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Diurnal Changes in Leaf Water Potential Components of *Chrysopogon gryllus* in the Field

By

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With 4 Figures

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Key words: Water stress, water potential, plant adaptation, C_4-plants, *Chrysopogon gryllus*.

Summary

Noïtsakis V. I. & Nastis A. S. 1985. Diurnal changes in leaf water potential components of *Chrysopogon gryllus* in the field. — Phyton (Austria) 25 (2): 193—203, with 4 figures. — English with German summary.

Measurements of hydrodynamic parameters for *Chrysopogon gryllus* (*Poaceae*) were determined to explain its adaptability to water stress. The resistance to liquid flow rate decreased slightly as transpiration increased through the day. Leaf water potential was maintained above —16 bars when relative water content of leaves was above 85 percent. For the 15 percent water loss a small decrease of leaf water potential was found, which was attributed mainly to osmotic potential decrease while turgor potential did not change significantly. At 85 percent relative water content, turgor potential was relatively high (5 bars) and depended mainly on cell elasticity.

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Zusammenfassung

Noïtsakis V. I. & Nastis A. S. 1985. Tägliche Änderungen der Blatt-Wasserpotential-Komponenten von *Chrysopogon gryllus* unter Freilandbedingungen. — Phyton (Austria) 25 (2): 193—203, mit 4 Abbildungen. — Englisch mit deutscher Zusammenfassung.

An *Chrysopogon gryllus* (*Poaceae*) wurden Messungen hydrodynamischer Parameter durchgeführt, um die Anpassungsfähigkeit dieser Pflanze an Wasserstreß zu erklären. Der Strömungswiderstand nahm während des Tages mit steigender Transpiration leicht ab, das Wasserpotential der Blätter blieb über —16 bar, solange der relative Wassergehalt der Blätter 85% überstieg. Bei 15% Wasserverlust wurde ein leichter Abfall des Wasserpotentials beobachtet, er ging hauptsächlich auf eine Abnahme des osmotischen Potentials zurück, während sich das Turgorpotential nicht deutlich änderte. Bei 85% relativem Wassergehalt war das Turgorpotential relativ hoch (—5 bar), es hing vornehmlich von der Elastizität der Zelle ab. (Editor transl.)

Introduction

Water deficit in plants brought about by drought may influence many important physiological processes which ultimately affect production (Hsiao 1973). Many plants have evolved physiological or morphological adaptations to drought conditions. Maintainance of leaf turgor above species-dependent critical levels is particularly necessary for continued growth (Boyer 1968) during drought periods.

Some plants have evolved mechanisms, known as osmoregulation, which actively accumulate solutes during stress and decrease osmotic potential so that turgor remains above a critical level (Turner 1979, Matsuda & Riazi 1981). Changes in cell wall elasticity in response to water stress can also regulate turgor pressure (Sancher-Diaz & Kramer 1971, Turner 1979). The pathway for water movement from the soil through the plant has been described by an Ohm's law analogy (Stoker & Weatherley 1971, Cowan 1965). The contribution of the resistance to liquid flow may be significant to the water state of the plant. Little is known about this resistance and relatively few systematic studies have been conducted in the field (Biscoe & al. 1976).

Chrysopogon gryllus (L.) Trin., an abundant C_4 plant (Eleftheriou & Noïtsakis 1978) in the Mediterranean low elevation rangelands, continues its growth during the summer, but the physiological mechanism of adaptation by which cell pressure is regulated, remains unknown.

This paper describes firstly the resistance to liquid flow through the plant in relation to the diurnal changes in xylem water potential and in the rate of leaf evaporation, secondly the relation between the hydrodynamic parameters during a day of the dry season. The know-

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ledge of how and under which conditions *Chrysopogon gryllus* modifies its physiological processes and attains a more effective water use would possibly enable managers to adopt better management schemes in order to increase forage yields.

Materials and Methods

The experiment was conducted in the field of the Range Experiment Station of the University of Thessaloniki. This station is located close to the city of Thessaloniki, at 15 m elevation. The environmental conditions of the experimental area in which the plants were grown are summarized in Table 1.

Table 1

Conditions under which the experimental plants of *Chrysopogon gryllus* were grown

Meteorological factors	March		April		May		June	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Temperature °C	13	4	15	8	23	11	30	18
Relative humidity %	86	56	91	65	87	49	90	39
Rainfall mm	80		116		12		29	
Potential evapotranspiration $mm \cdot d^{-1}$	2,3		2,9		3,8		5,3	

In the study area a group of similar plants was selected. On these plants measurements of: (1) water potential (Ψ_χ, xylem and Ψ_L tissue) (2) osmotic potential (Ψ_π), (3) turgor pressure (Ψ_P), (4) relative water content (RWC) and (5) transpiration rate were obtained on fully expanded leaves, at the seeding stage. Seeding stage was reached in late June, within 120 days since growth had initiated. In this period plants had entered the dry season. Measurements were obtained every two hours, from 05.00 to 15.00 hrs local time. All measurements presented are averages of five replicates.

Xylem water potential (Ψ_χ) was determined on leaves (cut at the ligule level) with a pressure chamber as described by SCHOLANDER & al. (1964) Tissue water potential (Ψ_π) and osmotic potential (Ψ_P) was determined with a thermocouple psychrometre system (NEUMANN & THURTELL 1972). Leaves were collected in the field, sealed in specimen tubes and transported to a nearby laboratory for measurements of tissue water potential. A portion of leaf was frozen at — 20° C for

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24 hrs, then thawed and its osmotic potential was measured after a 15 min. equilibration time. Values obtained with the pressure chamber technique for Ψ_χ are in close agreement with those obtained with the thermocouple psychrometer with which Ψ_L and Ψ_π were measured. Turgor potential was calculated by difference

$$\Psi_P = \Psi_L - \Psi_\pi \tag{1}$$

This procedure assumes that the matric potential is zero (BOYER 1967).

The relative water content was determined by the method of BARRS & WEATHERLEY (1962). When Ψ_χ was measured leaf segments were cut and promptly transfered to the laboratory. They were weighed and then floated in distilled water at 25° C under a 10 μE^{-2} sec^{-1} light. Six hours later excess water was removed by blotting them dry on filter paper and samples were weighed. The same samples were oven dried at 80° C for 24 hours and then reweighed. The RWC was calculated by the formula:

$$\text{RWC} = \frac{\text{fresh weight} - \text{dry weight}}{\text{turgid weight} - \text{dry weight}} \times 100 \tag{2}$$

Additionally the bulk volumetric elastic modulus "ε" was calculated from the relationship between Ψ_P and RWC. According to HELKVIST & al. (1974) and STEUDLE & al. (1977) "ε" can be defined:

$$\varepsilon = \frac{dp}{dv} = \frac{\Delta P}{\Delta Vr} \tag{3}$$

V = tissue volume, ΔVr = tissue volume at full turgor. Assuming that the volume of bound water in the leaf is small, formula (3) can be transformed into:

$$\varepsilon = \frac{\Delta P}{\Delta(RWC)} \times 100 \tag{4}$$

The rates of transpiration were determined on individual detached leaves by the cut-leaf method according to SLAVIK (1974). The resistance to liquid flow phase through the plant tissues was calculated by dividing the leaf water potential (bars) by the transpiration rate (g $H_2O \cdot dm^{-2} \cdot h^{-1}$), giving the water potential difference required to move 1 g of water per 1 dm^2 of leaf surface per hour through the plant (BARRS 1973).

Just before each excision for measurements of $\Psi_x \Psi_L$ and Ψ_π leaves were covered with a plastic bag. In this way, reliable estimates of their potentials can be obtained (TURNER 1981).

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Results and Discussion

Evaporative demand was increased through the course of the day reaching a maximum early in the afternoon ((14.30 h). This increased evaporative demand, driven by the increased transpiration, resulted in more negative xylem water potential values (Fig. 1). When the plant

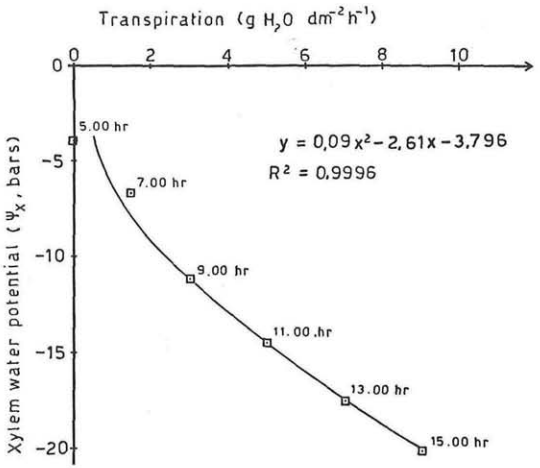


Fig. 1. Relationship between xylem water potential and transpiration rate for *Chrysopogon gryllus* during the day

transpires a gradient of water potential within the plant is established (Begg & Turner 1970, Jordan 1970, Hailey & al. 1973, Black 1979). Early in the day, when transpiration rate was relatively low, any increase in transpiration resulted in the rapid decrease of xylem potential. However, additional increase of transpiration resulted in a progressively smaller decrease of xylem potential. The flow of liquid water through the plant's tissues when transpiration exists can be described by an Ohm's law analogy (Stoker & Weatherley 1971, Neumann & al. 1974). This was applicable to *C. gryllus* only early in the day, while later on, when transpiration was increased, the relation between transpiration and xylem potential could not be explained by an Ohm's law analogy. When transpiration increased, xylem water potential was increased progressively less for the same increments of transpiration increase.

Resistance to liquid flow decreased as the transpiration rate increased (Fig. 2). This could be concluded even from the slope of the graph in Fig. 1, where at low values of xylem water potential,

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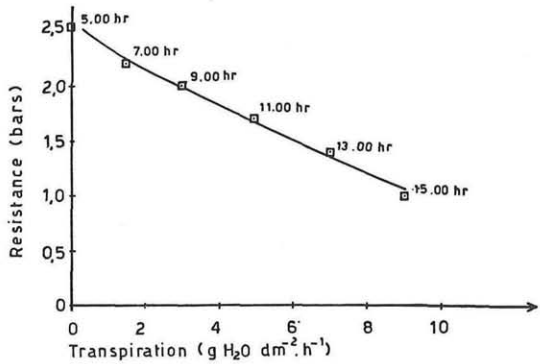


Fig. 2. Relationship between transpiration rate and the resistance to liquid flow in *Chrysopogon gryllus* during the day

increase of transpiration resulted in small decreases of xylem water potential (COWAN 1965, HAILEY & al. 1973). Findings for other plant species studied suggest that resistance to liquid flow declines as transpiration rate increases (BARRS 1973). The extent and the importance of this fact, though, varies among plant species. For *C. gryllus* at zero transpiration, the resistance was 2.5 bars $g^{-1} . dm^2 . h$ while at $9 g . dm^{-2} . h^{-1}$ the resistance was 1 bar $g^{-1} . dm^2 . h$. The capacity of *C. gryllus* to vary its resistance is an important water stress regulation mechanism. With this adaptation *C. gryllus* succeeds in reducing the gradient in leaf water potential within the plant tissues. This allows *C. gryllus* to cope with harsh environments and take advantage even of the slightest amount of available soil water.

The relation between leaf water potential and osmotic potential with relative water content for *C. gryllus* leaves is presented in Fig. 3. The decrease of leaf water content resulted initially in a reduction of the leaf water potential. When RWC was less than 85 percent any further reduction slightly effected the water potential which was above —16 bars. This agrees with the findings of NEUMANN & al. (1974) working with maize, soybean and sunflower, BEADLE & al. (1973) working with maize and sorghum, and GILES & al. (1974) working with maize. This decrease of leaf water potential is a result of the differences between turgor pressure and osmotic potential (formula 1). The initial decrease of leaf water potential was most probably a result of the decreased osmotic potential. The regression line of osmotic potential in relation to RWC was parallel to the regression of leaf water potential in relation to the RWC, for a RWC up to 85 percent (Fig. 3). For values of R.W.C. greater than 85% the two lines converge. This means that the difference between these two regression equations re-

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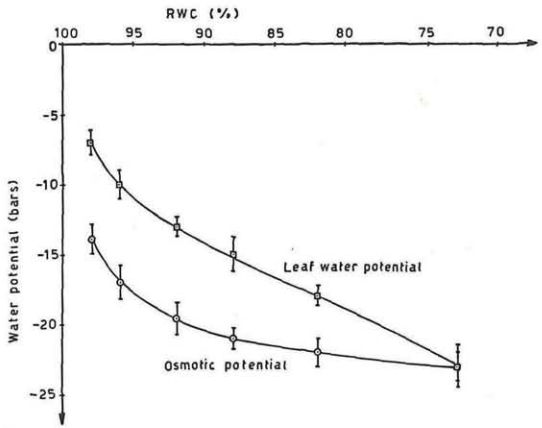


Fig. 3. Relative water content (RWC, %) in relation to leaf water potential in *Chrysopogon gryllus* during the day. Vertical lines represent the standard errors, means are indicated by the dots

mained constant for 15% of water loss and consequently the turgor potential remained constant.

Our measurements indicated that turgor pressure did not change significantly when RWC was reduced from 100 to 85 percent (Fig. 4).

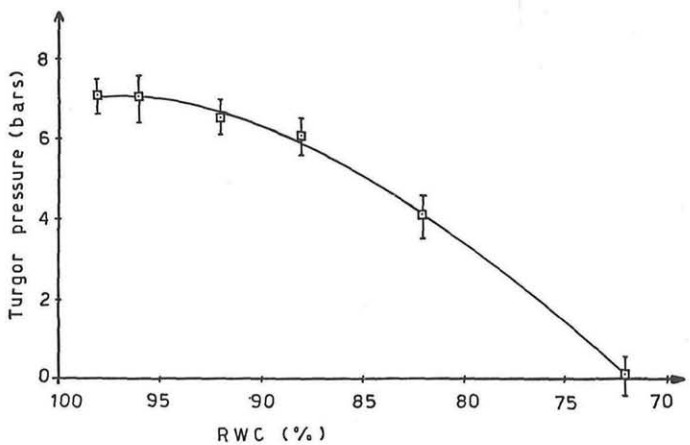


Fig. 4. Relationship between leaf water potential and osmotic potential for *Chrysopogon gryllus* during the day. Symbols see Fig. 3

Within this range we may suppose that stomata were open and apparently photosynthesis was maintained at relatively high rates. Leaf water potential was maintained above —16 bars, a critical point for

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most gramineous plants since below this value stomata resistance is increased markedly (TURNER & BEGG 1973, TURNER 1974). For other herbaceous species water potential of —16 bars occurs when their RWC is well above 87 percent (PASTERNAK 1971, TURNER 1974, NEUMANN & al. 1974). This advantage is probably a result of the low stomatal conductivity which characterizes the C_4 plants (GIFFORD 1974, LUDLOW 1976).

It is interesting that for *C. gryllus* turgor pressure was maintained high (6 bars) when RWC was 85%. This could be attributed to osmoregulation or to elastic modulus or to a combination of the two. Osmoregulation can be a result of the extensive change in the molality of cell cap due to concentration of osmotically active substances. This adjustment requires long dry periods with relatively constant and continuous diminishing water deficit (JONES & RAWSON 1979). If osmoregulation was the factor which maintained turgor pressure at its relatively high level when this sould approached zero, a drastic decrease of the osmotic potential would result (BROWN & al. 1976). This may occur in other herbaceous plants which maintain their turgor pressure by osmoregulation (BROWN & al. 1976, JONES & TURNER 1978, TURNER 1979, MATSUDA & RIAZI 1981). But for *C. gryllus* this did not hold because the osmotic potential is maintained constant after a 15% water loss (Fig. 3). The initial change in osmotic potential for water loss up to 15% could be attributed to the dehydration which changes the molality of the cell sap.

High volumetric elastic modulus implies a reduced tissue elasticity, as can be concluded from formula (3). Therefore, when RWC decreases the turgor pressure will remain higher for cell with elastic cell walls. The ratio $\frac{\triangle(\text{turgor potential})}{(\text{RWC})}$ was very small because large changes of RWC during the day affects turgor pressure only slightly (Fig. 4). A small ratio indicates that when a cell loses water its turgor pressure will decrease slightly. Its values will approach zero only when RWC is very low. This suggests that there is high tissue elasticity (SANCHEZ—DIAZ & KRAMER 1971, BLUM 1974, ELSTON & al. 1976, CUTLER & al. 1977), which maintains high turgor pressure and probably high photosynthesis rates when RWC is more than 87%. This probably is the main reason that *C. gryllus* maintains its growth even in late summer.

We concluded that high elastic modulus of *C. gryllus* cell was advantageous in maintaining high turgor potential, which was relatively insensitive to water stress and is apparently genetically controlled. This inforamation can be used in plant breeding to develop drought resistant cultivars of range plants. More work is needed to elucidate the relation

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between elastic modulus and turgor potential, which is not yet thoroughly tested.

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Recensiones

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