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THE WATER RELATIONS OF THE PINE (*PINUS PINASTER*)
AND THE SILVER TREE (*LEUCADENDRON ARGENTEUM*).*

By R. D. AITKEN, M.Sc.

(Union Government Research Scholar).

Communicated by Prof. D. THODAY.

(With one Text-figure.)

I. INTRODUCTION.

In two papers recently published in the 'Proceedings of the Royal Society,' Farmer (1) has given an account of experiments he has performed with a view to ascertaining, among other matters, whether "the efficiency of the wood can be usefully expressed in a quantitative form, and to what extent separate species differ." As a result of his experiments he concludes that the efficiency of the wood can be thus expressed, and describes a method of measuring it, and defines the "specific conductivity" of the wood as "the quantity of water transmitted through 1 sq. cm. of wood, 15 cm. long, in 15 minutes under a pressure of 30 cm. of mercury."

The clearest result of his experiments is that evergreens possess wood of markedly lower efficiency than that of the broad-leaved deciduous trees, and that the absolute range of variation in individual species is far narrower than in deciduous forms. A few examples from the tables in his papers will illustrate this :

<i>Evergreen.</i>		<i>Deciduous.</i>	
Name.	Spec. cond.	Name.	Spec. cond.
Scots pine	13 ± 2	Common oak	75 ± 15
<i>Euonymus japonica</i> . .	12.1	<i>Euonymus europaeus</i> . .	40.2

He further suggests that the xerophytic character of many of the evergreens may be due to the low conductivity of their wood, and says, "It becomes intelligible why a plant apparently xerophytic may yet be restricted to localities in which it is never really subject to drought. The wood is

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capable of transmitting a limited supply of water, the leaves are fitted just to utilise this amount with very little margin; in other words, though the plant requires little, it can hardly do with less."

In May of 1919 the present writer began, at the suggestion of Prof. D. Thoday, a series of measurements of the specific conductivity of the wood of certain South African trees with the object of ascertaining whether this property of the wood played any part in deciding the usual habitat of the various trees. It was soon realised, however, that this factor could not be considered independently, but that the transpiring power of the leaves must also be taken into account. For instance, a tree with wood of high specific conductivity and mesophytic leaves, which use up nearly all the water they can obtain from the stem, will probably be quite as much restricted as to its habitat as a tree with wood of low conductivity and xerophytic leaves. Accordingly it was decided to compare the transpiration rates and the water-conducting power of the wood of two trees, and see whether any indication could thus be obtained of the drought-resisting power of the trees.

For the preliminary work the two trees selected were *Pinus pinaster* and *Leucadendron argenteum*, both of which grow within practicable range of the University of Cape Town. The leaves of each of these evergreen trees are distinctly xerophytic. That of the Pine is so well known as to need no description. The leaves of the Silver Tree are sessile, $2\frac{1}{2}$ – $5\frac{1}{2}$ in. long, $\frac{1}{2}$ – $1\frac{1}{4}$ in. broad, and lanceolate. They are densely pubescent on both surfaces with adpressed, silvery, silky hairs. According to Marloth (2) these hairs are closely pressed to the surface of the leaf in dry weather, and stand out at an angle of about 30° from the surface during damp weather. With the naked eye, however, the present writer could observe no difference in the position of the hairs in dry and damp weather, though no critical experiments were conducted to test the statement. As in the case of other Proteaceae the stomata of *Leucadendron argenteum* are protected by a small raised pore.

II. METHODS.

A. *Measurement of conductivity*.—Lengths of 15 cm. were cut under water from the centre of the twigs chosen for the experiments, and placed in jars of water, over which the pressure of air was reduced by means of a suction pump. Half an hour to an hour was deemed sufficient to remove all the air from the stem, and to inject it with water.

To obtain the necessary pressure for the actual conductivity measurements an aspirator was placed on top of a cupboard and filled with distilled water. In order that the pressure might remain constant throughout the series of experiments, a glass tube was inserted through a cork in the top

of the aspirator. A long tube descended from the base of the aspirator, and the twig was attached to the lower end of this tube. In this way a head of water of 186 cm. was obtained. This is equivalent to a pressure of 13.68 cm. of mercury.

The amount of water passing through the twig in 15 minutes under this pressure was measured. The values thus obtained are referred to as the "standard transmission" (*i. e.* the amount of water transmitted under the standard conditions) of the twigs. In the early experiments four readings were taken for each twig, and it was found that in nearly every case the amount of water transmitted became less with each successive quarter of an-hour, *e. g.* :

Pine, first	quarter hour,	5.6 c.c.	.	Silver Tree, 16	c.c.
„ second	„	4.8 „	.	„	1.45 „
„ third	„	4.0 „	.	„	1.35 „
„ fourth	„	3.1 „	.	„	1.30 „

That this falling-off was due to clogging at the cut surface seems clear from the facts that it was not nearly so marked in the *Leucadendron* as in the Pine, and that it did not occur when the surfaces were shaved after each reading. The first reading was therefore taken as most nearly representing the true water-conducting power of the wood. In later experiments only one or two readings were taken, and the first of these was used.

Having measured the standard transmission of the twig it was bisected, and a cross-section cut from the centre. By means of a projection apparatus, fitted up at the suggestion of Prof. Thoday from materials available in the laboratory, a drawing of this section was made on squared paper, and the area of wood in the section was measured.

All the data were then available for calculating the specific conductivity of the wood.

B. Measurement of transpiration.—The twigs for these experiments were cut from the trees in the evening and kept overnight with their cut ends in water. They were then placed in small test-tubes of water, and the loss of weight per half hour measured. In some cases the twigs were kept in the laboratory throughout the experiment, in others they were exposed on the roof of the laboratory on both dull and bright days.

C. Measurement of leaf area.—In the case of *Leucadendron* the method was comparatively simple. The leaves were picked from the twig and classified according to their size into about six groups. A representative leaf was then chosen from each group, and placed under glass on a piece of photographic paper. The leaf shape thus obtained was cut out and weighed, and from this weight and the area and weight of the whole piece the area of the leaf print was calculated. Knowing this, and the number of leaves in each group, the leaf area was calculated for each group and then for the whole twig.

The determination of the leaf area of the Pine presented greater difficulties. The most hopeful method seemed to be to find an expression for the area involving the length of the leaf and the diameter of its flat side. As a first step towards this, sections were cut from various portions of a leaf and camera lucida drawings made of these sections. Measurement of the perimeter of the curved surface and of the diameter of the flat surface showed that the relation between the two was fairly constant and averaged 1·8, *e. g.*—

LEAF No. 1. Length, 16·7 cm.

Position of section.	Diameter.	Curved surface.	C/D.
Base	1·39 mm.	2·75 mm.	1·99
2·1 cm. from base	1·69 „	3·14 „	1·86
4·2 „ „	1·69 „	3·07 „	1·82
6·3 „ „	1·62 „	2·89 „	1·78
8·35 „ „	1·58 „	2·86 „	1·81
10·5 „ „	1·62 „	3·02 „	1·86
12·6 „ „	1·50 „	2·59 „	1·73
14·7 „ „	1·39 „	2·42 „	1·75
15·7 „ „	1·15 „	2·05 „	1·78
16·2 „ „	1·07 „	— „	—
16·6 „ „	0·54 „	0·57 „	—
			9)16·38
Average			1·8(2)

Two other leaves, one 16·9 cm. long, the other 10·1 cm. long, gave as the average ratio C/D 1·77 and 1·84 respectively. In the case of nine other leaves of varying length the diameter and circumference of the mid-section were measured, and the average ratio of C/D in these cases proved to be 1·77. The value of C/D was taken as the average of these four values, *i. e.* 1·8.

The next step was to measure as accurately as possible the area of the flat surface of the leaf. This was effected by cutting sections of a leaf at intervals from the base and plotting on squared paper the diameter of these sections against their distance from the base. In this way one obtained a magnified drawing of the flat surface of the leaf, and measured its area by counting the number of squares it contained. Knowing the magnification, the actual area of the flat surface was then readily calculated. The total area of the leaf was then taken as—

$$\text{Area of flat surface} \times (C/D + 1)$$

i. e. Area of flat surface $\times 2\cdot8$.

Comparison of the leaf area measured in this way with the area calculated from—

Length of leaf $\times$ Total perimeter of mid-section
showed that the latter was always slightly greater than the former, *e. g.*—

No.	<i>a.</i>		<i>b.</i>		<i>a</i> per cent. of <i>b.</i>
	Area from graph.		Area from Mid-section $\times$ length.		
1	7.08 sq. cm.	.	7.38 sq. cm.	.	95.9 per cent.
2	6.75 „	.	7.10 „	.	95.1 „
3	3.39 „	.	3.48 „	.	97.4 „

The actual leaf area was therefore taken to be 96 per cent. of the area calculated from the expression, *perimeter of mid-section $\times$ length.*

To obtain the total leaf area of a twig, the leaves were arranged in groups according to their length, and the diameter of the flat surface of representative leaves from each group measured. The leaf area of each group was then obtained from the expression, *number of leaves $\times$ length $\times$ diam. mid-section $\times$ 2.8 $\times$ 0.96.* As already explained, 2.8 is the value of $(C/D + 1)$ and 0.96 represents the necessary reduction to 96 per cent., just mentioned.

The total leaf area of the twig was then obtained by adding together the areas of the groups.

III. RESULTS.

A. The water-conducting power of the wood.—The first experiments were confined to measurements of the conductivity of the wood of the two trees, and showed a considerable difference between the two. It should be noted that the “conductivity” in these experiments differs from Farmer’s “specific conductivity.” The former is calculated for a pressure of 186 cm. of water, the latter for a pressure of 30 cm. of mercury. At the outset a few measurements were made of the conductivity of the wood of the Oak as well as of that of the Pine and Silver Tree. The results obtained for these three trees are in accordance with Farmer’s main conclusion that evergreens possess wood of markedly lower efficiency than that of the broad-leaved deciduous trees, and that the absolute range of variation in individual species is far narrower than in deciduous forms.

In the few measurements made of the conductivity of the wood of the Oak the values ranged from 18.9 to 107.8, the average of seven experiments being 46.6.

Of the three trees the Pine showed least variation in its conductivity. For the six preliminary measurements with Pine wood the average conductivity was 7.1, the values ranging from 5.9 to 8.2. These measurements were made in July, 1919; in January, 1920, further measurements were

made of both transpiration and conduction, the average conductivity then obtained being 7·9. In the later set of experiments, however, the range of values was greater, the lowest being 5·6 and the highest 9·3. The average conductivity obtained from all the experiments was 7·5.

In the case of the Silver Tree, nine experiments in July gave values ranging from 13·0 to 26·0, the average being 20·8. The January experiments gave lower values ranging from 10·0 to 24·6 with an average of 16·2. The average for all the experiments was 17·8.

These results are tabulated in Table I, in which some of Farmer's figures are included for comparison.

TABLE I.—Measurements of Conductivity.

	Oak.	<i>Pinus pinaster.</i>	<i>Pinus sylvestris.</i>
Range	18·9–107·8	5·6–9·3	—
Conductivity (average) (186 cm. water)	46·6	7·5	—
Specific conductivity (30 cm. mercury):			
Aitken	102·5	16·5	—
Farmer	75 ± 15	—	13 ± 2
	<i>Leucadendron argenteum.</i>	<i>Euonymus japonica</i> (evergreen).	<i>Euonymus europaeus</i> (deciduous).
Range	10·0–26·0	—	—
Conductivity (average) (186 cm. water)	17·8	—	—
Specific conductivity (30 cm. mercury):			
Aitken	39·2	—	—
Farmer	—	12·1	40·2

The present writer's figures show clearly that the wood of the deciduous Oak has a much higher conductivity than has that of the Pine or Silver Tree, and it also gives a larger range of values. This is in accordance with Farmer's main conclusion already quoted.

Comparing the two sets of values for the specific conductivity, a considerable divergence will be noticed in the case of the Oak. This is probably due to the small number of experiments performed by the present writer, for although the average is so much higher, the range of individual values is similar. The specific conductivity of *Pinus pinaster* is only a little greater than that of the species investigated by Farmer. For an evergreen tree *Leucadendron argenteum* has a remarkably high specific conductivity, its value being very nearly equal to that of the deciduous *Euonymus japonica*.

B. Rate of Transpiration.—In the experiments on transpiration two objects were kept in view, viz. :

(1) A comparison of the rate of transpiration of similar twigs of the Pine and Silver Tree under the same conditions.

(2) The relation, if any exists, between transpiration and water-conducting power of twigs of the same tree.

With regard to the first of these, all the experiments showed a much higher rate of transpiration both per twig and per unit area of leaf surface in the case of the Pine than of the Silver Tree. In view of the difference in water-conducting power of the wood this result seemed very surprising, but it was obtained under various sets of conditions, *e. g.* in the laboratory, and on the roof of the laboratory, on both dull and bright days. Table II gives the actual transpiration per twig and per unit area of leaf surface of those twigs, the transpiration of which was measured under similar conditions.

TABLE II.—*Transpiration in grammes per hour of Pine and Silver Tree under similar conditions.*

(The experiments bracketed together were concurrent with one another.)

No.	Leucadendron.				Pine.			
	Transpiration per twig.		Transpiration per square metre leaf surface.		Transpiration per twig.		Transpiration per square metre leaf surface.	
	Lab.	Roof.	Lab.	Roof.	Lab.	Roof.	Lab.	Roof.
1	1.0	—	—	—	6.2	—	—	—
2	1.54	5.74	5.95	22.25	4.62	14.88	31.9	103.0
3	—	6.54	—	37.5	—	7.1	—	65.2
12	0.41	1.09	3.09	8.2	—	—	—	—
13	0.36	0.90	3.64	9.1	—	—	—	—
14	—	—	—	—	2.26	6.77	16.25	48.67
15	—	—	—	—	2.00	5.81	47.8	139.0
16	0.94	2.05	6.35	13.84	—	—	—	—
17	0.64	1.28	7.23	14.45	—	—	—	—
18	—	—	—	—	1.60	4.37	15.49	42.32
19	—	—	—	—	—	4.47	—	44.87
21	—	1.62	—	15.43	—	—	—	—
27	—	1.20	—	10.07	—	—	—	—
28	—	2.13	—	10.96	—	—	—	—
29	—	—	—	—	—	3.9	—	35.5
30	—	—	—	—	—	6.62	—	38.72

In every case it will be seen that the actual transpiration per Pine twig is greater than that per Leucadendron twig, and that the transpiration per unit leaf area of Pine is greater than that per unit leaf area of Leucadendron.

It will also be noticed in the above table that in concurrent experiments the results for the transpiration per unit leaf area are reasonably concordant in the case of *Leucadendron*, *e. g.* Nos. 12 and 13, 16 and 17, 27 and 28. With the Pine twigs fewer measurements were made, and Experiments 14 and 15 show a considerable divergence in respect of transpiration per unit leaf area.

Two sets of experiments were performed to ascertain whether the high rate of transpiration continued in the Pine as the twigs were allowed to dry. Twigs of both Pine and Silver Tree were kept overnight in water and the following morning the cut ends were blocked with paraffin wax. The loss of weight was then followed in the one set for five hours and in the other for two days. Both sets showed that the rate of loss of the Pine twig was greater than that of the *Leucadendron* during the first two hours, but after this it became less.

Experiments Nos. 20 and 26: Date, January 20, 1920.

No. 20: <i>Leucadendron</i> .			No. 26: Pine.		
Time.	Weight of twig.	Loss of weight.	Time.	Weight of twig.	Loss of weight.
9.53 a.m.	37.82 grm.	—	9.57 a.m.	66.54 grm.	—
10.56 "	36.35 "	1.47 grm.	10.59 "	62.90 "	3.64 grm.
11.55 "	35.10 "	1.25 "	11.58 "	59.52 "	3.38 "
12.17 p.m.	34.93 "	0.17 "	12.22 p.m.	59.39 "	0.13 "
1.16 "	34.19 "	0.74 "	1.19 "	59.10 "	0.29 "
2.13 "	33.59 "	0.60 "	2.16 "	58.86 "	0.24 "
3.16 "	32.86 "	0.73 "	3.20 "	58.59 "	0.27 "

Experiment No. 33: Date, January 29, 30, 31, 1920.

No. 33: <i>Leucadendron</i> .			
Date.	Time.	Weight of twig.	Loss of weight.
January 29, 1920	11.6 a.m.	27.46 grm.	—
—	2.4 p.m.	26.69 "	0.77 grm.
" 30 "	9.20 a.m.	23.15 "	3.54 "
" 31 "	9.50 "	17.80 "	5.35 "

No. 33: Pine.			
Date.	Time.	Weight of twig.	Loss of weight.
January 29, 1920.	11.13 a.m.	36.05 grm.	—
—	2.8 p.m.	33.24 "	2.81 grm.
" 30 "	9.24 a.m.	31.57 "	1.67 "
" 31 "	9.54 "	30.17 "	1.40 "

These results are shown in graphical form in the figure on page 17.

In connection with Experiment No. 33 it is to be noted that at the end of the experiment the *Leucadendron* leaves were very dried up, while the Pine needles still appeared fairly fresh. In fact the *Leucadendron* leaves were quite shrivelled up several days before the Pine needles began to die and turn brown.

One or two determinations were made of the water content of fresh leaves, in the hope that this would throw some light on the results of the transpiration experiments. In Experiment No. 3 two twigs, one of *Leucadendron* and one of Pine, were kept in water overnight, and left on the roof of the laboratory with their cut ends in water for about an hour and a half the following morning. At the end of this period the fresh weight of the leaves was determined, and also their area; they were then dried and the dry weight determined. In Experiments Nos. 22 and 24, two twigs were kept overnight in water, and a few leaves were picked from each the following morning. The fresh weight, area, and dry weight of each set were then determined. The result of these experiments was to show that the Pine leaves have a larger water content per square metre of leaf surface than the *Leucadendron* leaves, but a lower water content per cent. of fresh weight.

Experiment No. 3.

	No. 3: <i>Leucadendron</i> .	No. 3: Pine.
Leaf area	1742.8 square cm.	1090 square cm.
Fresh weight of leaves	33.82 grm.	36.45 grm.
Dry " "	14.20 "	18.35 "
Water content " "	19.62 "	18.1 "
Water content per square metre leaf surface	112.6 "	166.1 "
Water content per cent. fresh weight	58.02 per cent.	49.66 per cent.

Experiments Nos. 22 and 24.

	No. 22: <i>Leucadendron</i> .	No. 24: Pine.
Leaf area	173.48 square cm.	115.2 square cm.
Fresh weight of leaves	2.995 grm.	3.145 grm.
Dry " "	1.08 "	1.326 "
Water content " "	1.915 "	1.819 "
Water content per square metre leaf surface	110.4 "	157.9 "
Water content per cent. fresh weight	63.93 per cent.	57.84 per cent.

A number of experiments were also performed with twigs of *Leuca-*

dendron of various thicknesses, but no very definite relation could be discovered between the rate of transpiration, and either the conductivity of the wood, or the area of the wood in cross section. The average of a number of experiments showed, however, that twigs of *Leucadendron* usually bear a larger leaf area per unit cross sectional area of wood than do those of the Pine.

From the results of all the experiments described a table has been compiled to show the relation between the actual transpiration per 15 minutes and the amount of water actually transmitted through 15 cm. of the twig in 15 minutes under the pressure of 186 cm. of water after injection of the wood, *i. e.* between the transpiration and the "standard transmission."

TABLE III.—*Relation between Transpiration and "Standard Transmission."*

No.	Leucadendron.			Pine.		
	Transpiration.	Transmission.	$\frac{\text{Transpiration.}}{\text{Transmission.}}$	Transpiration.	Transmission.	$\frac{\text{Transpiration.}}{\text{Transmission.}}$
2	1.44	3.9	0.37	3.72	2.5	1.5
3	1.30	2.9	0.45	1.80	1.8	1.0
4	1.37	2.3	0.60	—	—	—
5	2.50	4.0	0.625	—	—	—
6	1.28	1.5	0.85	—	—	—
10	0.72	0.9	0.80	—	—	—
11	0.68	0.6	1.1	—	—	—
12	0.27	3.2	0.08	—	—	—
13	0.23	1.0	0.23	—	—	—
14	—	—	—	1.69	1.65	1.0
15	—	—	—	1.45	1.2	1.2
19	—	—	—	1.12	0.5	2.2
21	0.41	1.9	0.22	—	—	—
27	0.30	2.7	0.11	—	—	—
28	0.53	3.0	0.18	—	—	—
29	—	—	—	1.00	1.4	0.71
30	—	—	—	1.66	0.9	1.8

(Concurrent experiments are bracketed together.)

In every case it will be noticed that the ratio Transpiration/Transmission is far higher in the Pine than in the Silver Tree. This must mean that the Pine leaves exert a much greater suction force than do the Silver Tree leaves.

IV. DISCUSSION.

For the purposes of discussion it will be convenient to summarise the outstanding results of the above experiments at this point.

The Pine tree possesses wood of very low water-conducting power, but twigs, kept with their cut ends in water, show a high rate of transpiration

both per twig and per unit of leaf area. The Silver Tree, on the other hand, possesses wood of fairly high water-conducting power, its conductivity being rather more than double that of the wood of the Pine, but twigs with their cut ends in water show a much lower rate of transpiration than do similar twigs of the Pine.

When transpiration is followed in twigs, as they dry, it is found that the Pine twigs at first transpire more rapidly than the Silver Tree twigs. After a short time, however, the transpiration of the Pine twigs suddenly drops and becomes less than that of the Silver Tree twigs.

Determinations of water content show that Silver Tree leaves have a greater water content expressed as a percentage of fresh weight than have Pine needles.

Comparing the relation between transpiration and water transmission in the two cases, we find that the ratio transpiration to transmission is far higher in the Pine than in the Silver Tree.

Great caution is necessary in the interpretation of these results owing to the absence of information as to how far experiments with isolated twigs afford a true idea of processes taking place in the intact tree. For instance, the fact that isolated Pine twigs transpire more rapidly than do *Leucadendron* twigs does not enable us to draw any conclusions as to the rate of transpiration of twigs attached to living trees. In all the experiments comparatively short twigs were used, and these were saturated with water overnight. Consequently the resistance to the flow of water to the leaves during transpiration would be minimal, and far lower than when the supply must be drawn from the roots of the tree through the trunk and branches. The measurements of conductivity show that the resistance to the flow of water to the leaves is very much greater in the Pine than in the Silver Tree, and this in itself would tend to lower the rate of transpiration of Pine twigs while attached to the tree.

One conclusion which may safely be drawn is that under the experimental conditions Pine needles exert a greater suction on the water in the stem than do Silver Tree leaves. In experiment No. 2, for example, the "standard transmission" of the twigs was—

Leucadendron 3.9 c.c. Pine 2.5 c.c.

Therefore to force water through the Pine twig at the same rate as through the *Leucadendron* twig would require a pressure or suction 1.56 times as great as that applied to the *Leucadendron* twig. The rate of transpiration of the Pine, however, was 2.58 times as great as that of the *Leucadendron*. Therefore the Pine leaves must have exerted a suction 2.58×1.56 , *i. e.* about four times as great as the *Leucadendron* leaves. In experiment No. 3 the Pine leaves must have exerted a suction twice as great as the Silver Tree leaves, and in Nos. 13 and 14 four and a half times as great.

One is tempted to infer from this that the greater suction, which our

experiments show can be exerted by the Pine needles, is a response to the structure of the wood, enabling them to obtain water sufficiently rapidly for their requirements. At the same time the much greater tensions, which must exist in Pine trees as compared with Silver Trees, probably neutralise the greater suction force of the Pine needles, so that the transpiration of twigs growing on the tree will probably be less in the case of the Pine than of the Silver Tree. Here, however, it must be remembered that we have no information as to the maximum tensions which the leaves of either tree are capable of exerting or withstanding, and without such information inferences as to the behaviour of twigs on the tree are of little value.

The experiments with drying twigs are suggestive in this connection. The figures for these experiments are repeated in the following table, the initial fresh weight of the twig being called in each case 100. Alongside is given the loss of weight per hour expressed as a percentage of the fresh weight, and the original water content per cent. of fresh weight, as determined in Experiments 3, 22, 24:

TABLE IV.—*Loss of Weight of Drying Twigs.*
Experiments Nos. 20 and 26.

No. 20: <i>Leucadendron</i> .			No. 26: <i>Pine</i> .		
Time.	Weight.	Loss of weight per hour per cent. of fresh weight.	Time.	Weight.	Loss of weight per hour per cent. of fresh weight.
9.53 a.m.	100	—	9.57 a.m.	100	—
10.56 „	96.12	3.7	10.59 „	94.54	5.3
11.55 „	92.81	3.4	11.58 „	89.43	5.2
12.17 p.m.	92.31	—	12.22 p.m.	89.28	—
1.16 „	90.40	1.9	1.19 „	88.82	0.46
2.13 „	88.82	1.7	2.16 „	88.45	0.38
3.16 „	86.90	1.8	3.20 „	88.06	0.43

Experiment No. 33.

Date.	<i>Leucadendron</i> .			<i>Pine</i> .		
	Time.	Weight.	Loss of weight per hour per cent. of fresh weight.	Time.	Weight.	Loss of weight per hour per cent. of fresh weight.
January 29, 1920	11.6 a.m.	100	—	11.13 a.m.	100	—
—	2.4 p.m.	97.21	0.95	2.8 p.m.	92.19	2.7
„ 30 „	9.20 a.m.	84.29	0.67	9.24 a.m.	87.58	0.24
„ 31 „	9.50 „	64.82	0.80	9.54 „	83.70	0.16

Water Content per cent. Fresh Weight.

Experiment No. 3, 58.02 per cent. . Experiment No. 3, 49.66 per cent.

" " 22, 63.93 " " " 24, 57.84 "

These results are shown in graphical form in the accompanying figure :

The striking difference in the behaviour of twigs of the two trees is that in the Silver Tree the rate of loss does not markedly fall off as the water content diminishes, whereas in the Pine the rate of loss falls after a few hours to less than one-tenth of the rate in the first hour. Tension may be taken to increase as the water content diminishes, unless at some point the resistance of the leaves begins to break down. If this happens the water columns in the vessels break, and the leaves lose water without being able to obtain fresh supplies from the stem. This may be the case with the Silver Tree. In the case of the Pine the bend in the curve suggests either stomatal or internal regulation of a far more drastic nature, and this brings us face to face with another difficulty—the absence of information as to the

behaviour of the stomata, both on the tree and under the experimental conditions.

Attempts were made to obtain this information by Lloyd's method of fixing strips of the epidermis in absolute alcohol, and measuring the size of the stomata and the degree of opening with a micrometer eyepiece. The method, however, proved unsatisfactory, and neither type of leaf is suitable for observations with the porometer.

It is evident, therefore, that any interpretation of the experimental results with reference to the behaviour of whole trees must necessarily be highly speculative. One possible interpretation is that the Silver Tree keeps its stomata only partially open; that it has relatively immobile stomata and that if the conditions become too severe, and the tension exceeds a limited value, the leaves dry back, as in the cut twig. In the Pine, on the other hand, the stomata are more mobile, open wider under favourable conditions, and close more effectively in dry. Another possible interpretation is that there may be a greater power of internal regulation in Pine leaves. That is there may be some way other than stomatal closure, or additional to it, of reducing water loss, probably connected with lowered water content. Apart from these purely speculative suggestions all that can definitely be said at present is that the Pine leaves appear to be more resistant to unfavourable conditions than the Silver Tree leaves.

Further research is needed to determine the effect of cutting on the stomata and internal condition of the leaves. In this connection transpiration measurements in the field are needed, (*a*) on twigs still attached to the trees, and (*b*) on twigs immediately after detachment.

Another line of research is the measurement of the actual tensions existing in trees, and hence of the resistances to be overcome by leaves transpiring on the tree.

V. SUMMARY AND CONCLUSIONS.

1. Farmer's experiments on the water-conducting power of the wood of trees have been extended to certain trees growing in the Cape Peninsula, and the results obtained are in general accordance with his conclusions.

2. *Pinus pinaster* has wood of low water-conducting power, its specific conductivity being a little higher than that recorded by Farmer for *P. sylvestris*.

3. *Leucadendron argenteum* has wood of high water-conducting power for an evergreen tree, its specific conductivity being rather more than double that of the Pine.

4. A method of estimating the surface area of Pine leaves is described.

5. Pine twigs, kept with their cut ends in water, show a far higher rate of transpiration, both per twig and per unit leaf area, than do similar twigs of the Silver Tree.

6. The ratio of transpiration to transmission is far higher in the Pine than in the Silver Tree. This is shown to indicate that under the experimental conditions Pine needles exert a greater suction on the water in the stem than do Silver Tree leaves.

7. When transpiration is followed in twigs, as they dry, it is found that the Pine twigs at first transpire more rapidly than the Silver Tree twigs. After a short time, however, the transpiration of Pine twigs suddenly drops and becomes less than that of the Silver Tree twigs.

8. Determinations of water content show that the Silver Tree leaves have a greater water content expressed as a percentage of fresh weight than have Pine needles.

9. The bearing of these results on the water relations of whole trees is discussed, and possible interpretations suggested. It is concluded, however, that all that can definitely be said at present is that the Pine leaves appear to be more resistant to unfavourable conditions than the Silver Tree leaves.

10. Further lines of research are indicated.

In conclusion, I should like to take this opportunity of thanking Prof. Thoday, at whose suggestion the above work was commenced, for his invaluable help and advice throughout the course of the investigation.

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REFERENCES.

1. FARMER, J. B.—'Proc. Roy. Soc.,' 90 B, 218-31, 232-50, 1918.
2. MARLOTH, R.—'The Flora of South Africa,' vol. i, p. 145.