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Effects of sowing and fertilisation in the establishment of annual legume rich permanent pastures

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Abstract

A field experiment tested the effect of three fertilisation strategies (nil, mineral and organic fertilisation) on pasture establishment, measured by plant species composition in spring sward in the two first years after sowing two pasture types (simple annual, legume-rich mixture and complex annual legume-rich mixture) compared with unsown pastures. There was a positive effect of organic fertilisation on the spring floristic composition through the increase of sown annual legumes, without an increase of ruderal species. Farmyard manure substituted, with advantages, conventional sowing mineral fertilization in these conditions.

Keywords: sown biodiverse permanent pastures rich in legumes, *Trifolium subterraneum*, organic fertilisation, pasture ecology

Introduction

Since Portugal joined the EU in 1986, low cereal prices and high fertilizer and fuel costs have lead to extensive abandonment of agricultural land, and simplification of mountain mixed farming systems. In the 1970s, Portuguese agronomist David Crespo devised a Mediterranean pasture system - the Sown Biodiverse Permanent Pastures Rich in Legumes (SBPPRL) (Crespo *et al*., 2004) - often mixing 10-12 improved cultivars of 6-7 pasture species, with Trifolium subterraneum in preponderance (3-4 cultivars; > 50% of the seed mixture by weight). Former cereal fields are easily converted to pastures by sowing these mixtures. SBPPRL are now rapidly expanding in Portugal due to their superior productivity and C sequestration in soil organic matter (Teixeira *et al*., 2011). Current SBPPRL fertilisation recommendations at sowing propose soil pH correction and mineral P, and sometimes K, fertilisation. P fertilisation represents almost 20% of establishment costs (Teixeira, 2010). As manure is available on many cattle or sheep mountain farms, the substitution of conventional mineral fertilisation by farmyard manure is an option for reducing establishment costs and contributing to a desirable increase in P recycling on a farm scale. The main objective of this paper is therefore to assess the effects of nil, current mineral, and organic fertilisation in the spring botanical composition of Mediterranean legume-rich permanent pastures in the first two years after establishment, in a soil with a medium available-P content.

Materials and methods

In the autumn of 2008 a hierarchical split-plot experiment was established in a field of 2.1 ha, previously cultivated with oats, in Bragança, Portugal (41°46‘N 6°48‘W, 741 mm yr^{-1} of rainfall and 11.9°C of mean annual temperature). Parent rock was schist and the initial soil before sowing had a pH (water) of 6.0, 1.6% organic matter, medium available P (65 mg P_2O_5 kg^{-1}, Egner-Rhiem) and high available K (113 mg K_2O kg^{-1}, Egner-Rhiem). Three types of pasture were established (main plots): i) unsown pasture (UP); 2) simple seed mixture (SM); 3) complex seed mixture (CM). SM combined *T. subterraneum* ‘Denmark’ (61%), *T. repens* ‘Winterwhite’ (9%), *D. glomerata* ‘Prairial’ (13%) and *L. perenne* ‘Victorian’ (17%) with the

same grass/legume weight proportion as in the CM. In CM, there was used a SBPPRL mixture with eight legumes and two grass species, dominated by *T. subterraneum*. All treatments were tilled to 15 cm deep, harrowed and rolled. Three fertilisation (Fert) treatments at sowing were tested in sub-plots of ca. 0.23 ha, in each of the main plots: i) conventional, routinely recommended, mineral fertilisation (MF) - 1000 kg lime ha^{-1}, 53 kg P_2O_5 ha^{-1} (superphosphate 26.5%) and 30 kg K_2O ha^{-1} (potassium chloride 60%); ii) cattle manure (OF) (with 3.25% of N, 1.38% of P_2O_5 and 7.5% of K_2O), 40 t ha^{-1}, just enough to supply P_2O_5 of the MF - 130 kg N ha^{-1}, 55 kg P_2O_5 ha^{-1} and 300 kg K_2O ha^{-1}; iii) no fertilisation (NF). The plots were not fertilised in 2009 or 2010. The botanical composition data were recorded in four replications (quadrats) in each sub-plot, paired along a microtopographic gradient, in the springs of 2009 and 2010. Species relative cover was evaluated by the point-quadrat method (70×70 cm quadrats with 49 points) in the third week of May, in the centre of 1×1 m permanent quadrats. In 2010 these quadrats were protected from herbivory with an exclosure cage during the preceding two weeks to allow species flowering and posterior identification. The sown legumes were merged into one unique response variable (SownLeg). There was one cleaning-grazing event in June of 2009. The experiment was subjected to rotational flash grazing by a local village sheep flock in November of 2009 and from February to the end of June of 2010.
Species relative covers were assumed as response variables in a RDA (Redundancy Analysis) and in a PCA (Principal Component Analysis) carried out in the CANOCO package (Ter Braak and Šmilauer, 2002). The RDA consisted of eight dummy explanatory variables: the treatment levels of Year (2009 and 2010), Pasture (UP, SM and CM) and Fert (NF, MF and OF). For the PCA, besides the treatment levels, based in Iberian phytosociological literature (e.g. Rivas-Martínez *et al*., 2001) four supplementary (passive) variables were constructed adding the relative cover of poor soils cereal weeds (CereWeed, *Aperetalia spicae-venti*), Mediterranean fallow land and ruderal species (Ruderal, *Thero-Brometalia* and *Sysimbrietalia*), annual oligotrophic species (MAnnPast, *Helianthemetea*), and annual-hemicryptophytic species adapted to trampled soils and heavy grazing (MHemPast, *Polygono-Poetea* and *Poetea bulbosae*). Relative covers were compared with *t* tests.

Results and discussion

A hierarchical decomposition of community variation with an RDA with a split-plot design (Lepš and Šmilauer, 2003) produced the following explained variability of species data: Year 26.2% (ns), Pasture 21.7% ($P < 0.01$), and Fert 25.5% ($P < 0.004$). Constraining the decomposition of community variation to sown plots (SM and CM plots), Year, Pasture and Fert explained, respectively, 36.8% (ns), 3.1% (ns) and 31.8% ($P < 0.02$) of species variation. So, in the all-data (UP, SM and CM plots) analysis, pasture flora control by Pasture (21.7%) was due to a UP effect. Fert had a significant effect in pasture species assembling.
The PCA biplot of Figure 1 shows that between 2009 and 2010 there was strong reduction in CereWeed (e.g. *Papaver rhoeas*), less evident in UP plots, and an expansion of plants adapted to trampled soils and intensive grazing (MHemPast, e.g. *Trifolium glomeratum*), or of annual oligotrophic species (MAnnPast, e.g. *Vulpia* sp.pl. a plant genus avoided by grazers after flowering). *Lolium rigidum* (a ruderal) and *Anthemis arvensis* (a cereal weed) relative cover, the two most abundant undesirable species in the experiment, was promoted by UP and depressed by pasture sowing (SM and CM). Ruderal species appear split in two groups: more nitrophilous species (e.g. *B. hordeaceus*, *B. sterilis* and *H. leporinum*) were encouraged by OF while more oligotrophic ones (e.g. *A. arvensis* and *L. rigidum*) preferred NF and MF plots. The Ruderal variable was not correlated with OF ($R = -0.13$).

The PCA biplot (Figure 1) also suggests that OF and a second year (2010) favoured SownLeg in the sown plots. These hypotheses were supported by two-tailed *t* tests comparing SownLeg relative cover means: 18.1% in 2009 *vs.* 65.1% in 2010, 23 df, $P < 0.001$, *t* test; 66.4% in OF *vs.* 29.8% in MF plots in 2009, 7 df, $P < 0.001$, paired *t* test; 66.4% in OF *vs.* 31.8% in NF plots in 2010, 7 df, $P < 0.001$, paired *t* test. Soil P content before sowing probably explains why MF and NF had a similar effect in SownLeg and in the autochthonous flora. Pires *et al.* (2008) also found a significant positive effect of farmyard manure on legume dominance in similar pastures. *L. perenne*, the main sown grass, did not show a clear trend.

Conclusions

Cereal-associated weeds decreased rapidly in recently sown, annual legume-rich sown pastures. Species adapted to trampled soils and heavy grazing followed the opposite trend. Fertilisation exerted a significant control on spring flora of the sown plots. In spite of an important N input (130 kg N ha^{-1}), the OF treatment increased relative cover of sown legumes without an expansion of low-palatable ruderal species. The two most important undesirable species - *A. arvensis* and *L. perenne* - were depressed by pasture sowing and had a higher relative cover in NF and MF. In the studied soil fertility conditions, conventional mineral fertilization can be replaced without disadvantages by farmyard manure at sowing.

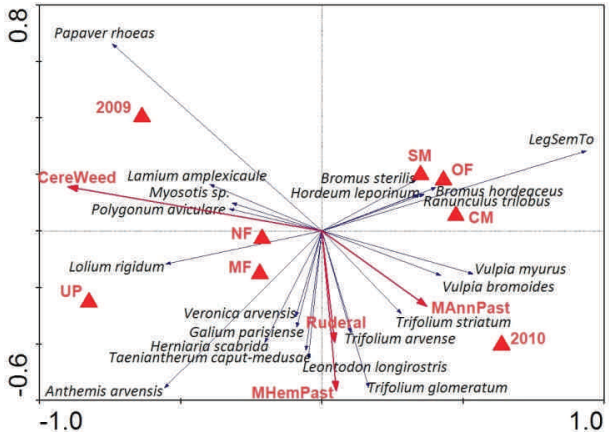

Figure 1. PCA species-treatment and supplementary variables biplot. All variables were passively projected. In the figure are represented the first twenty-one species with the highest fit with the first two axes.

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Session 2

Organic, low-input and alternative grassland farming systems