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# THE INFLUENCE OF THE TEMPERATURE OF THE CULTURE WATER ON THE WATER ABSORPTION BY THE ROOT AND ON THE STOMATAL APERTURE

By

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(With 8 Text-figures)

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It has long been known that the rate of intake of water by plant roots is considerably influenced by temperature. SACHS (1960) paid attention to the wilting of the plant during the midday hours of the warm early spring day, when the soil is still cold. Finding that wilting of pumpkin and tobacco plants in pot culture resulted from lowering the soil temperatures to 2°C, and that recovery from it happened when the soil was reheated, SACHS concluded that the wilting of the plant in this season is mainly due to the lowering of the soil temperature. KOSAROFF (1897) has observed that the root of *Phaseolus multiflorus* absorbs water as much as 210 mm of the potometer tube at 20°C during 20 minutes, while it measured only 140 mm at 0°C. Therefore at 0°C the root of *Phaseolus* plant can absorb about 3/4 or 2/3 as much water as at 20°C. BODE (1923) also found a parallel relation between the water absorption by the sunflower root and the water temperature and STILES and JØRGENSEN (1917) likewise recognized the same relation between the swelling of potato or carrot tissue and the water temperature. HEYL (1933) found that bleeding has a similar relation to the soil temperature. BOONSTRA (1935), however, could not find such influence of soil temperature on the root pressure of the pea.

In connection with the relation between transpiration and stomatal aperture, a number of interesting observations have been made, namely, those by DARWIN (1916), ILJIN (1922, 1933), KNIGHT (1916, 1916), LAIDLAW and KNIGHT (1916), LOFTFIELD (1921) and TRELEASE and LIVINGSTON (1916). Though it is without question that the shoot and root are intimately correlated in water economy, the direct relation between the water absorption

and the stomatal aperture seems hitherto to have been scarcely taken into consideration, and the water balance in a plant individual as a whole was rather neglected.

The writer, being engaged in studies on the problem under the present heading, wishes now to make a preliminary report of his experimental results. Material (seedling of *Phaseolus vulgaris*), methods and the expression of the measure value are similar to those reported in the previous papers (1934, 1936), so their full descriptions are omitted here.

Experiment 1: As shown in a previous paper (1936 a), the suction force of the shoot very probably exerts influence upon the water absorption by the root. This power is developed by the transpiration, and the stomatal aperture plays a main rôle in this relation. The writer has confirmed that under constant and continuous illumination the diurnal fluctuation of the stomatal movement stopped, leaving the stomatal aperture constant within five days after the transference from natural conditions, if the temperature and atmospheric humidity are kept constant. At the beginning of a series of experiments the writer investigated whether the plant thus derived can show a constant water absorption under the same conditions. The experiment was carried out on the 2nd and 3rd March, 1936. The results are shown in Table 1 and Figure 1.

Results: Accompanied by the elimination of the diurnal fluctuation of the stomatal movement under constant conditions as stated above, at a certain number of days after the transference from natural conditions, the water absorption became almost constant. Accordingly, the water absorption and the stomatal aperture under these constant conditions may be regarded as the standard for the same at varied temperatures. Practically the altered water absorption and stomatal aperture on the second day of each experiment were expressed in percentages, taking each corresponding standard value as 100.

Experiment 2: KOSAROFF (1897) has reported that the plant root can absorb water even from frozen soil. In the present work, the water absorption and the stomatal aperture were measured, keeping the root in ice water. The experiments were carried out on the 27th and 28th December, 1935 and 6th and 7th March, 1936. The result is shown in Tables 2 and 3 and Figure 2.

Results: As seen from the experimental data, the water absorption decreased suddenly after the root was transferred from water of 20°C into

ice water of 0°C. This point is indicated by the mark "↓" in the figure. Stomata showed a slight temporary closure shortly after the transference, soon followed, however, by a remarkable opening accompanied by the commencement of the wilting of leaf due to the deficiency of the water absorption by the root. Why the temporary opening of stomata occurred in spite of the decrease in the water absorption, can not be explained satisfactorily at present.

In accordance with the progress of the wilting, the stomata rapidly attained the maximum opening, again followed, however, by a little closure, when the leaves were distinctly flaccid.

On the second day of the experiment, the water absorption and the stomatal aperture became almost constant, showing no remarkable fluctuation all day. Under this condition of the plant, the water absorption was 56.6 % and the stomatal sperture 311.4 %. In this case attention should be called to the fact that the stomata opened wide in spite of the distinctly flaccid state of the leaf. After the removal of such plant root from ice water into water of 20°C (↑), a sudden increase of water absorption was observed accompanied by the rapid recovery of turgescence of the leaf. Such raised water absorption, however, began soon to decrease and again reached the initial degree.

Experiment 3: Similarly as in the previous experiments, the water absorption and the stomatal aperture were measured, keeping the root in water of 5°C. The experiments were carried out on the 24th and 25th January, and 10th and 11th March, 1936. The results are shown in Tables 4 and 5 and Figure 3.

Results: As in the previous experiment a rapid decrease in water absorption occurred shortly after the transference of the plant root from water of 20°C into that of 5°C (↓), accompanied by the wilting of the leaf. On the second day of the experiment, the leaf was still wilted, and the stomata opened as widely as on the previous day, while the water absorption decreased considerably, but went on almost constantly all day. The water absorption was 60.0 % and stomatal aperture 274.9 %.

Experiment 4: The root was transferred from water of 20°C into that of 10°C. The experiment was carried out on the 31th January and 1st February and 19th and 20th March, 1936. The results are shown in Tables 6 and 7 and Figure 4.

Results: As seen from the experimental data, a remarkable increase

of the stomatal aperture is also seen after the transference of the root from 20°C water into 10°C (↓), in spite of the distinct flaccid state of the leaf. But the degree of the wilting of the same leaf on the second day of the experiment was not so remarkable as was recognized in the previous experiments. When the balanced condition was reached on the second day the water absorption was 66.7 % and the stomatal aperture 168.6 %.

Experiment 5: Variations of the water absorption and of the stomatal aperture were examined, after the root was transferred from water of 20°C into that of 15°C. The experiments were carried out on the 21st and 22nd February and 22nd and 23rd April, 1936. The results are shown in Tables 8 and 9 and Figure 5.

Results: It will be seen that the variation of the water absorption and the behaviour of stomata are a little different from those observed in the previous experiments. Shortly after the transference of the root (↓), a temporary wilting of the leaf occurred, due to the rapid decrease of the water absorption, accompanied by a temporary remarkable opening of stomata. But soon afterwards the leaf recovered from the wilting according to the increase of the water absorption, and the stomata began to close. On the second day of the experiment no fluctuation of the water absorption was observed, and a constant stomatal aperture was kept. The turgid state of leaf under such constant condition is difficult to distinguish by appearance from that in the case of the water temperature 20°C. The water absorption was 81.3% and the stomatal aperture 116.5%.

Experiment 6: In the previous experiments, the variations of water absorption and of the stomatal aperture after the transference of the roots from water of 20°C into the colder water were measured, but in the present experiment the roots were transferred from water of 20°C into warmer water, viz., of 25°C, and the variations were measured. The experiments were carried out on the 27th and 28th May and 4th and 5th June, 1936. The results are shown in Tables 10 and 11 and Figure 6.

Results: The present results are widely different from the findings of the previous experiments. On the first day of the experiment, shortly after the transference from water of 20°C into that of 25°C (↑), the water absorption increased greatly, but it recovered the original lower rate on the second day. From these facts it may be said that the rise of temperature of 5°C exerted no remarkable accelerating effect on the water absorption. The stomatal aperture was gradually enlarged after the transference

on the first day of experiment, and the maximum opening was reached on the second day. This rose at least to 108.4%, if the value under the standard condition was taken as 100.

Experiment 7: Transference was made from water of 20°C into that of 30°C, and the variations of stomatal aperture and of the water absorption were measured. The experiments were carried out on the 17th and 18th June and 24th and 25th June, 1936. The results are shown in Tables 12 and 13 and Figure 7.

Results: A remarkable increase of the water absorption was recognized shortly after the transference (↑) on the first day of the experiment. On the second day, after a slight decrease, its constant value 130.0% was continuously kept. The similar relation was obtained as to the stomatal opening; that is, the reaction corresponded to the increase of the water absorption, after the transference on the first day, and a constant aperture 113.0% continued on the second day.

In order to facilitate the understanding of all the experimental results, they are summarized in the following Tables A and B and Figure A:

TABLE A

Water absorption in the varied water temperatures; the value obtained in the water of 20°C was taken as 100.

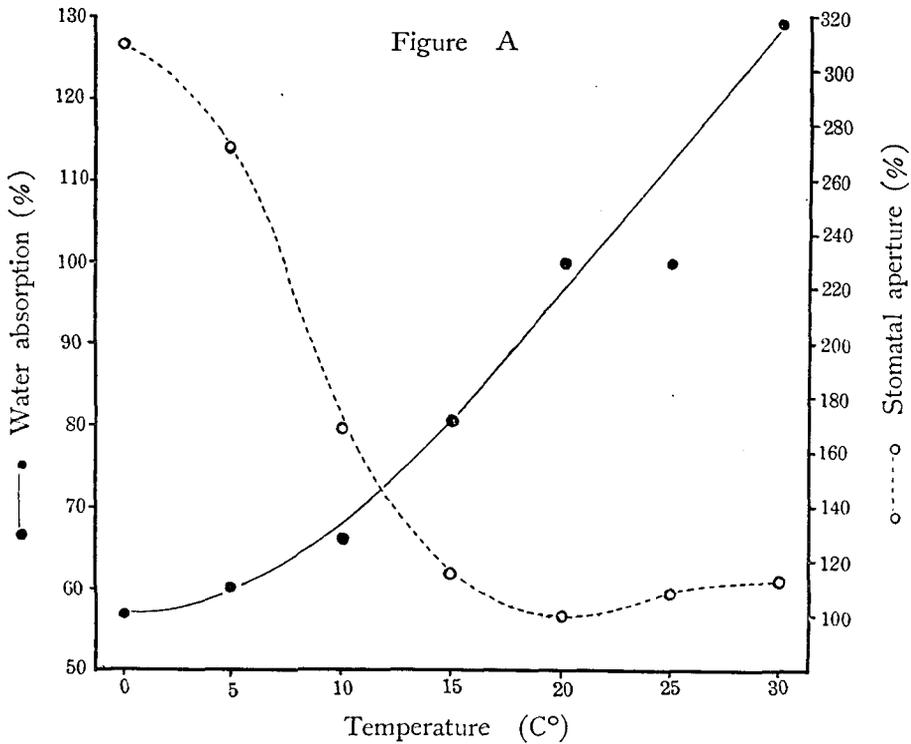
Temperature (C°)	0	5	10	15	20	25	30
Water absorption (%)	56.6	60.0	66.7	81.3	100.0	100.0	130.3

TABLE B

Variations of stomatal apertures, the roots being kept in the water of varied temperatures; the value obtained at 20°C was taken as 100.

Temperature (C°)	0	5	10	15	20	25	30
Stomatal aperture (%)	311.4	273.4	168.6	116.5	100.0	108.4	113.6

The results are quite comprehensible from Figure A.



### Discussion

In the present work the experiments were conducted with intact plants, keeping all external conditions constant. It was ascertained that the increase of the water absorption by the root went on in proportion to the rise of water temperature, with the exception of the case in the water of 25°C (Figure A). RYSELBERGHE (1901) and BODE (1925) found the critical temperature, which is peculiar to plant species and at which a rapid decrease of the resistance to water absorption by the root cell appears. This, however, could not be ascertained in the present work. Special attention should be paid to the curve which clearly shows the influence of the water temperature upon the stomatal aperture (Figure A). Upon being transferred into water of 0°C the stomata opened on the second day almost three times as wide as at the initial temperature 20°C, in spite of the flaccid state of the plant leaf, owing to the decrease of the water absorption

by almost half. Accompanied by the recovery of the turgid state of the leaf which was caused by the increase of the water absorption, when water temperature rose in a range between 0°C and 20°C, a gradual closure of the stomata was ascertained.

In a water temperature range higher than 20°C, a gradual increase of the stomatal opening, due to the rise of the water absorption, took place, but its degree was not so remarkable in comparison with that in the temperature range below 20°C. It is a phenomenon contrary to the general expectation that the wide opening of the stomata continued during many hours, in spite of the plant wilting caused by the decrease of water absorption in temperatures below 20°C.

The opening of the stomata of the wilting plant has already been observed by DARWIN and PERTZ (1916), ILJIN (1933), LAIDLAW and KNIGHT (1916), and WEBER (1927), but the quantitative relation between wilting of the leaf and the stomatal aperture in low temperature has scarcely been investigated. In a previous paper (1936 b) the writer has reported that the stomatal aperture and the transpiration rate run closely parallel. Essentially, it may be a difficult matter to treat the function of the stomata both in the turgid and wilting plant in the same manner. From the teleological point of view, it is very curious to see that the disturbance of the water economy in plant body is never controlled, which is caused by the unfavorable relation between the wide opening of stomata and the depression of water absorption.

According to THREN (1933), the injury to plants by cold in winter, observed at least in Germany, should be explained rather by the excess water loss by transpiration over the water supply from the root than by the direct influence of the cold weather itself. On this point the writer's results will furnish some substantiation for THREN's opinion.

### Summary

1. The present investigation was carried out in order to make clear the variation of the water absorption by the root and that of the stomatal aperture of a seedling of *Phaseolus vulgaris* cultured in water, when the water temperature was changed, while air temperature, atmospheric humidity and light intensity were kept constant.

2. Within a temperature range between 0°C and 30°C, a rise of the water temperature caused a gradual increase of the rate of water absorption by the root.

3. The stomata opened widely, when the root was kept in ice water of  $0^{\circ}\text{C}$ , yet the plant body was in a flaccid state, due to the decrease of water absorption by root. With a rise of the water temperature within a range between  $0^{\circ}\text{C}$  and  $20^{\circ}\text{C}$ , a gradual closure of stomata took place. Between  $20^{\circ}\text{C}$  and  $30^{\circ}\text{C}$ , a gradual opening of the stomata happened, hand in hand with an increase of water absorption, though the degree of its opening was not so remarkable as in the former case.

4. Accordingly, it is not unreasonable to consider that the cold injury may be caused in some cases rather by the disturbance of the water balance in plant body than by the direct influence of the coldness upon the plant.

The writer wishes to express his sincere gratitude and hearty thanks to Prof. T. SAKAMURA for his suggestions and guidance in the present work.

TABLE I

Amount of water absorbed by root under constant and continuous illumination, 5 and 6 days after transference from natural condition. Each measurement was made at intervals of 15 minutes. Air temperature 25°C, water temperature 20°C and atmospheric humidity 60%.

5 days after transference (Time)	Amount of water absorbed	6 days after transference (Time)	Amount of water absorbed
10.00	0.90	10.00	0.85
10.15	0.90	10.15	0.90
10.30	0.80	10.30	0.90
10.45	0.85	10.45	0.90
11.00	0.85	11.00	0.90
11.15	0.85	11.15	0.90
11.30	0.85	11.30	0.90
11.45	0.85	11.45	0.85
12.00	0.85	12.00	0.85
12.15	0.85	12.15	0.85
12.30	0.85	12.30	0.90
12.45	0.85	12.45	0.90
13.00	0.85	13.00	0.90
13.15	0.85	13.15	0.85
13.30	0.80	13.30	0.90
13.45	0.80	13.45	0.90
14.00	0.75	14.00	0.85
14.15	0.80	14.15	0.85
14.30	0.80	14.30	0.90
14.45	0.80	14.45	0.85
15.00	0.80	15.00	0.90
15.15	0.85	15.15	0.85
15.30	0.80	15.30	0.90
15.45	0.85	15.45	0.90
16.00	0.90	16.00	0.90
16.15	0.90	16.15	0.90
16.30	0.90	16.30	0.90
16.45	0.90	16.45	0.90
17.00	0.90	17.00	0.90
17.15	0.90	17.15	0.90
17.30	0.90	17.30	0.85
17.45	0.85	17.45	0.90
18.00	0.85	18.00	0.85

TABLE 2

Variation of the water absorption after the transference of the root from water of 20°C into that of 0°C.

5 days after transference (Time)	Amount of water absorbed		6 days after transference (Time)	Amount of water absorbed	
11.00	0.55		10.00	0.30	WW
11.15	0.60		10.15	0.35	WWW
11.30	0.55		10.30	0.30	"
11.45	0.50		10.45	0.30	"
12.00	0.55		11.00	0.25	"
12.15	0.50		11.15	0.30	"
12.30	0.50		11.30	0.30	"
12.45	0.50		11.45	0.30	"
13.00	0.50		12.00	0.30	"
Mean value	0.53		12.15	0.30	"
In water at 0°C.			12.30	0.30	"
13.30	0.25		12.45	0.35	"
13.45	0.25		13.00	0.30	"
14.00	0.25		13.15	0.35	"
14.15	0.35		13.30	0.30	"
14.30	0.35		13.45	0.30	"
14.45	0.40		14.00	0.30	"
15.00	0.45		14.15	0.25	"
15.15	0.50	W	14.30	0.30	"
15.30	0.60	"	14.45	0.25	"
15.45	0.60	"	15.00	0.25	"
16.00	0.60	WW	15.15	0.30	"
16.15	0.60	"	15.30	0.30	"
16.30	0.60	"	Mean value	0.30	
16.45	0.50	"	In water at 20°C.		
17.00	0.45	"	16.00	1.80	WW
17.15	0.55	WWW	16.15	2.60	WWW
17.30	0.50	"	16.30	1.80	WW
17.45	0.50	"	16.45	1.25	W
18.00	0.45	"	17.00	1.25	"
18.15	0.50	"	17.15	1.15	R
18.30	0.50	"	17.30	0.80	"
18.45	0.45	WWWW	17.45	0.65	"
19.00	0.50	"	18.00	0.50	"
			18.15	0.50	"
			18.30	0.50	"

W means wilting of plant leaf, and number of "W's" shows its degree.

R means the recovery from wilting of plant leaf.

TABLE 3

Variation of the stomatal aperture after the transference of the root from water of 20°C into that of 0°C.

5 days after transference (Time)	Stomatal aperture		6 days after transference (Time)	Stomatal aperture	
11.00	0.0182		9.30	0.0667	WWWW
11.30	0.0200		10.00	0.0689	"
12.00	0.0196		10.30	0.0689	"
12.30	0.0206		11.00	0.0667	"
13.00	0.0204		11.30	0.0645	"
13.30	0.0196		12.00	0.0625	"
14.00	0.0204		12.30	0.0606	"
14.30	0.0200		13.00	0.0556	"
15.00	0.0204		13.30	0.0556	"
Mean value	0.0199		14.00	0.0556	"
In water at 0°C.			14.30	0.0556	"
15.30	0.0196		Mean value	0.0619	
16.00	0.0192		In water at 20°C.		
16.30	0.0244		15.00	0.0556	WW
17.00	0.0318		15.30	0.0400	W
17.30	0.0500		16.00	0.0526	R
18.00	0.143	W	16.30	0.0529	"
18.30	0.286	WW	17.00	0.0769	"
19.00	0.400	"	17.30	0.0833	"
19.30	0.333	WWW	18.00	0.0500	"
20.00	0.286	"	18.30	0.0505	"
			19.00	0.0417	"

W and R, see above.

TABLE 4

Variation of the water absorption after the transference of the root from water of 20°C into that of 5°C.

5 days after transference (Time)	Amount of water absorbed		6 days after transference (Time)	Amount of water absorbed	
11.30	1.00		10.15	0.65	WWWW
11.45	1.15		10.30	0.60	"
12.00	1.10		10.45	0.65	"
12.15	1.10		11.00	0.60	"
12.30	0.95		11.15	0.65	"
12.45	0.90		11.30	0.60	"
13.00	0.95		11.45	0.60	"
13.15	0.90		12.00	0.60	"
13.30	0.95		12.15	0.55	"
Mean value	1.00		12.30	0.55	"
In water at 5°C.			12.45	0.60	"
13.45	0.45		13.00	0.55	"
14.00	0.55		13.15	0.55	"
14.15	0.70		13.30	0.60	"
14.30	1.00		13.45	0.60	"
14.45	1.05		14.00	0.60	"
15.00	1.05		14.15	0.60	"
15.15	1.05		14.30	0.60	"
15.30	1.25	W	14.45	0.60	"
15.45	1.50	"	15.00	0.60	"
16.00	1.40	"	15.15	0.60	"
16.15	1.75	"	15.30	0.65	"
16.30	1.75	WW	Mean value	0.60	
16.45	2.00	"	In water at 20°C.		
17.00	1.80	"	15.45	0.70	WW
17.15	1.80	WWW	16.00	1.20	W
17.30	1.85	"	16.15	1.30	R
17.45	1.95	"	16.30	1.25	"
18.00	1.90	"	16.45	1.20	"
18.15	1.90	"	17.00	1.10	"
18.30	2.00	"	17.15	1.10	"
18.45	2.00	WWWW	17.30	1.05	"
19.00	1.95	"	17.45	1.10	"
			18.00	1.10	"

W and R, see above.

TABLE 5

Variation of the stomatal aperture after the transference of the root from water of 20°C into that of 5°C.

5 days after transference (Time)	Stomatal aperture		6 days after transference (Time)	Stomatal aperture	
10.30	0.0286		10.00	0.0800	WWW
11.00	0.0294		10.30	0.0800	"
11.30	0.0294		11.00	0.0800	"
12.00	0.0294		11.30	0.0800	"
12.30	0.0294		12.00	0.0833	"
13.00	0.0286		12.30	0.0833	"
13.30	0.0286		13.00	0.0800	"
14.00	0.0303		13.30	0.0800	"
14.30	0.0299		14.00	0.0800	"
15.00	0.0313		14.30	0.0800	"
Mean value	0.0295		Mean value	0.0807	
In water at 5°C.			In water at 20°C.		
15.30	0.0323		15.00	0.0408	WW
16.00	0.0357		15.30	0.0500	W
16.30	0.0417		16.00	0.0556	R
17.00	0.0588		16.30	0.0667	"
17.30	0.1000		17.00	0.0500	"
18.00	0.143	W	17.30	0.0476	"
18.30	0.182	"	18.00	0.0500	"
19.00	0.143	WW	18.30	0.0500	"
19.30	0.167	"	19.00	00.500	"
20.00	0.200	WWW			

W and R, see above.

TABLE 6

Variation of the water absorption after the transference of the root from water of 20°C into that of 10°C.

5 days after transference (Time)	Amount of water absorbed		6 days after transference (Time)	Amount of water absorbed	
10.30	1.10		11.00	0.70	WW
10.45	1.05		11.15	0.70	"
11.00	1.15		11.30	0.70	"
11.15	1.10		11.45	0.70	"
11.30	1.10		12.00	0.65	"
11.45	1.05		12.15	0.65	"
12.00	0.95		12.30	0.70	"
12.15	1.00		12.45	0.70	"
12.30	0.95		13.00	0.70	"
12.45	0.95		13.15	0.70	"
13.00	0.95		13.30	0.65	"
13.15	0.95		13.45	0.70	"
13.30	1.00		14.00	0.70	"
Mean value	1.02		14.15	0.60	"
In water at 10°C.			14.30	0.60	"
13.45	0.00		14.45	0.70	"
14.00	0.20		15.00	0.75	"
14.15	0.25		15.15	0.75	"
14.30	0.35		15.30	0.60	"
14.45	0.40	W	15.45	0.65	"
15.00	0.40	"	Mean value	0.68	
15.15	0.40	"	In water at 20°C.		
15.30	0.45	"	16.00	0.60	WW
15.45	0.45	"	16.15	0.65	W
16.00	0.55	WW	16.30	0.65	R
16.15	0.60	"	16.45	0.65	"
16.30	0.65	"	17.00	0.70	"
16.45	0.70	"	17.15	0.75	"
17.00	0.75	"	17.30	0.80	"
17.15	0.75	"	17.45	0.80	"
17.30	0.75	"	18.00	0.75	"
17.45	0.75	WWW	18.15	0.75	"
18.00	0.85	"	18.30	0.75	"

W and R, see above.

TABLE 7

Variation of the stomatal aperture after the transference of the root from water of 20°C into that of 10°C.

5 days after transference (Time)	Stomatal aperture		6 days after transference (Time)	Stomatal aperture	
10.00	0.0128		9.30	0.0213	WW
10.30	0.0128		10.00	0.0222	"
11.00	0.0125		10.30	0.0222	"
11.30	0.0129		11.00	0.0222	"
12.00	0.0123		11.30	0.0217	"
12.30	0.0133		12.00	0.0213	"
13.00	0.0133		12.30	0.0222	"
13.30	0.0133		13.00	0.0213	"
Mean value	0.0129		13.30	0.0213	"
In water at 10°C.			Mean value	0.0217	
14.00	0.0139		In water at 20°C.		
14.30	0.0169		14.00	0.0213	W
15.00	0.0167		14.30	0.0222	R
15.30	0.0222		15.00	0.0222	"
16.00	0.0227		15.30	0.0270	"
16.30	0.0222		16.00	0.0222	"
17.00	0.0250	W	16.30	0.0233	"
17.30	0.0250	"	17.00	0.0213	"
18.00	0.0238	"	17.30	0.0233	"
18.30	0.0208	"	18.00	0.0250	"
19.00	0.0222	WW	18.30	0.0233	"
19.30	0.0222	"	19.00	0.0270	"
20.00	0.0227	WWW			

W and R, see above.

TABLE 8

Variation of the water absorption by the root after the transference from water of 20°C into that of 15°C.

5 days after transference (Time)	Amount of water absorbed		6 days after transference (Time)	Amount of water absorbed	
11.15	0.90		11.30	0.60	
11.30	0.90		11.45	0.65	
11.45	0.90		12.00	0.60	
12.00	0.90		12.15	0.65	
12.15	0.80		12.30	0.65	
12.30	0.80		12.45	0.60	
12.45	0.70		13.00	0.65	
13.00	0.70		13.15	0.65	
13.15	0.70		13.30	0.65	
13.30	0.70		13.45	0.65	
Mean value	0.80		14.00	0.65	
In water at 15°C.					
14.00	0.00		14.15	0.65	
14.15	0.10		14.30	0.65	
14.30	0.20	W	14.45	0.65	
14.45	0.30	"	15.00	0.65	
15.00	0.35	WW	15.15	0.65	
15.15	0.30	WWW	15.30	0.65	
15.30	0.35	"	15.45	0.65	
15.45	0.45	"	16.00	0.65	
16.00	0.40	WW	Mean value	0.642	
16.15	0.45	"	In water at 20°C.		
16.30	0.40	W	16.30	0.95	
16.45	0.45	"	16.45	0.85	
17.00	0.50	R	17.00	0.90	
17.15	0.50	"	17.15	0.95	
17.30	0.55	"	17.30	0.80	
17.45	0.50	"	17.45	0.80	
18.00	0.50	"	18.00	0.80	
			18.15	0.90	
			18.30	0.90	

W and R, see above.

TABLE 9

Variation of the stomatal aperture after the transference of the root from water of 20°C into that of 15°C.

5 days after transference (Time)	Stomatal aperture		6 days after transference (Time)	Stomatal aperture.
11.00	0.0667		11.30	0.0714
11.30	0.0714		12.00	0.0833
12.00	0.0667		12.30	0.0833
12.30	0.0625		13.00	0.0833
13.00	0.0625		13.30	0.0769
13.30	0.0667		14.00	0.0769
14.00	0.0667		14.30	0.0769
14.30	0.0689		15.00	0.0769
15.00	0.0667		15.30	0.0714
Mean value	0.0665		16.00	0.0769
In water at 15°C.			16.30	0.0769
15.30	0.0769		17.00	0.0769
16.00	0.1430	W	Mean value	0.0775
16.30	0.2500	WW	In water at 20°C.	
17.00	0.3330	WWW	17.30	0.0667
17.30	0.2860	"	18.00	0.0625
18.00	0.2220	"	18.30	0.0625
18.30	0.0741	WW	19.00	0.0588
19.00	0.0625	W	19.30	0.0625
19.30	0.0667	R	20.00	0.0769
20.00	0.0714	"		

W and R, see above.

TABLE IO

Variation of the water absorption after the transference of  
the root from water of 20°C into that of 25°C.

5 days after transference (Time)	Amount of water absorbed	6 days after transference (Time)	Amount of water absorbed
11.00	1.00	11.00	1.15
11.15	1.10	11.15	1.15
11.30	1.10	11.30	1.10
11.45	1.10	11.45	1.00
12.00	1.10	12.00	1.00
12.15	1.10	12.15	1.10
12.30	1.15	12.30	1.10
12.45	1.10	12.45	1.05
13.00	1.10	13.00	1.10
13.15	1.10	13.15	1.10
13.30	1.15	13.30	1.15
Mean value	1.10	13.45	1.10
In water at 25°C.			
13.45	1.35	14.00	1.15
14.00	1.35	14.15	1.15
14.15	1.40	14.30	1.10
14.30	1.45	14.45	1.10
14.45	1.45	15.00	1.10
15.00	1.45	Mean value	1.10
15.15	1.40	In water at 20°C.	
15.30	1.40	15.15	1.40
15.45	1.50	15.30	1.30
16.00	1.45	15.45	1.40
16.15	1.45	16.00	1.30
16.30	1.45	16.15	1.40
16.45	1.45	16.30	1.35
17.00	1.45	16.45	1.40
17.15	1.45	17.00	1.40
17.30	1.40	17.15	1.30
17.45	1.40	17.30	1.35
18.00	1.45	17.45	1.30
		18.00	1.30

TABLE II

Variation of the stomatal aperture after the transference of the root from water of 20°C into that of 25°C.

5 days after transference (Time)	Stomatal aperture	6 days after transference (Time)	Stomatal aperture
10.30	0.0370	10.30	0.0408
11.00	0.0385	11.00	0.0392
11.30	0.0365	11.30	0.0408
12.00	0.0365	12.00	0.0400
12.30	0.0385	12.30	0.0417
13.00	0.0365	13.00	0.0400
13.30	0.0365	13.30	0.0408
14.00	0.0365	14.00	0.0400
14.30	0.0365	14.30	0.0392
Mean value	0.0370	15.00	0.0385
In water at 25°C.		Mean value	0.0401
15.00	0.0365	In water at 20°C.	
15.30	0.0375	15.30	0.0400
16.00	0.0392	16.00	0.0385
16.30	0.0392	16.30	0.0392
17.00	0.0392	17.00	0.0400
17.30	0.0408	17.30	0.0385
18.00	0.0400	18.00	0.0351
18.30	0.0400	18.30	0.0357
19.00	0.0400	19.00	0.0351

TABLE 12

Variation of the stomatal aperture after the transference of the root from water of 20°C into that of 30°C.

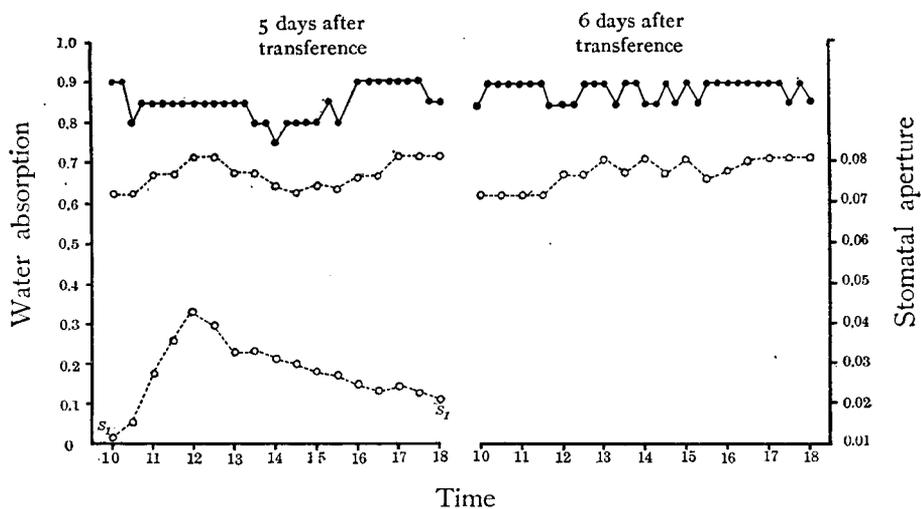
5 days after transference (Time)	Amount of water absorbed	6 days after transference (Time)	Amount of water absorbed
10.00	1.50	10.00	1.90
10.15	1.50	10.15	1.95
10.30	1.50	10.30	2.00
10.45	1.50	10.45	1.75
11.00	1.50	11.00	1.75
11.15	1.50	11.15	1.95
11.30	1.50	11.30	1.95
11.45	1.50	11.45	1.95
12.00	1.50	12.00	1.95
12.15	1.50	12.15	2.10
12.30	1.65	12.30	2.20
12.45	1.65	12.45	2.00
13.00	1.70	13.00	2.00
13.15	1.65	13.15	2.20
13.30	1.65	13.30	2.15
Mean value	1.55	13.45	2.20
In water at 30°C.		14.00	2.15
13.45	1.80	14.15	2.00
14.00	2.00	14.30	2.10
14.15	2.35	14.45	2.10
14.30	2.30	15.00	2.10
14.45	2.00	Mean value	2.02
15.00	2.00	In water at 20°C.	
15.15	2.00	15.15	2.00
15.30	2.00	15.30	1.65
15.45	2.15	15.45	1.70
16.00	2.10	16.00	1.90
16.15	2.30	16.15	1.90
16.30	2.35	16.30	1.90
16.45	2.30	16.45	1.90
17.00	2.30	17.00	1.90
17.15	2.55	17.15	1.90
17.30	2.60	17.30	2.00
17.45	2.55	17.45	1.90
18.00	2.20	18.00	1.90

TABLE 13

Variation of the stomatal aperture after the transference of  
the root from water of 20°C into that of 30°C.

5 days after transference (Time)	Stomatal aperture	6 days after transference (Time)	Stomatal aperture
10.00	0.0308	10.00	0.0370
10.30	0.0313	10.30	0.0367
11.00	0.0313	11.00	0.0357
11.30	0.0323	11.30	0.0357
12.00	0.0317	12.00	0.0364
12.30	0.0323	12.30	0.0370
13.00	0.0317	13.00	0.0367
13.30	0.0317	13.30	0.0357
14.00	0.0323	14.00	0.0357
Mean value	0.0317	14.30	0.0357
In water at 30°C.		15.00	0.0351
14.30	0.0313	15.30	0.0351
15.00	0.0315	16.00	0.0351
15.30	0.0323	Mean value	0.0360
16.00	0.0323	In water at 20°C.	
16.30	0.0303	16.30	0.0370
17.00	0.0305	17.00	0.0400
17.30	0.0317	17.30	0.0351
18.00	0.0328	18.00	0.0370
18.30	0.0317	18.30	0.0357
19.00	0.0317	19.00	0.0357

Figure 1



●—●; Water absorption.  
 ○·····○; Stomatal aperture. Curves were taken from Figure 5 in the previous paper (1936 b). Curve  $S_1-S_1$  shows the diurnal fluctuation of the stomatal aperture on the first day after the transference from natural conditions.

Figure 2

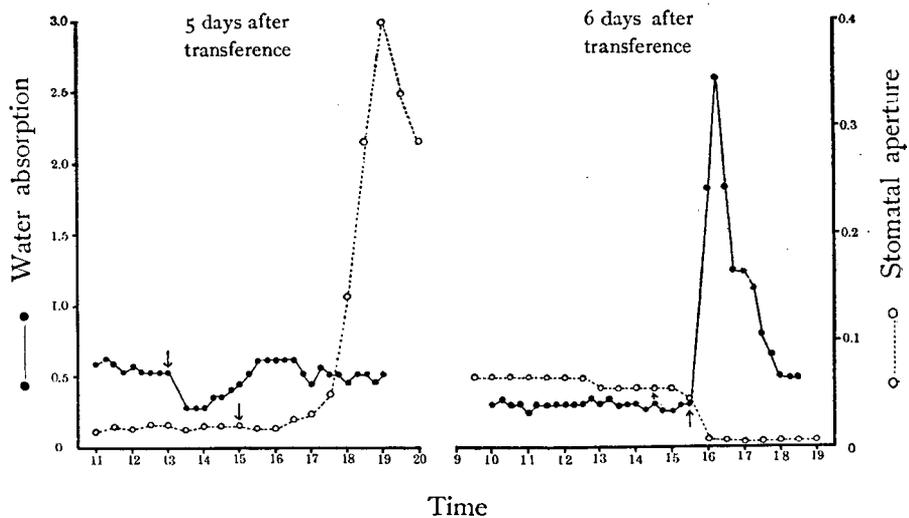


Figure 3

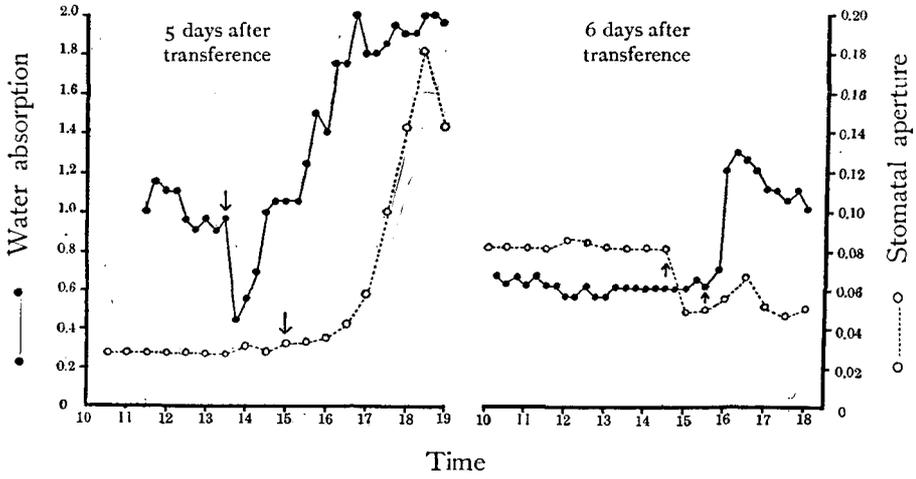


Figure 4

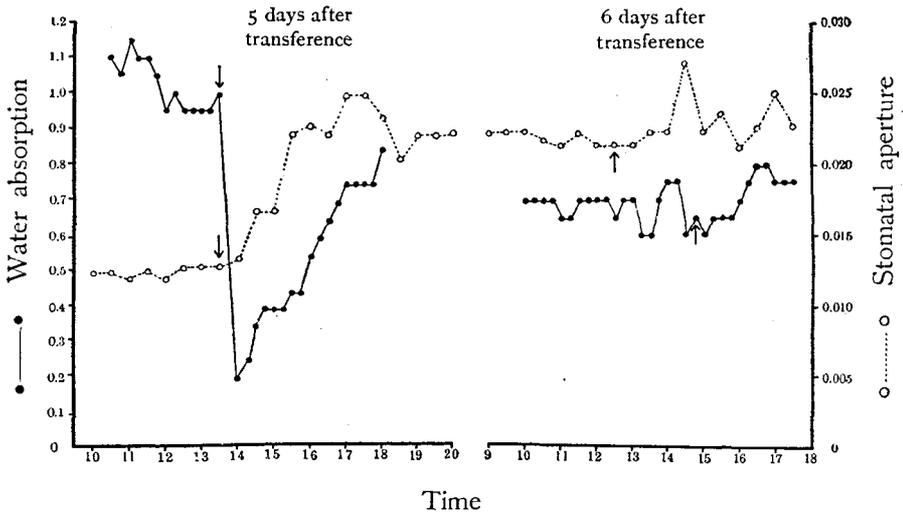


Figure 5

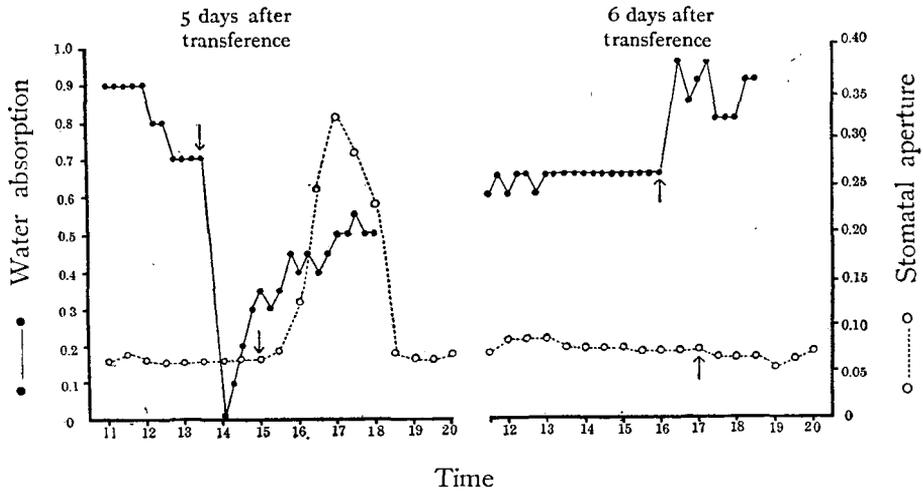


Figure 6

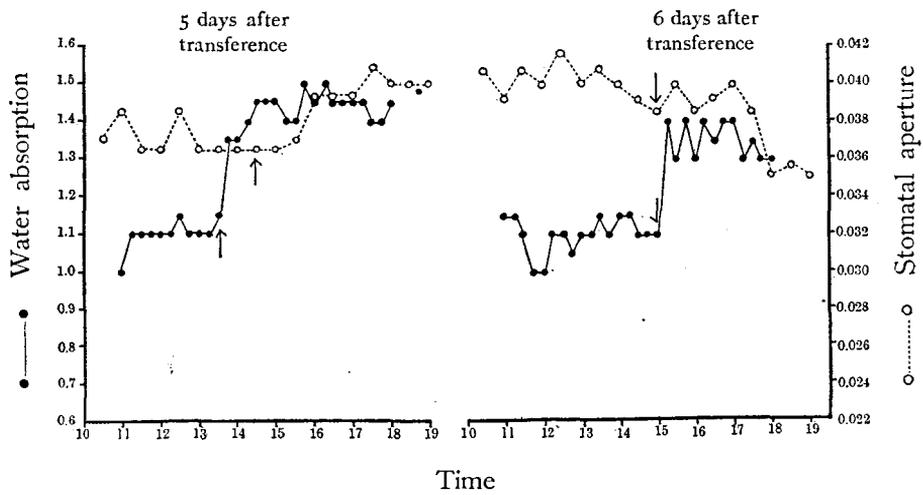
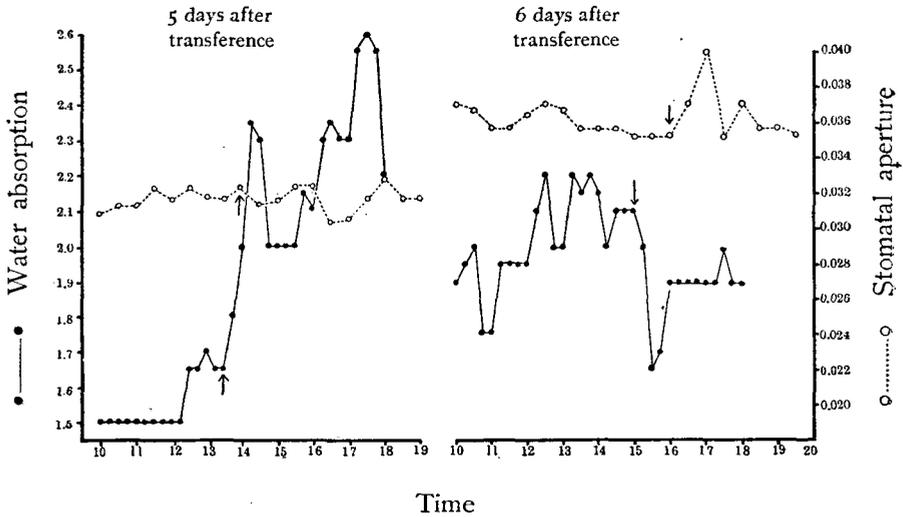


Figure 7



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