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Water relation in the leaves of *Dichanthium ischaemum* (L.) ROBERTY under water stress

By

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With 4 Figures

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Summary

NOÏTSAKIS B. 1987. Water relation in the leaves of *Dichanthium ischaemum* (L.) ROBERTY under water stress. – Phyton (Austria) 27 (1): 39–46, with 4 figures. – English with German summary.

The relationship among the tissue water potential (Ψ), osmotic potential (Π), turgor potential (P), and stomatal conductance (K) were examined in leaves of *Dichanthium ischaemum* (L.) ROBERTY under water stress conditions.

The small difference in the values of Ψ at the maximum value of turgor between well watered plants and water stressed ones and the fact that the magnitude of the diurnal change of Π was not as great as that of Ψ suggests that the osmotic adjustment is not a very important active mechanism of drought resistance. The sharp change of $\Delta P/\Delta\Psi$ in water stressed plants implies a low cell wall elasticity and may represent an adaptive mechanism also.

The critical value of Ψ for the stomatal closure was – 1.45 MPa and – 1.85 MPa, respectively in both well watered and water stressed plants. The stomatal conductance was lower in water stressed plants (0.25 $cm.s^{-1}$) compared with well watered ones (0.35 $cm.s^{-1}$).

Apparently the leaves of *Dichantium ischaemum* grown under water stress have low stomatal conductances and stomata remain open until tissue water potential reaches –1.85 MPa, which is an indication that *D. ischaemum* is well adaptive for growth under water stress conditions.

Zusammenfassung

NOÏTSAKIS B. 1987. Der Wasserzustand in den Blättern von *Dichanthium ischaemum* (L.) ROBERTY unter Wasserstreß. – Phyton (Austria) 27 (1): 39–46, mit 4 Abbildungen. – Englisch mit deutscher Zusammenfassung.

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Es werden die Beziehungen zwischen Gewebewasserpotential Π, osmotischem Potential Ψ, Turgorpotential P und der stomatären Leitfähigkeit von *Dischanthium ischaemum* (L.) ROBERTY unter Wasserstreß untersucht. Der geringe Unterschied von Ψ im Turgormaximum der gut mit Wasser versorgten und der unter Wasserstreß stehenden Pflanzen sowie die Tatsache, daß die Tagesschwankungen von Π nicht so groß wie die von Ψ war, deuten darauf hin, daß die osmotische Anpassung keine große Bedeutung für den Austrockungswiderstand besitzt. Die drastische Veränderung von $\triangle P/\triangle \Psi$ deutet auf eine geringe Elastizität der Zellwand hin und kann auch einen Anpassungsmechanismus darstellen. Der kritische Wert für den Stomaschluß lag bei den gut mit Wasser versorgten Pflanzen bei – 1,45 MPa und – 1,85 bei den unter Streß stehenden Pflanzen. Bei diesen war die stomatäre Leitfähigkeit mit 0,25 cm . s^{-1} geringer als bei den bewässerten Pflanzen (0,35 cm . s^{-1}). Augenscheinlich weist *D. ischaemum* unter Wasserstreß geringere Stomataleitfähigkeit auf und die Spaltöffnungen bleiben bis zu $\Psi = -1{,}85$ MPa offen, was eine gute Anpassungsfähigkeit von *D. ischaemum* für das Wachstum unter Wasserstreß anzeigt. (Editor transl.)

Introduction

Water potential is widely accepted as a measure of plant water stress. Critical threshold values of water potential causing stomatal closure have been reported in the literature for several species (FRANK & al. 1973, ACKERSON & KRIEG 1977, ACKERSON & al. 1977, CARLSON & al. 1979). Stomatal action in leaves controls water vapour and CO_2 exchanges, thus affecting crop production and plant water balance.

Regulation of stomatal conductance in an important physiological control for reducing water loss and preventing the development of water deficit. With increasing water stress stomatal conductance in the C_4-plants either shows no response to water deficit up to a certain value of water potential, after which a sharp decrease occurs, or it decreases continously as water potential decreases (DOLEY & TRIVETTE 1974). However, whether stomatal closure and reduction of water loss at more negative values of leaf water potential in advantageous is difficult to say. Although the superiority of C_4-plants is mainly due to higher rate of dry matter accumulation rather, than lower water loss, this superiority is partly associated with lower stomatal conductance (LUDLOW 1976).

This study was conducted in order to determine the effect of water stress on leaf turgor and water potential in *Dichanthium ischaemum* (L.) ROBERTY *(Poaceae)*, a C_4 grass species of range plant, as well as to determine its response of stomatal conductance to water deficit.

Material and Methods

Dichanthium ischaemum was grown in lam: peat mix in pots (46 cm high, 31 cm ∅) under field condition during the spring. 80 days after emergence of planting, two levels of irrigation were applied. In the first level, plants were watered frequently so that the soil was always near field

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capacity, as determined by a tensiometer (well watered plants); in the second level, plants received about one third of the water as the well watered plants. (water stressed plants). There were 4 pots with 20 plants per pot all well protected from occasional rain.

The next year during the vegetative period simultaneous measurements of tissue water potential (Ψ), osmotic potential (Π) turgor potential (P) and stomatal conductance (K) in the leaves of well watered and water stressed plants were made every two hours from 05.30 hr to 15.30 hr, over a period of 6 days with no important differences in climatic conditions. This conditions of the experimental area and for the 6 days of measurements are summarized in Table 1.

Table 1

Climatic condition over a 6 day of measurements.

Meteorological factors	23/6/80	24/6/80	25/6/80	26/6/80	27/6/80	28/6/80
Temperature Max./Min., °C	29/18	30/20	28/20	30/19	28/19	28/20
Rainfall, mm	–	–	–	–	2	–
P. Evapotranspiration, $mm.d^{-1}$	4.9	5.0	4.8	5.1	4.8	4.9

Each datum point represents the mean of four leaves. Tissue water potentials were determined by MPS pressure bomb. Before leaf excision, leaf blades were sealed with petroleum jelly to avoid rapid water loss. Osmotic potential were determined with thermocouple psychrometers on expressed sap from the same leaf after a 15 min equilibration in C-52 sample chambers. Sap was expressed by crushing the blade between a glass rod and glass plate and collecting the sap on a paper disc which was immediately introduced to the sample chamber. Output was measured with a Wescor HR-33-T dewpoint microvoltometer. Turgor potential were calculated as the difference between leaf water and osmotic potential: $P = \Pi - \Psi$. Leaf conductance was calculated as the reciprocal of leaf resistance to water vapour. Leaf resistance of the abaxial and adaxial surface was measured with the MK3 diffusive flow automatic porometer. It was calibrated by prescribed procedures before and after the sampling period. Since tissue water and osmotic potential involve destructive sampling, resistance measurements were made in leaves other than the ones used for the above two parameters. The fact that the measurements of tissue water potential

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and the stomatal conductance were not made on the same leaves should not have affected the data since an effort was made to sample identical leaves in each treatment.

Results and Discussion

Data presented in Fig. 1 show the changes in the tissue water potential, osmotic potential and turgor potential in the leaves of well watered and water stressed plants. At sunrise tissue water potential (05.30 hr) of well watered plants was –0.6 MPa, compared to –0.9 MPa of water stressed plant. As the day proceeded, the values of the tissue water potential rapidly decreased, attaining by 15.30 hr the values of –1.6 and –2.3 MPa in well watered and water stressed plants respectively.

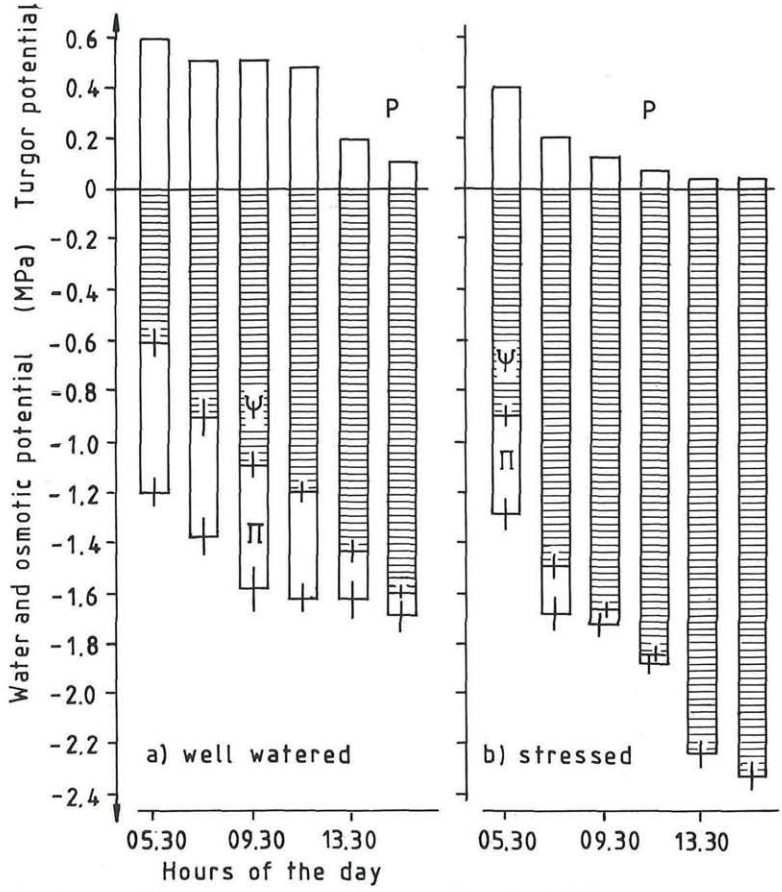


Fig. 1. Changes of the water potential (Ψ), osmotic potential (Π) and turgor potential (P) during the day in the leaves of *Dichanthium ischaemum*. Vertical lines represent standard errors of 24 measurements (6 days, 4 leaves each).

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Osmotic potential also decreased during the day with minimum values attained in early afternoon (15.30 hr) –1.7 and –2.35 MPa for well watered and water stressed plant respectively. It is evident that osmotic potential did not decrease in the well watered plants as rapidly as in the water stressed plants. Further, the magnitude of the diurnal change in osmotic potential was greater in the water stressed plants. A similar trend was observed for tissue water potential. The range of osmotic potential values between the maximum and the minimum was not as great as of tissue water potential. These differences are reflected by the values of turgor potential.

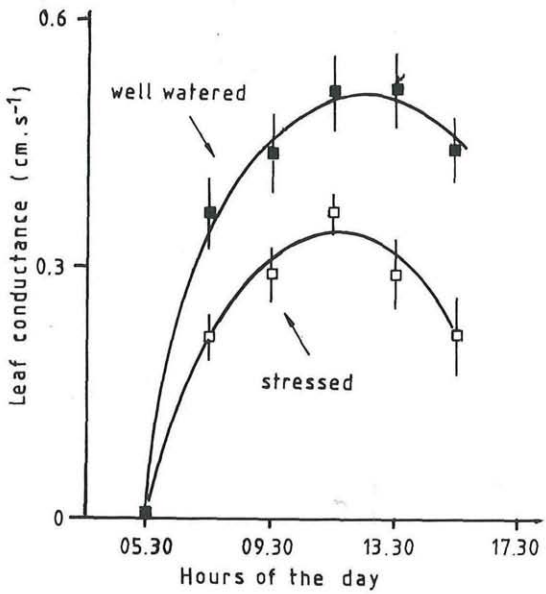


Fig. 2. Changes of leaf conductance in *Dichanthium ischaemum* grown under well watered (■) and water stressed conditions (□) during the day. Vertical lines represent standard errors of 24 measurements.

The diurnal changes in the leaf conductance were different in the well watered and water stressed plants (Fig. 2). With the developement of lower values of tissue water potential a decrease in leaf conductance occurred. As the day proceeded and tissue water potential decreased, concomitant decrease in leaf conductance occurred in both well watered and water stressed plants. Specifically, this decrease occurred at 12.30 hr for well watered plants when the value of tissue water potential was –1.65 MPa and at 11.30 hr for watered stressed plants when the value of tissue water potential was –1.2 MPa. A similar decrease in leaf conductance has also been found by others workers (BERGER 1973, BOYER 1970, JORDAN & RITCHIE 1971).

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In general, the decrease in tissue water potential during the day may be attributed to osmoregulation or/and the change of $\triangle P/\triangle \Psi$. The magnitude of the diurnal decrease in osmotic potential which implies a proportional decrease in tissue water potential depends on the molality of the vacuole and the degree of elasticity of the cell walls (TURNER 1974, WENKERT & al. 1978, CAMPBELL & al. 1979). In *D. ischaemum* a small difference was observed in the osmotic potential at the maximum value of turgor between the well watered and water stressed plants. Moreover, the fact that the diurnal magnitude of the decrease of osmotic potential was not as great as that of tissue water potential suggests that an osmotic adjustment does not interfere drastically as a mechanism to drought adaptation. Therefore, in spite of the osmotic adjustment, widely reported in the literature (WEATHERLEY 1965, CUTLER & al. 1977, ACKERSON 1981, MATSUDA & RIAZI 1981), the role of osmoregulation does not seem to be important in the grass species studied.

The small value $\triangle P/\triangle \Psi$ in the well watered plants compared to the water stressed ones (Fig. 3) suggest greater cell wall elasticity in the former. Moreover the greater value of turgor potential in the well watered plants compared to the water stressed plants at the same values of tissue water potential (Fig. 3) may be attributed to the smaller ratio of $\triangle P/\triangle \Psi$ in well watered plants.

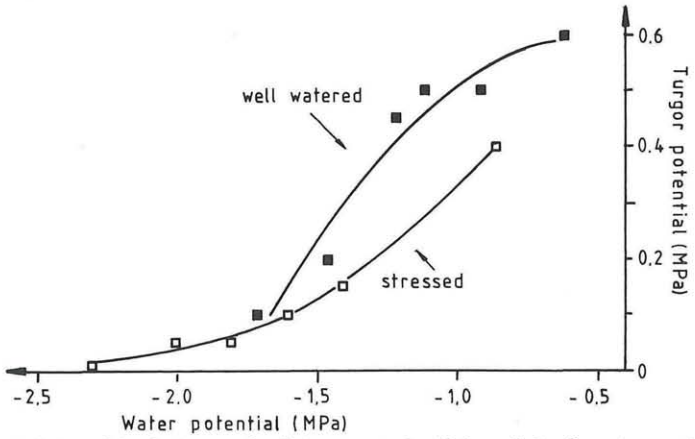


Fig. 3. Relationship between leaf turgor potential and leaf water potential in *Dichanthium ischaemum* grown under well watered (■) and water stressed conditions (□) during the day.

Figure 4 presents the changes of stomatal conductance in relation to turgor potential during the day. In well watered plants, when the turgor potential has fallen below the 0.45 MPa, the stomatal conductance appeared to be constant and independent of the turgor potential decrease until P reached 0.2 MPa, when stomatal conductance started to decrease. Similar

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observations were made by others (BEADLE & al. 1973, HSIAO 1973, TURNER 1974). These results lead to the conclusion that, under well watered conditions bulk tissue turgor potential is not a good index of the stomatal function. In water stressed plants stomatal conductance increased as turgor potential decreased until P reached 0.05 MPa, when stomatal conductance decreased sharply. Similar results were found in wheat (MILLAR & DENNEAD, 1976). These findings suggest that under water stress there is a

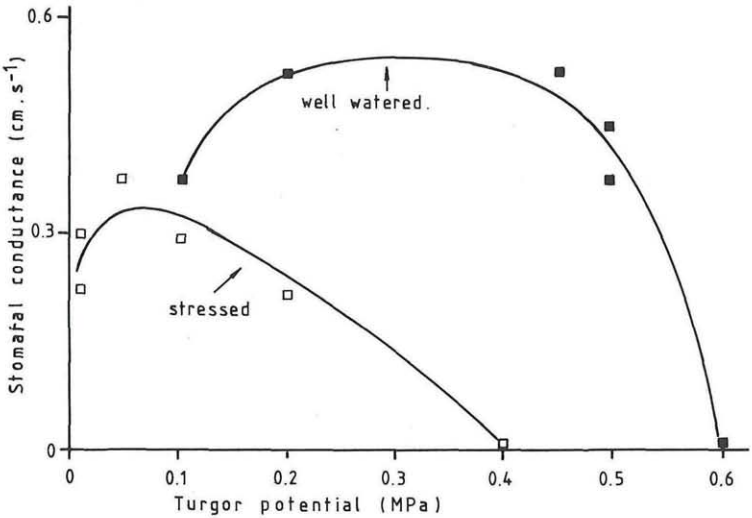


Fig. 4. Relationship between turgor potential and leaf conductance in well watered (■) and water stressed plants (□) of *Dichanthium ischaemum* during the day.

general relationship between stomata closure and bulk tissue turgor potential (BEADLE & al. 1978). Moreover at the same turgor potential, stomatal conductance in well watered plants was greater than in water stressed ones. This indicates that *D. ischaemum* can develop and adaptive mechanism for reducing transpiration at high evaporative demand when grown under water stress.

D. ischaemum being a C_4 species, exhibits an adaptive mechanism to water stress, that is expressed by a very low water potential before stomata are closed as well as a low stomatal conductance when plants are water stressed. This is an indication that it is well adapted for growth in dry environments.

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