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The effect of water saturation deficit on the volume of intercellular space in laeves

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Abstract

The volume of intercellular spaces in leaves at various stages of water saturation was determined by method of Czerski (1964, 1968).
The investigation were performed with the following plant species: *Vicia faba* L., *Nicotiana tabacum* L. var. *rustica*, *Solanum tuberosum* L. var. Flisak, *Helichrysum bracteatum* Wild., *Brassica napus* L. var. *oleifera*, *Beta vulgaris* L. var. *saccharifera*.

INTRODUCTION

The accessibility of water in soil and the air moisture greatly influence the morphological and anatomical structure of plants (Zalenski, 1904; Cygowa. 1930; Roguska-Wasilewska, 1957). The degree of saturation of plant tissues with water also regulates the type and intensity of metabolic processes (Crafts, Currier and Stocking, 1948; Strebeyko and Domańska, 1957; Wróblewska, 1973; Strebeyko, Bacławska-Krzemińska, 1973 and others).

The data on the ecological role of intercellular spaces (IS) (Areschoug, 1882; Gessner, 1959; Roguska, 1960) are much more numerous on plants from moist environment than on those growing in drought. The IS volume is not a constant value and, as demonstrated by Nius (1931) in leaves of various plant varieties, it decreases with dehydratation.

Apart of stomata in gas exchange in plants, i.e. in photosynthesis, respiration and transpiration, prompted us to study in detail the course of changes in IS as related to water deficit (WD) in leaves.

MATERIAL AND METHODS

The investigations were performed with the following plant species: *Vicia faba* L., *Nicotiana tabacum* L. var. *rustica*, *Solanum tuberosum* L. var. Flisak, *Helichrysum bracteatum* Wild., *Brassica napus* L. var. *oleifera* and *Beta vulgaris* L. var. *saccharifera*.

The plants were cultivated in the garden of the Department of Plant Physiology of the Warsaw University. The leaves were taken from the apical and lower the same tier. The measurements were repeated 5 — 10 times. The level of the leaves was referend to the lowest one, on the plant.

The hydration of the leaf blades and the IS volume were determined by the gasometric method (Czerski, 1964, 1968). The IS volume was measured at successive 5% increase in water deficit (WD) in the range 0 — 40%. Leaves with a negative water balance were obtained by detaching them from the plant and leaving under laboratory conditions. The IS volume of leaves in a state of turgor was measured immediately after their detachment from the plant early morning.

From the empirically obtained results a theoretical relation could be derived between the state of leaf hydration (WD) and the IS volume using the linear function equation:

$$y = a_0 + a_1 x$$

were y—IS volume

a_0 — IS value at WD=0

a_1 — change in IS volume with increase in WD by 1%

x — WD

The linearity of the regression function $y = a_0 + a_1 x$ was verified by the series test (Halwig, 1967) according to which the permissible length of series of empirical results higher or lower than those resulting from theoretical calculation (regression function value) is five at eight values of the variable x. If the series of results is longer than five, the relation cannot be considered as linear.

The experimentally obtained IS volumes at definite WD are marked on the graphs (No. 1 — 6) with points, whereas the theoretically calculated course of changes in IS volume was schown by a strainght line.

RESULTS AND DISCUSSION

Changes in IS volumes in leaves as related to WD are shown in graphs (Fig. 1). The course of these is linear, this resulting from the situation of the particular values in relation to the theoretical regression function. The deviations of the empirical values from calculated ones are insignificant and are above or below the theoretical curve and do not exceed the permissible length of the series.

The relation between IS volume and WD is characteristic for leaves of high and low IS as found with the lower leaves with large IS and leaves with low IS. In *Vicia faba*, tabacco, potato, rape and beet (Table 1) the extent of changes in IS of lower and apical leaves at the same WD is different and dependet on the primary IS in the state of turgor. Thus, the angle coefficient a_1 depends on the a_0 value (Table 1). This regularity was noted when comparing the leaves of various plant species. The same angle coefficient (Table 1) was found, in the twice larger IS in apical leaves of *Vicia faba* as compared with the apical leaves of potato. The lack of correlation

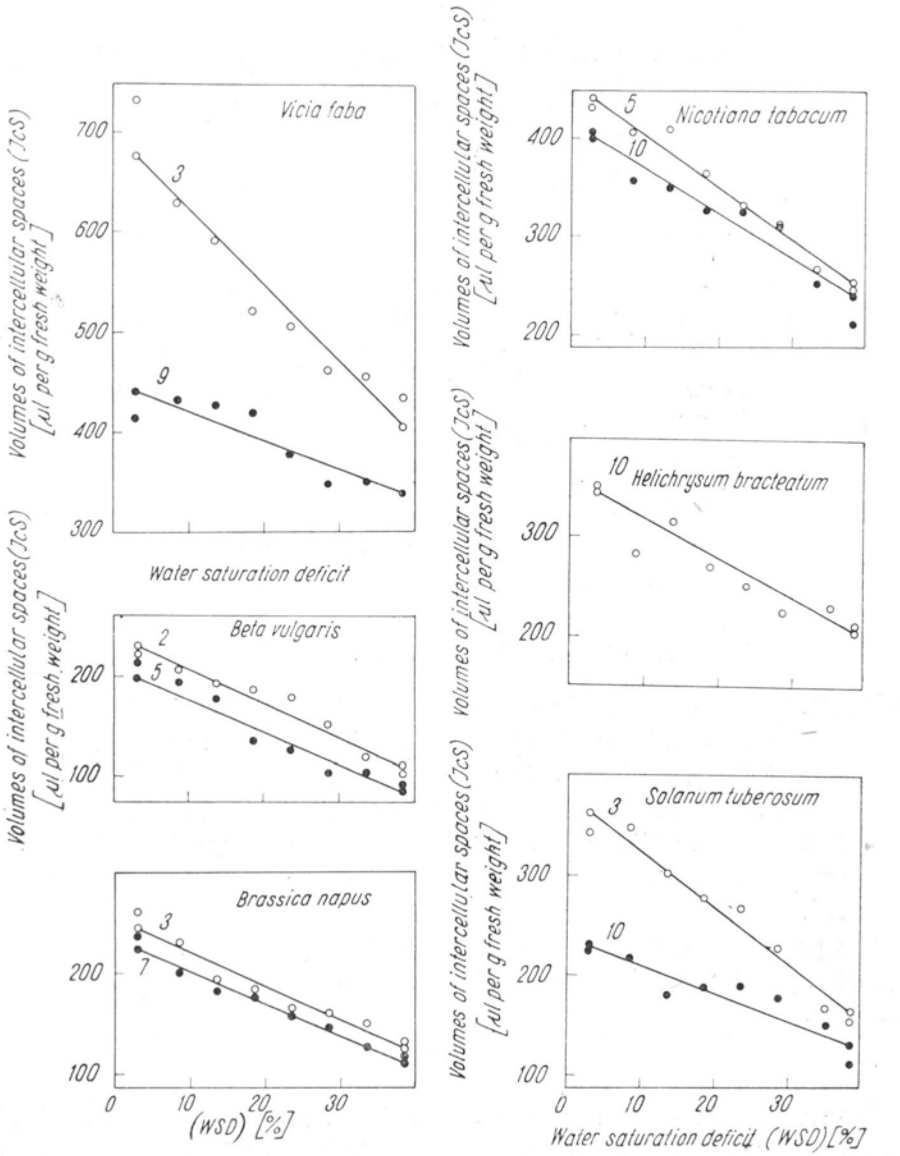

Fig. 1. Changes in IS volumes in leaves as related to WD

between IS and the angle coefficient a_1, when comparing leaves of various plant species is probably due to the following possible differences in:

1) structure and properties of the cell walls,
2) percentage of mechanical tissue,
3) osmotic potentials of the cell sap.

WD of the order of 40 per cent result in a more than 40 per cent decrease of IS. The difficulties in gas exchange in the leaves may be caused by the reduced potency of the ventilation system of IS. In porometric studies the cariance in resistance of IS

Table 1

Intercellular space volume in leaves in the state of turgor (a_0) in mm^3g^{-1} fresh mass, and the changes caused by a 1 per cent increase of water deficit (a_1)

Species	Leaf tier	a_0	a_1
Vicia faba	9	499	—2.89
	3	699	—7.58
Nicotiana tabacum	10	417	—4.60
	5	459	—5.37
Solanum tuberosum	10	238	—2.84
	3	380	—5.65
Helichrysum bracteatum	10	344	—4.33
Brassica napus	7	234	—3.24
	3	255	—3.41
Beta vulgaris	5	207	—3.12
	2	239	—3.35

are not taken into account, and the differences in air flow are attributed solely to the differences in the opening of the stomata. This simplification seems to be justifiable in porometric, investigations only with respect to the leaves in turgor or when WD is small. The variations in water balance of the leaves under natural conditions (Czerski, Wąsik, 1971) and the corresponding changes in IS indicate that it is necessary in porometric investigations to take into account the variable IS resistance.

The proportionality found between changes in IS and the state of leaf hydration suggest a possibility of calculation of WD. However the addional verification is necessary.

CONCLUSION

Intercellular space volume was measured in leaves under conditions of various water deficits from 0 to 40 per cent. The results obtained for six plant species indicate that:

1) the intercellular space value depends on the extent of leaf hydration and diminishes with the increase of water deficit,

2) changes in intercellular space are directly proportional to water deficit,

3) determination of the angle coefficient (a_1) enables us to calculate the current intercellular space for a defined water deficit in the leaves,

4) at a 40 per cent of water deficit a 40 per cent decrease in the intercellular space volume was noted. It seems that the results obtained with porometer particularly for leaves deprived of turgor, may be largely erroneous due to the changes in the resistance of the ventilation system.

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Wpływ deficytu wodnego na objętość przestrzeni międzykomórkowej liści

Streszczenie

Przy użyciu metod opisanych przez Czerskiego (1964, 1968) przebadano wpływ deficytu wodnego (D. W.) na objętość przestrzeni międzykomórkowych (P. M.) liści.

Przeprowadzone badania na liściach dolnych i szczytowych sześciu gatunków roślin wykazały ścisłą zależność pomiędzy D. W. a objętością P. M. liści.

Zmiany objętości P. M. spowodowane odwodnieniem były bardzo znaczne i wynosiły 40-50% przy D. W. wynoszącym 40%. Jak sądzimy wyznaczanie na liściach nie będących w turgorze rozwarcia szparek przy użyciu porometru może być obarczone poważnym błędem wynikającym ze wzrostu oporu stawianego przez P. M. przepływającemu powietrzu.

Wyznaczony współczynnik kątowy a_1 umożliwia wyliczenie aktualnej objętości P. M. dla określonego stanu uwodnienia blaszki liściowej.