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Quantifying morphological stage to improve crop management and enhance yield and quality of sulla and lucerne

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Summary - A better knowledge of forage legume production physiology in different environments is necessary to exploit their potential, through new harvesting and grazing systems. The paper reports the results of several experiments under different environmental conditions on lucerne (Po Valley) and sulla (Sardinia and central Italy) with the aim of relating the codified stage to forage quality. The OM digestibility, which is known to be the most important determinant of the nutritive value of forage, resulted to be inversely related to the stage evolution of both legumes. The use of the quantified morphological stage proved to be an easy pre-harvest tool to enhance yield and quality of legumes and to determine cutting or grazing schedules, for a profitable management of the crop.

Key-words: morphological stage, *Hedysarum coronarium* L., *Medicago sativa* L., digestibility, crude protein

Résumé - Une meilleure connaissance du rythme de croissance des légumineuses fourragères dans plusieurs environnements est nécessaire pour l'exploitation de leur potentiel par de nouveaux systèmes de récolte et de pâturage. Ce papier présente les résultats de plusieurs essais, conduits dans de différentes conditions environnementales sur la lucerne (Vallée du Po) et la sulla (Sardègne et Italie central) dans le but d'établir une corrélation entre le stade phénologique codifié et la qualité du fourrage.

La digestibilité de la matière organique, reconnue comme le plus important facteur qui détermine la qualité du fourrage, est bien corrélée à l'évolution du stade. Dans le but d'une bonne rentabilité de la culture, le stade codifié est résulté être un instrument efficace sur le terrain, pour améliorer la gestion des légumineuses et pour déterminer la date de la coupe et du pâturage.

Mots-clés: stade phénologique, *Hedysarum coronarium*, *Medicago sativa*, digestibilité, matières azotées

Introduction

Nowadays there is a renewed interest in forage legumes, because of their important role in sustainable feeding systems due to their ability to fix nitrogen and to their potential high feeding value for ruminants. A better knowledge of forage legume production physiology in different environments is necessary to exploit their potential, through new harvesting/storage and grazing systems.

Most harvest and storage management decisions are made with little or no knowledge of the forage chemical composition because of the time and costs required to obtain such data. Moreover, grazing management is often based on the nutritive requirements of the animals without taking the crop characteristics into consideration, thus limiting an optimal exploitation of the forage crop potential.

It has recently been shown that optimisation of the forage nutrient yield and concentration is preferable to maximisation of the DM yield (Sheaffer *et al.*, 1988). In order to support decisions about the efficient management and storage of a forage crop (Sulc *et al.*, 1997) and to produce optimal nutritive value forage for specific classes of livestock, it is essential to develop a reliable and user-friendly tool to estimate the chemical composition of forages.

The numerical codification of the morphological stage of development, which proved to be correlated to the main nutritional characteristics of the plant (Kalu and Fick, 1981), allows an estimation of the herbage quality and could represent an important step in the development of equations for the prediction of forage quality (Sanderson and Wedin, 1989).

Legume harvests are scheduled either using fixed interval, stage of growth, or crown bud development, or even a combination of these criteria. As shown by several authors (e.g. Sheaffer *et al.*, 1988), cutting according to stage of development is superior to other schedules in obtaining consistent forage yield and quality.

This paper presents data collected over four years under a wide range of conditions to evaluate the effectiveness of the codified stage as an easy pre-harvest management tool to determine cutting or grazing schedules during sulla and lucerne growing seasons.

Materials and methods

The data were obtained from experiments conducted in the 1995-98 period at three sites that differ according to climate, soil type and cropping systems: Ancona (43°N lat., cool Mediterranean climate, clay-loam, calcareous soil), Sassari (40°N lat., mild Mediterranean climate, sandy-loam calcareous soil) and the western Po plain (45°N lat., temperate climate, medium textured soil). Two crops were considered: lucerne (*Medicago sativa* L.) and sulla (*Hedysarum coronarium* L.) a short-lived Mediterranean perennial legume with remarkable growth in clayey and calcareous soils under dry conditions. Different weather and management conditions, cultivars, and growth cycles were considered in order to extend the inference of the results.

The numerical system used to classify the morphological stage of lucerne was the 10-stage classification system proposed by Kalu and Fick (1981) (Table 1). This classification system was slightly modified for sulla in the 0-2 stages, as reported by Borreani *et al.* (1999). To estimate the mean stage of the canopy the mean stage by weight (MSW) was calculated in a sub-sample of about 50 stems made from a random sample of stems collected at three sites within a location, using the following equation:

$$MSW = \Sigma(S \times D) / W$$

where: S = stage number, 0 to 9; D = dry weight of stems in stage S ; and W = total dry weight of stems in all stages.

Table 1. Codification of stages of development for lucerne.

Code	Stage name	Stage definition
0	Early vegetative	stem length < 15 cm; no buds or flowers
1	Mid vegetative	stem length 16 to 30 cm; no buds or flowers
2	Late vegetative	stems >30 cm, no buds or flowers
3	Early bud	1 to 2 floral buds, no open flowers
4	Late bud	> 2 floral buds, no open flowers
5	Early flower	1 node with open flowers
6	Late flower	open flowers, no green pods
7	Early seed pod	brown flowers, 1st green pod
8	Late seed pod	brown flowers, green pods
9	Ripe seed pod	ripe brown pods

The forage samples, dried at 65°C for 48 h, were analysed for crude protein (CP = N x 6.25), gross energy (GE), and organic matter digestibility (OMD) according to the two-stage rumen fluid technique (Tilley and Terry, 1963). The analysed parameters (n = 360) were regressed on the MSW and other pre-harvest factors that are known to influence the feeding value (such as age in days and cumulated growing degree days).

Results and discussion

The DM yields of the two legumes at a particular harvest are influenced by the environmental conditions, utilisation pattern, and the cultivar selection. The total DM accumulation within a lucerne growth cycle was more rapid and nearly linear until early flowering and decreased thereafter. The maximum DM yield for any single growth period usually occurs when plants are cut from early to late flowering (up to 6 t ha⁻¹ in the first cut and up to 3-4 t ha⁻¹ in the subsequent cuts). Lucerne harvest schedules based on first harvest at vegetative (MSW=2) with subsequent harvests at early bud stage (MSW=3) provided the greatest yields of high quality lucerne, even though this schedule did not provide the greatest total yields of digestible OM and CP.

In spring, the growth rates of sulla increased rapidly during the reproductive development of the crop, reaching a maximum DM yield (up to 12 t ha⁻¹) at late to the end of flowering (MSW>6), but OMD at these stages was very low. Under mild Mediterranean conditions (e.g. Sassari), the winter growth of sulla is strongly influenced by the time of the season break at the end of the summer. In this case, during late autumn or winter, DM yields of about 1 t ha⁻¹ were obtained around 100 and 50 days after the first effective rain in the year of sowing and in the subsequent year, respectively (Ligios *et al.*, 1997). DM accumulation is then limited by low temperatures in winter. Under cool Mediterranean climates and more fertile soils (e.g. Ancona), the autumn-winter growth of first year seedlings is almost absent if the crop is established at the end of the summer, while it is influenced by spring management in the second year, ranging from 1.8 to 3.7 t ha⁻¹ DM under frequent or extensive spring cutting management respectively. Similar productions were obtained in the autumn following a spring sowing (Sargenti, 1998).

The CP content of both legumes decreased with increasing stages from values higher than 270 to 100 g kg⁻¹ DM (Fig. 1a), with a great variability due to the difference in soil and environmental conditions.

The GE was almost constant over the stage evolution, weather, and environmental conditions with mean values of 17.9 ± 0.25 and of 18.5 ± 0.38 MJ kg⁻¹ DM for sulla and lucerne, respectively. The OMD declined linearly with increasing stages following similar trends for the two crops (Fig. 1b). The decreases were of 32.9 and 39.1 g kg⁻¹ OM per stage unit for sulla and lucerne, respectively. Since the nutritive value of forages mainly depends on GE and digestibility (INRA, 1988), OMD can be considered an effective variable to discriminate the nutritive value. The morphological stage of development of sulla and lucerne resulted to be an effective indicator of the variability of OMD (R² 0.72 and 0.64, respectively), because it incorporates both environmental factors and plant development into a quantitative index. The residual variability could partly be explained by the cumulated growing degree days effect (Borreani *et al.*, 1999).

Conclusions

The management choice of whether to obtain either considerable yields of high quality forage or the highest yield of DM depends on the feeding system and livestock requirements. The morphological stage of development proved to be an easy and reliable pre-harvest tool to

support these decisions and to optimise the utilisation (cutting or grazing) of both crops. It has been shown that numerical codification of the stage, through an accurate sampling of the forage in the field, allows technicians and farmers to immediately know the nutritional value of the forage and its evolution. This information is essential for a profitable management of the crop and hence for the efficient organisation of the feeding system.

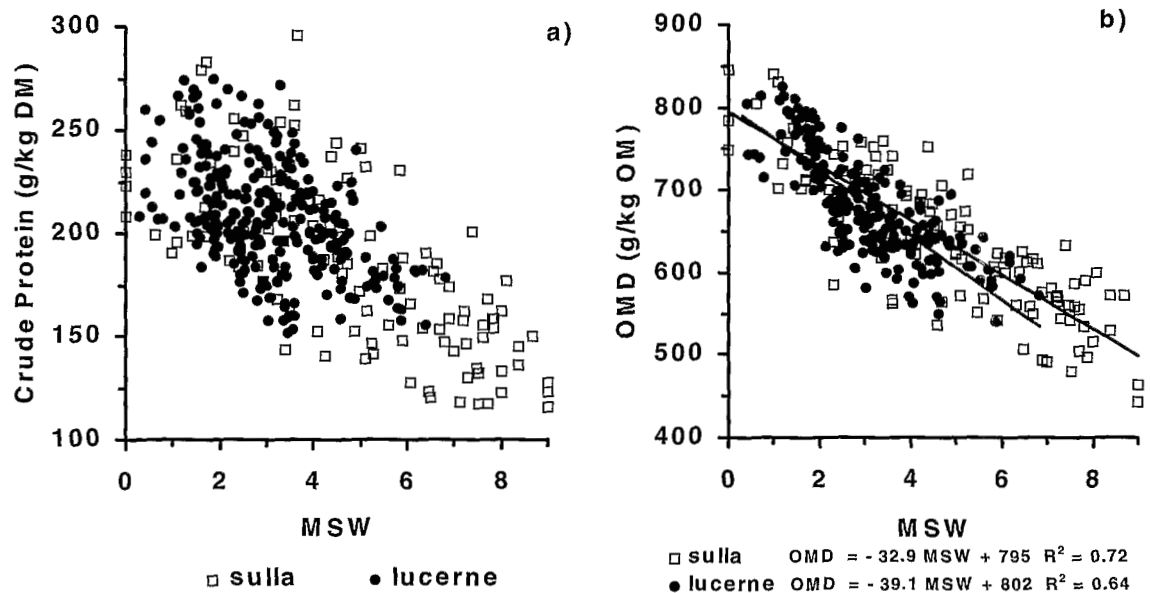


Figure 1. Crude protein (a) and organic matter digestibility (b) of lucerne (n=226) and sulla (n=134) in relation to the codified morphological stage (MSW).

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