RELATIONS BETWEEN YIELD AND NUTRITIVE VALUE OF GRASS OR GRASS-LEGUME MIXTURES AT DIFFERENT CUTTING REGIMES

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SUMMARY. *Six forage stands were used in this study. Four stands consisted of grasses and two stands were legume-grass mixtures: cocksfoot Y 220 (Dactylis glomerata), bromegrass Lehis (Bromus inermis), reed canarygrass Pedja (Phalaris arundinacea), timothy Y 54 (Phleum pratense), lucerne-grass mixture (Medicago sativa, Festuca rubra) and white clover-grass mixture (Trifolium repens, Festuca pratensis, Phleum pratense, Lolium perenne, Festuca rubra). Forage stand plots were randomly assigned in three blocks. Thus, a total of 18 main plots of 6×10 m each were established. For each main plot three cutting frequencies were applied i.e. 4-, 3-, and 2-cuts. Regardless of cutting frequency the first cut was taken at the leaf stage, the second cut at the heading stage, and the third cut at the flowering stage. Subsequent cuts were made according to the growth rate of herbage. The results of two successive years were recorded.*

Nutrient concentrations were highest in the early cut harvests. Both crude protein (CP) and metabolizable energy (ME) concentrations decreased and dry matter (DM) yield increased as herbage matured. As the decline in nutrient concentration was smaller than the gain in crop yield, nutrient yield increased, but at decreasing rates as the crops matured. Thus, nutrient yield should be taken into consideration when optimizing harvest management. The optimal time of the first harvest for obtaining high nutrient yields is when both CP and ME remain on an acceptable level. Thereafter harvest management is determined by growth rate. The inclusion of legumes in grass-legume mixtures contributed nitrogen corresponding to 200 kg N ha^{-1} when compared with grass in pure stands. Legume-grass mixtures also had higher CP concentrations than grass species alone and the decline in nutrients during growth was less. It is concluded that the optimal time of harvest is determined by both nutrient quality and quantity. In general, the 3-fold cutting frequency is more favourable than the others. The use of legumes or legume-grass mixtures is superior to grasses alone.

Key words: *Crude protein, crop, cut, cutting frequency, harvest, herbage, maturity, metabolizable energy, nutrient, quality, stage, yield.*

Introduction

Grass has always been regarded as a basic feed for dairy cows in Estonia. A typical feed ration consists of up to 75 % high quality grass, potentially resulting in 4000 kg milk cow^{-1} year^{-1} (Older *et al.*, 1987). Considering our climatic conditions, the grassland tillage is suitable and economical in Estonia, due to relatively stable crop yields which are approximately double the protein yields of other fodder crops (Older *et al.*, 1989).

Good quality grass is available during the whole growing season, provided it remains in the vegetative growth phase. Silage crop can be cut earlier and is superior to hay. The main problem is that the first cut often is taken too late. Therefore, the subsequent cuts are delayed or unharvested (Toomre *et al.*, 1993). Delayed harvests cause decrease in nutrients of the herbage due to advanced maturity. Losses of nutrients arising during conservation are well known. To obtain acceptable nutrient concentrations, especially of protein and metabolizable energy in herbage, the optimal time of the first cut must be found. The timing of this cut affects subsequent cuts and the number of cuts. Because little attention has been paid to the energy concentration of herbage, this issue deserves particular emphasis and consideration. From a nutritional point of view there are no essential differences between grazing and cutting. However, the frequency of cuts and the stage of maturity of herbage significantly affects the energy concentration. On the other hand, too early and too frequent cuts may result in too low nutrient yields. Young, fresh forage is usually rich in protein and metabolizable energy, while the dry matter concentration and yield is low. Therefore the total yield of nutrients may be considerably lower at frequent than infrequent cutting regardless of a high nutrient concentration. The cutting regime may also influence the vernal development of plants. Too frequent cutting may cause disturbances in plant development by slowing or reducing growth. As a consequence, shorter plants and lower yield may be expected in the following year (Tamm, U., Tamm, S., 1992). Some of the species may not even survive too frequent cutting and may soon be eliminated from the sward. This fact is detrimental to nutrient yield, and must be taken into consideration. When crops are harvested frequently, a lower total yield of nutrients may be obtained with a larger energy input leading to a lower energy output. Therefore, the efficiency of forage production may decline, irrespective of high nutrient concentration in the herbage.

Objective

The aim of the present investigation was to study nutrient quality and nutrient quantity at different cutting regimes with different types of sward. Energy concentration in the feed as one of the major nutrients is more pronounced depending on various factors.

Materials and Methods

The conditions for experiment. Six stands with different forage types were used in this study. Four stands consisted of pure grasses and two stands of legume- grass mixtures as follows: cocksfoot ‘Y 220’ (*Dactylis glomerata*), bromegrass Lehis (*Bromus inermis*), reed canarygrass ‘Pedja’ (*Phalaris arundinacea*), timothy ‘Y 54’ (*Phleum pratense*), lucerne-grass mixture (*Medicago sativa*, *Festuca rubra*) and white clover-grass mixture (*Trifolium repens, Festuca pratensis, Phleum pratense, Lolium perenne, Festuca rubra*). Stands were established by direct seeding on a 0.8 ha paddock at Juuliku Experimental Farm in 1989 (Table 1). Each of the six stands was randomly arranged in three blocks. The blocks were separated by alley. Thus, a total of 18 main plots was established, each measuring 6×10 m.

Table 1. Seeding rates

Plot	Species, mixtures	Seeding rate kg ha^{-1}
A	Cocksfoot Y 220 (*Dactylis glomerata*)	20
B	Bromegrass Lehis (*Bromus inermis*)	38
C	Reed canarygrass Pedja (*Phalaris arundinacea*)	15
D	Timothy Y 54 (*Phleum pratense*)	10
E	Lucerne (*Medicago sativa*), red fescue (*Festuca rubra*)	20, 12
F	White clover (*Trifolium repens*), meadow fescue (*Festuca pratensis*), timothy, ryegrass (*Lolium perenne*), red fescue	5, 10, 8, 4, 1.5

The study was conducted for two years in 1990 and 1992. Three cutting frequencies were applied for the six stands: i.e. 4-, 3- or 2-cuts depending on the time of the first cut. Each main plot was subdivided into three subplots of equal size to study the three cutting frequencies. The first cut in each subplot was carried out at leaf-, heading-, and flowering stage. The following cuts of regrowth were taken according to growth rate. The cutting times of crop within growing season in both years are listed in Table 2. Weather data are presented in Table 3.

Table 2. The cutting time of crops in 1990…1991. Depending on time of first cut 4-, 3-, and 2-cutting frequencies were used during the growing season. The first cut of grasses were conducted at leaf, heading and flowering emergence stages

Species	Early first cut (leaf emergence)	Medium first cut (head emergence)	Late first cut (flower emergence)

	cuts							cuts					cuts		
	1		2		3		4	1		2		3	1		2
		Days[1]		Days		Days			Days		Days			Days	
1990															
Cocksfoot	28.05	29	26.06	42	07.08	45	22.09	12.06	42	24.07	36	29.08	25.06	55	19.08
Bromegrass	28.05	29	26.06	42	07.08	45	22.09	15.06	39	24.07	36	29.08	27.06	53	19.08
Reed canary grass	28.05	29	26.06	42	07.08	45	22.09	17.06	40	27.07	33	29.08	28.06	50	23.08
Timothy	28.05	30	27.06	42	08.08	44	22.09	17.06	40	27.07	37	02.09	01.07	53	23.08
Lucerne-grass mixture	28.05	30	27.06	42	08.08	44	22.09	17.06	40	27.07	37	02.09	01.07	53	23.08
White clover	28.05	30	27.06	42	08.08	44	22.09	17.06	40	27.07	37	02.09	01.07	53	23.08
1991															
Cocksfoot	07.06	34	12.07	34	15.08	41	26.09	27.06	43	09.08	27	05.09	09.07	55	02.09
Bromegrass	07.06	34	12.07	34	15.08	41	26.09	27.06	43	09.08	27	05.09	09.07	55	02.09
Reed canary grass	07.06	34	12.07	34	15.08	41	26.09	27.06	43	09.08	27	05.09	09.07	55	02.09
Timothy	07.06	34	12.07	34	15.08	41	26.09	27.06	43	09.08	27	05.09	09.07	55	02.09
Lucerne-grass mixture	07.06	34	12.07	34	15.08	41	26.09	27.06	43	09.08	27	05.09	10.07	56	02.09
White clover	07.06	34	12.07	34	15.08	41	26.09	27.06	43	09.08	27	05.09	10.07	56	02.09

[1] Days between cuts

Table 3. The average rainfall and ambient air temperature during the vegetation period in 1990…1991

Month		Rainfall (mm)			Ambient air temperature (°C)		
		1990	1991	Long-time average	1990	1991	Long-time average
May	10	0	12	12	11.0	9.1	6.7
	20	10	12	14	8.6	8.2	8.4
	30	22	6	15	8.6	8.6	10.1
Average		32	30	41	9.4	8.6	8.4
June	10	0	10	13	13.6	12.2	11.6
	20	17	12	20	12.1	12.8	13.2
	30	3	9	17	16.6	15.4	14.6
Average		20	31	50	14.1	13.4	13.1
July	10	27	42	15	15.8	17.2	16.0
	20	93	45	19	14.8	16.8	16.6
	30	1	0	25	15.8	16.4	16.6
Average		121	87	59	15.5	16.8	16.4
August	10	19	13	27	17.0	17.1	16.0
	20	43	42	27	16.6	16.2	15.1
	30	38	50	21	14.0	15.2	14.0
Average		100	105	75	15.9	16.2	15.0
September	10	31	12	23	11.0	11.4	12.6
	20	9	18	21	8.5	10.2	11.1
	30	66	41	20	7.1	8.2	9.4
Average		106	71	64	8.9	9.9	11.0
5 month average		379	324	289	12.8	13.0	12.8

The soil type was classified as a limestone rendzina (rendzic leptosol by the classification UNESCO-FAO, 1986) with the following characteristics: humus layer 15…18 cm, pH_{KCl} 6.4…6.7, humus content 4.4…4.7 %, hydrolytic acidity 0.4…0.7 mg-eqv $100g^{-1}$, P_2O_5 22…35 mg $100g^{-1}$, K_2O 16…28 mg $100g^{-1}$.

Mineral fertilizers were applied as follows: phosphorus- potassium fertilizers were given only once each year after the growing season at a rate of 60 and 90 kg ha^{-1}, respectively

($P_{60}K_{90}$), nitrogen fertilizers were applied twice, i.e. before the intensive growth stage (at the end of April or beginning of May) and then in the first half of July (100 kg ha^{-1}, N100) in each year. The phosphorus-potassium fertilizer was applied to all crops, whereas the nitrogen fertilizer was applied to the grasses only.

Forages were harvested by a minimotor cutting machine (MF-70), with a scythe width of 1.0 m at a cutting-height of 6 cm. The cutting was done between 10^{00}…14^{00} and during dry conditions only. Forages were cut in the order of species composition with three replicate subplots harvested in succession. The weight of fresh crop of each subplot (1×10 m) was determined with a steelyard (preciseness ± 0.05 kg). One composite sample from three replicate plots (1.5…2.0 kg) was placed in a cheese-cloth bag for dry matter determination and chemical analyses. The following determinations were made: crude protein (Kjeldahl method), crude fibre, crude fat (Niine, 1982), crude ash, metabolizable energy (Oll, 1994), digestible crude protein (Pålson, 1973). Dry matter (DM) was determined by a two-step drying procedure: samples were dried at 65° C for 18 hours, and then dried at 105° C for 5 hours. Metabolizable energy was derived from gross energy by applying a coefficient of metabolizability (Oll, 1994). Gross energy was calculated as the sum of the energy concentration of each nutrient:

$$GE\ (MJ\ kg^{-1}\ DM) = 23.9 \times CP + 39.8 \times CFT + 20.1 \times CF + 17.5 \times NFE$$

where CP – crude protein (%/100), CFT – crude fat (%/100), CF – crude fibre (%/100), NFE – nitrogen free extractives (%/100).

$$ME\ (MJ\ kg^{-1}\ DM) = GE \times q$$

where q – coefficient of metabolizability of gross energy

$$q = \frac{ME}{GE}$$

The coefficient of metabolizable energy was calculated for the different species as follows:

$$q_{grass} = 0.864 - 0.0108 \times CF$$

$$q_{legume + grass} = 0.807 - 0.0093 \times CF$$

where CF – crude fibre (%).

The coefficient of digestibility crude protein was calculated according to Pålson (1973):

$$k = 93.9 - 3130/CP,\ \%$$

where CP – crude protein concentration, g kg^{-1} DM.

Digestible crude protein (DCP) was calculated as follows:

$$DCP = k \times CP,\ g\ kg^{-1}\ DM.$$

Statistical methods. The results were examined statistically by analysis of variance. Total yield of nutrients was examined by the following model:

$$Y_{ijkl} = \mu + species_i + year_j + (year \times species)_{ij} + cuts_k + (species \times cuts)_{ik} + error_{ijkl}$$

(i=6 species, j=2 years, k=3 cutting frequencies)

μ=overall mean n=36

The yield of nutrients and chemical composition of single cuts was examined by the following model:

$$Y_{ijkl} = \mu + species_i + year_j + (species \times year)_{ij} + cuts_k \times error_{ijkl}$$

(i=6 species, j=2 years, k=9 cuts)

μ=overall mean n=108

When grasses and legume-grass mixtures were separated the following model was used:

$$Y_{ijkl} = \mu + crop_i + year_j + (crop \times year)_{ij} + cuts_k + error_{ijkl}$$

(i=2 crops type, j=2 years, k=9 cuts)

μ=overall mean n=108

All statistical analyses were carried out by using the GLM procedure of the computer package SAS (SAS Institute Inc., 1989).

Results

The results will focus on the general effects of the number of cuts, type of crops and stage of maturity on nutrient quality and nutrient yield. The results of the chemical analyses are presented as averaged for cuts and/or species.

Dry matter yield. The harvest times and intervals between cutting are presented in Table 2. The results of dry matter yield (DMY) from both years are listed in Tables 4, 5 and 6. The DMY of herbage followed the yield of fresh matter (FM) and the changes in DM concentration. The DM concentration was lower when the crop was harvested early and frequently, but the DM of the first cut increased as herbage matured (Tables 4, 5, 6 and Fig. 1, 2).

Table 4. Cutting frequency effect on total crop yield

Cutting frequency	DMY[a] 10^2 kg ha^{-1}	GEA[b] GJ ha^{-1}	MEA[c] GJ ha^{-1}	CPY[d] kg/ha^{-1}
4	85.0	157.5	92.9	1282
3	93.3	171.5	96.6	1304
2	124.1	219.6	122.9	1324
Mean	100.8	182.7	104.1	1303
$LSD_{0.05}$[e]	5.6	13.1	5.5	134
P>F[f]	0.0001	0.0001	0.0001	0.8

[a] Total dry matter yield
[b] Total gross energy accumulation (yield)
[c] Total metabolizable energy accumulation (yield)
[d] Total crude protein yield
[e] Least significant difference of a cutting frequency mean. The means are based on 12 observations
[f] Probability of a larger F-value

Table 5. Species in pure or mixed stands and their effect on total yield averaged over cuts

Species	DMY[a] 10^2 kg ha^{-1}	GEA[b] GJ ha^{-1}	MEA[c] GJ ha^{-1}	CPY[d] kg/ha^{-1}
Cocksfoot	112.7	190.0	114.4	1336
Bromegrass	122.7	226.7	125.2	1507
Reed canary grass	103.4	192.8	106.7	1246
Timothy	100.2	184.4	103.3	1192
Lucerne-grass mixture	81.2	148.5	84.0	996
White clover-grass mixture	84.6	154.1	91.5	1542
Mean	100.8	182.7	104.1	1303
$LSD_{0.05}$[e]	29.9	50.8	31.8	367.5
P>F[f]	0.09	0.07	0.13	0.07

a, b, c, d, e, f – See Table 4

Table 6. Cutting frequency effect on crop yield of cuts. The results are averaged over cuts, 4-cuts n=48, 3-cuts n=36, 2-cuts n=24

Cutting frequency	DMY[a] 10^2 kg ha^{-1}	GEA[b] GJ ha^{-1}	MEA[c] GJ ha^{-1}	CPY[d] kg/ha^{-1}

4	21.3	39.4	23.2	320.4
3	31.1	57.0	32.2	435.0
2	62.1	114.0	64.4	661.7
Mean	33.6	61.9	34.7	434.0
LSD$_{0.05}$[e]	7.6	13.9	7.5	91.6
P>F[f]	0.0001	0.0001	0.0001	0.0001

[a] Dry matter yield of cuts
[b] Gross energy accumulation of cuts
[c] Metabolizable energy accumulation of cuts
[d] Crude protein yield of cuts
[e] Least significant difference of a cutting frequency mean. The means are based on harmonic mean. n=33.2
[f] Probability of a larger F-value

In the intensive growing phase biomass increased rapidly. The lowest DMY value of 2.2 ton ha^{-1} was obtained from earlier cuts when the herbage was harvested at the leaf stage. The DMY was doubled to 4.6 ton ha^{-1} at the heading stage, while the highest DMY of 7.5 ton ha^{-1} was obtained at the flowering stage. The intervals between cuts were at first 15…20 days and then 28…33 days. The differences in DMY were considerably larger at the beginning of growth.

The average total DMY from all species was 10.1 ton ha^{-1}. Total DMY between species varied but the differences were not significant ($P<0.09$, Table 5). When comparing the cutting frequencies, average total yield was lowest at 4-cuts and highest at 2-cuts ($P<0.0001$, Table 4). Cutting frequency affected the DMY of single cuts ($P<0.0001$, Table 6). The differences in yields between years and species were significant because cocksfoot is an early maturing species. Bromegrass and reed canarygrass are medium maturing species and timothy is late. The DMY of the white clover-grass mixture was considerably lower in 1990 than in 1991 resulting in lower yields of legume-grass mixtures.

Crude protein yield. The results of crude protein yield (CPY) are presented in Tables 4, 5, 6 and Fig. 3. The CPY increased according to stage of maturity (Fig. 3). In the first cut the CPY was higher at heading. Thereafter the CPY generally decreased at flowering because of low protein concentration in the herbage. Despite the considerable high CP concentrations of herbages at the early harvest (4-cuts), total CPY did not differ at different cutting frequencies due to higher DMY in the later harvest (Table 4). However, it is notable that the average CPY still was higher when crops were harvested less frequently. There were almost no significant differences between species in total protein yield ($P<0.07$). The average yields of the white clover-grass mixture and bromegrass were higher than those of other stands (Table 5). The low yield of the lucerne-grass mixture depended on poor winter survival of lucerne.

Gross energy and metabolizable energy yield. Changes in gross energy yield (GEY) followed changes in the DMY. Metabolizable energy decreased in herbage with advanced maturity and when the crop was less frequently harvested. The slope of this decline of legume-grass mixtures was less than that of the grasses (Fig. 4). Metabolizable energy yield (MEY) was calculated as DMY multiplied by ME of herbage. As absolute changes in DMY were large, most of the results were influenced by changes in DMY (Tables 4, 5 and 6).

Crude protein. The average CP concentration (182 g kg^{-1} DM) was highest in early cut crops, harvested at the leaf emergence stage. The protein concentration decreased approximately by 24 % for 15…20 days later at the heading stage (decreasing 2.2…2.9 g CP kg^{-1} DM day^{-1}). When herbage was harvested at flowering, protein decreased by 43 % compared to the first cutting time (2.4…2.8 g CP kg^{-1} DM day^{-1}). The decline in protein was similar in grass species, but in the white clover-grass mixture protein decreased by 18 % only (1.1 g CP kg^{-1} DM day^{-1}).

Figure 1. Dry matter yield of grasses and legume-grass mixtures. LSD=3.8 of each cuts mean, grasses mean=36.6 and legume-grass mixture mean=27.6, based on harmonic mean n=48; LSD=7.6 of cuts mean, overall mean=33.6, based on harmonic mean n=33.2; LSD=5.6 of a total yield mean, overall mean=100.8, based on 12 observations

Figure 2. Dry matter concentration of grasses and legume-grass mixtures. LSD=13.8 of each cuts mean, grasses mean=244 and legume-grass mixture mean=247, based on harmonic mean n=48 (P<0.65); LSD=23 of cuts mean, overall mean=245, based on harmonic mean n=33.2 (P<0.0001)

Figure 3. Crude protein yield of grasses and legume-grass mixtures. LSD=58.4 of each cuts mean, grasses mean=431.9 and legume-grass mixture mean=423.0, based on harmonic mean n=48; LSD=90.4 of cuts mean, overall mean=428.9, based on harmonic mean n=33.2; LSD=133.9 of a total yield mean, overall mean=133.9, based on 12 observations

Figure 4. Metabolizable energy yield of grasses and legume-grass mixtures. LSD=3.8 of each cuts mean, grasses mean=37.5 and legume-grass mixture mean=29.2, based on harmonic mean n=48; LSD=7.5 of cuts mean, overall mean=34.7, based on harmonic mean n=33.2; LSD=5.5 of a total yield mean, overall mean=104.1, based on 12 observations

Differences in average protein concentrations between cuts were significant when three cutting frequencies were used or when grasses and legume-grass mixtures were compared (P<0.0001, Tables 7, 8 and Fig. 5). These results imply that the protein concentration decreased slowly in early and moderately harvested crops and more rapidly at the later stage.

Table 7. Cutting frequency effect on chemical composition of crop. The results are averaged over cuttings, 4-cuts n=48, 3-cuts n=36, 2-cuts n=24

Cutting frequency	DM	CP	CF	CFT	Crude ash	GE	ME	DCP
	gkg^{-1}	$g\ kg^{-1}$ DM				$MJ\ kg^{-1}$ DM		$g\ kg^{-1}$ DM
4	229	155	246	31	88	18.3	10.9	114
3	231	144	268	28	81	18.3	10.4	104
2	299	112	284	26	72	18.3	10.1	74
Mean	245	142	262	29	82	18.3	10.6	102
$LSD_{0.05}$[a]	23.0	13.1	11.7	2.3	6.0	0.12	0.24	12.3
P>F	0.0001	0.0001	0.0001	0.0001	0.0001	0.9	0.0001	0.0001

[a] The means are based on harmonic mean n= 33.2

Table 8. Species effect on chemical composition of crop. The results are averaged over cuts

Species	DM	CP	CF	CFT	Crude ash	GE	ME	DCP
	gkg^{-1}	$g\ kg^{-1}$ DM				$MJ\ kg^{-1}$ DM		$g\ kg^{-1}$ DM
Cocksfoot	239	129	278	31	83	18.3	10.3	90
Bromegrass	248	135	273	28	73	18.4	10.5	96
Reed canarygrass	240	138	272	29	81	18.3	10.4	99
Timothy	250	130	269	30	76	18.4	10.6	91
Lucerne-grass mixture	273	128	246	27	81	18.2	10.6	89
White clover-grass mixture	222	190	231	29	100	18.2	11.0	147
Mean	245	142	262	29	82	18.3	10.6	102
$LSD_{0.05}$[a]	37.4	15.0	28.9	8.8	8.4	0.3	0.66	14.5
P>F	0.18	0.001	0.05	0.84	0.004	0.30	0.31	0.001

[a] The means are based on 18 observations

Crude fibre. The average CF concentration increased from 219 g kg^{-1} in early crops to 279 after 15…20 days later (increasing 3…4 g kg^{-1} day^{-1}). In the late cut crops, harvested at the flowering emergence stage the CF increased by 35 % (2.3…2.8 g kg^{-1} day^{-1}). The more frequently crops were harvested during the growing season, the lower CF concentration (Tables 7 and 8). At 4-cuts the average CF concentration was 246 g kg^{-1} DM, which increased approximately by 8 % and 15 % in subsequent cuts. The average CF concentrations for grasses and legume-grass mixtures were 273 and 239 g kg^{-1} DM, respectively (P<0.0001). The crude fibre concentrations of legume-grass mixtures were always lower than those of grasses, even when herbages were harvested at the late flower emergence stage.

Crude fat. The concentration of crude fat was slightly higher in earlier harvested crops, but decreased with advanced maturity and with less frequent cuts.

Crude ash. The concentration of ash decreased with advanced maturity. The average ash concentrations of grasses and lucerne-grass mixtures were similar but a significantly higher concentration was found in the white clover-grass mixture (Table 8).

Gross energy. The average GE concentration of herbage was 18.3 MJ kg^{-1} DM. Despite slight variations among the different crops these values were not related to crop type.

Metabolizable energy. Herbages harvested at the leaf stage had the highest concentration of ME. The average ME of first cut declined as the herbage matured when it was harvested at the flower emergence stage. Overall, ME decreased from 11.6 to 9.8 MJ kg^{-1} DM in grass species and from 11.5 to 10.1 MJ kg^{-1} DM in legume-grass mixtures (decline 0.055 and 0.042 MJ kg^{-1} DM day^{-1}, respectively). This decline was more rapid in grasses and larger when subsequent growth was harvested. The ME in regrowth was high and similar in legume-grass mixtures, indicating advantages of legume-grass mixture systems. As expected the cutting frequency significantly affected the ME value (Table 7). Differences between the highest and lowest levels of ME were about 0.8 MJ kg^{-1}. The means for the grass species were fairly similar (Table 8), but legume-grass mixtures had higher ME concentrations than pure grasses, 10.8 MJ kg^{-1} DM versus 10.5 MJ kg^{-1} DM (Fig. 6).

Discussion

In this study the harvest strategy considered the influence of cutting frequencies on stage of maturity and nutritive value of herbage. Different types of swards were used to study forage quality. The first cuts were conducted as early, medium and late harvest and 4-, 3-, and 2-cuts were applied during growth of the herbages. In the second year the cuts were made slightly later as the growth of forage grass was delayed due to less favourable weather during the spring.

The results indicate the importance of timing the first cut, because growth rate determines the number of cuts thereafter. The CP and ME concentrations were the main parameters describing forage quality. The concentrations of CP and ME were highest and CF lowest in the earlier cuttings. As the ME value is strongly related to the CF concentration, the values of ME followed the changes in CF. Both the concentrations of CP and ME declined and CF increased in the grass and legume-grass mixture during growth and as the plants matured. In general, decreases in CP and CF were similar to those found by Kivimäe (1959) in a long-term field experiment carried out in Uppsala and Öjebyn. Kivimäe (1959) obtained an average decrease of 2.79 g CP kg^{-1} DM day^{-1} in timothy from pre-shooting to full flowering in years with normal spring weather. The similar results reflect similar growing conditions at high latitudes. Kivimäe (1959) found that ambient temperature and precipitation may have a considerable influence on forage composition. In fact, the long-term average temperature was 12.8° C, *vs.* 12.9° C and long-time average rainfall 276 mm, *vs.* 289 mm during the growing season in Uppsala and in Saku, respectively. The results of Kivimäe showed that a warm spring and sufficient precipitation led to high concentrations of CP at the beginning of growth which then decreased following a sigmoid curve. A cold and/or dry spring delays growth and grass has a low CP concentration and a subsequently lower decline in CP.

On the other hand the DMY of the early cut crop was always low. This resulted in a low yield of nutrients, despite high nutrient concentrations in the herbage. Moreover, the yields of the following regrowth were relatively low after frequently harvesting. This resulted in a lower total MEY and CPY compared to fewer cuttings.

There was a significant relationship between nutrient quality and crop quantity of first cut herbage in this study (Fig. 7 and 8). As both ME and CP concentrations declined curvilinearly during growth, the DMY increased progressively r^2=0.79-0.85 ($P<0.0001$). Similar results were obtained for the legume-grass mixtures, but nutrient concentrations declined at lower rates. The relationship between CP concentration and DMY became less obvious, r^2=0.13, due to low CP concentration in the lucerne-grass mixture.

Figure 5. Crude protein concentration of grasses and legume-grass mixtures. LSD=12.0 of each cuts mean, grasses mean=133 and legume-grass mixture mean=159, based on harmonic mean n=48 (P<0.0001); LSD=13.1 of cuts mean, overall mean=142, based on harmonic mean n=33.2 (P<0.0001)

Figure 6. Metabolizable energy concentration of grasses and legume-grass mixtures. LSD=0.17 of each cuts mean, grasses mean=10.5 and legume-grass mixture mean=10.8, based on harmonic mean n=48 (P<0.0001); LSD=0.24 of cuts mean, overall mean=10.6, based on harmonic mean n=33.2 (P<0.0001)

Figure 7. Concentration of crude protein and crude fibre of first cut herbage of grasses and legume-grass mixtures depending on dry matter yield

Figure 8. Concentration of metabolizable energy of first cut herbage of grasses and legume-grass mixtures depending on dry matter yield

The optimum time for making the first cut is determined by the decline in nutrient concentration and gain in DMY. Because the quantity of DM increased rapidly during growing, much higher nutrient yields may be expected in crop harvested at the optimal time. The criterion of optimal cutting time could be expected to occur before nutrients reached the maximal yield. In Sweden the critical level of nutrients is regarded to be 120 g digestible CP kg^{-1} DM (CP 160 g kg^{-1} DM) and ME not below 10 MJ kg^{-1} DM at a N fertilizer rate of between 70 and 100 kg N ha^{-1} before the first cut in a pure grass ley (Fagerberg, 1988; Gustavsson, 1994). However, the optimal energy value of forage for high yielding dairy cows is recommended to be even higher, being in the range of 11.5 to 12.5 ME kg^{-1} OM (Lindgren, Lindberg, 1988). In a balanced ration fed to dairy cows forage DM intake should exceed 1.5 % of live weight (Bertilsson, Burstedt, 1983).

In Estonia more grass is used in the feed ration and less concentrate, resulting in a generally low milk yield per lactation. In addition, the grass often has a low nutritive value due to delayed harvest and conservation. Therefore, one expects a lower milk yield than in Sweden for instance, which only reaches to a moderate level in most cases. On the other hand, milk yield and nutrient quality are closely related. When lower milk yield, then lower nutrient requirements are expected. It is estimated that at a milk production level of 10 kg cow^{-1} day^{-1}, the ME in grass should be 6.4 MJ kg^{-1} DM and the digestible crude protein (DCP) 53 g DCP kg^{-1} DM, but at a production level of 20 kg cow^{-1} day^{-1}, the ME and DCP has to be much higher i.e. 10.2 MJ kg^{-1} DM and 93 g DCP kg^{-1} DM, respectively (Older *et al.*, 1987). As a consequence, to obtain an acceptable milk yield, the CP and ME concentrations in grass must be high enough to cover animal requirements. A suitable forage conservation method must also be chosen to preserve nutrients in the herbage with low losses.

Considering the average criteria, the CP concentration reached the critical level at a DM yield between 3.5…4.0 t ha^{-1} in the grass species. The ME decreased to 10.5…10.6 MJ kg^{-1} DM and CF did not exceed 250 g kg^{-1} DM. For legume-grass mixtures at 3.5 t DM ha^{-1} the ME and CP values decreased to the critical level, but the decline in concentration of CP and ME was small.

In general, these results showed that a cutting frequency of three cuts per season was more favourable than two or four cuts. However, in the present study the first cut in the 3-cut system was obviously carried out too late because nutrient concentrations were below the critical limit. The highest DMY and also nutrient yields were obtained in the 2-cut system, but the grass herbages had a very low nutritive value. Therefore harvesting too late (at the end of June or beginning of July) does not favour high quality feed.

The choice of ensiling versus hay is determined by the stage of development of the herbage. With early or medium harvested crops (leaf, heading emergence stage) silage making is indicated, but at a later stage, (beginning of flowering or full flowering) hay making is preferable. Silage making is less dependent on weather and is a suitable conservation method for young grass, giving the greatest potential to minimize the losses and preserve the nutrients in the herbage (McDonald *et al.*, 1991). Haymaking has long been a traditional technique, but this requires a delayed harvest with high DM concentration. This decreases the nutrient concentration and digestibility of grass crops. Further, haymaking is to a large extent dependent on the weather, with potentially very high losses during the drying process.

The results also imply the importance of growing legumes. Unlike grasses, legumes are capable of fixing atmospheric N. Because legumes require no N-fertilizer, leaching of nitrate to the ground water may be reduced and the cost of 100…300 kg fertilizer N ha^{-1} $year^{-1}$ may be saved. In this study it was estimated that legumes fixed 200 kg N ha^{-1}, an amount which was applied to pure stands of grasses. Despite the slightly higher DMY and MEY of grasses, white clover-grass mixture had considerably higher nutrient concentrations and lower nutrient decline. These results imply that legumes play an indispensable role as a source of nitrogen for grassland and as a crop to obtain high quality feed rich in nutrients.

When nitrogen fertilizers were easily available, grass swards usually dominated, because in comparison with legumes they are more persistent and have a higher and more stable yield especially on unsuitable soils and under unfavourable climatic conditions. However, when the usage mineral nitrogen is expensive and the growing conditions for legumes are good or satisfactory the legume-grass mixtures deserve greater emphasis.

Conclusions

To obtain high quality grass feed the results of this experiment showed the importance of estimating the optimal time of first harvest. This faciliates the choice of subsequent cutting times or rhythmicity in harvesting. From an economical point of view the optimal harvest should include aspects of both nutrient quality and nutrient quantity of herbage during growth. The results showed also the importance of growing legumes to reduce the need of N-fertilizers. Legume-grass mixtures also had higher nutrient concentrations and a lower nutrient decline.

KOKKUVÕTE: Kõrreliste ja kõrreliste liblikõieliste heintaimikute rohusaagi ja toiteväärtuse vahelistest seostest erineva niitmisrežiimi korral. *Käesoleva töö eesmärgiks oli selgitada eri heintaimeliikide ja nende koosluste saagikust ja rohu toiteväärtust sõltuvalt niitmisrežiimist. Katses oli kuus heintaimikut, neli neist olid puhasliigid, kaks liblikõieliste ja kõrreliste segud. Puhasliikidest olid katses harilik kerahein, ohtetu püsikluste, päideroog ja põldtimut. Ühes segus olid harilik lutsern ja punane aruhein, teises valge ristik koos hariliku ja punase aruheina, põldtimuti ning inglise raiheinaga. Ühtekokku oli katses 18 lappi (6 varianti kolmes korduses). Iga lapp oli omakorda jagatud kolmeks, kusjuures ühte kolmandikku niideti kaks, teist kolm ja kolmandat neli korda vegetatsiooniperioodi jooksul. Neljakordsel niitmisel tehti esimene niide võrsumise, kolmekordsel niitmisel loomise ja kahekordsel niitmisel õitsemise staadiumis. Järgmiste niitmiste aja määras rohukasvu kiirus. Uurimise all olid kahe aasta (1990 ja 1992) saagiandmed ja katselappidelt võetud proovid.*

Varase niite rohu kuivaine oli toitaineterikkam. Vananedes väheneb selles proteiini ja metaboliseeruva energia sisaldus, kuivaine saak aga suureneb. Et aga teatava piirini vananedes kaalub toitainete saagise suurenemine üles nende sisalduse vähenemise kuivaines, saadakse optimaalne tulemus mitte väga varasel niitmisel (võrsumise staadiumis), vaid mõnevõrra hilisema niitmise korral. Et tagada korralik toitainete saak, ei saa taotleda ainuüksi rohu kuivaine suurt proteiini ja metaboliseeruva energia sisaldust, vaid pigem tuleb silmas pidada, et need ei langeks headele piimalehmadele etteseatud kontsentratsioonimääradest allapoole. Liblikõieliste lülitamine heintaimede seemnesegusse aitab lämmastikväetisi kokku hoida, võrreldes kõrreliste heintaimikuga 200 kg N hektari kohta. Liblikõielisi sisaldavas rohus on rohkem proteiini, vananedes vähenevad selles toitainete kontsentratsioonid aeglasemalt kui kõrreliste rohus.

Üldjärelduseks on, et heintaimede niitmise aja määravad nii rohu kvantiteet (rohu saak) kui kvaliteet (toitainete ja energia sisaldus kuivaines). Kolmekordsel niitmissagedusel on eeliseid nii kahe- kui ka neljakordse niitmissageduse ees. Kõrrelistest heintaimikutest on paremad liblikõielistest või nende ja kõrreliste segust koosnevad heintaimikud.

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