
Ternstrœmia		1.5	2.0	3.0	0.5	7.0	1.750	0.254	7.7	19.7
Thea		3.0	6.0	6.0	3.5	18.5	4.613	0.281	9.3	13.3
Eriobotrya.........		4.0	5.0	4.0	1.5	14.5	3.613	0.388	12.0	24.9
Photinia		3.5	5.0	5.5	3.0	17.0	4.250	0.373	13.8	29.7
Fatsia		4.0	6.5	5.5	1.5	17.5	4.375	0.404	9.9	34.2
Daphniphyllum...		7.5	7.0	7.0	3.0	24.5	6.125	0.418	17.1	41.1

TABLE V (January 31–February 4).*

Only on the first day, the glass cover was removed. The weather was fine throughout the day. Weighings were made at 4 p.m. on the first and the last days.

Names of plants.	Total amount of transpiration.	Average of daily amount of transpiration.	Transpiration during 24 hours.		
			per □ dm. of surface.	per 100 gr. of fresh weight.	per 100 gr. of dry weight.
Cryptomeria	—	—	—	—	—
Pinus	23.0	5.750	—	5.4	14.8
Podocarpus	26.0	6.500	—	5.7	13.0
Torreya	31.0	7.750	—	19.8	52.0
Chamæcyparis	10.0	2.500	—	6.6	13.8
Quercus	27.5	6.875	1.238	54.7	113.7
Pittosporum	34.5	8.625	0.684	22.1	57.6
Illicium	29.5	7.375	0.491	15.9	31.0
Ternstrœmia	12.0	3.000	0.436	13.1	33.8
Thea	32.5	8.125	0.495	16.3	23.5
Eriobotrya	24.5	6.125	0.658	20.3	42.3
Photinia	30.5	7.625	0.668	24.8	53.2
Fatsia	14.0	3.500	0.323	7.9	27.4
Daphniphyllum	32.5	8.125	0.555	22.7	54.5

		1st	2nd	3rd	4th.
* Temperature	Mean	2.3	2.9	3.9	3.4
	Maximum	8.4	8.1	9.5	9.8
	Minimum	−3.2	−3.5	−0.6	−2.0
Relative humidity		45.0	40.5	43.5	58.6

TABLE VI (February 14–21).

Of the seven days two were snowy and on them weighings were omitted; of the rest one was partly fine, and the others were very fine. Weighings at 4 p.m.

Names of plants.	Daily amount of transpiration.								Total amount of transpiration.	Average of daily amount of transpiration.	Average of daily amount of transpiration of 15, 20 and 21.	Transpiration during 24 hours†		
	Date.	14–15	16	17	18	19	20	21.				per □ dm. of surface.	per 100 gr. of fresh weight.	per 100 gr. of dry weight.
	Temp. Mea.	3.4	-0.8	3.1	1.3	3.1	3.4	5.9						
	Max.	8.3	2.1	8.3	4.6	7.7	10.5	11.8						
	Min.	-0.8	-2.6	0.2	-1.0	0.4	-1.0	1.2						
	Humid.	40.5	93.6	76.6	81.3	80.1	72.0	59.2						
Cryptomeria		8.5		10.0*		7.0*	6.0	10.0	41.5	5.928	8.167	—	11.0	23.2
Pinus		14.5		7.5		15.5	6.0	10.5	54.0	7.714	10.333	—	9.7	26.9
Podocarpus		8.0		11.0		9.5	5.5	15.5	49.5	7.071	9.667	—	8.5	19.3
Torreya		12.5		11.0		11.0	6.0	3.0	43.5	6.214	2.167	—	18.3	48.2
Chamæcyparis		3.0		3.5		1.0	1.0	2.5	11.0	1.571	9.167	—	5.7	12.1
Quercus		9.5		9.0		5.9	6.5	11.5	46.0	6.571	9.167	1.651	72.9	152.0
Pittosporum		8.0‡		12.5		8.0	10.0	12.5	51.0	7.257	10.167	0.823	26.4	69.1
Illicium		8.5		5.5		10.0	8.4	11.0	43.0	6.014	9.167	0.610	19.8	38.6
Ternstrœmia		2.5		4.0		3.0	2.0§	6.0	17.5	2.500	3.500	0.518	15.5	31.2
Thea		4.0		4.0		4.5	6.0	8.5	27.0	3.857	6.167	0.376	12.4	17.9
Eribotrya		10.5		11.5		12.5	6.0	15.5	56.0	8.000	10.667	1.146	35.4	73.5
Photinia		6.0		11.5		10.5	9.5	12.0	49.5	7.071	9.167	0.804	29.8	64.0
Fatsia		11.0		11.5		12.5	9.0	15.5	59.5	8.500	11.800	1.091	26.7	92.2
Daphniphyllum		9.0		11.0		12.5	7.0	13.5	53.0	7.571	9.833	0.671	27.5	66.0

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* Numerical values given in these two columns show the amount of transpiration during two days.

† Calculated from the mean amount of the transpiration on fine days only, i. e., on the 15th, 20th and 21st.

‡ Five leaves had fallen off.

§ Three leaves had fallen off.

TABLE VII (February 25–28).

Only the last day was cloudy. Weighings were made every day from 8 to 9 a.m.

Names of plants.	Daily amount of transpiration.				Total amount of transpiration.	Average of daily amount of transpiration.	Transpiration during 24 hours.		
	Date.	25	26	27			per □ dm. of surface.	per 100 gr. of fresh weight.	per 100 gr. of dry weight.
	Temp. Mea.	6.0	7.7	8.5					
	Temp. Max.	11.4	15.1	13.3					
	Temp. Min.	1.9	-0.5	4.9					
	Humid.	69.2	76.5	76.2					
Cryptomeria		7.0	9.5	5.5	22.0	7.333	—	10.0	20.9
Pinus		14.0	13.0	8.0	35.0	11.667	—	11.0	30.0
Podocarpus		19.0	21.0	14.0	54.0	18.000	—	15.9	36.0
Torreya		14.0	20.0	10.5	44.5	17.833	—	38.0	99.6
Chamæcyparis		3.5	5.5	5.0	14.0	4.667	—	12.4	25.9
Quercus		12.0	14.0	11.0	37.0	12.333	2.221	98.0	204.5
Pittosporum		16.5	21.0	14.0	51.5	17.167	1.390	44.7	116.7
Illicium		14.0	12.5	13.5	40.0	13.333	0.887	28.7	56.1
Ternstrœmia		4.5	5.0	2.0	11.5	3.833	0.576	17.2	44.4
Thea		14.0	19.0	14.0	47.0	15.667	0.955	31.4	45.3
Eriobotrya		17.0	13.0	13.5	43.5	14.500	1.558	46.0	100.0
Photinia		15.5	13.0	10.0	38.5	12.833	1.126	41.7	90.0
Fatsia		20.0	24.0	13.0	57.0	19.000	1.756	43.0	148.6
Daphniphyllum		14.0	13.0	11.0	38.0	12.667	0.865	35.4	85.0

TABLE VIII (March 21–24).*

The glass cover was placed aside during both day and night. The weather was very fine, and weighings were made on the first and the last days.

Names of plants.	Total amount of transpiration.	Average of daily amount of transpiration.	Transpiration during 24 hours.		
			per □ dm. of surface.	per 100 gr. of fresh weight.	per 100 gr. of dry weight.
Cryptomeria	70.0	23.33	—	31.5	66.3
Pinus	54.0	18.00	—	16.5	46.4
Podocarpus	95.0	31.66	—	27.9	63.4
Torreya	93.0	31.00	—	79.3	208.2
Chamæcyparis	46.0	15.33	—	40.6	85.1
Quercus	61.0	20.33	3.661	161.6	339.2
Pittosporum §	69.0	23.00	2.012	56.2	167.4
Illicium	89.0	29.66	1.974	64.0	124.8
Ternstrœmia	36.0	12.00	1.802	53.8	124.8
Thea	46.0	15.33	0.934	30.7	44.3
Eriobotrya	56.0	18.66	2.006	61.9	128.8
Photinia	39.0	13.00	1.140	42.2	90.8
Fatsia	80.0	26.66	2.464	60.3	208.5
Daphniphyllum	55.0	18.33	1.251	51.2	123.0

§ Fourteen leaves had fallen off before the experiment was begun.

		22nd	23rd	24th.
* Temperature	Mean	8.3	10.4	6.4
	Maximum	14.7	17.5	9.4
	Minimum	1.2	3.5	4.0
Relative humidity		61.2	73.2	83.1

II. Transpiration of Cut–

TABLE

Number of experiment.	Date.	Weather.	Plant.					Air temperature.	Water temperature.
			Name.	Age of branch.	Number of leaves.	Fresh weight of leaves.	Area of leaves.		
						gr.	□dm.	C.	C.
1	5. Dec.	Fine	*Aucuba japonica*†	1	6	18.812	6.794	11.5	12.5–12.6
2	6. „	Cloudy	*Pittosporum Tobira*	1	15	3.372	0.833	10.6-10.5	11.0
3	7. „	Fine	*Ligularia Kœmpferi*	1	1	8.077	1.686	10	10.5–11.0
4	8. „	„	*Quercus glauca*	3	19	10.640	4.007	8.8	10.0
5	„ „	„	*Thea japonica*	4	12	7.940	1.965	9.2	10.0
6	11. „	„	*Pasania cuspidata*	1	10	7.152	2.217	9.4–9.5	10.0
7	„ „	„	*Ilex crenata*	7	172	—	2.251	9.9-10	11.0
8	12. „	Cloudy	*Photinia glabra*	3	23	9.550	3.347	9.9	10.2
9	14. „	Fine	*Gardenia florida*	4?	35	9.870	5.263	9.1–9.2	10.0–10.2
10	„ „	„	*Daphniphyllum macropodum*	1	16	19.840	5.862	9.6–9.7	10.5
11	15. „	„	*Cinnamomum Loureirii*	1	11	13.500	5.433	8.7	9.5
12	„ „	Rainy	*Ligustrum japonicum*	5	60	28.220	8.195	9.0	10.0
13	16. „	Fine	*Ternstrœmia japonica*	3	42	9.830	2.876	9.2–9.0	9.2–9.6
14	„ „	„	*Eriobotrya japonica*	2	9	5.055	1.878	9.3–8.8	10.0
15	17. „	„	*Thea Sasanqua*	5	29	9.525	2.680	10.2	10.0
16	18. „	„	*Nandina domestica*	1	130	—	8.197	9.2–9.0	8.9–9.0
17	19. „	„	*Aspidistra elatior*	1	1	8.700	3.186	7.7–7.8	8.0–8.2
18	21. „	„	*Gymnogramme japonica*	1	21	8.930	5.456	2.9–9.1	9.0
19	22. „	Cloudy	*Podocarpus macrophylla*	5	64	35.370	6.166	7.4	6.4–6.5
20	11. Jan.	Fine	*Fatsia japonica*	1	1	10.265	2.570	9.0–8.0	8.8–9.0
21	17. „	Cloudy	*Daphniphyllum macropodum*	1	13	18.010	5.518	0.6	0.0
„	18. „	Fine	„ „	„	„	„	„	1.8	1.0
22	20. „	„	*Aucuba japonica*	1	10	17.655	5.510	2.6	2.0
23	23. „	„	*Pasania glabra*	1	9	15.410	4.407	1.4	0.5
24	22. „	„	*Thea japonica*	5	28	17.257	4.386	2.0	1.0
25	27. „	„	*Ternstrœmia japonica*	4	48	9.942	2.028	2.6–2.8	1.5
26	28. „	Cloudy	*Aucuba japonica*	1	9	12.759	4.132	2.8	2.0
27	„ „	„	*Pittosporum Tobira*	2	63	9.322	3.925	3.2	2.0

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* One millimeter of water column in the capillary tube corresponds

† The branches were cut off on the preceding day and placed in

‡ The branch had been cut off 4 hours before.

§ The absorbing surface had been renewed 4 hours before.

‖ The branches had been cut off 3 hours before.

BRANCHES UNDER DIFFUSED LIGHT.

IX.

Relative humidity.	Time at the beginning of experiment.	Column of water in the tube absorbed in each succeeding interval of 10 minutes.*	Total absorption of water.	Amount of transpiration per □ dm. per hour.
%			mgr.	mgr.
84.5	11.00 a.m.	**80, 80, 81, 80, 79, 79.**	371.225	**54.64**
85.1–87.7	3.10 p.m.	**11, 10, 10, 9.5, 9.5, 9.5.**	64.112	**55.36**
84.3	3.10 „	**26, 26, 26, 26, 26, 26.**	120.900	**71.71**
81.2	11.00 a.m.	**84, 89, 89, 81, 79, 79, 78.**	447.175	**95.66**
75.9–78.5	2.20 p.m.	**28.5, 29.5, 28, 28, 28, 24, 23, 25, 25, 24.**	203.826	**62.24**
86.6	10.50 a.m.	**21, 20.5, 20, 19.5, 18, 19, 20.**	106.950	**41.30**
84.3–86.8	3.00 p.m.	**12.5, 12.5, 12.5, 11, 11, 12, 12.5, 11.5.**	74.013	**24.62**
72.9	11.20 a.m.	**25.5, 25, 23, 23, 23, 21.**	108.888	**32.53**
81.1–81.2	10.40 „	**67, 70, 67, 66, 63, 57, 60, 58, 57.**	439.375	**53.54**
78.9–80.4	3.00 p.m.	**85, 82, 79, 79, 78, 79.**	373.550	**63.72**
79.4	11.00 a.m.	**45, 48, 47, 45, 46, 45, 46.**	259.550	**40.95**
82.4	3.00 p.m.	**63.5, 54, 55, 55, 51, 58, 55.**	301.413	**31.53**
79.6	11.00 a.m.	**18, 19.5, 18, 18, 19, 20, 20, 19, 19.**	146.476	**30.56**
74.8–79.7	2.30 p.m.	**28, 29, 25, 24, 22, 21, 22, 22, 22.**	166.625	**59.15**
77.1	2.10 „	**52, 46, 48.5, 45.5, 48, 45, 44.**	254.976	**81.55**
69.8–73.1	2.40 „	**81, 88, 83, 82, 77, 96, 64, 78.**	502.975	**46.02**
84.4	12.20 „	**4.5, 5, 4.5, 4, 5, 4, 4.5, 4.**	27.514	**6.48**
69.4–64.6	2.00 „	**110, 108, 105, 110, 110, 114, 116, 116, 114, 110.**	862.575	**96.86**
69.6	3.00 „	**85, 79, 71, 69, 57, 69, 58.**	378.200	**52.57**
56.6–72.2	1.00 „	**28, 28, 30, 33, 37, 29.**	143.375	**55.79**
96.0	12.30 a.m.‡	**30, 30, 29, 25, 26, 25, 25.**	147.250	**22.87**
67.8	11.30 „ §	**25, 25, 25, 25.**	77.500	**21.07**
86.8	11.00 „ ‖	**18, 16, 16, 16, 16, 15.**	75.175	**13.60**
62.8	11.20 „ ‖	**10, 9, 9, 10, 9, 8.**	42.625	**9.90**
68.7	11.20 „ ‖	**23, 26, 24, 24.**	75.175	**25.71**
91.0–74.6	10.30 „	**12, 12, 11, 10, 10, 10.**	50.375	**24.84**
72.1	10.30 „	**13, 12, 12, 12, 12, 12.**	56.575	**13.69**
72.6	1.10 p.m.	**19, 19, 18, 16, 16, 17, 15, 15.**	104.625	**19.99**

to 0.775 mgr.

water in the room until the experiment was made with new cutting surface.

III. Mode of the Absorption of Water by Cut-Branches at Low Temperature.

TABLE X.

January 17, 1899—Weather very fine.
Plant: *Daphniphyllum macropodum.*
Air temperature, at the time when the branch was cut off, was 0.8°C. and the leaves were drooping.
Time of preparation—8.30 a.m.

Time.	Column of water absorbed in mm.	Air temperature.	Water temperature.	Remarks.
9.00 a.m.	—	0.2	0	
9.10	1	0.2	0	
9.20	1	0.2	0	
9.30	1	0.2	0	
9.40	1	0.2	0	
9.50	2	0.2	0	
10.00	2	0.2	0	
10.10	3	0.2	0	
10.20	3	0.2	0	
10.30	4	0.2	0	
10.40	73	0.6	0	Inclination of a leaf was 65.°
10.50	223	0.6	0	
11.00	**245**	0.6	0	
11.10	180	0.6	0	
11.20	110	0.6	0	
11.30	80	0.6	0	
11.40	57	0.6	0	
11.50	58	0.6	0	70.°
12.00	44	0.6	0	
12.10 p.m.	38	0.6	0	78.°
12.20	35	0.6	0	
12.30	31	0.6	0	
12.40	30	0.6	0	81.°
12.50	30	0.6	0	
1.00	29	0.6	0	
1.10	25	0.6	0	
1.20	26	0.6	0	
1.30	25	0.6	0	
1.40	25	0.6	0	

TABLE XI.

January 18, 1899—Weather very fine.

Plant: The same branch after the first experiment was placed in water outside the laboratory during the night until the next morning and then after making a new absorbing surface experiment was repeated.

Air temperature at 7 a.m. was 1.1°C. and temperature of water in which the branch remained immersed was 0°C.

Time of preparation—7.30 a.m.

Time.	Column of water absorbed in mm.	Air temperature.	Water temperature.	Remarks.
8.50 a.m.	5	1.2	0.3	At the beginning of observation, i.e., at 7.30 a.m. the temp. of air and water in the room was 1°C. and 0°C. respectively. Inclination of leaves remained constant during observation.
9.00	4	1.2	0.3	
9.10	3	1.2	0.3	
9.20	4	1.2	0.3	
9.30	4	1.2	0.5	
9.40	3	1.2	0.5	
9.50	7	1.2	0.5	
10.00	25	1.4	0.5	
10.10	**115**	1.4	0.5	
10.20	82	1.4	0.5	
10.30	63	1.4	0.5	
10.40	53	1.4	0.5	
10.50	45	1.4	0.5	
11.00	36	1.6	0.5	
11.10	33	1.6	0.7	
11.20	32	1.6	0.7	
11.30	25	1.6	0.7	
11.40	25	1.6	1.0	
11.50	25	1.6	1.0	
12.00	25	1.6	1.0	

TABLE XII.

January 20, 1899—Weather very fine.
Plant: *Aucuba japonica.*
Air temperature, 0°C. at 8 a.m.
The leaves drooped and were curled up. Ten minutes after they were brought in the room, all the leaves became turgescent.
Time of preparation—8.05 a.m.

Time.	Column of water absorbed in mm.	Air temperature.	Water temperature.	Remarks.
8.30 a.m.	—	2.4	2	A leaf took horizontal
8.40	5	2.4	2	position.
8.50	6	2.4	2	
9.00	5	2.4	2	
9.10	6	2.4	2	
9.20	11	2.5	2	
9.30	12	2.5	2	Here it took the normal
9.40	26	2.6	2	erect position.
9.50	50	2.6	2	
10.00	35	2.6	2	
10.10	29	2.6	2	
10.20	23	2.6	2	
10.30	22	2.6	2	
10.40	20	2.6	2	
10.50	14	2.6	2	
11.00	23	2.6	2	
11.10	18	2.6	2	
11.20	16	2.6	2	
11.30	16	2.6	2	
11.40	16	2.6	2	
11.50	16	2.6	2	
12.00	15	2.6	2	

TABLE XIII.

January 28, 1899—Weather cloudy.
Plant: *Aucuba japonica.*
The branch was brought from open air at -4°C. into the room at 2.6°C. The leaves were covered with frost.
Time of preparation—8.30 a.m.

Time.	Column of water absorbed in mm.	Air temperature.	Water temperature.	Remarks.
8.30 a.m.	—	2.7	2	
8.40	2	2.7	2	
8.50	1.5	2.7	2	
9.00	1.5	2.6	2	
9.10	3.5	2.5	2	
9.20	6.5	2.5	2	
9.30	6	2.4	2	
9.40	14	2.4	2	
9.50	**20**	2.4	2	
10.00	18	2.5	2	
10.10	14	2.5	2	
10.20	14	2.5	2	
10.30	13	2.7	2	
10.40	12	2.7	2	
10.50	12	2.8	2	
11.00	12	2.8	2	
11.10	12	2.8	2	
11.20	12	2.8	2	

TABLE XIV.

January 27, 1899—Weather very fine.
Plant: *Ternstrœmia japonica.*
The branch was brought from open air at 0°C. into the room at 2.2°C.
Time of preparation—8.20 a.m.

Time.	Column of water absorbed in mm.	Air temperature.	Air temperature.	Remarks.
8.30 a.m.	—	2.3	1.0	
8.40	12	2.4	1.0	
8.50	72	2.4	1.0	
9.00	57	2.4	1.5	
9.10	44	2.4	1.5	
9.20	31	2.4	1.5	
9.30	25	2.4	1.5	
9.40	21	2.4	1.5	
9.50	20	2.5	1.5	
10.00	17	2.5	1.5	
10.10	16	2.5	1.5	
10.20	15	2.6	1.5	
10.30	13	2.6	1.5	
10.40	12	2.6	1.5	
10.50	12	2.6	1.5	
11.00	11	2.6	1.5	
11.10	10	2.8	1.5	
11.20	10	2.8	1.5	
11.30	10	2.8	1.5	

TABLE XV.

January 23, 1899—Weather very fine.

Plant: *Pasania glabra.*

Air temperature out of doors was –8°C. at 6 a.m. the minimum of this month.

Time of preparation—7.20 a.m.

Time.	Column of water absorbed in mm.	Air temperature.	Water temperature.	Remarks.
7.30 a.m.	—	—	—	
7.40	—	—	—	
7.50	16	0.4	0.5	
8.00	16	0.4	0.5	
8.10	16	0.4	0.5	
8.20	21	0.4	0.5	
8.30	23	0.7	0.5	
8.40	**25**	0.8	0.5	
8.50	20	1.0	0.5	
9.00	17	1.0	0.5	
9.10	14	1.0	0.5	
9.20	12	1.0	0.5	
9.30	12	1.0	0.5	
9.40	11	1.0	0.5	
9.50	10	1.0	0.5	
10.00	12	1.2	0.5	
10.10	10	1.3	0.5	
10.20	9	1.3	0.5	
10.30	10	1.3	0.5	
10.40	9	1.1	0.5	
10.50	9	1.3	0.5	
11.00	10	1.4	0.5	
11.10	9	1.4	0.5	

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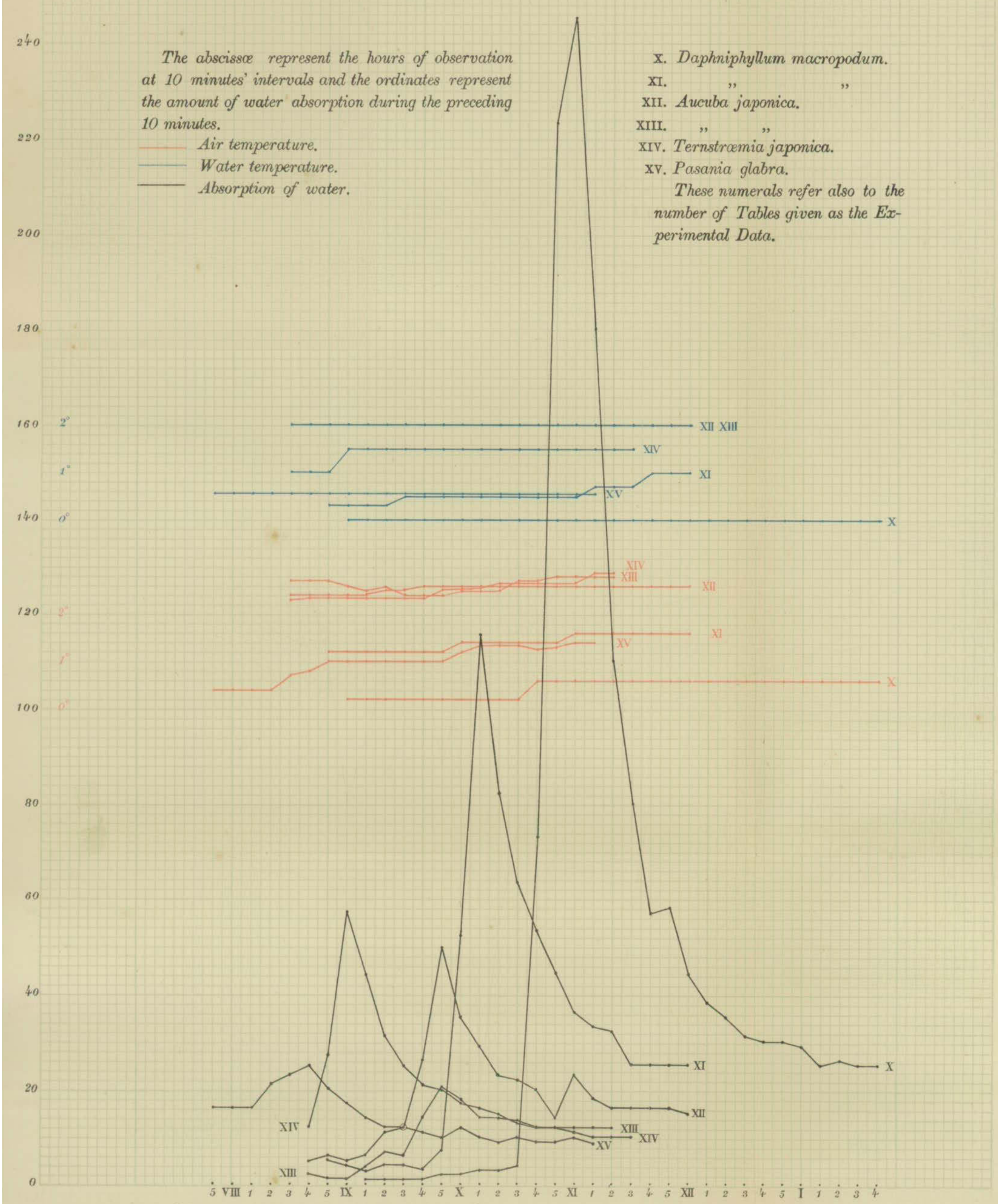
Graphic Representation of the Mode of the Absorption of Water by Cut-Branches at Low Temperature.



The abscissæ represent the hours of observation at 10 minutes' intervals and the ordinates represent the amount of water absorption during the preceding 10 minutes.

🟥	*Air temperature.*
🟦	*Water temperature.*
⬛	*Absorption of water.*

X. *Daphniphyllum macropodum.*
XI. ,, ,,
XII. *Aucuba japonica.*
XIII. ,, ,,
XIV. *Ternstrœmia japonica.*
XV. *Pasania glabra.*

These numerals refer also to the number of Tables given as the Experimental Data.