

The Relationship between Sublethal Water Saturation Deficit and the Dynamics of Soil Moisture in Some Xerophilous Grasses

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Abstract. The paper deals with the resaturation of water saturation deficit in four *Stipa* species tested under various ecological conditions. Attention is paid to the relations between the saturation and oversaturation types of curves, on the one hand, and soil moisture on the other. The oversaturation type appears in plants well supplied with soil moisture. The explanation of this phenomenon is discussed.

While studying the ecology of xerophilous steppe plants we have often been confronted with the problem of determining their drought resistance, their accomodation to prolonged desiccation, and their ability to survive the conditions of water stress, which was, in some periods, permanent. We have endeavoured to determine the degree to which their water saturation deficit is still reversible, and the moment in which the plants suffer irreversible changes, that is when they are damaged by drought (RYCHNOVSKÁ 1963, 1965b, RYCHNOVSKÁ and KVĚT 1965). Water-loss curves plotted from our measurements of shoots were of little use for this purpose (KVĚT and RYCHNOVSKÁ 1965). In many species of xerophilous grasses their course was almost linear; thus, it was not easy to decide at what moment the leaves still retained their ability to recover to the fully turgid state and when they were already damaged. For this reason we worked out a new method for the assessment of the sublethal water saturation deficit, corresponding to that which with a similar aim in view OPPENHEIMER (1963) and DAVISON (1964) applied to their work.

Our previous experiments showed that, as a rule, saturation curves attain their initial values in the initial phases of wilting; however, during the incipient drying of some plants, we could observe a tendency to oversaturation with water above the initial values. This was first observed in the case of *Chrysopogon gryllus* and later in a group of other plants (RYCHNOVSKÁ and KVĚT 1965). The aim of the present paper is to find out the ecological conditions under which simple saturation or oversaturation takes place.

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Material and Methods

The leaves of the following plants were used for experiments: *Stipa capillata* L., *S. pulcherrima* C. KOCH, *S. joannis* ČELAK., and *S. stenophylla* ČERNĚ. The oscillation of resaturation curves was observed in relation to time and space. On the rocky steppe near Moravský Krumlov the samples

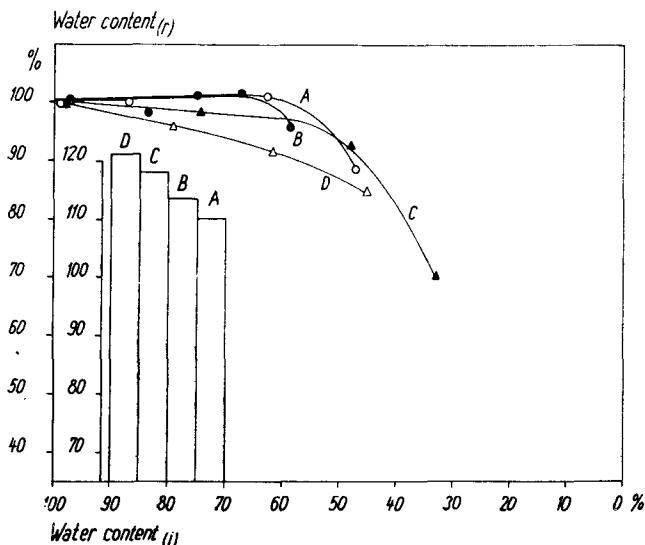


Fig. 1. Water saturation curves obtained with leaf segments of *Stipa pulcherrima*. Abscissa: Water content of the leaves exposed to desiccation. Ordinate: Water content of the leaf segments after resaturation. The water content of the fully turgid leaf segments has been taken as 100%.

A — Steppe near Moravský Krumlov, B — Steppe near Mohelno, C — Steppe on the hill of Květnice near Tišnov, D — Steppe near Pouzdřany. The water content of fully turgid leaves (in %) in relation to their dry weight is shown in the histogram in which A, B, C and D relate to plants from the above localities.

of plants from the homogenous vegetation cover of four species under study were tested for a period of two years. The description of the locality can be found in another paper (RYCHNOVSKÁ and ŮLEHLOVÁ 1966). On the other hand, plants from various localities were subject to the test described below in one period of time. Our attention was predominantly paid to steppe localities in southern Moravia with a natural occurrence of *Stipa pulcherrima*, which show both edaphic and climatic differences. As the water relations of the habitat are a complex phenomenon impossible to be reduced to a mere enumeration of conventional macroclimatic and pedological data, we purposely omit them. The water relations of the habitat are to a certain degree integrated in the relation of water content and dry matter in the plant at full turgidity. As this ratio decreases with the increasing water stress in the habitat, it was employed as characteristic of the degree of xeromorphosis, and thus indirectly characteristic of the locality in general. The measurements were performed in June 1962. Further experiments were

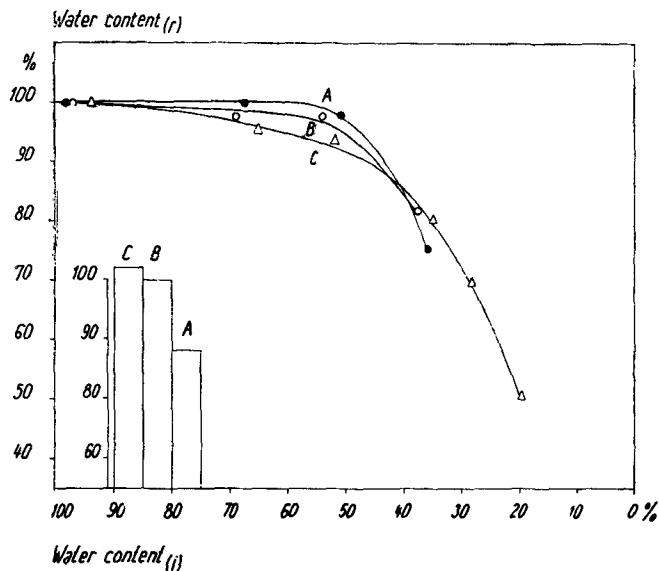


Fig. 2. Water saturation curves obtained with leaf segments of *Stipa joannis*. Explanation as for Fig. 1.
A — Steppe at Szentendre-Sziget, B — Steppe on the hill of Csomád, C — Steppe on the Tihany Peninsula.

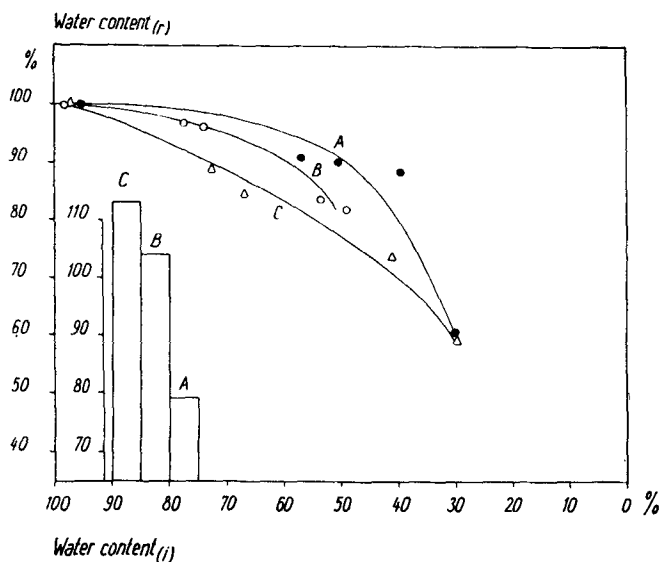


Fig. 3. Water saturation curves obtained with leaf segments of *Stipa capillata*. Explanation as for Fig. 1.
A — Steppe at Szentendre-Sziget, B — Steppe on the hill of Csomád, C — Steppe on the Tihany Peninsula.

conducted in July 1962 in Hungary. The localities studied there were described in another work (KÁRPÁTI and KÁRPÁTI 1965, KVĚT and RYCHNOVSKÁ 1965) and the degree of the xeromorphosis of the tested plants was evaluated according to the same criterion.

The following method was adopted: The leaves, cut off the plants under study, were kept in darkness with their bases submerged in water, in a water-saturated atmosphere for 16–20 hours, until they were fully turgid. Then they were dried in a controlled incubator, so that they gradually wilted and passed into various stages of water saturation deficit (Water content [$_i$]). After fixed periods of time the wilted leaves were again saturated with water (Water content [$_r$]). This resaturation, however, was not carried out on intact leaves but on segments cut from the leaf blade. This is done by applying water-saturated polyurethane foam to the cut surfaces for two hours in the same manner as described in the paper by ČATSKÝ (1960) and that by RYCHNOVSKÁ and BARTOŠ (1962). The extent of wilting and that of the resaturation were determined gravimetrically.

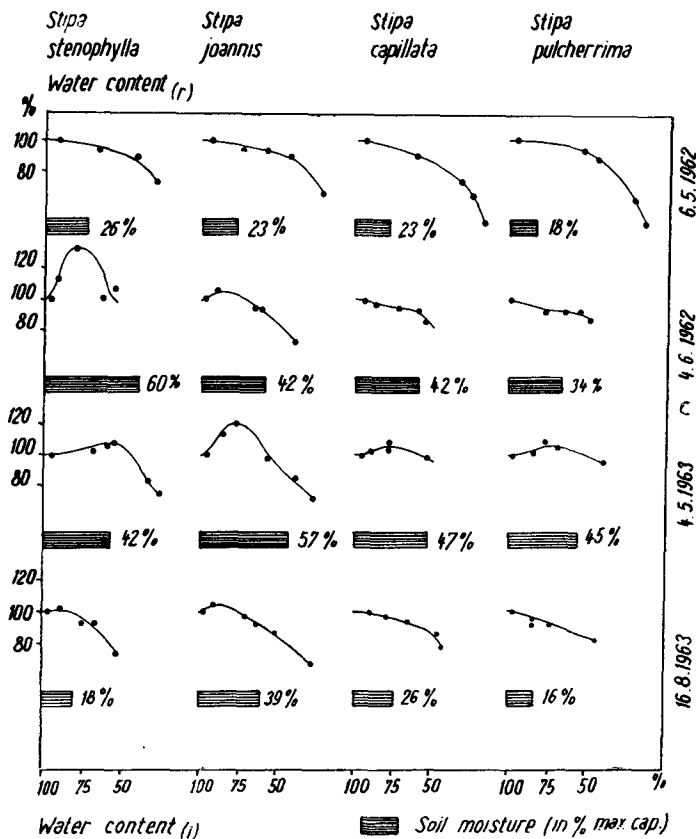


Fig. 4. Seasonal variation of resaturation curves obtained with leaves of *Stipa stenophylla*, *S. joannis*, *S. capillata* and *S. pulcherrima*. Explanation as for Fig. 1. Soil moisture is expressed in % of maximum capillary capacity. Steppe near Moravský Krumlov.

Results

The results of the measurements are graphically depicted in Figs. 1–4. They show that the resaturation curve exhibits lower values when the degree of xeromorphosis of plants from various localities decreases (Figs. 1 to 3). A distinct coincidence between the type of resaturation curve and the soil moisture supply in the rhizosphere, having specific properties for each species under study (Fig. 4), can be easily observed.

Discussion

The loss of water by wilting was found to be reversible up to a certain limit corresponding to the sublethal water saturation deficit. During further desiccation the ability of the plant to gain full turgidity decreases very rapidly and soon disappears altogether. The position of the limiting point on the resaturation curve adds much to our knowledge of the water relations of the plant investigated. The ability of the plants to survive periods of water saturation deficit and the reversibility of their water deficit depends to a great extent on environmental conditions and on their habitats. The more extreme the conditions of the habitat, the greater is the ability of the plant to cope with the increasing water saturation deficit immediately and without irreversible changes.

This statement is based on a series of curves plotted from results of experiments with the same plant species in the same period of time but from different localities. The aridity and extremity of conditions of the habitat increases in proportion to the ratio of water content to dry weight in the leaves after maximum saturation. The resaturation curves also shift accordingly (Figs. 1–3).

These facts suggest that the above relationship is the result of an adaptation of the plant to life in dry habitats. In those places the insufficient amount of soil moisture results in a prolonged decrease of turgidity. The inability of a plant to survive this period without damage would prevent its permanent settlement at the site. However, we discovered in a series of previous experiments that the simple recompensation of the water saturation deficit, i.e. saturation which restores only the original water content of the plant, does not always take place. We found that some plants increased their active resistance to drought by increasing the water absorbing capacity of their leaves during their wilting and desiccation. The mechanism of this phenomenon has not yet been fully understood, but it may be assumed that it is based on increasing osmotic values; this is shown by the work of JEREMIAS (1965). However, its function — the increase of drought resistance — seems to be quite obvious. This property of the plants is obviously of great ecological importance, for it increases the drought resistance of the shoots and thus probably affects the other physiological functions of the plants, especially photosynthesis.

The relations between the water régime of the habitat and the reaction of the plant do not appear to be unambiguous and direct. While studying the resaturation curves it was found that the oversaturation type of curve occurs, as was pointed out in a previous paper (RYCHNOVSKÁ 1965b), mostly among hygrophytes and mesophytes. Among the xerophytic grasses under

study the oversaturation type of curve prevails in those which resemble the mesophytes also in other properties. Among the four *Stipa* species under observation for several years in the same locality, the oversaturated type was mostly found in *Stipa stenophylla* and in *Stipa joannis*; to a smaller extent it occurred in *Stipa capillata*, and exceptionally (only once) in *Stipa pulcherrima* (Fig. 4). Independently it was found that the *Stipa* species can be arranged in the same sequence according to the degree of their xerophily (ŮLEHLOVÁ 1964, RYCHNOVSKÁ 1965a, 1966).

Thus, it is possible to draw the conclusion that the oversaturation curve is the result of plant reactivity, by which the water loss of the plant is actively compensated. We tried to verify this suggestion in various stages of the ontogenetic development of the plant, but we found no direct link between the stage of development and the type of the resaturation curve (RYCHNOVSKÁ 1965b). Nevertheless, there is an interesting coincidence between the fluctuation of the values of soil moisture and the type of the curve as revealed by the following figure: A relatively high water content in the soil corresponds to the oversaturation curve. In a dry period the simple saturation type can be observed (Fig. 4). Thus, it seems that the phenomenon observed is a sign of dynamic equilibrium between the diffusion pressure deficit and the available soil moisture at the site. A possible explanation may be offered as follows: If the biotope is dry to such a degree that the amount of water available decreases, the plant obviously mobilizes all its osmotic reserves at the site, so that during the experimental treatment the water potential cannot increase so much as to induce oversaturation. If a sufficiently adaptable plant lives in a habitat with adequate supply of soil moisture, its osmotic reserves are not fully mobilized, its diffusion pressure deficit being proportional to the availability of soil moisture. If this plant is suddenly submitted to an experiment in which it is subject to desiccation, it apparently mobilizes its reserves and increases its diffusion pressure deficit up to oversaturation. Further experiments will show whether and to what extent this explanation is correct.

However, this phenomenon definitely throws much light on the connexion between the water relations of the plant and its habitat; it clearly marks the species permanently adapted to dry habitats, the species whose physiological processes are not accelerated or intensified by increased water supply. *Stipa pulcherrima* can serve as an example. As we found in our previous studies, its rate of transpiration, daily course of water deficit and daily production of carbohydrates do not vary whether it is well or badly supplied with soil moisture (RYCHNOVSKÁ 1965a). On the other hand, the rate of transpiration and the daily production of carbohydrates of *Stipa stenophylla*, one of the most reactive and most mesophytic feather-grasses, decreases, as we have observed during a period of insufficient saturation with soil moisture, and the plant obviously suffers from drought; however, when it is supplied with water, its rate of transpiration and photosynthesis quickly increase until they almost reach mesophytic values. The reactivity of the plant is also documented by its varying saturation curve sensitive to all sorts of changes. To a smaller extent similar relations may be found in *Stipa joannis* whose properties are similar to those of mesophytes with only a greater degree of resistance to drought.

This paper shows that ecological studies of the water relations in plants must be many-sided, taking into account the results of various physiological tests performed in different time and space intervals. The paper is also a contribution to the causal explanation of the phytogeographical problems of the plants discussed here.

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M. RYCHNOVSKÁ, Ekologické odd. Botanického ústavu ČSAV v Brně: [Souvislost mezi subletálním vodním deficitem a dynamikou půdní vláhy u některých xerofilních trav. — Biol. Plant. 9: 135—141, 1967.

Práce přináší nová pozorování o vzniku a vyrovnávání vodního deficitu v listech 4 druhů kavyly za různých ekologických podmínek. Ukazuje koincidenci mezi kolísáním půdní vláhy na stanovišti a typem dosycovací křivky, přičemž přesycování se objevuje převážně jen při dobré zásobě půdní vláhy, kdežto pouhé dosycování souvisí s xerofytními podmínkami. Vysvětlení tohoto jevu je diskutováno.

M. РЫХНОВСКА, Экологическое отделение Ботанического института, ЧСАН, Брно: Связь между сублетальным водным дефицитом и динамикой влажности почвы у некоторых видов ксерофильных трав. — Biol. Plant. 9 : 135—141, 1967.

V работе приведены дальнейшие наблюдения о возникновении и выравнивании водного дефицита в листьях 4 видов ковыля при разных экологических условиях. Указано на связь между колебанием влажности почвы в месте обитания и типом кривой насыщения. Пересыщение имеет место главным образом лишь при достаточном запаса влажности почвы, в то время как простое насыщение связано с ксерофильными условиями. Дискутируется объяснение этого явления.