Europ. J. Agronomy 34 (2011) 144–152

Contents lists available at ScienceDirect

European Journal of Agronomy

journal homepage: www.elsevier.com/locate/eja

Dry matter and qualitative characteristics of alfalfa as affected by harvest times and soil water content

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ARTICLE INFO

Article history:
Received 4 August 2010
Received in revised form 6 December 2010
Accepted 13 December 2010

Keywords:
Alfalfa
Mediterranean environment
Harvest times
Irrigation
Yield
Qualitative traits

ABSTRACT

The best trade-off between quantity and quality in forage crops is one the most important targets of the agronomic research, since quantitative and qualitative traits are generally inversely correlated. With the aim of exploring the effect of harvest time (early and late), soil water content (irrigated and rainfed) and variety (Equipe, Europe and Midi) on duration, yield and quality of alfalfa, a four year trial was carried out in a Mediterranean environment. Early cut resulted in a reduction of forage yield (12%) with a faster reduction of longevity, but with a higher quality characteristics in terms of protein (20.2%) and fibre (23.1%) compared to the late cut (18.0 and 25.9%, respectively for protein and fibre). Dry treatment led to a limited reduction of yield and quality traits, suggesting alfalfa is a potential forage resource for the improvement of hilly areas of Mediterranean environment. The tested varieties show all a good regrowth capability allowing three, sometimes four, cut per year. The obtained results pointed out that the combination of early and late harvest times would allow a better distribution of the forage production between the months of June and September as well as a fair useful forage regrowth during the months of October and November.

1. Introduction

The area of the Nebrodi mountains of Sicily (southern Italy), characterized by a climatic trend (temperature and rainfall) more favourable compared to the Mediterranean one typical of the plains of the same region, is traditionally devoted to the stock-breeding. The diet of the cattle in this area is nearly exclusively based on forages productions, characterized by a low-quality and a short period of production, and with a minor extend, from the cultivation of autumn to winter forage crops (Cosentino and Litrico, 1992).

In the hilly areas of Mediterranean environment characterized by pastures and annual forages, a contribution to the increase of the yield, to the extension of the forage time-frame availability and to an higher qualitative forage yield, in terms of energy and protein content, can come from the introduction of legume meadow species. Among these, alfalfa (*Medicago sativa* L.) may be considered a potential valuable crops, due to its high yield (Cosentino et al., 2003), its relevant nutritional characteristics and its role of great importance in crop rotation (Jia et al., 2009; Pietsch et al., 2007; Cosentino et al., 2003).

However, with the aim of exploring the best conditions for alfalfa cultivation, particular attention must be paid to the harvest timing. This represents, in fact, an extremely important variable being a trade-off among quantity, quality, annual production calendar and duration of the meadow (Teixeira et al., 2007a, 2008). Moreover, these parameters are strictly linked to climatic conditions, management techniques (irrigation, etc.) (Sanchez et al., 2010) regrowth capability of the varieties (Dhont et al., 2003) and nutritional requirements of the livestock. This aspect has been widely studied in cold environments, but much less in warm areas and in inland Mediterranean areas (Lloveras et al., 1998).

The best moment for the cut is generally associated with the flowering time. However, the aim to improve the forage quality without reducing the yields can be obtained by increasing the cut frequency and therefore the number of the cuts per year (Lemaire and Allirand, 1993; Marten et al., 1988). The early cut reduces and increases the leaf/stem ratio guaranteeing a higher protein content. However the excessively early cut regimes are not amenable, because the higher protein content and the better forage digestibility do not compensate the lower dry matter production (Hodgkinson, 1973; Grignani, 1990) and moreover the meadow persistence may be seriously compromised (Teixeira et al., 2007b; Rotili et al., 1997).

On the basis of these preliminary remarks, the aim of the present investigation was to test the influence of the harvest time and the

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doi:10.1016/j.eja.2010.12.001

irrigation on the productive and qualitative characteristics of three cultivar of alfalfa cultivated in a high-hill area in the southern Italy.

2. Materials and methods

The trial was carried out on *M. sativa* over a 4-year period (1995–1998), in low mountain environment of southern Italy (Sicily, 1230 m a.s.l. 37°57′N, 14°57′E) on sand-clay, depth, sub-acid soil.

The following factors have been studied:

- 3 alfalfa varieties: Equipe, Europe, Midi;
- 2 harvest times: (T1) early cut at the bud flowers appearance; (T2) late cut at the full flowering according to the phenological stage using the method proposed by Kalu and Fick (1981);
- 2 soil water contents: natural water condition and restoration of 100% maximum evapotranspiration (ETm) estimated by means of class A evaporation pan.

The varieties used were chosen on the basis of tolerance to the frequent cuts, rapid regrowth, high yield, low fibre content and adaptability to hill and high hill environment (CRPA, 1992; Tabacco et al., 2002).

A four time replicated split-plot experimental design with single plots of 20 m^2 (5 m × 4 m) was adopted, assigning the soil water content to the main plot, the variety to the sub-plot and cutting time to the sub-sub-plot. The cuts were performed 3 cm high from soil level, in order to preserve the regrowth capability.

Irrigation was performed using a sprinkler system with a single main pipeline with branches to serve experimental plots. The water volume was determined on the maximum amount of water available in the first 60 cm of soil, using the following formula;

$$V = 0.66(\mathrm{FC} - \mathrm{WP}) \times \Phi \times D$$

where V is the amount of water (in kg m^{-2} converted into mm); 0.66 = readily available water not limiting for evapotranspiration; FC is the field capacity (27% of dry soil); WP is the wilting point (11% of dry soil); Φ is the bulk density (1.1 kg m^{-3}); and D is the roots length (0.6 m).

Water was applied when soil water content was equal to the 2/3 of available water.

In each cut, 500 g sample of fresh biomass, was weighted, separated in 3 plant components (leaf, stem and flower) and dried at 65 °C in a oven until constant weight to determine the dry matter content, on which leaf/stem ratio was calculated.

Dried samples of different plant parts were merged, grounded to pass through a 1 mm mesh mill and analyzed for total nitrogen (Kjeldahl method) and fibre content. Protein content was calculated as $N \times 6.25$ and protein yield was also obtained multiplying protein percentage × dried yield. Crude fibre content was determined according to Weende for the first two years and sequential fibre (NDF – neutral detergent fibre and ADF – acid detergent fibre) according to Goering and Van Soest (1970) for the last two. Since in 1995 and 1998 the last T1 harvest time was brought forward due to the low temperature and the stop of the vegetative growth, only the first three samples cut were used for the analytical determination.

Net energy for lactation (NEL) was estimated in the samples of the last two years using the following general equation reported by Conrad et al. (1984):

$$\mathrm{NEL} = 2.28 \times \left[(0.93 \times P + \mathrm{EE} + 0.92 \times (1 - A - P - \mathrm{NDF}) + 0.75 \times (\mathrm{NDF} - L) \times \left(1 - \frac{L^{2/3}}{\mathrm{NDF}^{2/3}}\right)\right] - 0.10$$

where P is the protein, EE is the ether extract, A is the ash, NDF is the neutral detergent fibre, and L is the lignin.

Values of ether extract and lignin was assumed equal to 2.5% and 6.4% as obtained in other researches carried out in similar Sicilian environment on alfalfa (Licitra et al., 2001), then the NEL was estimated with negligible errors.

A three way ANOVA was performed and differences among means of statistically significant parameters were expressed by the Student–Newman–Keuls test. Percentage values were previously arcsin $\sqrt{\%}$ transformed.

During the trial, the main meteorological parameters (temperature, solar radiation and rainfall) were also collected by an automatic meteorological station located at the experimental site. Thermal sum was calculated by the equation $\mathrm{TS} = \sum(\mathrm{DAT} - 5\,°\mathrm{C})$, in which DAT is the daily average temperatures (°C) and 5 °C is the value considered as base temperature of growth for alfalfa (Fick, 1984). The average daily temperature was calculated as follow: $\mathrm{DAT} = (\max T + \min T)/2$, in which $\max T$ is the daily maximum temperature (°C) and Min$T$ is the daily minimum temperature (°C). Intercepted radiation was calculated, between the beginning of the regrowth and each cut, adopting the following equation:

$$\text{Intercepted radiation} = \sum_{i=1}^{n} \mathrm{PAR}_i \times (1 - e^{-k \times \mathrm{LAI}_i})$$

where: PAR is the photosynthetically active radiation; k is the extinction coefficient for solar radiation (0.5) (Confalonieri and Bechini, 2004), LAI_i is the leaf area index. LAI values between two following cuts has been interpolated with a linear regression. In agreement with Avice et al. (2001) and Teixeira et al. (2008) the regression was not forced through the origin, since perennial crop may have a translocation of dry matter from roots to shoots during the early regrowth. The b coefficient of the regression equation ($y = a + bx$) represent the radiation use efficiency (RUE).

3. Results

3.1. Weather data

The temperature course (Fig. 1) during the 4-year trial was similar to the 30-year period trend with the highest temperature (25–28 °C) recorded in July and August, whereas the lowest, just below 0 °C, recorded in December–January (except for the 1998 when the minimum temperature peak occurred between March and April). The average of total annual rainfalls was about 700 mm, not much different from the average of the 30-year period. Generally, the rainfalls were mainly recorded in the period from September to March.

3.2. Yield characteristics

During the trial periods, three cuts for each year were performed except the T1 treatment in the first and the last years, during which the fourth cut was executed due to the favourable climate (Fig. 1). Full flowering, corresponding to the late harvest time, generally occurred 15–20 days after early cut, with an average extra accumulation of 250 °C thermal degree compared to the early harvest one (626 °C for T1, and 996 °C for T2, on average of the 4 years). Except for the first year more than 75% of the DM yield was harvested in the first two cuts which were carried out between July and September, for both harvest times and soil water contents.

Significant effect of the three-way interaction on the biomass production was observed in the third and fourth year, while significant 2-way interaction I × V was observed in 1995 and in the 1998 (Table 1). Positive effect of irrigation was recorded in all the 4-year trial on dry matter. Varieties showed significant difference only in the second year, during which Equipe yielded less than Europe and