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Wild herbaceous legumes for pasture restoration in the Sierra Nevada Natural Park: forage and seed yields

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Abstract. This study evaluates the forage and seed yield of 16 wild annual legume species which were grown in two different forest sites in the Sierra Nevada Natural Park (Granada, SE Spain). Because "Soportújar", an abandoned tree nursery, had been used as a sheepfold in recent years, its soil fertility was very high. "Lanjarón" was a pine plantation (*Pinus pinaster*) with low soil fertility. Rainfall during the growing cycle reached only 53% and 66% of the mean historical rainfall levels for Soportújar and Lanjarón, respectively. Nevertheless, productivity was found to be high in Soportújar, with yields of up to 7850 kg ha^{-1}, while Lanjarón recorded yields of only up to 487 kg ha^{-1}. *Vicia monantha* had the highest forage productivity levels in both sites. *Vicia disperma, Lathyrus clymenum, L. cicera* (only in Lanjarón), *Medicago truncatula* (only in Soportújar) and *M.rigidula* (only in Lanjarón) were the most productive species. In Lanjarón, weather and soil conditions resulted in very poor fructification levels (almost inexistent). In Soportújar, *Vicia monantha* had the highest seed yield (1234 kg ha^{-1}), followed by *Vicia lutea* and *L. clymenum* (460 and 457 kg ha^{-1}, respectively). Our results indicate that *V. monantha, V. disperma, L. cicera, L. clymenum, M. rigidula and M. truncatula* are the species best adapted to the environmental conditions of our experiment. More research needs to be carried out to confirm our findings and to develop new seed and soil management systems to improve forage and seed yields.

Keywords. Mediterranean rangeland – *Vicia* – *Lathyrus* – *Trifolium* – *Medicago.*

Légumineuses herbacées sauvages pour la restauration des pâturages dans le Parc Naturel de Sierra Nevada: production de fourrage et de semences

Résumé. *Ce travail évalue la production de fourrage et de semences de 16 espèces légumineuses annuelles qui ont été cultivées dans deux domaines forestiers du Parc Naturel de Sierra Nevada (Grenade, Espagne). Le site "Soportújar" était une pépinière forestière abandonnée, utilisé comme une bergerie au cours des dernières années, avec un niveau de fertilisation du sol élevé. Le site "Lanjarón" était une plantation de* Pinus pinaster, *avec une faible fertilité des sols. La pluviométrie pendant notre étude fut seulement 53% et 66% de la moyenne pluviométrique historique (Soportújar et Lanjarón, respectivement). Cependant, une productivité élevée a été trouvée à Soportújar (jusqu'à 7850 kg ha^{-1}); au contraire, Lanjarón n'atteignit que 487 kg ha^{-1}.* Vicia monantha *eut la productivité fourragère la plus élevée pour les deux sites.* Vicia disperma, Lathyrus clymenum, L. cicera *(seulement à Lanjarón),* Medicago truncatula *(uniquement à Soportújar) et* M. rigidula *(seulement à Lanjarón) étaient aussi entre les espèces les plus productives. À Lanjarón, la production de semences fut presque nulle, à cause des conditions climatiques et du sol. À Soportújar,* V. monantha *eut le rendement le plus élevé des semences (1234 kg ha^{-1}), suivie par* Vicia lutea *et L. clymenum (460 et 457 kg ha^{-1}, respectivement). Nos résultats indiquent que V. monantha,* V. disperma, L. cicera, L. clymenum, M. truncatula *et* M. rigidula *sont les espèces les plus adaptées aux conditions environnementales de cette étude. D'autres expériences sont nécessaires pour confirmer nos résultats, ainsi que pour trouver d'autres modes de gestion du sol et des semences pour augmenter la production.*

Mots-clés. *Pâturage méditerranéen* –Vicia – Lathyus – Trifolium – Medicago.

I – Introduction

Pasture restoration is considered to be one of the keys to mitigating the impact of climate change (Lal, 2003). Annual self-reseeding legumes have great potential for improving and restoring pastureland in semiarid areas given their good fodder quality, mainly due to their high protein content, low establishment requirements, their N fixation capacity and, thus, their ability to satisfy the nutritional needs of other plants (Porqueddu and González, 2006). However, their use in pasture improvement and restoration programs in natural areas should be restricted to autochthonous species and ecotypes, for which seeds that have been collected and/or produced in those areas are required. This study therefore evaluates the forage and seed yields of 16 wild legume species whose seeds were harvested in the field and grown in two different mountain forest sites in the Sierra Nevada Natural Park (Granada, SE Spain).

II – Materials and methods

The trials were carried out at two sites in the Sierra Nevada National Park: (1) Lanjarón (Cortijo Quemado), which used to be a pine plantation (*Pinus pinaster*), and (2) Soportújar (Vivero de la Sombra), an abandoned tree nursery, which had been used as a sheepfold in recent years. Table 1 summarizes the main characteristics of each site.

Table 1. Characteristics of the two study sites. N.D.: non detectable

	Lanjarón	Soportújar
UTM coordinates	30 S 455850 4088670	30 S 463814 4088725
Altitude (m.a.s.l.)	1320	1352
Rainfall (mm)†	281 (428)†	366 (685)†
Soil parameters		
– Texture	Sandy loam	Sandy loam
– ECC (meq /100 g^{-1})	11.13	14.78
– pH (1/2.5,v/v)	6.5	5.9
– Organic Matter (%)	2.7	3.7
– Total N (%)	0.162	0.202
– Total P (p.p.m.)	N.D.	34
– Total K (p.p.m.)	154	550

† Rainfall during growing cycle and, in brackets, historical average for the sites.

Seeds were collected in the field (fallows, slopes, shoulders of roads, grasslands, etc.) during late spring and early summer 2013 and were sown in October. The following species were sown, with the seeding rate given in brackets: *Medicago* L. spp. (3 g m^{-2}), *Medicago polymorpha* L. (3 g m^{-2}), *M. rigidula* L. (All). (4 g m^{-2}), *M. orbicularis* (L.) Barta (4 g m^{-2}), *Lens nigricans* (M. Bieb.) Godr. (6 g m^{-2}), *Trifolium cherleri* L. (3 g m^{-2}), *T. glomeratum* L. (1.5 g m^{-2}), *Lathyrus cicera* L. (15 g m^{-2}), *L. clymenum* L. (12 g m^{-2}), *L. sphaericus* Retz. (10 g m^{-2}), *L. tingitanus* L. (15 g m^{-2}), *Vicia amphicarpa* L. (9 g m^{-2}), *Vicia disperma* DC (10 g m^{-2}), *V. monantha* Retz. (9 g m^{-2}), *V. lutea* L. (12 g m^{-2}) and *V. sativa L.* (12 g m^{-2}). *Medicago* spp. is mainly composed of *M. truncatula* and also of *M. polymorpha,* and *M. rigidula.*

The experimental design used was a randomized block with four replicates per species. Each replicate consisted of a 2 x 1.5 m plot. Prior to the establishment of the plots, the entire experimental area (in both sites) was ploughed to create a suitable seedbed. Each plot was then fertilized with a pelletized organic amendment composed of a mixture of turf and sheep manure (81.7% organic

matter, 2.6% total organic nitrogen, 2% P2O5 and 3.9% K_2O_5). The seeds were sown by hand in furrows 25-cm apart and were slightly covered with soil.

Forage yield was estimated in mid-May 2014 by hand-clipping plant forage in 4 randomly selected 25 x 25 cm quadrats in each plot. Samples were oven dried at 60º C to constant weight (48 h) to determine dry weight and dry matter (DM). Averaged data were extrapolated to one hectare. Seed yield was estimated (only in Soportújar) using the same procedure as that for forage yields. The seeds were manually extracted from each sample and weighed. In Lanjarón, spring drought together with poor soil quality led to very poor fructification (almost zero). However, in Soportújar, thanks to better soil conditions and higher precipitation rates, fruits grew and matured, thus enabling seed yield to be estimated. Forage yield data were analysed using the GLM procedure of SPSS. The Levene and Shapiro-Wilk tests were used to check homoscedasticity and normality, respectively, in order to ensure that the model's assumptions were met. No data transformation was needed. In each site, one way ANOVA and the LSD *post hoc* test were used to determine differences among species. Seed yield data were analysed using the non-parametric Kruskal-Wallis test, as homoscedasticity and normality were not accomplished, and also by using the pair-wise comparison *post-hoc* test.

III – Results and discussion

Forage yield in Lanjarón was low, ranging from 45.9 to 487 kg DM ha^{-1}. The most productive species, with over 300 kg DM ha^{-1}, were *V. monantha, L. cicera, V. disperma* and *M. rigidula,* while the least productive species, with up to 110 kg DM ha^{-1}, were *V. lutea*, *Medicago* spp., *V. sativa, T.cherleri* and *M. polymorpha* (Fig.1). These low values are probably due to the higher water requirements of *V.sativa, M. polymorpha, M. truncatula* and *V. lutea* and/or to higher levels of hardseedness which might have led to low germination and consequently low establishment of *T. Cherleri* and *V. lutea* plants *(*Ramos *et al.*, unpublished*)*. Similar results were obtained by Robles *et al.* (2015) in an analogous experiment carried out in the same area in 2009/2010, although the better rainfall conditions favoured slightly higher productivity for most species.

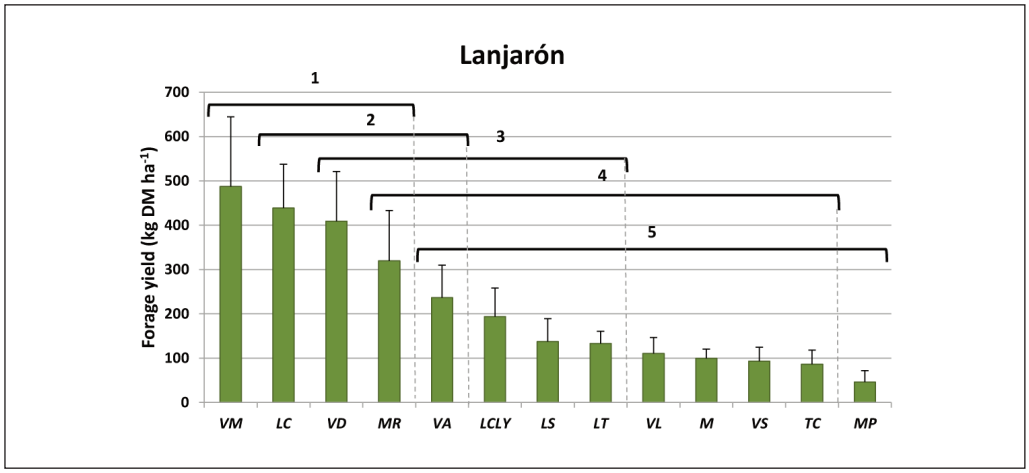

Fig. 1. Forage yield (kg DM ha^{-1}) in Lanjarón. VM: *Vicia monantha*, LC. *Lathyrus cicera,* VD: *Vicia disperma*, MR: *Medicago rigidula,* VA: *Vicia amphicarpa,* LCLY: *Lathyrus clymenum,* LS: *Lathyrus sphaericus*, LT: *Lathyrus tingitanus,* VL: *Vicia lutea,* M: *Medicago* spp., VS: *Vicia sativa*, TC: *Trifolium cherleri*, MP: *Medicago polymorpha*. The numbers above the horizontal brackets indicate significant differences among treatments (F = 3.158, d.f. = 12, p = 0.004; LSD test, p<0.05).

As a whole, forage yields in Soportújar, ranging from 265 to 7570 kg DM ha^{-1}, (Fig. 2), were notably higher than in Lanjarón, probably due to improved soil fertility, especially with regard to phosphorus (Porqueddu and González, 2006), and higher rainfall levels (see Table 1). *V. monantha* yielded the highest forage values (7570 kg DM ha^{-1}), followed by *V. disperma* (3622 kg DM ha^{-1}), *L. clymenum* (2796 kg DM ha^{-1}), *Medicago* spp. (2576 kg DM ha^{-1}) and *L. tingitanus* (2320 kg DM ha^{-1}) (Fig. 2). The lowest values were recorded by *M. orbicularis, L. nigricans, T.cherleri, T. glomeratum* and *L. sphaericus,* ranging from 265 to 665 kg DM ha^{-1}, probably due to the higher hardseedness levels of these species which might have led to low germination and consequently low establishment (Ramos *et al.*, unpublished).

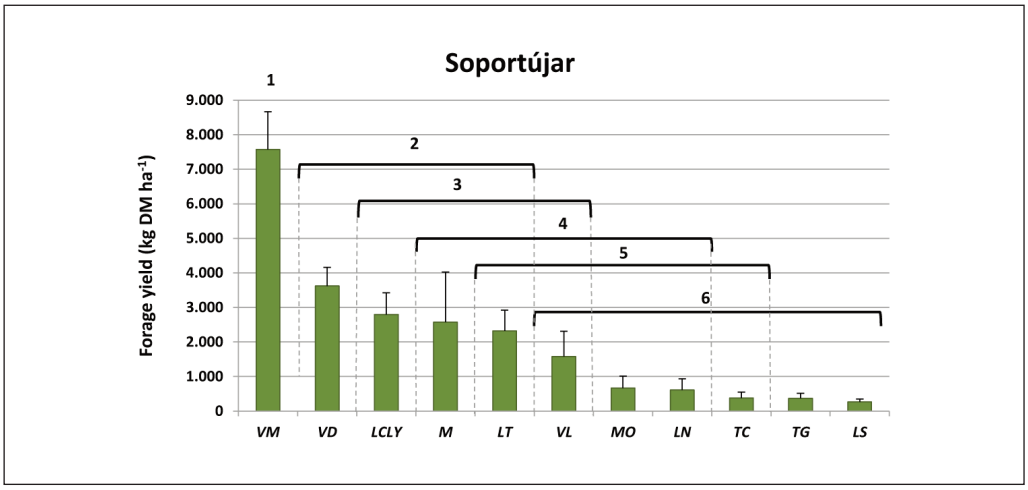

Fig. 2. Forage yield (kg DM ha^{-1}) in Soportújar. VM: *Vicia monantha*, VD: *Vicia disperma*, LCLY: *Lathyrus clymenum*, M: *Medicago* spp., LT: *Lathyrus tingitanus*, VL: *Vicia lutea*, MO: *Medicago orbicularis*, LN: *Lens nigricans,* TC: *Trifolium cherleri*, TG: *Trifolium glomeratum*, LS: *Lathyrus sphaericus*. The numbers above the horizontal brackets indicate significant differences among treatments (F = 3.158, d.f. = 12, p = 0.004; LSD test, p<0.05).

In Soportújar, seed yield was consistent with forage yield, as the most productive species in terms of forage yielded more seeds (*V. monantha*: 1234 kg seeds ha^{-1}), while the least productive species produced the poorest seed yields (*L. sphaericus*: 66.7; *T. glomeratum*: 49.1; *T. cherleri*: 21.6 kg seeds ha^{-1}). Only *V. lutea*, which had a medium forage yield but the second highest seed yield (460 kg seeds ha^{-1}), showed a different pattern.

IV – Conclusions

On the basis of our findings, we would recommend *V. monantha, V. disperma, L. cicera, L. clymenum, M. rigidula* and *Medicago spp.* (predominantly *M. truncatula*) as the best species for the restoration and improvement of pastures, as they appear to be better adapted to the pedoclimatic conditions of the Sierra Nevada Natural Park. As soil fertility and rainfall may determine forage and seed yields, fertilization and irrigation could be necessary in order to increase seed and forage yields.

Despite these promising results, further research is required in order to increase productivity, especially with regard to species with very low yields.

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