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in

Kyriazopoulos A.P. (ed.), López-Francos A. (ed.), Porqueddu C. (ed.), Sklavou P. (ed.). Ecosystem services and socio-economic benefits of Mediterranean grasslands

Zaragoza : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 114

2016
pages 195-199

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

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http://om.ciheam.org/article.php?IDPDF=00007509

To cite this article / Pour citer cet article

Ovalle C., Espinoza S., Barahona V., Gerding M., Del Pozo A. **Productivity of alfalfa cultivars in dryland Mediterranean environments of central Chile.** In : Kyriazopoulos A.P. (ed.), López-Francos A. (ed.), Porqueddu C. (ed.), Sklavou P. (ed.). *Ecosystem services and socio-economic benefits of Mediterranean grasslands*. Zaragoza : CIHEAM, 2016. p. 195-199 (Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 114)

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Productivity of alfalfa cultivars in dryland Mediterranean environments of central Chile

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Abstract. Deep-rooted perennial legumes such as lucerne (*Medicago sativa*) can be an alternative for dryland production systems increasing pasture availability for grazing during autumn-winter as well in early summer, where it is more limited in Mediterranean environments. The objective of this study was to evaluate plant survival and biomass production of nine alfalfa cultivars from Australian and North American breeding programs in four Mediterranean environments of central-south of Chile. Cultivars were evaluated in four Mediterranean environments of central-south Chile during three seasons (2012/13-2014/15). The sites located at the Andean foothills (Yungay) and coastal dryland (Hidango) presented the highest values of soil water content on the top 100 cm. Plants survival varied between 71 and 97% of the plants established. Plant biomass production during winter differed between sites and among cultivars, and was positively correlated to the winter activity class of cultivars. The total biomass production was significantly ($P < 0.05$) different among environments; in 2013/14 was higher in the Andes foothill (Yungay) and in 2014/15 was higher in the interior dryland (Cauquenes).

Keywords. *Medicago sativa* – Biomass production – Survival rate – Cultivars.

Productivité de cultivars de luzerne en environnements méditerranéens dans les terres arides du centre du Chili

Résumé. *Les légumineuses vivaces profondément enracinées telles que la luzerne (*Medicago sativa*) peuvent être une alternative pour les systèmes de production des terres arides en augmentant la disponibilité des pâturages pour le broutage au cours de l'automne-hiver ainsi qu'au début de l'été, où elle est plus limitée en milieu méditerranéen. L'objectif de cette étude était d'évaluer la survie des plantes et la production de biomasse de neuf cultivars de luzerne des programmes d'amélioration australiens et nord-américains dans quatre environnements méditerranéens du centre-sud du Chili. Les cultivars ont été évalués dans quatre environnements méditerranéens du centre-sud du Chili au cours de trois saisons (2012/13-2014/15). Les sites localisés sur les contreforts des Andes (Yungay) et les terres arides côtières (Hidango) ont présenté les plus hautes valeurs de teneur en eau du sol sur les premiers 100 cm. La survie des plantes a varié entre 71 et 97% des plantes établies. La production de biomasse végétale pendant l'hiver différait entre les sites et entre les cultivars, et était positivement corrélée au type d'activité hivernale des cultivars. La production totale de biomasse était significativement différente ($P < 0,05$) parmi les environnements ; en 2013/14 elle a été plus élevée sur les contreforts de la cordillère des Andes (Yungay) et en 2014/15 elle a été plus élevée dans les terres arides de l'intérieur (Cauquenes).*

Mots-clés. Medicago sativa – *Production de biomasse – Taux de survie – Cultivars.*

I – Introduction

In Mediterranean regions pasture productivity and its distribution along the year is of great importance for livestock production. Unfortunately, the growth rate of annual legumes is usually low during autumn and winter, and also plant senescence starts by the end of spring due to low soil water availability. Deep-rooted perennial legumes of Mediterranean origin have emerged as new alternative for dryland production systems (Dear *et al.,* 2003; Davies, 2005; Li *et al*., 2008).

Medicago sativa (lucerne) is one of the most drought tolerant perennial legumes (Li *et al*., 2008) and can survive long dry periods because of its deep root system (Fillery and Poulter, 2006; Benabderrahim *et al*., 2015). When the availability of soil water is low or absent in summer, lucerne is dormant, and when the rains begin in early autumn, growth restarts (Humphries and Auricht, 2001). In dryland Mediterranean environments, lucerne can attain high yields (Dear *et al*., 2003; Testa *et al*., 2011) and amounts of nitrogen fixation.

The objective of this study was to evaluate plant survival and productivity of nine alfalfa cultivars from Australian and North American breeding programs, differing in dormancy rate and sensitivity to drought, in four Mediterranean environments of central-south of Chile.

II – Materials and methods

Nine alfalfa cultivars from Australia and USA, with different winter activity class (WAC) were evaluated in four Mediterranean environments of central-south Chile during three seasons (2012-2104) Within the Australian cultivars, Sardi ten (WAC 10), Sardi seven (7) Sardi five (5) Sardi Grazer (6), Venus (5), Aquarius (8) and Genesis (7) were evaluated. The cultivars from USA were: WL458HQ (6) WL326HQ (4). The sites were: Hidango (34º21'; 72º00') located in the coastal dryland (marine terrace, Mollisol); Cauquenes (35º57'; 72º19') and Los Guindos (36º30'; 72º12'), located in the interior dryland (granitic soils, Alfisol); and Yungay (37º07'; 72º01'), located in the Andes foothill (volcanic ashes, Andisol). Long term average precipitations were 800, 650, 850 and 1200 mm, respectively. Soil water content (% v/v) was evaluated using EC-5 sensors (Decagon Device, USA), installed at 20, 40, 80, and 100 cm depth and connected to a data logger EM50 (Decagon Device, USA).

Two months old seedlings of each cultivar were planted at a density of 60 plants per plot in four replicates, in June-July 2012. Seedlings were grown in a glasshouse from seeds inoculated and lime pelleted with strain WSM2141. Fertilization free of nitrogen was applied at seedling establishment, using 90 kg ha^{-1} of P_2O_5, 2000 kg ha^{-1} of $CaCO_3$, 100 kg ha^{-1} of K_2SO_4 and 20 kg ha^{-1} of boron calcite.

The percentage of surviving plants was evaluated at the end of the summer period; February 2013 and April 2014; Aboveground biomass was evaluated at the end of the growing season (December) in the first year of the experiments, and in September, November and January in the second and third seasons. For dry matter determination the whole plot was harvested at 5 cm of ground and samples were oven-dried at 70 ºC until reaching a constant weight.

III – Results and discussion

The Chilean Mediterranean climate is characterized by a strong concentration of the precipitations during winter (May to August) and by a prolonged period of water deficit from October to April, particularly in the interior dryland (Cauquenes and Los Guindos; Fig. 1). The sites located at the Andean foothills (Yungay) and coastal dryland (Hidango) presented the highest values of soil water content between 0 and 100 cm. At Yungay, the soil is derived from volcanic ashes (Andisol) and presents very high content of organic matter (14.8%) and water holding capacity. At Hidango, the soil is derived from marine terrace (Mollisol), with high content of organic matter (3.9%) and clay, also present high water holding capacity. By contrast, in both sites of the interior dryland (Cauquenes and Los Guindos), the soils are granitic (Alfisols) of sandy loam texture and very low content of organic matter, therefore present much lower water holding capacity.

Alfalfa cultivars presented high plant survival in the four environments, varying between 71 and 97% of the plants established at the beginning of the season, with no statistical differences between environments or cultivars (Table 1). Even in the interior dryland (Cauquenes and Los Guindos) the survival was < 80% where soil water content in summer is very low (Fig. 1), and

confirm previous reports that referred alfalfa as a drought tolerant species (Dear *et al*., 2003). During summer lucerne becomes dormant and regrowth after the firsts rainfall in autumn (Humphries and Auricht, 2001).

Biomass production during winter differed between sites and among cultivars, but the interaction GxE was not significant (P>0.05). The average winter production (mean of the four sites and two seasons) for each cultivar was positively correlated (r = 0.80; P < 0.01) with winter activity class, and cv. Aquarios was the more productive. The total dry matter production was significantly (P <0.05) different among environments; in 2013/14 was higher in the Andes foothill (Yungay) and in 2014/15 was higher in the interior dryland (Cauquenes). There were no significant differences (P> 0.05) among cultivars (Table 1). At the Andean foothill (Yungay) the winter growth was lower due to lower temperatures compared to the costal or interior dryland. However, dry matter production during the whole growing season was higher at Yungay, which was the most favorable environment in terms of soil water availability (Fig. 1).

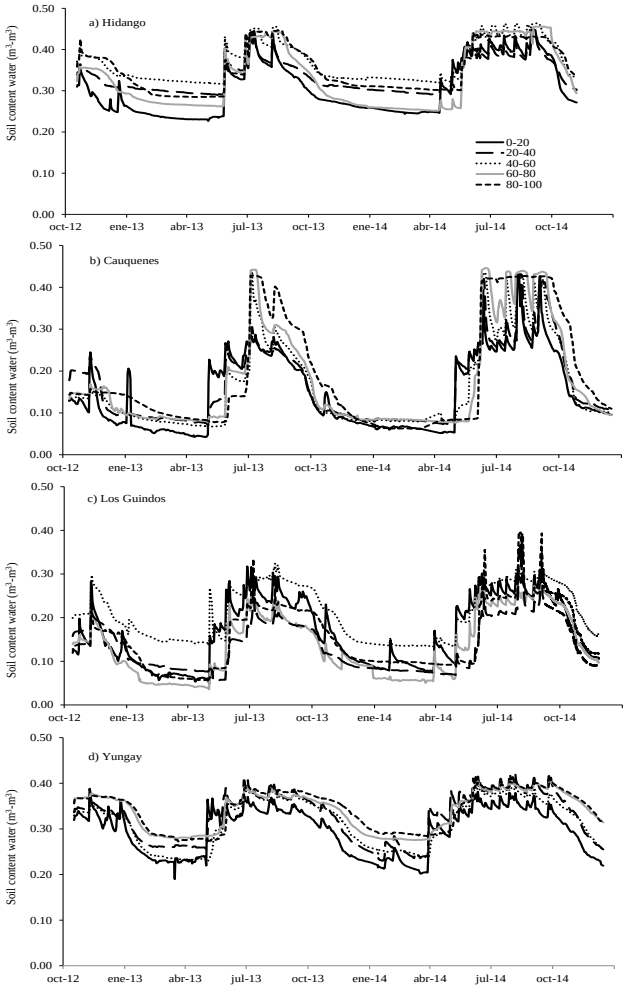

Fig. 1. Volumetric water content in the soil at five depths and four sites in the Mediterranean region of Chile, between October 2012 and November 2014.

The total dry matter production obtained by the alfalfa cultivars at the interior dryland of Cauquenes in the second and third years were comparable to that obtained by annual legumes like cvs of *B. pelecinus* and *O. compressus*, in the third year of evaluation (del Pozo and Ovalle, 2009). However, there are differences between perennial and annual legumes in the distribution of the production; in the former the growth and dry matter production during autumn and winter is much higher than in annuals. Thus, the incorporation of alfalfa into farming systems would increase pasture availability for grazing during the time where it is more limited in Chilean Mediterranean environments. In addition, the use of alfalfa into cropping rotations can contribute to the improvement of soil structure and increase crop yield in the following crop (Dear *et al.*, 2003). There were no signs of cold or waterlogging damage, nor aluminum, toxicity in the nine cultivars evaluated in the four sites.

Table 1. Means ± standard deviation and F values of ANOVA for plant survival (%) and dry matter production (DM, g m^{-2}) during winter period and total biomass, for nine cultivars of alfalfa grown at four Mediterranean environments in central Chile. Results of ANOVAs are also shown; G is genotype and E is environment

Trait	Year	Hidango	Cauquenes	Los Guindos	Yungay	G	E	G x E
Plant survival	2013	87.7 ± 5.2	95.4 ± 1.5	91.8 ± 4.8	80.3 ± 4.8	n.s	*	n.s
	2014	86.2 ± 5.5	84.8 ± 3.6	93.4 ± 4.8	91.2 ± 4.8	n.s	*	n.s
Winter DM	2013	141 ± 21	162 ± 37	251 ± 34	132 ± 12	*	**	n.s.
	2014	191 ± 29	199 ± 32	156 ± 28	88 ± 19	*	**	n.s.
Total DM)	2012	154 ± 17	161 ± 13	75 ± 5	233 ± 20	n.s.	**	n.s.
	2013	434 ± 40	732 ± 90	707 ± 40	939 ± 110	n.s.	**	n.s.
	2014	365 ± 28	924 ± 106	493 ± 44	n.a.[1]	n.s.	**	n.s.

*: P < 0.05; ** : P < 0.001; n.s.: not significant.
n.a: data not available because the plots were accidentally grazed by the end of spring.

IV – Conclusions

Australian and North American alfalfa cultivars have high survival rates and productivity under conditions of severe summer water stress that prevailed in the Mediterranean zone of central Chile. Furthermore, the production in late spring-early summer can prolong animal grazing for approximately two months, compared with grazing with annual legumes.

Acknowledgements

This study was supported by Fondo Nacional de Desarrollo Científico and Tecnológico, Project FONDECYT Nº1128829. We are grateful to Dr. Alan Humpries to contribute with alfalfa germplasm. To Mr. José Cares for his support in statistical analysis and to Teresa Aravena research assistant at INIA-Cauquenes, for her selfless work in the field.

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