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**Baumont R. (ed.), Carrère P. (ed.), Jouven M. (ed.), Lombardi G. (ed.), López-Francos A. (ed.), Martin B. (ed.), Peeters A. (ed.), Porqueddu C. (ed.).**
**Forage resources and ecosystem services provided by Mountain and Mediterranean grasslands and rangelands**

**Zaragoza : CIHEAM / INRA / FAO / VetAgro Sup Clermont-Ferrand / Montpellier SupAgro**
**Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 109**

**2014**
pages 173-177

# Impact of limited irrigation on the growth characteristics of *Lotus corniculatus*

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**Abstract.** Drought is the most important environmental stress for plants. Inadequate amount of rainfall or irrigation can reduce plant growth and forage production more than all the other environmental stresses combined. In this experiment the influence of water stress on the growth parameters of *Lotus corniculatus* was investigated. Plants from a natural population of a semi-arid area of Northern Greece (Drama) were selected and transplanted to pots. After a period of plant establishment, two irrigation regimes were used: (a) irrigation up to field capacity and (b) partial irrigation in order to maintain water shortage conditions in the soil. All measurements were taken during the growing season at four different phenological stages. Total shoot weight, stem weight (SW), leaf weight (LW) and leaf area (LA) were measured during the growing season. Also, the specific leaf area (SLA), leaf area ratio (LAR) and leaf weight ratio (LWR) were calculated. The results showed that the limited irrigation significantly reduced the growth parameters LA, dry SW and LW, while it did not affect the allometric parameters SLA, LAR, and LWR of *L. corniculatus.*

**Keywords.** Leaf area – Leaf weight – Stem weight – Specific Leaf Area.

***Impact d'une limitation de l'irrigation sur les caractéristiques de croissance de* Lotus corniculatus**

***Résumé.*** *La sécheresse est la contrainte environnementale la plus importante pour les plantes. Une quantité insuffisante de pluie ou d'irrigation peut réduire la croissance des plantes et la production de fourrage plus que toutes les autres contraintes environnementales combinées. Dans cette expérience, l'influence du stress hydrique sur les paramètres de croissance de* Lotus corniculatus *a été étudiée. Des plantes d'une population naturelle d'une zone semi-aride du nord de la Grèce (Drama) ont été sélectionnées et transplantées dans des pots. Après une période d'installation, deux régimes d'irrigation ont été utilisés: (a) l'irrigation à la capacité au champ et (b) l'irrigation partielle afin de maintenir des conditions de pénurie d'eau dans le sol. Toutes les mesures ont été prises au cours de la saison de croissance à quatre stades phénologiques différents. La masse sèche de la partie aérienne, des tiges (SW), des feuilles (LW) et la surface foliaire (LA) ont été mesurées au cours de la saison de croissance. En outre, la SLA, le LAR et le LWR ont été calculés. Les résultats ont montré que l'irrigation partielle réduit significativement les paramètres de croissance (LA, sec SW et LW) et n'affecte pas les paramètres allométriques (SLA, LAR et LWR) de* Lotus corniculatus.

***Mots-clés.*** *Surface foliaire – Masse sèche de la feuille – Masse sèche de la tige – Surface Foliaire Spécifique.*

## I – Introduction

Plants under natural or agricultural conditions are exposed to various abiotic or biotic stresses. Water deficit arises from both insufficient rainfall and soil water during the growing season (Lipiec *et al*., 2013). Inadequate amount of rainfall or irrigation can inhibit photosynthesis, limiting plant growth and survival more than all the other environmental stresses combined (Wang *et al*., 2003; Zlatev *et al*., 2012). Moreover, prolonged drought can restrict plant growth and biomass produc-

tion and modify the biomass allocation patterns and even cause plant death (Puri and Swamy, 2001; Rodiyati *et al*., 2005; Li *et al*., 2009). The allocation pattern that maximizes growth or water use efficiency depends on the availability of water. Plants can acclimate to water stress through physiological, morphological and biochemical responses (Xiong *et al*., 2006; Lambers *et al*., 2008). Higher acclimation capacity and greater resistance is determined by the plant capacity to maintain its physiological processes (Valladares *et al*., 2007).

Legumes are important components of pastures because they are the main crude protein source in the animal food. Legumes are second after grasses in significance to agriculture and there is an essential need to increase drought tolerance in these species (Sanchez *et al*., 2012). The genus *Lotus* is widespread and includes a large number of species. *Lotus corniculatus* L. is the most important and widely distributed crop from the *Lotus* genus and grows under a wide range of environmental conditions (Díaz *et al*., 2005a; Escaray *et al*., 2012). The aim of the current study was to investigate the impact of limited irrigation on the growth and allometric parameters of *Lotus corniculatus* in four phenological stages.

## II – Materials and methods

The experiment was conducted in the farm of the Aristotle University of Thessaloniki, Northern Greece (longitude: 40°31'91'', latitude: 23°59'58''), at an altitude of 6 m a.s.l. The climate of the area could be characterized as Mediterranean semiarid with dry summers. The mean annual precipitation is approximately 400 mm and the mean annual air temperature is 15.5°C.

Plants of *L. corniculatus* from a natural population of a semi-arid area of Northern Greece (Drama) were selected in September and October of 2012 and transplanted in small pots. At the beginning of March 2013, 32 plants were transferred in large pots (16 cm diameter and 45 cm height), filled with natural soil of medium texture and placed under a transparent shelter. After a period of plant establishment, drip irrigation was applied at two levels: full irrigation up to field capacity (FI) and limited irrigation (LI) that lasted nine weeks (40% water of that received by FI). The pots were placed in completely randomized design with four replicates. Measurements were taken during spring 2013 on four different dates corresponding to four phenological stages: early vegetative, vegetative, flowering and start of fruit formation. At each phenological stage four plants were harvested, and the leaf area (LA), as well as, the fresh weight of shoots, stems and leaves were measured. Leaf area was measured using the portable leaf area measurement system Li-3000A (LiCor Lincoln, Nebraska, USA). Then the samples (leaves, stems) were placed into an oven for 48 hours at 70°C to determine their dry weight. Specific leaf area (leaf area/leaf weight: SLA), leaf area ratio (leaf area/total shoot dry weight: LAR) and leaf weight ratio (leaf dry weight/total shoot dry weight: LWR) were calculated (Gurevitch *et al.,* 2006).

Analysis of variance (ANOVA) was used to determine effects of the irrigation treatments and the plant phenological stage ($P < 0.05$). Independent *t*-test was used to compare two means (Steel and Torrie, 1980). Statistical analysis was performed using the statistical package SPSS (SPSS for Windows, release 21.0; SPSS, Inc., Chicago, USA).

## III – Results and discussion

Both water treatment and plant phenological stage affected shoot dry weight (SW), leaf dry weight (LW) and LA of *L. corniculatus* ($P<0.05$). Likewise, the interaction between these two factors was significant ($P<0.05$). Mean leaf and stem dry weights were significantly reduced under water limited conditions (Table 1). However, throughout the growing season plants under limited irrigation had significantly lower leaf dry weight (Fig. 1) compared to plants subjected to full irrigation. Only, at the early phenological stages, plants presented the same leaf dry weight in the

two treatments. It is well demonstrated that increasing in water stress could decrease plant dry weight (Rad *et al.*, 2011). Moreover, throughout the growing season plants under limited irrigation had significantly lower mean leaf area compared to plants under full irrigation (Table 1). The decrease in total leaf area is considered one of the most important ways to reduce plant water consumption (Carter *et al.*, 1997; Moreno *et al.*, 2008).

**Table 1. Average values (± SE) of growth parameters of *Lotus corniculatus* under two irrigation treatments of four phenological stages (n = 16)**

| Treatment | SW | LW | LA | SLA | LAR | LWR |
|---|---|---|---|---|---|---|
| Full irrigation | 14.2 ± 0.8 | 10.65 ± 0.5 | 2194.8 ± 183.6 | 216.5 ± 5.9 | 92.5 ± 4.8 | 0.43 ± 0.02 |
| Limited irrigation | 6.8 ± 0. | 5.084 ± 0.5 | 967.63 ± 78.2 | 218.8 ± 6.6 | 85.1 ± 5.7 | 0.40 ± 0.02 |
| Sign. P<0.05 | * | * | * | ns | ns | ns |

From the changes of SLA (Table 1, Fig. 2) during the growing season it becomes apparent that *L. corniculatus* plants under limited irrigation had similar mean values compared to plants under full irrigation. Only, at the stage of fruit formation (Fig. 1) plants under limited irrigation presented significantly ($P$<0.05) higher SLA than under full irrigation. SLA is considered an essential trait of plants to survive through a Mediterranean climate, since it is associated with relative growth rate, leaf thickness and plant ability to use environmental resources, mainly light. The increased trend in SLA, especially under limited irrigation, and the decreasing pattern of leaf weight at the stage of fruit formation indicates that the species in the fruit formation stage developed thinner leaves (Carter *et al.*, 1997). Thus, similar SLA of *L. corniculatus* could be probably due to adaptation to resource poor environments (Li *et al.*, 2005). Moreover, no significant differences ($P$<0.05) in the values of mean LAR and LWR between the two treatments were found. This result is in accordance to the maintenance of *L. corniculatus* photosynthetic and photochemical performance under water deficit that we have found (unpublished data). Therefore, although limited water irrigation decreased the plant size, it did not change the plant morphology. It seems that *L. corniculatus* is capable of maintaining optimum water balance under drought conditions, allowing the function of its photosynthetic machinery (Díaz *et al.*, 2005b).

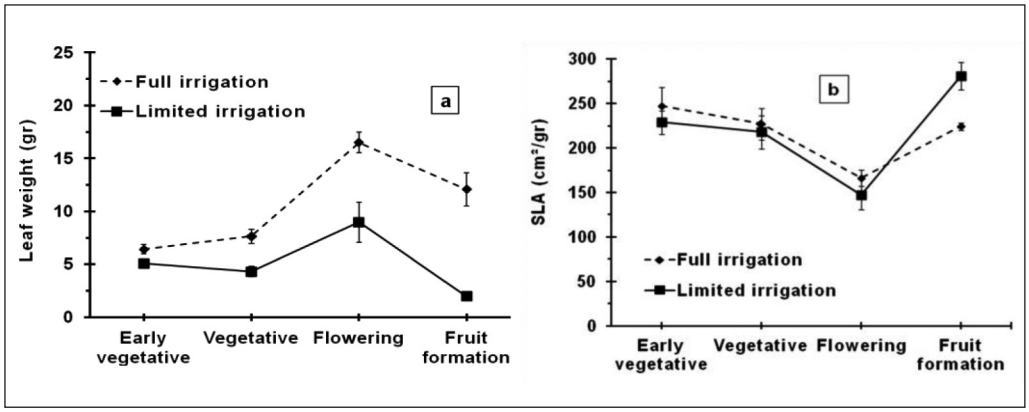


**Fig. 1. Changes of a) leaf dry weight and b) Specific Leaf Area (SLA) of *Lotus corniculatus* at four different phenological stages under two irrigation treatments.**

## IV – Conclusions

The present pot study indicated that limited irrigation significantly reduced the growth parameters SW, LW and LA but it did not affect the allometric ones, SLA, LAR and LWR of *L. corniculatus*. However, further work is needed to test this population, including additional morphological and physiological traits and more severe drought conditions.


## Acknowledgments

This research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) – Research Funding Program: ARCHIMEDES III. Investing in knowledge society through the European Social Fund.


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