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Water Relation and Growth in Two Years Old Seedlings of *Medicago arborea* Under Short-time Water Stress

By

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With 5 Figures

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Summary

NOITSAKIS B., RADOGLOU K. M. & JARVIS P. G. 1991. Water relation and growth in two years old seedlings of *Medicago arborea* under short-time water stress. – Phyton (Horn, Austria) 31 (1): 111–120, 5 figures. – English with German summary.

Two years old seedlings of *Medicago arborea* L. *(Fabaceae)* were grown in pots under unirrigated conditions to evaluate the growth performance under water stress and to determine the physiological mechanism of adaptation to leaf water stress, as well as its ecological implications. Stomatal conductance, leaf water potential and its components (osmotic and turgor potential), transpiration rate and leaf area were measured periodically from June 4 to July 7, 1988. Turgor potential was higher in the unirrigated plants (UR) and the osmotic potential lower than in the plants under the natural rainfall (R) in response to the decline of leaf water potential. Leaf area was larger in the R plants, but decreased sharply at low leaf water potential. The slower decrease of leaf area in the UR plants compared with the R plants may be partly attributed to the slower decline of turgor potential. In the UR plants stomatal conductance and leaf area were maintained for longer periods but at lower values, probably because of the small variation in turgor potential over a wide range of leaf water potential. This response of *Medicago arborea* ecologically implies probably the maintenance of its biological activity over the summer.

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Zusammenfassung

NOITSAKIS B., RADOGLOU K. M. & JARVIS P. G. 1991. Wasserzustand und Wachstum zweijähriger Pflanzen von *Medicago arborea* unter kurzzeitigem Wasserstreß. – Phyton (Horn, Austria) 31 (1): 111–120, 5 Abbildungen. – Englisch mit deutscher Zusammenfassung.

Zweijährige Sämlinge von *Medicago arborea* L. *(Fabaceae)* wurden ohne Bewässerung in Töpfen gezogen, um das Wachstumserhalten unter Wasserstreß zu bestimmen. Es sollten der physiologische Mechanismus der Blattadaption an den Wasserstreß sowie die ökologische Anpassung bestimmt werden. Spaltöffnungsleitfähigkeit, Wasserpotential der Blätter (osmotisches – und Turgorpotential), Transpirationsrate und Blattfläche wurden regelmäßig von 4. Juni bis 7. Juli 1988 gemessen. In Zusammenhang mit der Abnahme des Wasserpotentials in den Blättern der unbewässerten Pflanzen (UR) war das Turgorpotential höher, das osmotische Potential niedriger, verglichen mit Pflanzen unter natürlichen Regenverhältnissen (R). Die Blattfläche war in den R-Pflanzen größer, aber nahm bei niederem Wasserpotential der Blätter stark ab. Die im Vergleich zu den R-Pflanzen langsamere Verringerung der Blattfläche in den UR-Pflanzen könnte teilweise auf eine langsamere Abnahme des Turgorpotentials zurückzuführen sein. Bei den UR-Pflanzen sind die stomatäre Leitfähigkeit und die Blattfläche über einen längeren Zeitraum, allerdings bei geringeren Werten, konstant. Dies ist wahrscheinlich auf die geringe Schwankung im Turgorpotential über einen großen Bereich des Wasserpotentials der Blätter zurückzuführen. Diese Reaktion von *Medicago arborea* bedeutet in ökologischer Sicht, daß Trockenheit während der Wachstumsperiode für die Aufrechterhaltung der biologischen Aktivität während des Sommers hilfreich ist.

Introduction

Medicago arborea L. is a perennial leguminous shrub native to the Mediterranean area, in forest, in degraded back forest and in pastures of hilly sub-mountainous zones (Quercetalia ilicis, Quercetalia pubescentis) (DAFIS 1973). This shrub produces forage of high quality and in large quantity during the winter when it shows high biological activity (AYAT 1985, ROCHON & COBY 1987). During the summer in drought periods, the shrub appears to decrease its biological activity and consequently its forage production.

It is well known that the availability of water is the most important environmental variable affecting plant growth and leaf production in Mediterranean ecosystems. (KRAMER 1980, 1983, HSIAO & al. 1985, BROWN 1986, HATTENDORF & al. 1988). Field experiments have indicated that restriction of leaf expansion is one of the first symptoms of water stress (HSIAO & al. 1985). This leaf restriction has been attributed to a reduction of the photosynthesis rate as well as to a reduction of cell turgor associated with a decrease in leaf water potential BLAKE-JACOBSON 1987, BEYSCHLAG & al. 1987, TENHUNEN & al. 1987).

Leaf water relations have been a major focus of numerous studies on crop and forest plants, but relatively few shrubs have been thoroughly studied, although the latter have vital significance for increase of forage production in Mediterranean ecosystems. The capacity of many shrubs to develop very low leaf water potentials is well recognized (ROBERTS 1982, SOBRADO 1986). The important question is the role of turgor and osmotic potential changes as a function of water deficit. In other words, how the water potential is partitioned into its components.

The present study was initiated to evaluate the seasonal growth performance of seedlings of *Medicago arborea* under water stress and to determine the physiological mechanism of adaptation to leaf water stress, as well as its ecological implications.

Material and Methods

Two year-old seedlings of *Medicago arborea* L. were transplanted into plastic pots (18 cm diameter, 20 cm deep), filled with sandy loam soil. The plants were grown in the nursery of the Forest service in Langada Thessaloniki, Greece (lat. 40 38 N, long. 23 01 E). Following an adjustment period of two weeks the pots were well watered up to field capacity and fertilized with a commercial water soluble fertilizer (15, 30, 15 N, P, K).

Two treatments were applied. Plants in the first treatment were received non irrigation other than natural rainfall (R) (Fig. 1) and plants in the second treatment did not receive any irrigation during the period of measurements (UR). A randomized block design with five replications of each treatment was used.

Seasonal measurements of stomatal conductance, transpiration rate, leaf water potential and its components (osmotic and turgor potential) were made on leaves

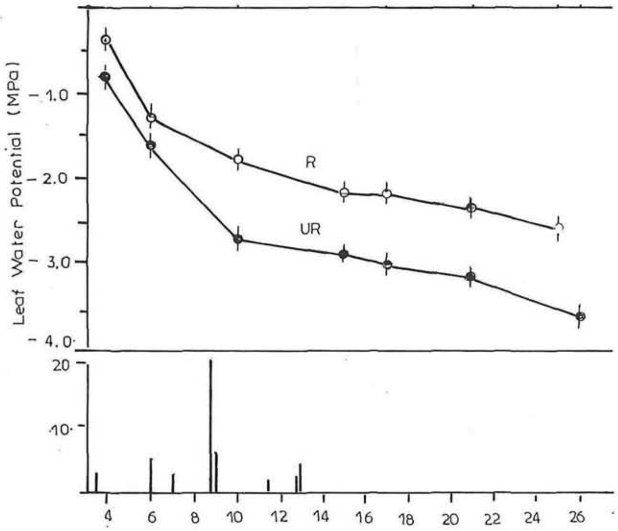

Fig. 1. Change of mid-afternoon leaf water potential in irrigated (R) and unirrigated (UR) plants of *Medicago arborea* and daily distribution of rainfall during the measurement period. All the points are means of five measurements with ± one standard error shown.

from the upper one third of the adult shoot on the following afternoons in 1988: June 4, 10, 13, 17, 21, and 26, at 14.00 to 15.00 o'clock. The values indicated in the figures are the mean values of eight leaves for each parameter.

Leaf water potential (xylem potential) was measured after cutting the stem and rapidly inserting it into the pressure chamber. In order to obtain reliable values of the leaf water potential, the part to be sampled was enclosed in a plastic sheath before being cut (TURNER 1981). The osmotic potential was measured in single leaf discs of 0.24 cm^2 area that were cut from the centre of the sampled leaf, using the psychrometric method (JOHNSON & al. 1986). Thermocouple psychrometer chambers containing the samples were frozen for 24 h at – 27° C to dissrupt cell membranes. After thawing and equilibration at 30° C in a water bath, osmotic potential was measured on microvoltmeter (HR 33–T Wescor Inc., Logan, Utah, USA). Readings were corrected for temperature and were converted to MPa against a standard calibration curve. We have also measured the leaf water potential with psychrometric method and the values obtained have not statistically significance differences compared with these obtained by pressure chamber. Turgor potential was calculated as the difference between water potential and osmotic potential. Leaf diffusive conductance was measured with a transient automatic porometer (MK3, Delta-T Devices. Cambridge, U. K.) from the abaxial leaf surface before cutting off the leaf to measure the water potential components. Transpiration rate was measured by the method of short-term weighing of cut leaves (SLAVIK 1974). Leaves were weighed immediately after cutting and weighed again after 2 min. For production measurements five pots randomly selected from each treatment were harvested on June 1, 6, 13, 26 and July 7, 1988 and the leaves were enclosed immediately in a polyethylene bag, placed in a portable refrigerator and transported to the laboratory for dry weight and leaf area measurements (Li-3000, LI-Cor Inc., Lincoln, Nebraska, USA).

Results and Discussion

The mid-afternoon leaf water potential decreased during the period of water stress reaching minimum values of the −3.6 and −2.6 MPa for the UR and R plants, respectively (Fig. 1). After 10 day of water stress the leaf water potential in the both treatments seems to decreases slower. The diagrams of water potential component (Fig. 2) indicate that the rate change of turgor potential was broadly similar below −1.5 MPa for both R and UR treatment. However, at any given water potential over the range from −0,8 to −2,5 MPa the UR plants had higher values of turgor potential than the R plants, probably, because the latter had a lower (i. e. more negative) osmotic potential (Fig. 2 b). The difference in osmotic potential between the R and UR plants can be regarded as evidence that the UR plants lower their osmotic potential (Fig. 2 b) by accumulating solutes in response to the decline in leaf water potential over the growth period. This osmotic adjustment enables the UR plants to maintain their turgor potential at a higher level than the irrigated plants (TURNER & Jones, 1980, HSIAO & al. 1985). On the other hand, the decrease of osmotic potential after the lack of cell turgor (turgor potential was about zero) is an indication that the UR plant were able to accumulate solutes and to obtain osmotic adjustment.

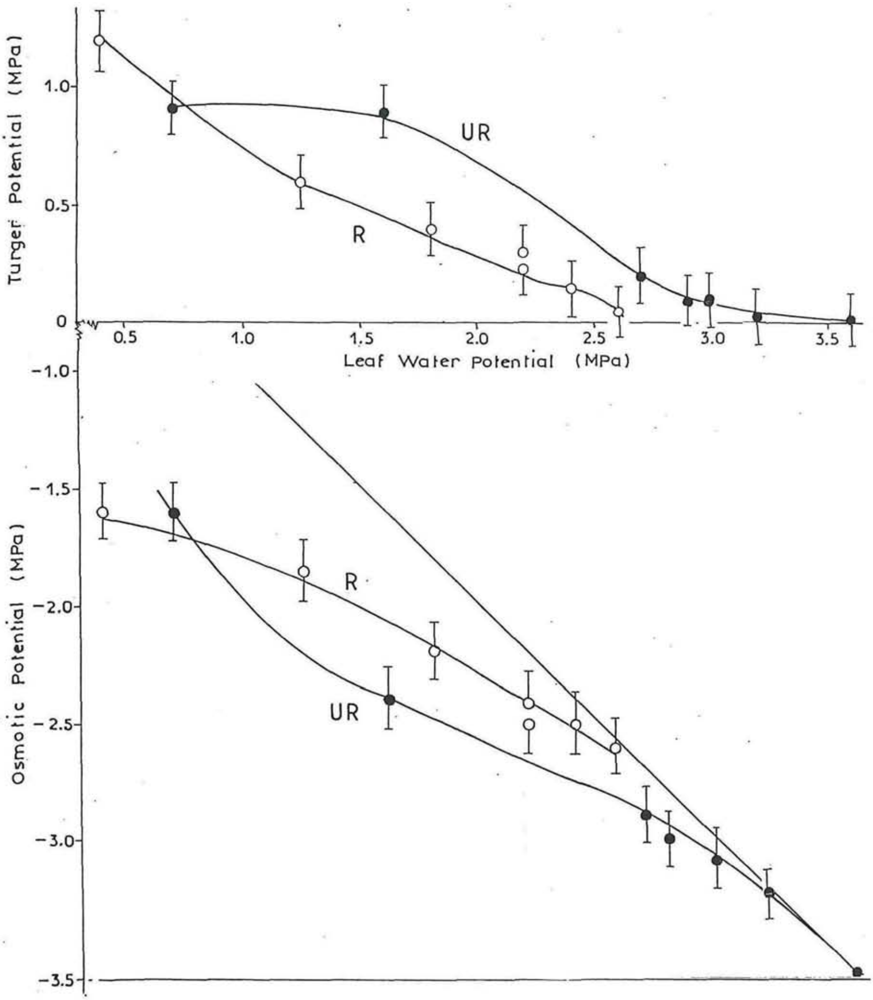

Fig. 2. Change of (a) turgor potential and (b) osmotic potential as functions of leaf water potential for irrigated (R) and unirrigated plants (UR) during the period of observations. All the points are means of five measurements with ± one standard error shown. The curves fitted by hand.

Osmotic adjustment plays an important role in the maintenance of stomatal opening under water stress by assisting the maintenance of turgor (Beadle & al. 1978, Jarvis 1980, Turner & Jones 1980, Ludlow 1980, Dale & Sutcliffe 1986). The difference in stomatal conductance of the R and RU plants may be attributed to osmotic adjustment occurring in the latter as the season progresses (Fig. 2 b). This adjustment assists the maintenance of turgor potential over the range of water potential from −0.8 MPa to −1.5 MPa (stomata are closing) to 3.5 MPa (stomata are practically closed) (Fig. 3), whereas in the R plants the sharp decrease of turgor potential probably implies stomatal closure at 1,2 MPa. Thus, the threshold of water potential at which the stomata began to close and stomatal conductance to

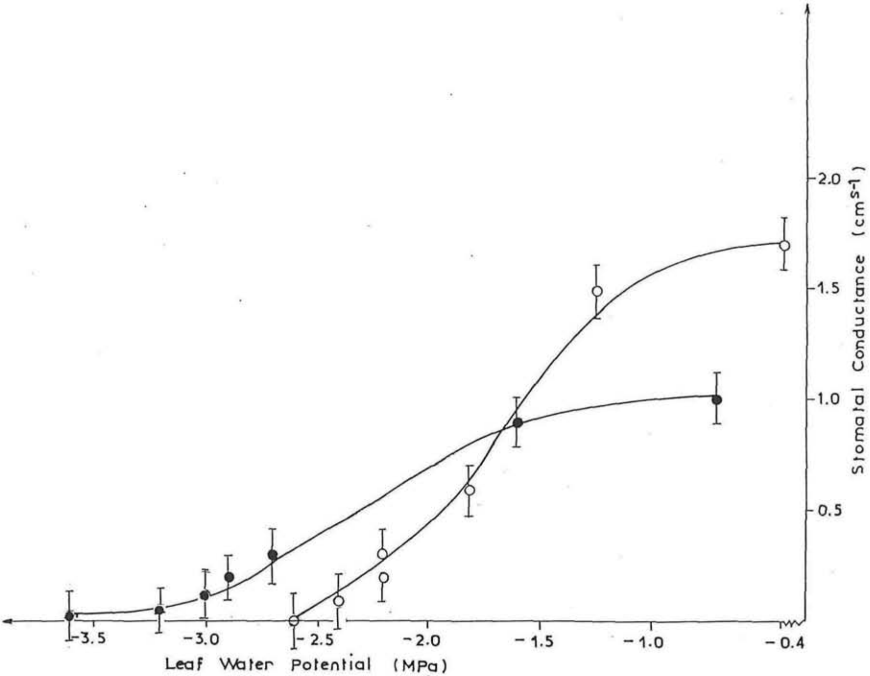

Fig. 3. Changes of stomatal conductance as function of leaf water potential for the irrigated (R) and unirrigated (UR) seedlings of *Medicago arborea* in the course of experiments. All the points are means of four measurements with ± one standard error shown. The curves fitted by hand.

decline was much lower for the UR plants (−1.6 MPa). This critical level of water potential is a useful characteristic, because it is probably closely related to decrease in turgor potential (Fig. 2 a).

The UR plants seem to maintain higher turgor pressure by a combination of stomatal closure and osmotic adjustment at least for a period of 10 days water stress period.

Leaf area idex was larger in the R plants than in the UR plants fact attributed obviously to more favourable internal water status in the R after 10 days of water stress (Fig. 4) when the leafwater potential was −1.7 MPa.

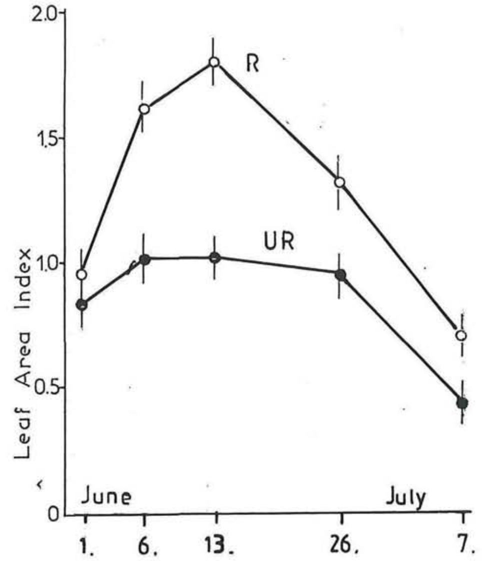

Fig. 4. Changes of leaf area in the irrigated (R) and unirrigated (UR) seedlings of *Medicago arborea* during the period of observations. All the points are means of five measurements with ± one standard error shown.

The slower decrease of leaf area in the UR plants may be partly attributed to the slower decline of turgor potential (Fig. 2 a). In general for the short period water stress in the early stages of growth, root growth is promoted in comparison to the leaf growth (NAGARAJAH & SCHULZE 1983) which in turn caused a reduction in the exponential phase of leaf growth (SCHULZE 1986).

The changes of leaf area resulted analogous changes in dry matter production which was higher in the R plants than in UR plants (Fig. 5). Furthermore the ratio shoots/leaves in percentage seems to increase during the drought period in the UR plants while it remained almost invariable in the R plants after the 5th day of experiment. In any case the dealing with whole plant growth analysis is rendered very difficultly. A study of physiological mechanism which intervenes in the relation of plant water status and the carbon partitioning will more elucidate the whole plant growth during the drought period. The ecological implication of small variation in the turgor potential in correlation with the slower decrease of stomatal conductance is that this physiological mechanisms renders Medicago arborea able to maintain partly its biological activity at least over the short dry period of summer.

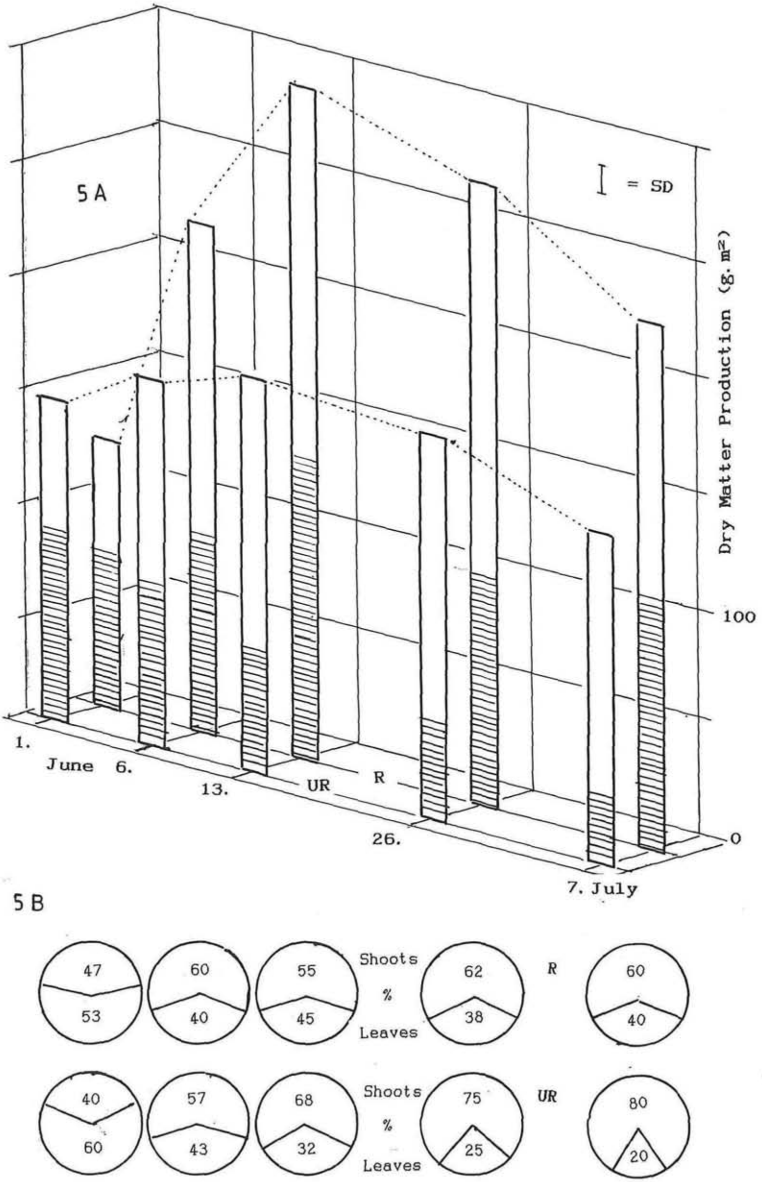

Fig. 5. Changes of dry matter production in the irrigated (R) and unirrigated seedlings of *Medicago arborea* in the course of observations (A). The hatched parts of the colums refer to leaves, the blanc ones refer to the respective shoots. The percentages of these relations are shown in 5B.

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