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in

Ferchichi A. (comp.), Ferchichi A. (collab.).
Réhabilitation des pâturages et des parcours en milieux méditerranéens

Zaragoza : CIHEAM
Cahiers Options Méditerranéennes; n. 62

2004
pages 65-68

Soil water deficit effects on photosynthesis, water use efficiency and growth of three Mediterranean shrubs: *Medicago arborea*, *Medicago citrina* and *Medicago strasseri*

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RESUME – *"Effets du déficit hydrique dans le sol sur la photosynthèse, l'efficience d'utilisation de l'eau et la croissance de* Medicago arborea*,* Medicago citrina *et* Medicago strasseri*". L'effet du stress hydrique sur le développement des plantes de* Medicago arborea *(MA),* Medicago citrina *(MC) et* Medicago strasseri *(MS), juste après germination, a été étudié à la parcelle expérimentale de la UIB. Des plantes ont été cultivées dans des pots à partir du mois d'avril jusqu'au mois de juin en conditions d'irrigation (à capacité au champ) et de déficit hydrique dans le sol (50% de la capacité au champ). En conditions irriguées, MS a montré une production de biomasse et une surface foliaire plus élevée, suivie par MA et MC. Le déficit hydrique dans le sol a provoqué des réductions importantes des paramètres étudiés (autour de 50%) gardant le même ordre d'espèces. En irrigué l'efficience d'utilisation de l'eau était plus haute pour MC et MS, mais sous le régime déficitaire en eau, MC a montré des valeurs supérieures. Les deux espèces endémiques (MC et MS) ont gardé un rapport racine/partie aérienne plus élevé que MA.*

Mots-clés : Medicago *sp., légumineuses arbustives, assimilation de carbone, croissance, stress hydrique.*

Introduction

The effect of drought conditions on vegetation has justified the initiation of several agronomic and ecological studies with legume shrubs. They present a promising vegetation in dry areas, as they facilitate the initiation of a complex and durable agro-sylvo-pastoral systems. These shrubs protect degraded soils in the semi-arid areas (Andreu *et al.,* 1998a) and maintain their fertility (Wezel *et al.,* 2000). Moreover, they offer a forage with a high quality during the most critical season (Le Houérou,1989) when the herbaceous plants are in a dormancy state.

The availability of water in the soil is the main limiting factor for Mediterranean pasture production (Medrano *et al*., 1998) and plant survival. Some species develop morphological and physiological changes (reduction of leaf area, increase of root growth, stomatal control, osmotic adjustment, etc) in order to improve their water use efficiency, and consequently, to ameliorate their survival. These changes largely depend on the degree and the duration of the stress and especially on the stage of plant development. Just after germination, the establishment of plants is a critical development phase that depends on the availability of water and nutrients. This dependency is closely linked to root growth. The exploitation of a major soil volume, by extension and branching of roots, is important for resources acquisition.

The objectives of this paper are to study the response of three Mediterranean fodder shrubs of *Medicago* to soil water deficit and to evaluate their establishment capacity.

Materials and methods

The experiment was initiated at the University of Balearic islands (Spain) on April, 2001 and the fodder shrubs of *Medicago* were planted in pots. After seed germination of *Medicago arborea* (seeds from Mallorca, Spain), *Medicago citrina* (seeds from Cabrera, Balearic islands) and *Medicago strasseri* (seeds from valencia, originated from Greece), the seedlings (stage two cotyledons) were transplanted in pots (one plant per pot) with 18 cm of diameter and 20 cm of depth. Pots were a mixture of ground (40%), peat (40%) and pearlite (20%). Throughout the experiment (80 days), two

irrigation regimes were applied: plants maintained at field capacity (well irrigated) and plants irrigated at 50% of the field capacity (MSWD: moderate soil water deficit). The MSWD regime was applied from the 18th day and measurements were taken just after transplantation (T_1), at 54 (T_2) and 80 days (T_3). For each treatment, 6 plants were used to measure gas exchange parameters (A_n: net photosynthetic rate; gs: stomatal conductance; E: the transpiration rate) by using a portable photosynthesis system (LI 6400). Dry matter partitioning (TDW: the total dry weight of the plant; SDW: the shoot dry weight; LAP: leaf area per plant; H: the height of plants) was measured by cutting 6 plants per treatment and separating stems and leaves.

Results and discussion

The environmental conditions of the experiment characterize the typical Mediterranean climate, with a high temperature and low relative humidity, which generate considerable water losses by evapotranspiration (ETP). The values of ETP increased during June and July (6 to 7 l m^2 d^{-1}) and cause relatively high water tensions.

Figure 1 shows that irrigated plants were maintained between 4 - 12% SWD. Plants under water stress reached 50% of SWD 12 days after stopping the irrigation. Then, SWD was maintained between 55 and 60%.

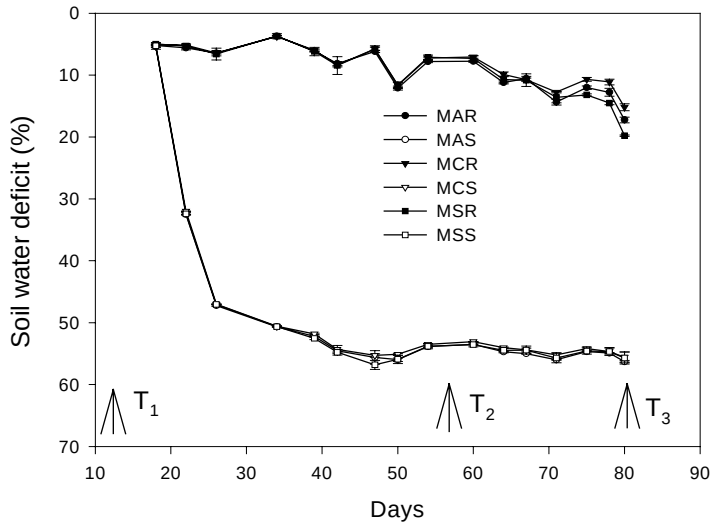

Fig. 1. Changes of the water deficit (WD) throughout the experiment for two irrigation regimes: WD is the percentage of soil water deficit at the moment of measurements with respect to the maximum water available at field capacity.

A considerable decrease in RWC was observed for all treatments (Fig. 3A) especially caused by a significant increase of ETP values and plant leaf area (Fig. 2D). Drought treatment caused a larger RWC decreases especially for the two endemic species: MC (56.87±2.21%) and MS (60.64±1.91%). On the other hand, RWC was sustained and similar to the irrigated treatments, for MAS (68.79±0.87%). The lowest values of RWC, in both irrigation and drought conditions, were registered for MC (Fig. 3A). Plant height increased linearly in all species and treatments. By the end of the experiment, the three species had similar, although under dry conditions (Fig. 2A), only MA and MC were significantly lower (20.03±1.51 and 16.9±1.12 cm respectively). Growth parameters, total biomass (Fig. 2B) and leaf area (Fig. 2D) showed significant differences only at the end of the experiment (June). Irrigated MS had the highest growth capacity (shoot and root growth). Soil water deficit caused reductions on TDW and LAP in all species, with MS being, percently, the most sensitive. Under water stress, the tow endemic species maintained a higher root/shoot ratio (Fig. 2C). MC is especially characterized by a slow growth under irrigation and moderate drought (Fig. 2B and 2D).

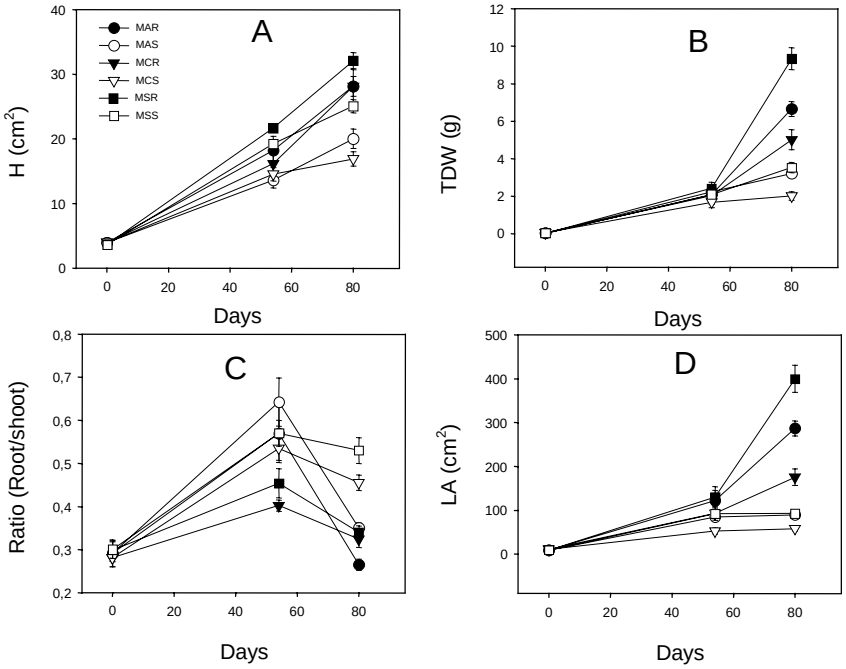

Figure 2. Changes in plant heigh (H), total dry weight per plant (TDW), leaf area per plant (LA) and the ratio (root/shoot) of *Medicago arborea, Medicago citrina and Medicago strasseri* under two irrigation regimes.

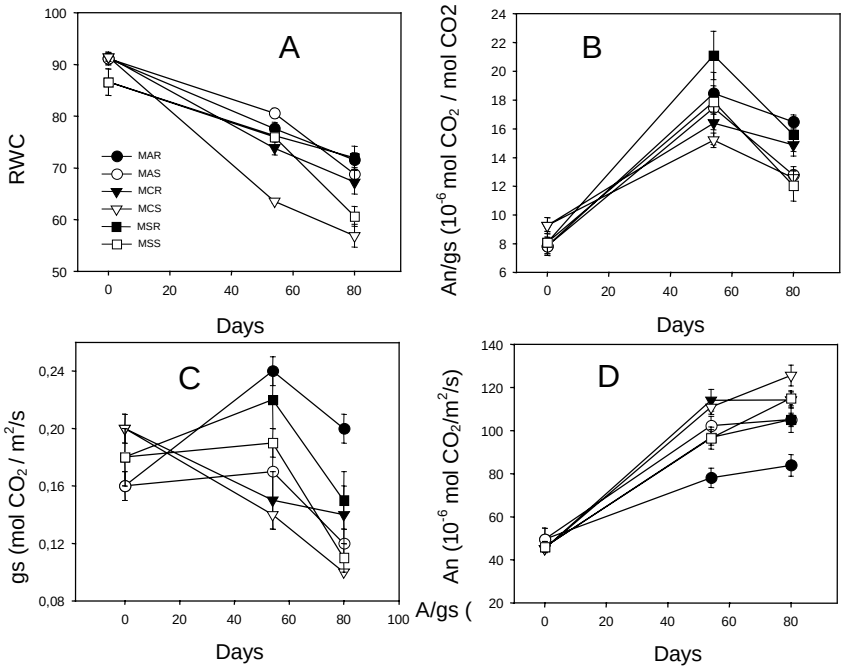

Fig. 3. Changes in relative water content (RWC), photosynthesis rate (An), stomatal conductance (gs) and An/gs for leaves of *Medicago arborea, Medicago citrina* and *Medicago strasseri* under two irrigation regimes.

Figure 3 shows that gs was clearly affected by soil water deficit especially in June when values of

ETP and plant leaf area are higher (Fig. 3C). On average, an increase in soil water deficit of 55% reduced the stomatal conductance by (33%). Stomatal conductance (gs) in MA was most sensitive to variations of water tensions, followed per MS, and finally MC. MC maintained a low and stable gs in both irrigated and water stress conditions. At moderate drought, net photosynthesis (An) decreased by 18% (Fig. 2B), consequently, water use efficiency increased for all species, especially for MC.

Conclusion

Soil water deficit caused decreases in leaf gas exchange and plant growth, and increases on root/shoot ratio and water use efficiency in all treatments. Among the species studied, MS showed the highest plant production and leaf area in both well irrigated and water stress conditions. MC showed the lowest but more stable growth capacity with high water use efficiency. Plant establishment, a critical development phase, is closely related with the availability of water, especially in MC.

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