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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 309-313

Water stress effects on perennial grasses growth and behaviour

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SUMMARY – In a glasshouse experiment, six cultivars of perennial grasses were tested under imposed water stress. The aim of the trial was to analyse some drought effects on grasses behaviour and water use efficiency. Some physiological indicators associated with drought were used (such as osmotic regulation and sugar accumulation). Differences in varieties response under water constraints were highlighted. Dry matter production was higher for festuca cultivars, followed by phalaris and then cocksfoot. Correlation between dry matter production and water consumption was highly significant. Moderate water stress gave the best results. Festuca cultivars were the most water efficient. The phalaris Atlas and cocksfoot Kasbah had the lowest WUE. In contrast, Lutine fescue had the highest WUE followed by Fraydo, Medly and Sirolan, which gave comparable values. The two cocksfoot, Medly and Kasbah, and the phalaris Sirolan seemed to maintain their leaf relative water content while experiencing drought conditions, assuming some traits of drought tolerance. The varieties Atlas, Sirolan and Medly made better adjustments by maintaining their osmotic potentials almost unchanged over the drought period and then by decreasing their osmotic potential more quickly afterwards.

Keywords: Perennial grasses, water stress, RWC, osmotic potential.

RESUME – *"Effets du stress hydrique sur la croissance et le comportement des graminées pérennes". Une expérimentation conduite en conditions contrôlées a été conçue pour analyser de près certains effets directs du stress hydrique sur le comportement de 6 variétés de graminées pérennes. Dans les conditions expérimentales imposées, des différences de comportement variétal vis-à-vis de la contrainte hydrique ont été mises en évidence. Lorsque l'offre en eau est réduite, les fétuques Lutine et Fraydo présentent un avantage de production de biomasse. L'effet dépressif du stress hydrique a été exprimé chez les variétés testées. Les dactyles Medly et Kasbah et le phalaris Sirolan ont pu maintenir leur teneur en eau relative en passant des conditions d'eau non limitantes aux conditions de stress et peuvent être considérés comme ayant un potentiel de tolérance à la sécheresse. Les variétés Atlas, Sirolan et Medly s'ajustent mieux, d'abord en maintenant leur potentiel osmotique presque inchangé en régimes hydriques stressés et ensuite en diminuant leur potentiel osmotique plus vite.*

Mots-clés : *Graminées pérennes, stress hydrique, teneur relative en eau, potentiel osmotique.*

Introduction

Water potential, osmotic potential and relative water content are among the main physiological criteria indicating plant water status in relation with water stress (Blum *et al*. 1989; Singh *et al*. 1990). In many studies, these parameters differ between sensitive and tolerant cultivars (Singh *et al*. 1990). Water status is considered as good indicator for differentiating cultivars behaviour facing water stress (Keim and Kronstrad, 1981).

Sensitive cultivars showed higher water potential even under stress conditions (Winter *et al*. 1988). The adaptation process by low water potential involves osmotic adjustment (Blum *et al*. 1989). Morgan, 1984 had qualified this parameter as a possible mechanism of drought resistance. The decrease of osmotic potential under water stress follows solutes accumulation in plant tissues. Therefore, maintain turgor under low water potentials.

Relative water content is another important physiological parameter in assessing water stress (Ritchie *et al*, 1990). Significant differences had been reported between cultivars. Resistant cultivars maintain high RWC than sensitive ones (Ritchie and al. 1990).

The purpose of the study is to evaluate some physiological criteria for drought tolerance on 6 cultivars of perennial grasses (cocksfoot tall fescue and phalaris).

Material and methods

In the experiment, two cocksfoot (cvs Medly and Kasbah), 2 tall fescue (cvs Fraydo and Lutine) and 2 phalaris (cvs Atlas and Sirolan) having different behavior to drought, were tested in controlled conditions under 3 water regimes and control. Three adult plants were transplanted at tillering stage in 30.5 cm PVC pots filled with 15 kg of sand loamy soil. Moisture at field capacity was 33.4%. Four levels of water stress were applied: R1, which is the control kept at 95% of its saturation moisture; 75% of saturation moisture for the slight stressed treatment R2; R3 and R4 were kept at 50 and 25% of their saturation moisture and were considered as moderate and severe stress. Treatments started 4 weeks after transplantation. All cultivars were cut at 5 cm of height.

The experiment was designed in RCBD with 3 replications. Dry matter was recorded for all pots at each mowing by putting the fresh biomass in an oven at 70℃ for 48 hours. RWC (relative water content) was done on fully expanded young leaves just before cutting.

RWC=((fresh weigh-dry weight)/(turgor weight-dry weight)). Turgor weight was determined by putting leaf in distilled water over 12 hours. Osmotic potential was recorded in morning, on fully expanded young leaves. Leaves were cut and put in eppendorf (1.5 ml) and put immediately in liquid nitrogen for 2 to 5 minutes to destroy cell walls. After thawing out in ambient temperature and put in centrifugation (10000 rev/minute), the extract was used to measure the osmotic potential (osmometer, Wescor 520).

Results and discussion

Since water consumption was quantified regularly from the start of the experiment. We define the water deficit index for each treatment as: $(ETR_{control} - ETR_{stressd}) / ETR_{control.}$

ETR is the real evapotranspiration of the control and the stressed regimes.

The obtained values of deficit index characterized the levels of consumed water for each regime and were and were 27, 45 and 62% respectively for 75, 50 and 25% of maximal soil moisture. This confirms that they reach the appropriate stress levels. The water consumed differed significantly ($p=0.005$) among cultivars and water regimes. Cocksfoot Kasbah consumed less water than others.

Relative water content

There was significant effect of cultivars and water regimes for this parameter ($p=0.05$). RWC was higher in case of non limited water regimes (Fig. 1).

At the first harvest, cultivars did not differ in their RWC in the extreme treatments. But significant differences were obvious for the intermediate regimes. At the second harvest, these differences were apparent in treatments. RWC decrease depend on the cultivars.

Tall fescue cultivars (Fraydo and Lutine) showed higher RWC compared to the other cultivars. They tend to loss more water when passing to stress regimes. Cocksfoot Kasbah had the lowest RWC, but had lost less water between the control and the most stressed regime, particularly in the second mowing.

The cultivars Kasbah, Medly and Sirolan had lost less water or maintained their RWC from non limiting to stressed conditions for the two mowing. It has been demonstrated that cultivars which maintain their RWC through stressed regimes could be considered as drought tolerant (Schonfeld *et al.*,1988; Ritchie *et al*., 1990). It is the case of cocksfoot and Sirolan Phalaris.

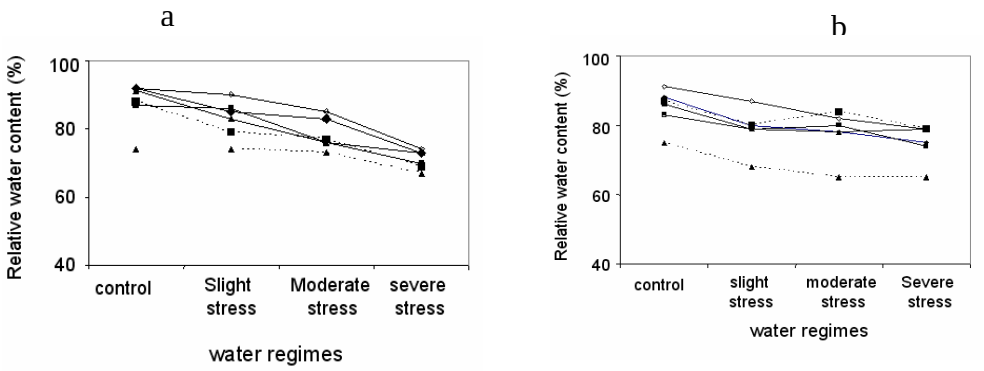

Fig. 1. Relative water content (%) at first mowing (a) and second mowing (b) of 6 perennial grasses tested under 4 water regimes in controlled conditions (Atlas —◆—, Lutine —◇— , Fraydo —▲—, Medly ···■···, Kasbah ···▲···, Sirolan —■—).

Osmotic potential

Osmotic potential had differed significantly (p=0.005) through water regimes and cultivars for the two mowing. There was not interaction between cultivars and water regimes. Means of osmotic potential decrease with the levels of water stress (Fig. 2). They reached -3MPa in the case of dactylis Kasbah under severe water stress. The decrease occurred differently according to the cultivars. Important osmotic potential drops happened from slight to moderate and severe water stress for tall fescue Lutine, Fraydo and dactylis Kasbah, particularly in the first mowing. Phalaris cultivars had maintained their osmotic potential in stressed water regimes. Medly cocksfoot did not recorded great changes in its osmotic potential. It seems that these three varieties had adjusted better by maintaining their osmotic potential unchanged at stressed regimes and also by decreasing their osmotic potential faster than the others cultivars (at the slight stress).

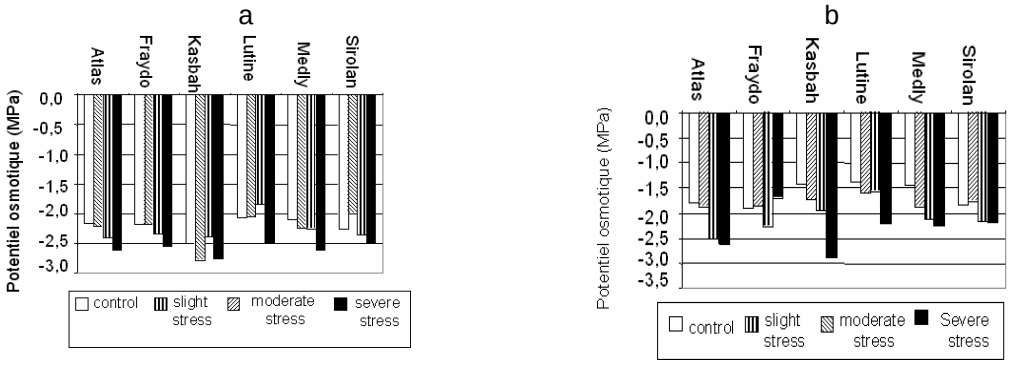

Fig. 2. Relative water content (%) at first harvest (a) and second harvest (b) of 6 perennial grasses tested under 4 water regimes in controlled conditions.

Dry matter production

Dry matter yield varied significantly (p=0.005) among cultivars and water regimes for the two mowing dates.

Data shows different potential of cultivars dry matter production (Fig. 3). Tall fescue (Fraydo and Lutine) yielded higher quantities compared to phalaris and cocksfoot cultivars. These trends had been lost approaching to summer. Some cultivars prepared their entrance in summer dormancy, such as Kasbah, Atlas, Sirolan.

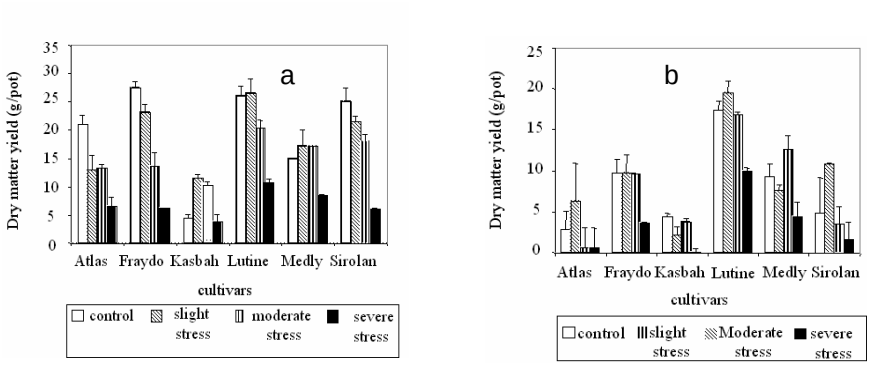

Fig. 3. Dry matter production at first mowing (a) and second mowing (b) of 6 perennial grasses tested under 4 water regimes in controlled conditions.

At the first harvest occurring at flowering, Cultivars were classed as Lutine, Fraydo and Sirolan followed by Atlas, then Medly. Kasbah's yield was significantly lower than the others. The two water regimes R1 and R2 were not different.

The tested cocksfoot produced lower biomass under non limited water regime. Tier water absorption was less all over the growth cycle, probably due to root system type, which is rather drought adapted. Normally, cocksfoot produce longer root to seek moisture from deep soil layers. In pot conditions, plants seem incapable to absorb the water excess. In contrast, dactylis cultivars used well the available water under limited water regimes.

Water use efficiency

The water use efficiency (WUE) was evaluated over the first growth cycle for three water regimes (control, moderate stress and severe stress) as the produced dry matter on consumed water to produce this biomass (Fig. 4).

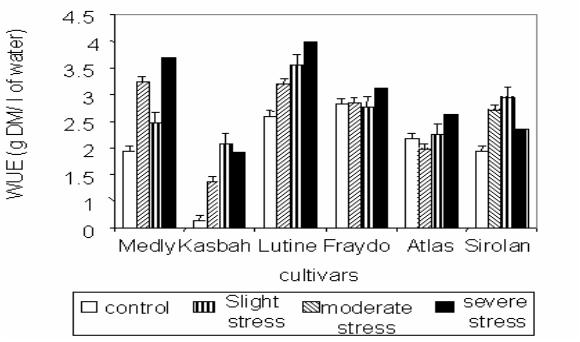

Fig. 4. Water use efficiency of 6 perennial grasses tested under 4 water regimes in controlled conditions.

Variance analysis (ANOVA) showed highly significant effect of cultivars and water regimes for this parameter. Lutine fescue recorded the highest WUE before Fraydo, Medly and Sirolan which had comparable WUE. Atlas was less water efficient than others but best than Kasbah which was the lowest (Fig. 4).

Water stress improved WUE. When water availability was under 50% of maximum moisture capacity, the WUE were higher than non limited regimes. There was clear improvement of WUE at the moderate stress.

There was significant correlation between dry matter production and consumed water at the first mowing (r^2= 0.65 **). Which mean that plants produce according to water consumed.

Conclusion

Biomass production was higher for tall fescue and phalaris cultivars followed by cocksfoot. Festuca cultivars were the most water efficient. The phalaris Atlas and dactylis Kasbah had the lowest WUE. In contrast, fescue varieties had highest WUE. The depressive effect of water stress on relative water content was emphasized according to the stress severity. Medly, Kasbah and Sirolan cultivars had maintained their RWC when put in drier conditions. They could be considered as drought tolerant. Atlas, Sirolan and Medly had better adjustments than the other cultivars, firstly by keeping their osmotic potential unchanged at severe water stress and secondly by decreasing their osmotic potential at moderate stress.

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