Effect of Cutting Height and Stage of Development on Lucerne Quality in the Po Plain

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Abstract

To improve pre-harvest forage quality of lucerne an increase of the cutting height was studied under two high quality cutting schedules in a two year experiment. Two different harvest schedules (VB, first cut at late vegetative and following cuts at bud stage; VF, first cut at late vegetative and following cuts at early flowering) and two cutting height (4 and 14 cm) were compared to evaluate dry matter (DM) yield, morphological stage of development, crude protein (CP), NDF, ADL, and enzymatic organic matter digestibility (OMD). The stratified quality was analysed in six canopy segments for a summer cut. Increasing the cutting height improved the protein and digestibility contents in both schedules without compromising the stand persistence. In the VB schedule the increase in the cutting height resulted in an NDF that was lower than 370 g kg^{-1} DM, while the OMD were always higher than 700 g kg^{-1} OM, both considered as threshold values for quality purposes. The OMD of the bottom parts of stem remained almost constant till 22 cm with values of 470 and 400 g kg^{-1} OM for VB and VF, respectively. Leaves showed a constant quality with a CP content of 318 g kg^{-1} DM and OMD of 769 g kg^{-1} OM. The increase in the cutting height leads to relevant improvement in the forage quality when performed at vegetative and early bud stages, while on more mature forages the increase in the height of cut proved to be a valuable method to increase forage quality only when performed over 20 cm.

Key-words: cutting height, organic matter digestibility, *Medicago sativa* L., NDF, stratified forage quality.

1. Introduction

Home-grown lucerne (*Medicago sativa* L.), conserved as silage or hay, represents the most reliable source of high quality forage and can contribute in reducing costs of ruminant production. In order to satisfy the nutrient requirements of high performing dairy cows, forages should be characterised by high OMD (> 680 g kg^{-1} OM) and NDF lower or equal to 370 g kg^{-1} DM (Broderick, 1995; Nelson and Satter, 1992). This means that the pre-harvesting quality of forage had to be better than the previously stated values, because of the unavoidable harvesting and conservation losses (Demarquilly, 1987). It is widely recognised that the quality of lucerne decreases as the crop grows and matures (Nelson and Moser, 1994). The two major factors contributing to the low quality of mature legumes are primarily the decrease in the leaf to stem ratio and the increase in the cell-wall concentration and lignification which is much faster in stems than in leaves (Marten et al., 1988). In legumes where stems are structural organs and leaves metabolic organs, the quality of leaves is almost constant over the growth cycle (Van Soest, 1994). Furthermore, stem segments are not uniform in digestibility and crude protein content with a lower quality in the bottom part (Buxton et al., 1985). Buxton and Casler (1993) observed that the quality of the forages decreases rapidly with the increase in the stem weight; the basal portion, in particular, is characterised by higher level of collenchyma cells and lignin which are only marginally digestible.

Since most of the lucerne protein (70% of total plant) is located in the leaves, and most of the leaves are found in the upper parts of the

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plant canopy, Downs and Taylor (1989) propose an approach to improve forage quality by harvesting the top part of the plants separately. However, in order to determine the cutting height, it is necessary to analyse and quantify the average protein content and digestibility of the plant above or below the cut. Ogden and Kehr (1965) found that the top half of first cut lucerne contained 62% of the total protein and 39% of the crude fibre content. Nevertheless, an increase of the cutting height leads to a reduction of the herbage yield (Gervais and Girard, 1987).

Therefore, it is necessary to determine the maximum level to raise the cutting height without compromising the DM yield, profitability and persistence of the lucerne stand.

The objectives of this study were to evaluate the practical applicability and the possibility of further improving the pre-harvesting forage quality of lucerne by increasing the cutting height under two cutting schedules without influencing stand persistence.

2. Materials and methods

2.1 Description of the site and experimental treatments

The research was carried out over the 1996-1997 period in the Western Po Valley near Torino (44° 50' N, 7° 40' E, altitude 232 m a.s.l., annual mean temperature 11.5° C, and annual average rainfall 747 mm) on recent alluvium soil (Typic Udifluvents; USDA, 1997) with a sandy-loam texture and pH (in water) of 7.6. The soil sand, silt, and clay contents were 480, 430, and 90 g kg^{-1}, respectively, at 0- to 30-cm depth. Organic C was 11.5 g kg^{-1} and organic N was 1.39 g kg^{-1}. Stands of lucerne cv. Equipe were sown on 4 April 1996, at 35 kg ha^{-1} of pure live seed, and 10 cm row-spaced. All the plots were fertilised prior to sowing with 100 kg P_2O_5 ha^{-1} and 150 kg K_2O ha^{-1}. No fertiliser or herbicide were applied after sowing. On 16 May 1996, a pre-cut was made to control weed development; no sampling was performed on this cut. Temperature and rainfall data were collected from a weather station that was 60 m from the experiment site.

Two heights of cut, 4 and 14 cm, defined as standard and high, respectively, were managed under two cutting schedules:

- VB, first cut at late vegetative with crop height of 50-60 cm, and following cuts at early bud stage;
- VF, first cut at late vegetative as VB, and following cuts at early flowering.

Cuttings were made according to the phenological stage utilising the system proposed by Kalu and Fick (1981). Dates of cutting are reported in Table 1.

Treatments were assigned to experimental units using a randomised complete block design. Each treatment had three replications. The total plot size, including pathways, was 20 m^2. Samples for yield and quality were performed at each sampling time with a Haldrup forage plot harvester (modified to obtain the different cutting heights) on subplots of 12 m^2 to avoid border effects between two neighbouring plots cut at different times. Plants were dug and counted from a random meter squared area of each plot in late October 1997 to determine the stand persistence.

The quality in canopy segments was evaluated in 1997 on the second regrowth of VB and VF. Approximately 1 kg of herbage was collected by hand clipping at ground level and taken to the laboratory for separation into six layers on three replications. The layers were: 0-4, 4-8, 8-14, 14-22, 22-40 and over 40 cm. Three sub-samples for each fraction were separated into stems and leaves.

2.2 Analytical procedures

Forage samples were taken from each plot to determine the dry matter content at 90° C, and

Table 1. Cutting date in the two experimental years for the two cutting stages.

Schedule	1996					1997						
	†1st	2nd	3rd	4th	5th	1st	2nd	3rd	4th	5th	6th	7th
VB	15 May	12 June	9 July	7 Aug.	29 Sept.	22 April	21 May	18 June	23 July	11 Aug.	18 Sept.	31 Oct.
VF	15 May	25 June	30 July	5 Sept.	29 Oct.	22 April	4 June	26 June	28 July	29 Aug.	4 Oct.	

†The first cut was made to control weed development and no sampling was performed.

Table 2. Monthly and annual mean temperatures and cumulated rainfall for the studied period and the means for 25 years.

Month	Temperature (° C)			Rainfall (mm)		
	1996	1997	mean 1976-1999	1996	1997	mean 1976-1999
January	2.3	1.0	0.6	105	47	35
February	2.1	5.6	3.3	35	0	33
March	6.6	10.1	7.6	27	1	53
April	11.8	11.3	10.8	81	12	99
May	16.2	16.9	15.9	95	19	108
June	20.4	19.3	19.5	60	253	76
July	20.9	21.2	22.0	33	39	36
August	20.8	22.2	21.3	108	40	65
September	14.5	19.2	17.3	75	50	66
October	12.0	12.6	12.1	136	3	94
November	7.0	6.2	5.6	79	45	53
December	3.0	2.9	1.7	129	21	29
Annual	11.6	12.4	11.5	963	530	747

the morphological stage, following the mean stage by weight (MSW) method proposed by Kalu and Fick (1981).

Samples for qualitative analyses were dried in a forced-draft oven to constant weight at 65° C, air equilibrated, weighed, ground in a Cyclotec mill (Foss Tecator, Hoganas, Sweden) to pass a 1 mm screen.

The dried samples were analysed for total nitrogen (TN), by dry combustion according to the Dumas method (Kirsten, 1983) using a NA 1500 elemental analyser (CE Instruments, Milan, Italy), and crude protein (CP) calculated as TN × 6.25. Neutral-detergent fibre (NDF) and acid detergent lignin (ADL) were determined according to Van Soest et al. (1991). Enzymatic organic matter digestibility (OMD) was carried out as described by Aufrère (1982).

2.3 Statistical analysis

DM yield and chemical compositional data, within each cut, were analysed for statistical significance via analysis of variance, with significance reported at 0.05 probability level using the general linear model of the Statistical Package for Social Science (Norusis, 1998). When calculated values for F were significant, the Ryan-Einot-Gabriel-Welsch range test (Hochberg and Tamhane, 1987) was used to interpret significant differences among the means.

3. Results and discussion

The weather conditions were characterised by a cool spring and rainy season in 1996 (total rainfall 963 mm) and an early spring and warm September in 1997 with lower total rainfall (530 mm) (Table 2). No frost damage was recorded during winter over the years. No irrigation was supplied, due to soil reserves and good rain distribution.

3.1 Dry matter yield, quality and persistence of lucerne harvested at two cutting heights

The individual and total harvest DM yield for the two cutting heights and schedules are reported in Table 3. Four cuts were performed in 1996 for each treatment, while the longer growing period in 1997, due to the early spring, allowed 7 and 6 cuts to be made for the VB and VF, respectively. In both years, the standard VB schedule yielded lower than the standard VF schedule; the difference of DM yield was -20% in 1996 and -17% in 1997. The reduction of total annual DM yield due to the increase of the cutting height was of 1.0 t ha^{-1} (9.7 vs. 8.7) and 1.2 t ha^{-1} (15.0 vs. 13.8) for the VB schedule, whereas for VF it was of 0.5 t ha^{-1} (12.2 vs. 11.7) and 3.7 t ha^{-1} (18.1 vs. 14.4) for 1996 and 1997, respectively.

The digestibility values of each cut for the two cutting heights and schedules are reported in Table 4. An increase in OMD was observed with the more frequent cutting schedule (VB), as highlighted in the same environment by Tabacco et al. (2002). For the VB schedule, the higher cutting height increased the mean values of OMD by about 18 and 38 g kg^{-1} OM in 1996 and 1997, respectively. Similar results were achieved for VF schedule with mean values of 19 and 31 g kg^{-1} OM for the two years.

Table 3. Individual cutting and total annual yield (t DM ha^{-1}) in the two experimental years. TDM, total annual dry matter yield; VB, first cut at late vegetative and following cuts at bud stage; VF, first cut at late vegetative and following cuts at early flowering; NS, not significant; **P* < 0.05; ***P* < 0.01; ****P* < 0.001.

Schedule	Cutting height	1996					1997							
		2nd†	3rd	4th	5th	TDM	1st	2nd	3rd	4th	5th	6th	7th	TDM
VB	standard	3.1	2.5	2.1	2.0	9.7	4.4	2.1	2.1	2.6	1.1	1.5	1.2	15.0
	high	2.3	2.6	2.0	1.8	8.7	3.6	1.9	2.0	2.4	1.3	1.5	1.1	13.8
VF	standard	4.4	3.7	2.7	1.4	12.2	4.5	4.3	2.1	3.2	2.3	1.7		18.1
	high	4.4	3.6	2.6	1.1	11.7	3.1	3.3	1.7	2.8	2.1	1.5		14.4
LSD		0.2	0.2	0.3	0.1	0.3	0.8	0.4	0.4	0.8	0.4	0.4	-	0.8
Schedule		***	***	***	***	***	NS	***	NS	NS	***	NS	-	***
Cut height		***	NS	NS	***	***	**	***	NS	NS	NS	NS	NS	***
Schedule × cut height		***	NS	NS	NS	*	NS	*	NS	NS	NS	NS	-	*

†The first cut was made to control weed development and no sampling was performed.

Table 4. Organic matter digestibility (g kg^{-1} OM) in the two years. VB, first cut at late vegetative and following cuts at bud stage; VF, first cut at late vegetative and following cuts at early flowering; NS, not significant; **P* < 0.05; ***P* < 0.01; ****P* < 0.001.

Schedule	Cutting height	1996				1997						
		2nd†	3rd	4th	5th	1st	2nd	3rd	4th	5th	6th	7th
VB	standard	725	712	675	627	757	724	655	652	684	659	746
	high	742	736	699	632	815	756	674	702	714	687	796
VF	standard	646	607	657	598	759	679	676	668	655	631	
	high	682	636	659	607	810	698	728	684	660	672	
LSD		45	36	38	27	34	36	42	30	23	27	
Schedule		***	***	*	*	NS	***	*	NS	***	*	-
Cut height		*	*	NS	NS	***	*	*	**	*	**	**
Schedule × cut height		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-

†The first cut was made to contrast weed development and no sampling was performed.

Table 5. Crude protein, NDF and ADL (g kg^{-1} DM): average values of all cuts in 1996, values of the first cut and of the average of all the other following cuts in 1997. CP, crude protein; NDF, neutral detergent fibre; ADL, acid detergent lignin; VB, first cut at late vegetative and following cuts at bud stage; VF, first cut at late vegetative and following cuts at early flowering; NS, not significant; **P* < 0.05; ***P* < 0.01; ****P* < 0.001.

Schedule	Cutting height	1996			1997					
		CP	NDF	ADL	CP		NDF		ADL	
		All other cuts			1st cut	Other cuts	1st cut	Other cuts	1st cut	Other cuts
VB	standard	204	381	70	215	210	301	400	51	68
	high	213	369	65	228	221	276	358	53	62
VF	standard	192	412	79	217	191	302	418	51	74
	high	201	401	77	227	202	274	398	54	70
LSD		15	11	4	12	10	17	27	3	9
Schedule		*	***	***	NS	***	NS	**	NS	*
Cut height		NS	**	*	*	**	***	**	*	NS
Schedule × cut height		NS	NS	NS	NS	NS	NS	NS	NS	NS

The CP, NDF and ADL are reported in Table 5, as the average values of all cuts in 1996, values of the first cut and of the average of all the other following cuts in 1997. The cutting schedule VB improved the quality in terms of CP, NDF and ADL, except for the first cut in 1997 which is performed at the same late vegetative stage of development.

The higher cutting height significantly improved the quality parameters except for the CP content in 1996 and the ADL content in the summer cuts of 1997. The higher cutting height

Table 6. Plant number at the end of the second year. VB, first cut at late vegetative and following cuts at bud stage; VF, first cut at late vegetative and following cuts at early flowering; NS, not significant; *$P < 0.05$.

	Plant (n° m^{-2})	
	VB	VF
Cutting standard	44	56
Cutting high	58	61
LSD	10	
Schedule	*	
Cut height	*	
Schedule × cut height	NS	

in particular decreased the NDF content with a mean difference of about 27 g kg^{-1} DM. Values of NDF and ADL observed for the high VB schedule over the whole season can be considered to be of great interest for nutritional purposes when their quality can be successfully conserved till animal feeding (Mertens, 2000).

The VB schedule significantly reduced plant number at the end of the second year (Table 6). The higher cutting height in the more frequent cutting schedule resulted in a number of plants similar to those observed for the VF schedule. It is clearly demonstrated that frequent cutting schedules can influence carbohydrate root reserves and the vigour of lucerne stands (e.g. Gossen et al., 1994), while tall stubble furnishes additional energy for initial regrowth after cutting (Sheaffer et al., 1988). These results confirmed those obtained by Reyneri et al. (1995) in the same environment with a cutting height of 4 and 8 cm. However, in environment with little risk of winter chilling damage, a number of about 40-50 plants per squared meter at the end of the second growth year is sufficient to ensure a good yield in the subsequent year (Sheaffer et al., 1988).

3.2 *Quality of stem segments and leaves*

The digestibility of the stems resulted in a great stratification from the bottom to the top parts in both schedules (Table 7). In the bottom parts, digestibility resulted to be very low and constant till 22 cm, with values of around 470 and 400 g kg^{-1} OM for VB and VF, respectively. In the upper zone, it reached a mean value of 564 g kg^{-1} OM in both schedules. The CP content varied with the increasing height of cut, from 80 to 151 g kg^{-1} DM and from 80 to 134 g kg^{-1} DM for the VB and VF, respectively. Downs and Taylor (1989) noted that the protein quality of stemmy portions improves considerably in the top one half of the plant. The CP and OMD of the leaf were almost constant with a mean value of 318 ± 3 g kg^{-1} DM and 769 ± 27 g kg^{-1} OM, respectively (data not shown in table). These values are in agreement with the statements of Mowat et al. (1965) and Kalu and Fick (1983) which found a relative constant value for CP and OMD of lucerne leaf over the whole growth cycle.

3.3 *Forage quality of stratified canopy*

The DM yield and quality of forage harvested at different cutting heights in the second regrowth of 1997 is shown in Figures 1 and 2. A linear reduction in DM yield was observed till 22 cm of cutting height for both schedules. Comparing the standard cutting height (4 cm) with the 22 cm height, a yield reduction of 29% and 21% was observed for VB and VF, respectively, whereas cutting at 40 cm reduced the yield by 68% and 63% for the two cutting schedules (Figure 1a). The yield harvested with cut at 40 cm was similar to the yield of the whole leaves.

The increase in OMD, compared to the standard cutting height, was of 38 and 31 g kg^{-1} OM for 22 cm cutting height and of 96 and 98 g kg^{-1} OM for 40 cm in the two schedules, respectively (Figure 1b). When the cutting height increased from 4 to 40 cm, the CP content of the whole plant ranged from 215 to 279 g kg^{-1} DM for VB and from 196 to 267 g kg^{-1} DM for VF (Figure 2a). At the same time the NDF content decreased from 394 to 258 g kg^{-1} DM and from 413 to 270 g kg^{-1} DM for VB and VF, respectively

Table 7. Organic matter digestibility (OMD) and crude protein (CP) of stem segments of the second regrowth of 1997 for the two cutting schedules. VB, first cut at late vegetative and following cuts at bud stage; VF, first cut at late vegetative and following cuts at early flowering; NS, not significant; **$P < 0.01$; ***$P < 0.001$.

Stem segment (cm)	OMD (g kg^{-1} OM)		CP (g kg^{-1} DM)	
	VB	VF	VB	VF
0-4	446	398	80	80
4-8	467	401	93	75
8-14	472	409	107	75
14-22	482	428	106	86
22-40	514	456	128	104
>40	564	563	151	134
LSD	21		11	
Schedule	***		***	
Cut height	***		***	
Schedule x cut height	***		**	

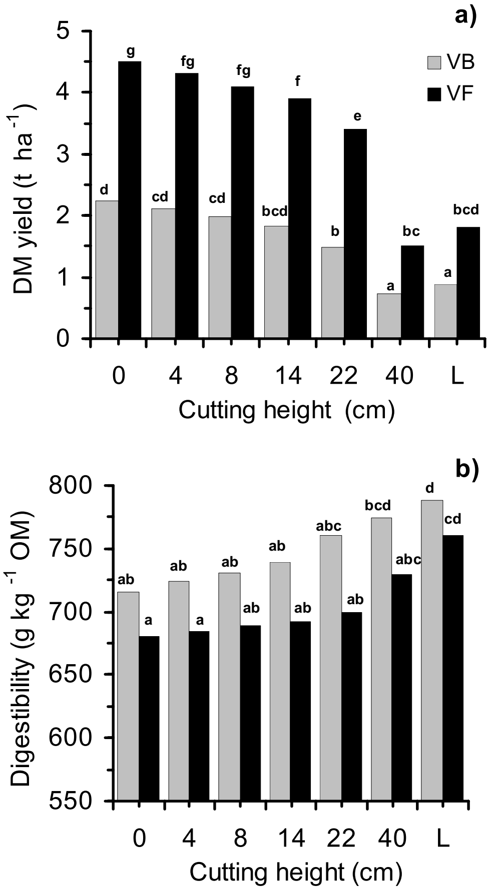

Figure 1. DM yield (a) and digestibility (b) in the second regrowth of 1997 at different cutting height. L, leaf.

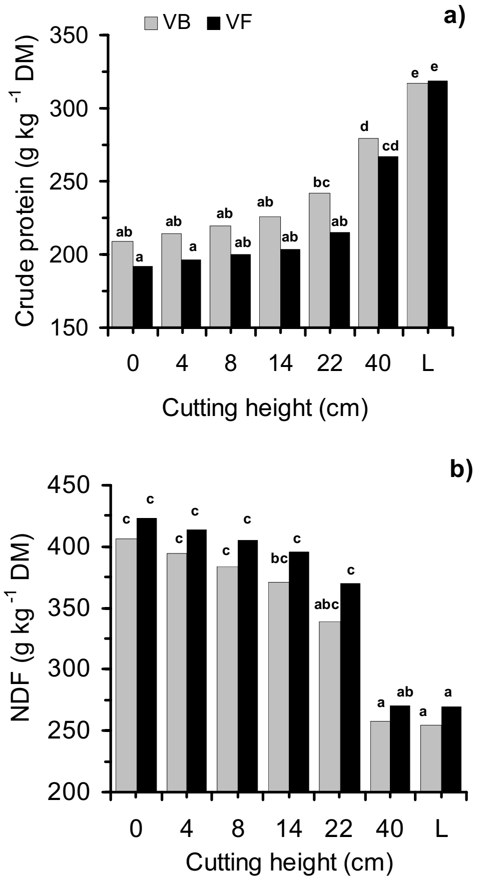

Figure 2. Crude protein (a) and NDF (b) content in the second regrowth of 1997 at different cutting height. L, leaf.

(Figure 2b). Downs and Taylor (1989) found that CP and fibre content of the plant cut at two stages of maturity (early- and mid-flowering) increased faster, with increasing height of cut, in the more mature crop and reached the same values of the younger herbage at a cutting height of 50% of the total plant height (around 35-40 cm).

The same authors (Downs and Taylor, 1989) stated that a cutting height higher than 20 cm at farm scale level requires that the lower portions should be subsequently cut and windrowed for field curing, or green chopped thus increasing harvesting costs and traffic damage to the crop.

The present results have shown that forage pre-harvesting quality can be increased by raising the cutting height, but it should also be considered that following mechanical harvest operations and conservation method can influence the final feeding quality.

4. Conclusions

Increasing the cutting height of lucerne from 4 to 14 cm produces a forage with considerably higher protein and digestibility.

Furthermore higher cutting resulted in a positive influence on the stand persistence. Increase in the cutting height leads to relevant improvement in the forage quality when performed at vegetative and early bud stages, resulting in forage with lower NDF than 370 g kg^{-1} DM, higher CP than 210 g kg^{-1} DM and always higher OMD than 700 g kg^{-1} OM for all the harvests. When cutting was performed on more mature forages, the increase in the height of cut proved to be a valuable method to increase forage quality only with a higher cutting height than 20 cm. This cutting height cannot be applied in the field without creating problems for the subsequent cuts due to the presence of a low quality stubble. Obviously, the cutting height can be raised to 15 cm only when stands are not lodged. Therefore a higher cutting height is applicable in the field when harvesting is performed at early growth stages, especially in the first growth.

Further research is necessary to verify the possibility of harvesting and conserving this high pre-harvest quality under conventional harvesting methods at a farm scale level.

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