Drought Resistance and Constancy of Osmotic Ascension caused by Wilting in Soybeans*

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福田八十楠, 賀来章輔: 大豆の凋萎による滲透圧上昇の固定と耐乾性

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In the former reports (33) the authors affirmed in soybean plant, as other plants (1, 13, 23, 29, 31, 32, 37, 38, 41), the one grown on drought spot has higher osmotic value than the one grown on moist place. But they observed that the temporary drought resistance, which acquired on extremely dry spot in hot season, relaxates in cool season. Fortunately some of these samples were studied to see the regulation of osmotic value by subjecting them to wilting. Temporary wilting is believed to give the plant drought resistance (16, 42), like the temporary cold resistance (30, 31, 35, 39, 40).

Whether the experience of former drought, which has influenced to increase the cell sap concentration (6, 7, 34, 36, 43) still effects osmotic ascension or not on the part produced from the growing point after the soil moisture is regained is a problem not yet investigated.

Material and Methods

The material is a autumn-soybean Tamanishiki which is the same in Rep. 1. The plants were grown in cylindrical, galvanized iron pots 15 cm in diameter and 17 cm height. The soil used was sandy loam and the saturated water capacity of this soil was estimated approximately 26%. A watering tube containing crushed stone extended down the side of each pot to the bottom. The pots were divided into two groups of 80% and 50% of water capacity, and the pots were weighed daily and adjusted by watering. The pot of 80% water capacity which had been subjected to wilting stopped being watered, and in several days it reached near the point of permanent wilting. After that the soil was once more watered to regain the optimum soil moisture, 80% of water capacity.

Experimental Results

Experiment 1. Ascension of Osmotic Values

Example A) **Control plants grown in constant soil moisture.** The results (Fig. 1) are described in the former report (33).

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Example B) **Plants wilted 4 times.** After the plant in 80% soil moisture had been wilted four times, the soil moisture held 80% constant (Fig. 1). For 70 days, from Sept. 6 when the flowers fell to the middle of Nov. when the plant withered, the osmotic value did not show much fluctuation, only increasing a little as the season advanced. The curve is always higher ($0.51-0.47=0.04$ mol) than that of

Fig. 1. From the late growing season to the ripening period.

the control A), in spite of both plants growing at 80% moisture condition. It may be considered that the effect of hardening remains all through the life. The real water content of the soil where the wilted example grew was calculated as 50% by the bisection of the four triangles of moisture variation at wilting. The plant grown in 40 or 50% soil moisture (illustrated in Report 1) has 0.04 mol higher osmotic value than that grown in 80% moisture after the flowers have fallen. Therefore the hardening effect of wilting four times corresponds with the effect of the different conditions of 80% and 40% constant moisture.

Example C) **Plants wilted 8 times.** As seen in Fig. 1, at the flowering time both Example B) and C) were subjected to wilting 4 times. The osmotic value rises at the wilting and drops at the recovering. But the curve of mean values ascends as wilting repeats. From Sept. 6, the samples were divided into two, i.e., B) and C). The C) plant was subjected to wilting continuously. The ascending tendency of the mean osmo-value is also maintained, but the degree of dropping resumed by recovering becomes less and less as the experience repeats. After the 8th wilting the minimum becomes equal to the maximum and so fixes (Fig. 1). By these examples it is confirmed that the effect of repeated wilting builds up an acquired character which makes plasma contain the hypertonic cell sap through the life.

Example A and B) In Fig. 2 are illustrated osmotic variations of **all the leaves from the lowest to the uppermost** of the plant B), grown on 80% for 40 days after being wilted 4 times, and those of the control A) on constant 80%. The lowest 5 leaves had dropped when the observation began. Up to the 13th leaf, B) is 0.04 mol

higher and above that 0.06 mol lower than A). The lower leaves of B) are the ones which have grown during the season when wilting repeated, but the upper leaves are the ones which have developed after the normal water condition was regained. It indicates that the new shoot which sprouted from the rejuvenated growing point

of the hardened plant adapts to regained condition, and the experience of the former water economy does not effect any more. Like a young shoot in the early stage of growth, the rejuvenated shoot of B) has much lower osmotic value than that of an adult shoot of A).

Fig. 2. Osmo-values of the epideamal cells.

Fig. 3.

Experiment 2. Outer Morphological Differences of the Hardened, the Rejuvenated after being Hardened and the Nonhardened (Fig. 3)

The forms of the **plants grown in the constant water condition**, 100, 80 and 65% have the same size, but when moisture becomes less than 65% then the plants become dwarf.

Table 1. The result of growth and the yield on Nov. 5.

Soil moisture	Height of the plant	Nos. of pods	Nos. of beans	Weight of total beans	Weight of a bean
80%	73 cm	21	36	75.5 g	0.21 g
50	62	17	20	46.0	0.23
80, but 4 wilt (av. 50)	70	22	29	78.0	0.28
80, but 8 wilt continued	71	1	1	—	—

On the other hand the example of **4 times wilting B**) is as tall as that on constant 80% (Fig. 3). The 4 times wilting does not effect growth if the standard soil moisture is kept at 80% both before and after the wilting; **8 times wilting** also does not effect growth (Tab. 1); if it does, it causes the shedding of leaves and makes the plant look poor (Fig. 3). Even the plant wilted 4 times looks more prosperous when a new shoot grows from the rejuvenated top. Even the same average amount of variation is given in the soil, when it is kept constant or when it varies, it gives different effect on plants.

Experiment 3. Drying Speed of Leaves According to the Order
of Position Estimated by the Way described in Rep. 1

In A) the position of leaves has nothing to do with the surface developement (Tab. 2), but k) and kn) are larger in the upper leaves. Stronger physical transpiration in the upper leaf than in the lower, denoted by the value k), is due to the

Table 2. Drying speed of leaves of Axample A) on Nov. 5.

Leaf position	Surface develepe- ment (s.d.)	Drought coeffi- cient (k)	Normal coeffi- cient $k/s.d.=kn$	Ecotype
8th	6.900	0.0452	0.00650	Hardened
9	5.900	0.0535	0.00909	⋮
10	6.700	0.0811	0.01205	⋮
11	6.900	0.0940	0.01361	⋮
12	6.300	0.1220	0.01940	⋮
15	5.850	0.1690	0.03151	Non-hardened

water passability of the leaf surface kn) and not to the surface development of a leaf. It suggests that the drought resistance does not differ with the seasonal changes but differs according to the age of leaves; that is, the older the leaf is the less the water passability of a leaf becomes. In Example B) (Tab. 3) the 8-12th **leaves which developed during wilting treatment** have small passability like the oldest leaves of the control, which suggests that the former had been hardened.

Table 3. Drying speed of leaves of Example B) (4 wilt) on Nov. 5.

Leaf position	Surface development	k	kn	Ecotype
8th	6.200	0.0582	0.00938	Hardened
12	8.250	0.0692	0.00838	Do.
15	6.800	0.1384	0.02040	Non-hardened
16	8.000	0.2350	0.02940	Do.
17	6.300	0.3690	0.05820	Do.

But in **the leaves which grew after the normal water condition was regained**, the surface development is not changed, but k) and kn) are very large and indicate that the ability of drought resistance is weak, showing that they are not hardened. In all the leaves of Example C) the value of three characteristics relating to the water economy do not differ much (Tab. 4).

Table 4. Drying speed of leaves of Example C) (8 wilt) on Nov. 5.

Leaf position	Surface development	k	kn	Ecotype
8th	6.350	0.0470	0.00738	Hardened
9	7.500	0.0525	0.00701	Do.
10	7.800	0.0581	0.00745	Do.
11	8.000	0.0581	0.00730	Do.

These values of Example C) are the same as those of the hardened ones in Example B). **Every leaf of Example C) is hardened.**

Conclusion

In the wilted examples the leaves which generated after the normal soil moisture was regained have lower osmotic value than that of the control and the leaves which developed during the treatment have higher osmotic value which is irreversible. Now coming to the drying speed of these leaves, the smaller k) value in the latter old one suggests that it has acquired greater drought resistance. Now, the modification in osmotic value coincides with the acquirement of drought resistance. In Example C), after 8 wilting the high osmotic value irreversibly remained and also the smallness of the drought coefficient k) shows all leaves are strongly drought resistant. In Example A) which was kept in 80% constant soil moisture, the 8th but now the lowest leaf alone is drought resistant. In each example the osmotic value and the three drought features of the uppermost leaves are as follows (Tab. 5):

Table 5.

	Osmotic value	Surface development	k	kn	Ecotype
Example A	0.60	0.585	0.1690	0.3151	Mesomorph
Example B					
regenerated one	0.53	0.630	0.3690	0.5820	Non-hardened
hardened one	0.63	0.825	0.0692	0.0838	Hardened
Example C	0.64	0.800	0.0581	0.0730	Hardened

Now, the modification of the irreversible increase of osmotic value and the decrease of water-passability through the leaf surface are acquired by wilting. In the publication of other writers the increase of osmotic value by wilting was recognized as

the acquirement of the ability of drought resistance without exact testimony, but the present writers experimentally confirmed that the leaves which developed during wilting treatment have acquired the drought resistance, and also the increase of osmotic value by wilting is an indication of the drought resistance. That the fixed hardening effect is recognizable in the leaves which developed during wilting treatment, is due to that the leaf growth is an irreversible phenomenon. The period of growth of a leaf, however, lasts longer than the drought duration, so that a leaf subjected to wilting may not develop to a morphological xeromorph.

Water deficit of the soil effects the plant in the following manner:

- 1) Constant water deficit results the xeromorphic dwarfism of plant.
- 2) Temporary water deficit results the type hard to drought. The latter has not been hindered its growth as the former, but both have been hardened to drought.
- 3) The hardened leaf of the latter has large surface development and small water passability through the leaf surface. So that the leaf type which is hard to drought is not the xeromorph.

The high osmo-value and small drought coefficient and perhaps the large amount of solute may be indications of the drought resistance but are not the special features limited to the xeromorph.

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