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in

Porqueddu C. (ed.), Tavares de Sousa M.M. (ed.).
Sustainable Mediterranean grasslands and their multi-functions

Zaragoza : CIHEAM / FAO / ENMP / SPPF

Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 79

2008

pages 335-339

Article available on line / Article disponible en ligne à l'adresse :

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To cite this article / Pour citer cet article

Mingo A., Cristaudo A., Vitale L., Magliulo V. **Differential response to drought, disturbance and increasing temperature of endemic and non-endemic species of a mountain-Mediterranean grassland.** In : Porqueddu C. (ed.), Tavares de Sousa M.M. (ed.). *Sustainable Mediterranean grasslands and their multi-functions* . Zaragoza : CIHEAM / FAO / ENMP / SPPF, 2008. p. 335-339 (Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 79)



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Differential response to drought, disturbance and increasing temperature of endemic and non-endemic species of a mountain-Mediterranean grassland

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SUMMARY – Autochthonous and widely distributed plant species coexist in most natural pastured grasslands. The aim of this work was to differentiate autochthonous and widely distributed species of a mountain-Mediterranean grassland regarding their ability to face drought and disturbance. A group of species from a natural pasture in the Nebrodi mounts (Sicily) were analysed for their response to light, temperature, water availability and cutting. The species were pot-cultivated and subjected to different experimental treatments. Growth, allocation and plant architecture were determined during the experiments; photosynthetic activity, transpiration and water use efficiency at different temperatures and PPFD were determined by gas-exchange analysis. Local taxa were characterized by different strategies to face water stress, whereas non-endemic pabular species showed higher growth rates and better ability to withstand cutting. The species studied showed different responses to increasing temperatures, pointing out the relevant effects that climatic changes may induce on grassland species composition.

Keywords: Compensatory growth, gas-exchange, growth analysis, Sicily, water stress.

RESUME – "Réponse différentielle à la sécheresse, aux perturbations, et à l'augmentation de température d'espèces endémiques et non endémiques de pâturages des montagnes méditerranéennes". Dans les pâturages naturels les espèces autochtones coexistent avec celles à large distribution. Le but de ce travail a été de diversifier les espèces autochtones d'un pâturage méditerranéen-montagnard par rapport aux espèces largement distribuées, pour leur tolérance à l'aridité et aux perturbations. Un groupe d'espèces des Monts Nebrodi (Sicile) a été cultivé en pot et étudié en termes de réponse à la lumière, température, disponibilité en eau et coupe. On a évalué la croissance, répartition de biomasse et architecture des plantes ; on a aussi mesuré l'activité photosynthétique, transpiration et efficacité d'utilisation de l'eau. Les taxons locaux se sont diversifiés dans les stratégies pour faire face aux carences hydriques, tandis que les espèces fourragères non endémiques ont montré un taux de croissance plus élevé et une meilleure tolérance à la coupe. On a observé des réponses différentes à la température, ce qui indique l'importance des changements climatiques sur la composition des prairies.

Mots-clés : Croissance compensatoire, échanges gazeux, analyse de croissance, Sicile, stress hydrique.

Introduction

Recent progresses on grassland management suggest that mountain Mediterranean grasslands should be carefully protected against overgrazing in order to preserve their biodiversity (Papanastasis *et al.*, 2002). Loss of species diversity in fact is one of the major problems Mediterranean-type ecosystems will face during next years, due to increasing influence of global environmental changes (Lavorel, 1998). Particularly water availability, which is world wide the most relevant limiting factor for plant productivity (Nemani *et al.*, 2003), is supposed to be strongly reduced during following years as a consequence of temperature increase (IPCC, 2001).

Sicily has one of the richest flora of Mediterranean basin (Abbate *et al.*, 2007), with lot of endemics distributed along mountain areas. Nebrodi mounts have large grassland extensions above 1000 m a.s.l. that are traditionally grazed, with vegetation adapted to tolerate moderate disturbance effects by cattle (Brullo and Grillo, 1978). During recent years the area was protected as a regional park, and the

traditional grazing activities had to be made compatible with new environmental goals, such as soil protection and biodiversity conservation.

In the framework of a wider study on these grasslands (Mingo *et al.*, 2008), endemic and non-endemic species of Nebrodi grasslands were compared for their resistance to water stress, disturbance and temperature, in order to draw possible responses of such communities to different management options and/or to climate changes

Materials and methods

Twelve species were selected as representative of the main adaptive traits recorded on grazed plant communities (Table 1). Both seeds and vegetative material were used to reproduce the species. Plants were grown in 750 cc plastic pots filled with natural soil and put in full light under a plastic rain shelter, laterally open in order to allow natural air movement.

Table 1. List of the tested species, with Raunkier classification and chorology. Only the six species denoted with a star* were submitted to gas exchange analyses

Species	Raunkier	Chorology	Ecology and distribution (Sicily)
<i>Anthemis arvensis</i> L. subsp. <i>sphacelata</i> (C. Presl) R. Fern.	H	Endemic (south. Italy, Sicily)	xeric grasslands on shallow soils
<i>Cynosurus cristatus</i> L. *	H	European-Caucasian	mesic grasslands on deep brown soils
<i>Genista aristata</i> C. Presl	Ch	Endemic (Sicily)	slopes, on clay/arenaceous skeletal soils
<i>Holcus lanatus</i> L. *	H	Circumboreal	humid grasslands
<i>Lathyrus nissolia</i> L. *	T	Euri-Mediterranean	humid grasslands
<i>Lolium perenne</i> L. *	H	Eurasianic	mesic grasslands on deep brown soils
<i>Lotus angustissimus</i> L.	T	Euri-Mediterranean	winter wet/summer dry depressed basins
<i>Plantago cupani</i> Guss.*	H	SW-Mountain-Medit.	xeric grasslands on shallow soils
<i>Plantago lanceolata</i> L.	H	Eurasianic	mesic grasslands on deep brown soils
<i>Trifolium bivonae</i> Guss.	H	Endemic (Sicily)	xeric grasslands on shallow soils
<i>Trifolium pratense</i> L. subsp. <i>semipurpureum</i> (Strobl)	H	Euri-Mediterranean	mesic grasslands on deep brown soils
<i>Vulpia sicula</i> (C. Presl) Link *	H	W-Mediterranean	xeric grasslands on shallow soils

H: Hemicryptophytæ

Ch: Chamaephytæ

T: Terophytæ

Two drought levels were applied by providing a differential water supply. Control plants were regularly watered at field capacity (about 30% soil water content), whereas water stressed plants were kept at 20 and 10% for low and high water stress, respectively. Half of the plants were cut once at about 2 cm from soil level, as to mimic a severe grazing, and their growth was measured during the following weeks.

Basal diameters, plant height and number of shoots/branches were measured weekly. At the end of the experiment, about 6 weeks after starting, all plants were harvested. The plants were then washed and dried at 70°C until constant weight. Separate measures of dry weight were kept for above and below-ground biomass. An estimate of the differential water consumptions by species was obtained by measuring % water content on soil samples taken by the pots two days after last watering, keeping as control the values obtained on pots containing just soil substrate, submitted to the same watering treatments.

Gas exchange measurements were performed by means of an IRGA system (Li-6400, LiCor, NE) on six of 12 selected species. Measures were taken at 8 different levels of photosynthetic photon flux density (PPFD): 10, 50, 100, 200, 500, 1000, 1500 and 2000 $\mu\text{mol m}^{-2} \text{s}^{-1}$, and at 4 temperatures: 15, 20, 25 and 30°C. Water use efficiency (WUE) was calculated as the ratio between net photosynthetic rate and transpiration rate, measured at PPFD of 1000 $\mu\text{mol m}^{-2} \text{s}^{-1}$.

A hyperbolic model was fitted to photosynthetic response to PPFD, whereas responses to temperature were modelled through an asymmetric log-normal model, in order to identify the optimal temperatures and photosynthetic rate achieved at these temperatures. ANOVA models followed by post-hoc LSD test were used for data analysis.

Results and discussion

Both final plant height and total dry weight differed significantly ($P < 0.001$) among species, water treatments and their interactions. The highest final size was attained under optimal water availability by the non-endemics *L. perenne*, *T. pratense* subsp. *semipurpureum* and *H. lanatus* (Fig. 1). Under water stress condition, however, local taxa, such as *P. cupani*, *T. bivonae*, *G. aristata* and *A. arvensis* subsp. *sphacelata* behave relatively better, though a similar pattern was also found on the eurasiatic *P. lanceolata*. Water consumption reflected growth patterns: local species appeared to need relatively lower water resources compared to more productive ones; if measured on a per-gram basis, however, their water consumption resulted sensibly higher, due to the lower biomass production.

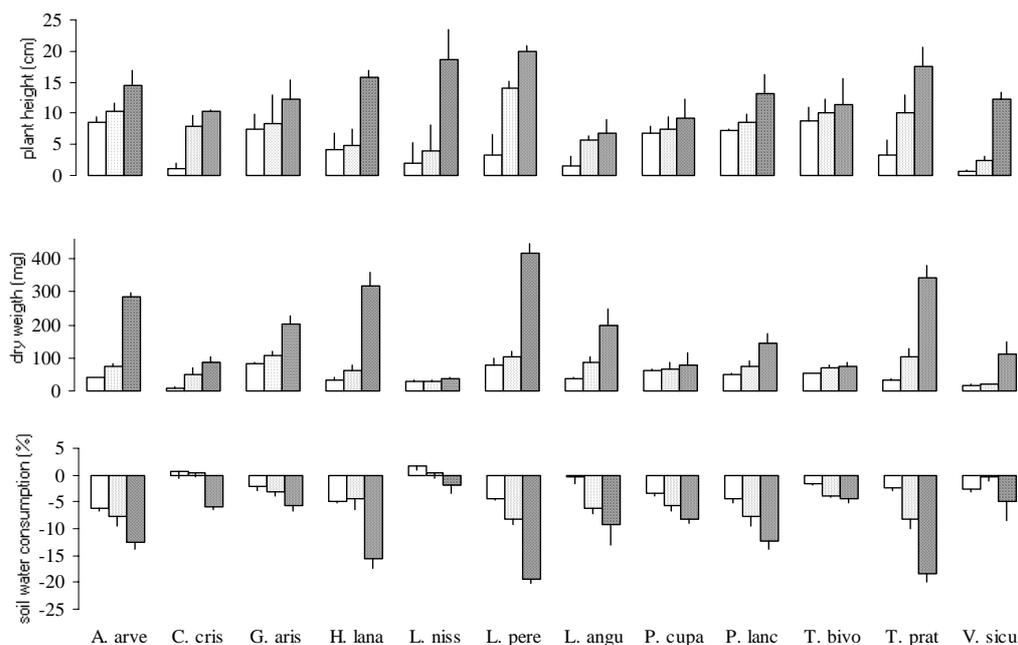


Fig. 1. Final plant height, final dry weight and soil water consumption of twelve species of a Sicilian mountain Mediterranean grassland. Plants were pot cultivated under three water availability levels, respectively at high water stress (open bars), medium water stress (light grey) and field capacity control (dark grey). Data are means of 10 replicates \pm standard error. See Table 1 for details on the tested species.

Photosynthetic activity differed significantly ($p < 0.001$) among species, temperature and light levels. Temperature effects, analyzed species by species, were always significant but for *C. cristatus* and *P. cupani*. Significant temperature *per* light interactions were found on *H. lanatus* and *L. nissolia*. Maximum levels of photosynthetic activity at saturation were attained by *H. lanatus*, *L. nissolia* and *L. perenne* (Fig. 2); *P. cupani* showed the lowest levels of photosynthetic activity, whereas *C. cristatus* and *V. sicula* reached intermediate values.

The species responded differently to temperature: *L. perenne*, *C. cristatus* and *V. sicula* peaked respectively at 25.5, 26.8, and 25.8 °C; the other three species showed their maximum value at temperatures higher than 30 °C. Water use efficiency (WUE) was significantly different among species ($P < 0.001$) and temperatures ($P < 0.01$). Maximum WUE was found for all species at 15°C, due to lower transpiration rates. The highest WUE was found on *L. nissolia* ($9.8 \mu\text{mol CO}_2 \text{ mmol}^{-1} \text{ H}_2\text{O}$) and *H. lanatus* ($8.1 \mu\text{mol CO}_2 \text{ mmol}^{-1} \text{ H}_2\text{O}$), whereas *P. cupani* and *V. sicula* showed the lowest values (1.5 and $1.9 \mu\text{mol CO}_2 \text{ mmol}^{-1} \text{ H}_2\text{O}$ respectively).

The three grasses *L. perenne*, *C. cristatus* and *H. lanatus* showed the best response to cutting, recovering almost totally relative to undisturbed ones. Cutting in some case allowed these species to

better withstand drought through reduced canopy transpiration. The two clovers (*T. pratense* ssp. *semipurpureum* and *T. bivonae*) compensated cut biomass in a relatively little time, whereas the other species showed slower recovery, with some occurrence of root diseases at root level in watered replicates. Only the annual species *L. nissolia* did not recover at all after cutting.

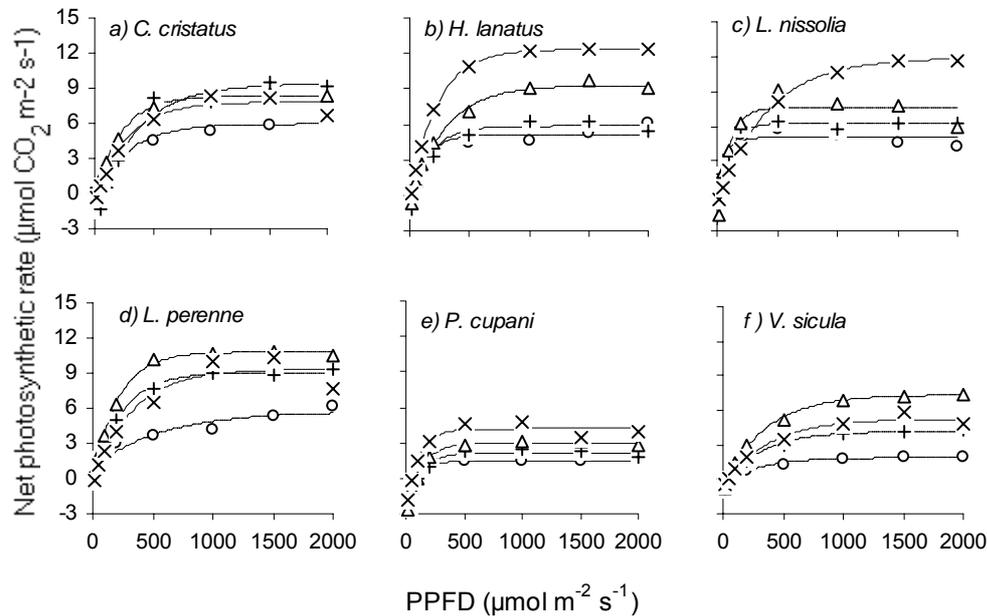


Fig. 2. Photosynthetic response of the six tested species to increasing PPFD, measured respectively at 15 (○), 20 (+), 25 (Δ) and 30°C (x).

Conclusions

Non-endemic pabular species showed higher productivity values compared to endemics, similarly to the findings of Gulias *et al.* (2003). These species also showed a good response to cutting, getting some advantage under drought condition, confirming that pabular species may need some amount of herbivory to get their best performance in grazed lands (Mc Naughton, 1983; Oestherheld and Mc Naughton, 1991).

When not subjected to disturbance, however, endemics resulted to be sensibly more resistant to water stress than non-endemic, probably performing a parsimonious strategy aimed at saving water resources rather than competing for its acquisition (Grime, 1978).

Referring to field conditions, stress-tolerant endemic species could finally play a major role to prevent soil erosion during summer, when intense sun radiation would rapidly mineralize soil organic matter of the bared substrates subjected to intense grazing and water stress conditions. Grazing pressure, in conclusion, should be carefully reduced during this season, in order to prevent loss of both biodiversity and soil fertility.

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