Influence of cutting frequency in Alpine permanent grassland on nutritive value, DM yield and agronomic parameters of milk production

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Abstract

The objective of the study was to investigate the impact of cutting frequency and fertilisation on yield and nutrient content in Alpine permanent grassland as well as on agronomic parameters of milk production with dairy cows depending on these grassland management factors. The experiment was based on a 3 × 3 two-factorial design, consisting of 3 levels of cutting frequency (2, 3, 4 cuts per year) and 3 levels of fertilisation (80, 160, 240 kg N per hectare). The nutrients were supplied both by liquid manure (15, 30 and 45 m³ per ha) and mineral fertilizers. Cutting frequency showed a highly significant impact on an all nutrient parameters investigated (10.5, 13.0, 16.4 % CP; 60.0, 52.4, 45.1 % NDF; 54.4, 65.7, 74.2 % dOM *in vitro*; 69.1, 75.9, 82.1 % *in situ* DM degradability). DM yield was highest at medium cutting frequency (10717, 11198, 10756 kg DM), but differences were not great, although significant.

Based on the results of the grassland experiment, model calculations were carried out for both a feeding regime without concentrate and a concentrate supply according to animal requirements. The impact of forage quality on feed intake is of major consequence. By higher forage intake – accompanied with lower DM yield of grassland – the possible stocking rate is significantly reduced with cutting frequency (1.62, 1.60, 1.47 and 2.21, 1.87, 1.55 cows per ha with the two concentrate levels). From this it follows that the improved feed intake (and therefore milk yield) on animal level does not necessarily result in higher milk productivity on area level (i.e. milk yield per hectare). The same is true for N excretion. Furthermore, there is a significant interaction between cutting frequency of grassland and concentrate level in dairy cow feeding. At low concentrate levels, the increase of individual milk yield and N excretion exceeds the effect of the reduced stocking rate, resulting in higher milk yield (4654, 7049, 8310 kg) and N excretion (127, 149, 181 kg) per hectare forage area. The opposite is true for concentrate levels necessary to fulfill nutrient requirements of the cows. The highest milk yield (14207, 12003, 10118 kg) and N excretion (207, 183, 189 kg) per hectare forage area can be expected at low cutting frequency. However, when the results are related to the total area necessary for milk production (i.e. forage plus concentrates), the highest milk yield and N excretion is achieved with high cutting frequency of grassland.

As a conclusion, optimal cutting frequency of permanent grassland on the one hand has to consider a sustainable grassland management aiming at a stable botanical composition, nutrient content, DM yield and dense swards. From the point of view of dairy cow nutrition it has to be stated that the forage quality required to feed dairy cows has to be enhanced in proportion with the intended and expected milk yield.

It is concluded that optimal cutting frequency of permanent grassland has to consider a sustainable grassland management aiming at a stable botanical composition, nutrient content, DM yield and dense swards. From the viewpoint of dairy cow nutrition, the forage quality required to feed dairy cows has to be enhanced in proportion with the intended milk yield.

Keywords: Grassland management – nutritive value – DM yield – milk production – N excretion – animal level – farm level

1 Introduction

Like in many countries of temperate climates, also in Austria fresh and conserved grass is the main home-grown forage for ruminants (BMLFUW, 2005). Grassland accounts for 60% of total farmland, of which over 92% is permanent grassland (46% productive grassland, 46%

extensive grassland, 8% ley farming). Therefore, DM yield of grassland and its nutrient content are essential criteria for the economics of milk production in a dairy farm.

For a long-term economic success in milk production, dairy cows have to be fed according to their nutrient requirements (Daccord, 1992). This allows a level of production corresponding to the genetic potential of the cows and therefore minimize metabolic diseases. Further, it is well established that the economic efficiency of milk production increases with milk yield mainly due to a relative reduction of maintenance requirements. This was demonstrated both in model calculations (BMLFUW, 2002) and economic investigations on practical dairy farms (BMLFUW, 2006). However, the needs regarding feeding and ration increase with milk yield, since the feed intake capacity of the cows does not rise to the same extent as milk yield does. Besides feeding more concentrates, the increase of forage quality is a good means for improving the nutrient concentration of the ration.

While the advantage of cutting grassland early, i.e. high forage quality, is generally accepted on animal level because of the above-mentioned reasons and confirmed in many feeding trials (Spahr et al., 1961; Kristensen et al., 1979; Gruber et al., 1995) as well as by many economic calculations (e.g. BMLFUW, 2002 and 2006), the milk productivity on farm level, i.e. milk production per area unit, is not necessarily the highest with the highest forage quality. Gruber et al. (1999, 2000) found the highest milk production per area at a medium cutting frequency, when comparing cutting regimes of 2, 3 and 4 cuts per year. The results could be explained due to two reasons: (1) The DM yield of grassland is reduced with increasing cutting frequency and (2) The high forage intake as a consequence of high forage quality. Both factors result in a lower stocking rate, i.e. number of cows per hectare, which leads to lower milk production per area, besides the higher milk yield per cow. Moreover, a significant interaction between forage quality and concentrate level was established: the milk production per hectare is highest with high forage quality and low (zero) concentrate levels, the milk production is lowest when feeding concentrates according to nutrient requirements. It should be taken into consideration that the nutrient excretions of the cows follow the same pattern on an area level (Gruber et al., 1999). The importance of relating the milk production not only to the animal level but also to the area level was pointed out by Van Soest (1994) and Thomet (1999), too. According to Van Soest (1994) the relative costs determine which criterion has to be applied. The objective of this study was to investigate the influence of grassland management in Alpine permanent grassland on nutritive value, DM yield and agronomic parameters (milk production, nutrient excretion), both on an animal and on farm level.

2 Materials and methods

The study was conducted at the Federal Agricultural Research and Education Centre Raumberg-Gumpenstein (HBLFA) in the province of Styria (Austria) for six years from 1998 – 2003.

2.1 Experimental design

The experiment was planned in order to investigate the impact of cutting frequency and fertilisation level on yield and nutrient content in Alpine permanent grassland as well as on agronomic parameters of milk production with dairy cows depending on these grassland management factors. The experiment was based on a 3 × 3 two-factorial design, consisting of 3 levels of cutting frequency and 3 levels of fertilisation each (Table 1).

Table 1: Experimental design

Fertilisation level	kg N/hectare	Cutting frequency		
		2 cuts/year	3 cuts/year	4 cuts/year
Low	80	2-L	3-L	4-L
Medium	160	2-M	3-M	4-M
High	240	2-H	3-H	4-H

Cutting frequency and harvest dates

The harvest dates for the 3 cutting frequency levels are shown in Table 2. The dates were scheduled in order to yield similar DM portions of the growths and regrowths within each cutting frequency level. The dates are based on long-term experiences of our research station and take the climatic growing conditions of the region into account.

Table 2: Harvest dates in the cutting frequency levels

Harvest date	Cutting frequency		
	2 cuts/year	3 cuts/year	4 cuts/year
Date 1	25 June	30 May	20 May
Date 2	30 September	30 July	30 June
Date 3		30 September	10 August
Date 4			30 September

Fertilisation level

The fertilisation levels cover the low, medium and high extent of nutrient supply regarding Austrian grassland management, i.e. 80, 160 and 240 kg N per hectare and year (Table 3). The nutrients were supplied both by liquid manure and mineral fertilizers. The amounts of slurry were 15, 30 and 45 m³ per hectare and year in fertilisation levels L, M and H, respectively. The medium amount of slurry (30 m³ per hectare) can be expected under the mean growing conditions and intensity of dairy production in Austria. Starting from this mean value the amount of slurry was defined as 15 and 45 m³ in treatments L and H. The calculations were based on literature data (Schechtner et al., 1991, 1993; Windisch et al., 1991; Gruber & Steinwidder, 1996), on official guidelines for appropriate fertilisation in Austria (BMLF, 1996) and on experimental results of our institute (Gruber et al., 1999). A nutrient content of 4.48 g N (75% efficiency), 0.65 g P and 3.93 g K per kg slurry was assumed (based on long-term analyses on the experimental farm of the institute). The difference between the nutrient level intended by the experimental design and the nutrient supply with liquid manure was supplemented by mineral fertilizers (Table 3). The P and K supply was calculated from expected DM yields and mean P und K contents of the forage according to BMLF (1996). The nitrogen level in treatment H is a little above recommendations for medium N fertilisation when high DM yields are expected (Schechtner, 1993). The level of nitrogen planned in treatment L corresponds to an amount which is supplied by animal excretions at extensive production conditions (Schechtner, 1993). Slurry and mineral N were proportionally administered to each growth, whereas the P and K fertilizers were given once a year in spring. According to a strict cross-classified design the fertilisation levels were kept constant in each cutting frequency level in order to calculate possible statistical interactions between cutting frequency and fertilisation.

Table 3: Fertilisation regime in the grassland experiment
(per hectare and year)

Nutrient or Fertilizer		Fertilisation level		
		Low	Medium	High
Nutrient supply				
Nitrogen (N)	kg	80	160	240
Phosphorus (P)	kg	26	31	37
Potassium (K)	kg	161	196	230
Amount of slurry				
Slurry (10% DM)	m³	15	30	45
Mineral fertilizers				
N (Nitramoncal, 27% N)	kg	126	253	379
P (Hyperkorn, 26% P_2O_5)	kg	130	87	44
K (Kali 40, 40% K_2O)	kg	309	236	164

2.2 Experimental locations and climatic conditions

Experimental locations

The experimental locations are described in Table 4. The plant communities investigated belong to the Lolio perennis-Cynosuretum on a deep non-calcareous Cambisol with a balanced water regime, to a wet Lolio perennis-Cynosuretum on a gleyic Fluvisol, and to the Ranunculo repentis-Alopecuretum pratensis on an extremely gleyic Fluvisol. The Ranunculo repentis-Alopecuretum pratensis is a typical wet meadow on hydromorphic soils (Bohner, personal communication).

Table 4: Description of experimental locations

Location	Meadow A	Meadow B	Meadow C
Exposition	flat site	flat site	flat site
Soil type	non-calcareous Cambisol	gleyic Fluvisol	extremely gleyic Fluvisol
Soil texture	sandy loam	sandy silt	silt
Soil depth	deep	medium	medium
Plant community	Lolio perennis-Cynosuretum with Poa trivialis, Elymus repens and Dactylis glomerata	Lolio perennis-Cynosuretum with Alopecurus pratensis and plant species indicating wet soil conditions	Ranunculo repentis-Alopecuretum pratensis

Climatic conditions

The climatic conditions during the six years of experimentation are shown in Table 5. The mean temperature was 14.5 °C; in the years 2000 and 2003 it was clearly above average and in the year 2001 significantly below the mean value. Global radiation and sunshine duration correlate significantly with the mean temperature ($r = 0.652$ and 0.646), whereas temperature and precipitation are negatively correlated (-0.728), as expected. The mean rainfall during the vegetation period (April – September) was 681 mm, 2000 and 2003 clearly being “dry years” (571 and 560 mm), 2002 a wet year (808 mm).

Table 5: Climatic parameters in the experimental years (means 01 Apr – 30 Sept)

		1998	1999	2000	2001	2002	2003	Mean
Temperature	°C	14.3	14.7	15.0	13.9	14.5	15.6	14.5
Relative humidity	%	73.7	72.3	69.2	71.6	74.5	72.5	72.4
Global radiation	MJ/m²	15.9	16.7	17.5	16.3	17.3	18.4	17.1
Sunshine duration	h/d	5.3	5.7	6.4	5.7	6.1	7.1	6.0
Precipitation	mm/m²	758	587	571	669	808	560	681

2.3 Investigations and nutrient analyses

Dry matter yield

The experimental allotments were 11 × 6 m (66 m²) with 2 replications, in order to yield forage sufficient for *in vivo* digestibility trials using wethers (Gruber, unpublished results). A margin of 0.5 m was applied on each side of an allotment to prevent experimental errors. The DM content was determined immediately after cutting by oven drying (105 °C for 24 h). After harvesting, the fresh forage was wilted for some hours and conserved by barn drying. For digestibility trials and chemical analyses the growths of each harvest year were bulked within a treatment to yield a pooled "year sample" representing the proportional DM yield of the single growths.

Nutrient analyses

Chemical analyses: The chemical analyses were carried out by conventional methods as described by VDLUFA (1976) and ALVA (1983) using devices of Tecator® (Weende crude nutrients, cell wall analyses; Van Soest et al., 1991) as well as atomic absorption spectroscopy (minerals and trace elements).

in vitro digestibility: The procedure as outlined by De Boever et al. (1986) and modified by VDLUFA (1993) was carried out, using the cellulase enzyme of type Onozuka R-10 from Trichoderma viride. In this method the sample is treated successively with pepsin-HCL and cellulase at 40 °C. Starch is hydrolized at 80 °C for 45 minutes between these two steps. The energy content (ME, NEL) was computed applying the regression equations of GfE (1998), which are based on *in vitro* digestibility (cellulase) and Weende crude nutrients.

in situ degradability: The *in situ* degradability measurements and analyses were conducted as described by Ørskov et al. (1980), Michalet-Doreau et al. (1987), Madsen & Hvelplund (1994), Huntington & Givens (1995), NRC (2001) and Südekum (2005). Four ruminally fistulated steers (1,130 kg mean LW) were used for the incubations (Model 1C, Bar Diamond, Parma, ID, USA). They were fed near energy maintenance level, the ration consisting of 75% forage (⅓ hay, ⅓ grass silage, ⅓ maize silage) and 25% concentrates (35% barley, 25% wheat, 15% dried beet pulp, 15% soybean meal, 7% wheat bran, 3% minerals). Incubation times were 0, 3, 6, 10, 14, 24, 34, 72, 96, 120, according to recommendations of Mertens (2005). Nylon bags of Ankom Technology (Fairport, New York, USA) were used (pore size 53 µm, 20 × 10 cm), the ratio of sample weight to bag surface area being about 15 mg/cm² (6 g sample per bag). The method used at our institute is described in more detail at Gruber et al. (2005). The degradation data were fitted to the model of Ørskov & McDonald (1979) and McDonald (1981), in case of lag-time > 0:

$$deg = a + b \times (1 - \exp(-c \times (t - lag)))$$

deg = degradation of feedstuff (nutrient) at time t (%)
a = soluble and completely degradable fraction (%)
b = insoluble, potentially degradable fraction (%)
c = rate constant of degradation (per h)
lag = lag phase (h)

Since the degradability is essentially influenced by the rate of passage, the effective degradability (ED2, ED5, ED8) was calculated, considering rates of passage of k_p = 0.02, 0.05 and 0.08 (per h), following the equations of Ørskov & McDonald (1979) and Südekum (2005):

$$EDk = a + [(b \times c) / (c + k)] \times \exp(-k \times lag)$$

2.4 Calculation of feed intake and nutrient excretion

The DM intake has been calculated using the feed intake prediction equation of Gruber et al. (2001). In this equation both nutritional factors (forage quality and composition, concentrate level) and animal factors (milk yield, live weight, stage of lactation, breed) are used as predictors for feed intake. It is well established that feed intake of dairy cows is controlled by these physiological and nutritional factors (e.g. Wangsness & Muller, 1981; Van Soest, 1994; Forbes, 1995). The feed intake prediction equation is based on feeding experiments performed at HBLFA Raumberg-Gumpenstein for 20 years (n = 4,555, R^2 = 0.914, RSD = 0.88 kg DM). To obtain realistic results when modelling in milk production, it is necessary to account for stage of lactation and the dry period since nutrient requirements and therefore feed intake change during lactation and dry period as a consequence of variable nutrient outputs (milk and foetus). In the present model the calculations were performed for every week of lactation and of dry period. Additionally, the effect of lactation number was also taken into account, by applying the results of the official milk recording data of Austria both regarding yield and breed frequency as well as parity (ZAR, 2006). As a standard practice in Austria, the "Recommendations for the Supply of Energy and Nutrients of Cows and Heifers" of the Society of Nutrition Physiology (GfE, 2001) were used as feeding standards in the model calculations.

The calculation of nitrogen excretion of dairy cows followed the guidelines of the European Commission (2002), where the N excretion is the difference between N intake with feed and N output in products:

$N_{manure} = N_{diet} - N_{products} - N_{gaseous\ losses}$

$N_{diet} = \text{DM Intake} \times \text{N content}$

2.5 Statistical analyses

Check of data, descriptive analyses and calculation of degradation parameters were performed using the respective procedures of Statgraphics Plus (2000). All data (n = 162) were statistically analyzed by carrying out a multifactor analysis of variance, the main effects being cutting frequency (2, 3, 4), fertilisation level (L, M, H), meadow (A, B, C) and year (1998 – 2003) together with their two-way interactions, using the statistical package of Harvey (1987). Multiple comparisons were carried out to identify statistically significant differences among means using the method of Student-Newman-Keuls (confidence level $P \leq 0.05$).

3 Results and discussion

3.1 Nutrient and mineral content of the forage

As expected, cutting frequency showed a highly significant impact on an all nutrient parameters investigated (Table 6). Crude protein content increased with cutting frequency (10.5, 13.0, 16.4 % in cutting frequency levels 2, 3 and 4, respectively). On the other hand the content of crude fibre (32.6, 28.8, 24.3 %) and the Van Soest cell wall substances (NDF, ADF, ADL) decreased with cutting frequency (60.0, 52.4, 45.1 % NDF). This was accompanied with increased digestibility (54.4, 65.7, 74.2 % dOM [*in vitro*]) and energy concentration (8.4, 9.3, 9.9 MJ ME). This was due to morphological changes of the plants during vegetation towards a higher stem portion and its increasing lignification (Kühbauch, 1987; Minson, 1990; Van Soest, 1994, Jung & Allen, 1995; Südekum et al., 1995; Gruber et al., 2000). The protein content was increased to a higher extent than the energy content, which leads to N surplus in the rumen, i.e. positive ruminal nitrogen balance (-0.9, +0.9, +4.1 g RNB). Further, the content of minerals as well as trace elements was significantly higher in forage cut more frequently (e.g. 4.7, 6.2, 7.4 g Ca; 2.4, 3.2, 3.7 g P; 28, 33, 37 mg Zn). This was also shown in a comprehensive evaluation of forage samples of Austrian farms (Gruber et al., 1994). Both morphological and botanical changes are responsible for higher mineral contents with more frequent cutting (DLG, 1973; Kühbauch, 1987). The mineral content is higher in leaves than in stems and legumes are higher in alkaline earth metals than grasses.

Compared to cutting frequency, the impact of fertilisation regarding nutrient content was much smaller (Table 6). There was no significant difference between the 3 fertilisation levels concerning the content of crude fibre and cell walls (52.2, 52.5, 52.8 % NDF) and consequently digestibility (64.9, 64.8, 64.5 % dOM) and energy concentration. However protein content was highest at the high N fertilisation level (12.9, 12.9, 14.0 % CP), which can be explained both by a higher N supply and a change in botanical composition. As regard minerals, the influence of fertilisation was quite varied. The content of Ca, Mg and Mn decreased with increasing fertilisation level and the content of K and Cu increased, whereas no significant influence was found in case of P, Na and Zn.

Table 6: Nutrient and mineral content of forages depending on main effects (cutting frequency and fertilisation)

Parameters	**Cutting frequency**			**Fertilisation**			**RSD**	**P values**				**R²**
	2	**3**	**4**	**L**	**M**	**H**		**C**	**F**	**M**	**Y**	
Crude nutrients												
DM g/kg FM	845 [a]	841 [b]	839 [b]	842	842	840	7	0.001	0.354	0.000	0.000	0.772
CP g/kg DM	105 [a]	130 [b]	164 [c]	129 [a]	129 [a]	140 [b]	9	0.000	0.000	0.001	0.000	0.940
CFat g/kg DM	18 [a]	22 [b]	25 [c]	22	22	21	2	0.000	0.148	0.000	0.000	0.895
CF g/kg DM	326 [a]	288 [b]	243 [c]	284	286	287	14	0.000	0.500	0.133	0.000	0.918
NfE g/kg DM	449	448	442	453 [a]	452 [a]	435 [b]	15	0.044	0.000	0.420	0.000	0.709
CAsh g/kg DM	102 [a]	112 [b]	126 [c]	112 [ab]	111 [a]	117 [b]	13	0.000	0.043	0.076	0.000	0.706
Cell walls												
NDF g/kg DM	600 [a]	524 [b]	451 [c]	522	525	528	21	0.000	0.251	0.000	0.000	0.938
ADF g/kg DM	357 [a]	318 [b]	277 [c]	318	318	317	13	0.000	0.977	0.083	0.000	0.919
ADL g/kg DM	50 [a]	39 [b]	31 [c]	40	40	40	3	0.000	0.372	0.000	0.000	0.960
Digest. and energy												
dOM %	54.4 [a]	65.7 [b]	74.2 [c]	64.9	64.8	64.5	2.5	0.000	0.689	0.000	0.018	0.946
DOMD g/kg DM	489 [a]	583 [b]	649 [c]	576	576	569	22	0.000	0.226	0.000	0.008	0.935
ME MJ/kg DM	8.42 [a]	9.27 [b]	9.88 [c]	9.22	9.21	9.14	0.27	0.000	0.283	0.000	0.011	0.899
NEL MJ/kg DM	4.86 [a]	5.47 [b]	5.91 [c]	5.43	5.43	5.38	0.18	0.000	0.283	0.000	0.015	0.904
Protein value												
UDP % CP	19.8 [a]	19.8 [b]	19.7 [c]	19.7	19.8	19.8	0.003	0.000	0.506	0.134	0.000	0.918
nXP g/kg DM	110 [a]	125 [b]	138 [c]	124	124	125	4	0.000	0.058	0.000	0.000	0.943
RNB g/kg DM	-0.9 [a]	0.9 [b]	4.1 [c]	0.9 [a]	0.9 [a]	2.4 [b]	1.1	0.000	0.000	0.029	0.000	0.901
Minerals												
Ca g/kg DM	4.7 [a]	6.2 [b]	7.4 [c]	6.5 [a]	6.1 [b]	5.7 [c]	0.6	0.000	0.000	0.000	0.000	0.874
P g/kg DM	2.4 [a]	2.8 [b]	3.2 [c]	2.8	2.8	2.8	0.3	0.000	0.560	0.000	0.004	0.880
Mg g/kg DM	2.4 [a]	3.2 [b]	3.7 [c]	3.2	3.1	3.0	0.5	0.000	0.072	0.001	0.000	0.797
K g/kg DM	22.5 [a]	25.3 [b]	26.6 [c]	24.2 [a]	24.3 [a]	25.8 [b]	2.0	0.000	0.000	0.017	0.000	0.745
Na g/kg DM	0.21 [a]	0.40 [b]	0.62 [c]	0.40	0.40	0.42	7.18	0.001	0.354	0.000	0.000	0.772
Trace elements												
Mn mg/kg DM	97 [a]	105 [b]	111 [b]	112 [a]	102 [b]	98 [b]	18	0.001	0.000	0.000	0.000	0.822
Zn mg/kg DM	28 [a]	33 [b]	37 [c]	33	33	33	3	0.000	0.308	0.011	0.003	0.818
Cu mg/kg DM	8.7 [a]	10.4 [b]	12.4 [c]	10.2 [a]	10.2 [a]	11.2 [b]	0.7	0.000	0.000	0.000	0.000	0.924

Cutting frequency: 2, 3, 4 cuts per year
Fertilisation level: L, M, H; 80, 160, 240 kg N per hectare
Main effects: C = cutting frequency, F = fertilisation level, M = meadow, Y = year

DM = dry matter
CP = crude protein, Cfat = crude fat, CF = crude fibre, NfE = nitrogen-free extracts, CAsh = crude ash
NDF = neutral detergent fibre, ADF = acid detergent fibre, ADL = acid detergent lignin
dOM = digestibility of organic matter (OM), DOMD = digestible OM in DM, ME = metaboliable energy, NEL = net energy lactation
UDP = undegraded protein, nXP = utilizable protein at duodenum, RNB = ruminal nitrogen balance (GfE, 2001)
Ca = calcium, P = phosphorus, Mg = magnesium, K = potassium, Na = sodium
Mn = manganese, Zn = zinc, Cu = copper

Different letters in a row indicate that the means are significantly ($P \leq 0.05$) different between the treatments (Student-Newman-Keuls test)

Interaction between cutting frequency and fertilisation occurred only in a few cases, especially with protein content. It was higher at the two-cut regime with high levels of N fertilisation. Further interactions were detected regarding the content of phosphorus, zinc and copper. It should be pointed out that besides cutting frequency and fertilisation, the meadows and years exhibited highly significant influences on most of the nutrient parameters. This can be explained primarily by the multifactorial impact of locations acting by soil, exposition, plant community etc. (Kühbauch, 1987; Minson, 1990) as well as by climatic influences of the individual years.

Table 7: Nutrient and mineral content of forages depending on interaction (cutting frequency × fertilisation)

	Fertilization L			Fertilization M			Fertilization H			P values					
Cutting frequency	**2**	**3**	**4**	**2**	**3**	**4**	**2**	**3**	**4**	**C×F**	**C×M**	**C×Y**	**F×M**	**F×Y**	**M×Y**
Crude nutrients															
DM g/kg FM	846	841	840	845	840	841	843	841	838	0.823	0.002	0.000	0.229	0.621	0.000
CP g/kg DM	95	131	162	103	124	161	117	136	168	0.000	0.000	0.000	0.036	0.704	0.000
CFat g/kg DM	19	22	25	18	22	25	18	21	25	0.934	0.545	0.001	0.636	0.872	0.004
CF g/kg DM	326	284	242	330	286	242	321	294	246	0.044	0.306	0.000	0.001	0.664	0.000
NfE g/kg DM	462	449	447	447	460	448	438	435	431	0.009	0.000	0.000	0.160	0.365	0.000
CAsh g/kg DM	98	114	123	101	108	123	107	113	131	0.525	0.111	0.000	0.006	0.394	0.008
Cell walls															
NDF g/kg DM	599	518	448	603	521	452	599	533	454	0.509	0.001	0.000	0.000	0.862	0.000
ADF g/kg DM	359	316	278	361	317	275	352	323	277	0.071	0.516	0.008	0.009	0.981	0.000
ADL g/kg DM	50	39	31	50	39	30	50	40	30	0.433	0.000	0.005	0.642	0.435	0.000
Digest. and energy															
dOM %	54.5	66.4	73.8	54.0	65.9	74.6	54.8	64.7	74.1	0.204	0.216	0.004	0.177	0.831	0.000
DOMD g/kg DM	491	589	646	486	588	654	490	573	645	0.273	0.104	0.013	0.460	0.829	0.000
ME MJ/kg DM	8.47	9.34	9.85	8.38	9.31	9.94	8.40	9.17	9.86	0.453	0.007	0.007	0.464	0.992	0.020
NEL MJ/kg DM	4.90	5.51	5.89	4.84	5.49	5.95	4.85	5.39	5.90	0.392	0.008	0.010	0.437	0.993	0.019
Protein value															
UDP % CP	19.8	19.7	19.7	19.8	19.8	19.7	19.8	19.8	19.7	0.043	0.301	0.000	0.001	0.656	0.000
nXP g/kg DM	109	125	137	110	124	138	113	125	138	0.092	0.026	0.011	0.250	0.987	0.001
RNB g/kg DM	-2.2	0.8	4.0	-1.0	0.1	3.7	0.6	1.8	4.7	0.000	0.000	0.000	0.043	0.640	0.000
Minerals															
Ca g/kg DM	5.0	6.6	7.8	4.7	6.1	7.4	4.5	5.8	6.9	0.758	0.000	0.002	0.005	0.525	0.000
P g/kg DM	2.5	2.8	3.2	2.3	2.9	3.2	2.3	2.7	3.3	0.019	0.228	0.000	0.389	0.733	0.000
Mg g/kg DM	2.4	3.4	3.9	2.4	3.4	3.6	2.4	3.0	3.6	0.121	0.012	0.033	0.016	0.093	0.000
K g/kg DM	22.1	24.9	25.7	22.0	24.9	26.1	23.5	26.0	27.8	0.878	0.001	0.113	0.210	0.866	0.001
Na g/kg DM	0.18	0.44	0.60	0.21	0.41	0.58	0.24	0.36	0.67	0.823	0.002	0.000	0.229	0.621	0.000
Trace elements															
Mn mg/kg DM	106	115	116	93	101	111	92	99	105	0.856	0.000	0.000	0.001	0.370	0.000
Zn mg/kg DM	27	34	37	28	32	38	30	33	37	0.049	0.000	0.000	0.077	0.821	0.035
Cu mg/kg DM	7.9	10.6	12.1	8.5	10.0	11.9	9.6	10.8	13.2	0.001	0.000	0.000	0.002	0.572	0.000

Cutting frequency: 2, 3, 4 cuts per year
Fertilisation level: L, M, H; 80, 160, 240 kg N per hectare
Main effects: C = cutting frequency, F = fertilisation level, M = meadow, Y = year

DM = dry matter
CP = crude protein, Cfat = crude fat, CF = crude fibre, NfE = nitrogen-free extracts, CAsh = crude ash
NDF = neutral detergent fibre, ADF = acid detergent fibre, ADL = acid detergent lignin
dOM = digestibility of organic matter (OM), DOMD = digestible OM in DM, ME = metabolizable energy, NEL = net energy lactation
UDP = undegraded protein, nXP = utilizable protein at duodenum, RNB = ruminal nitrogen balance (GfE, 2001)
Ca = calcium, P = phosphorus, Mg = magnesium, K = potassium, Na = sodium
Mn = manganese, Zn = zinc, Cu = copper

In Figure 1 the relationship between cell wall content and essential nutrients as well as minerals is illustrated, using the data of all cuts (n = 162). There is a close negative correlation between NDF and protein as well as NEL (R^2 = 77.9 and 64.8%). Whereas the relationship between NDF and crude fibre is very close (R^2 = 84.5%), the correlation between NDF and the ratio of ADF/NDF as well as of ADL/NDF is not as high (R^2 = 24.4 and 23.1%), which means that the proportion of the cellulose-lignin-complex and of lignin in NDF is quite variable. This might be due to botanical differences in the individual treatments. The correlation between NDF and minerals is also variable (close relationships to Ca and Zn but not to P).

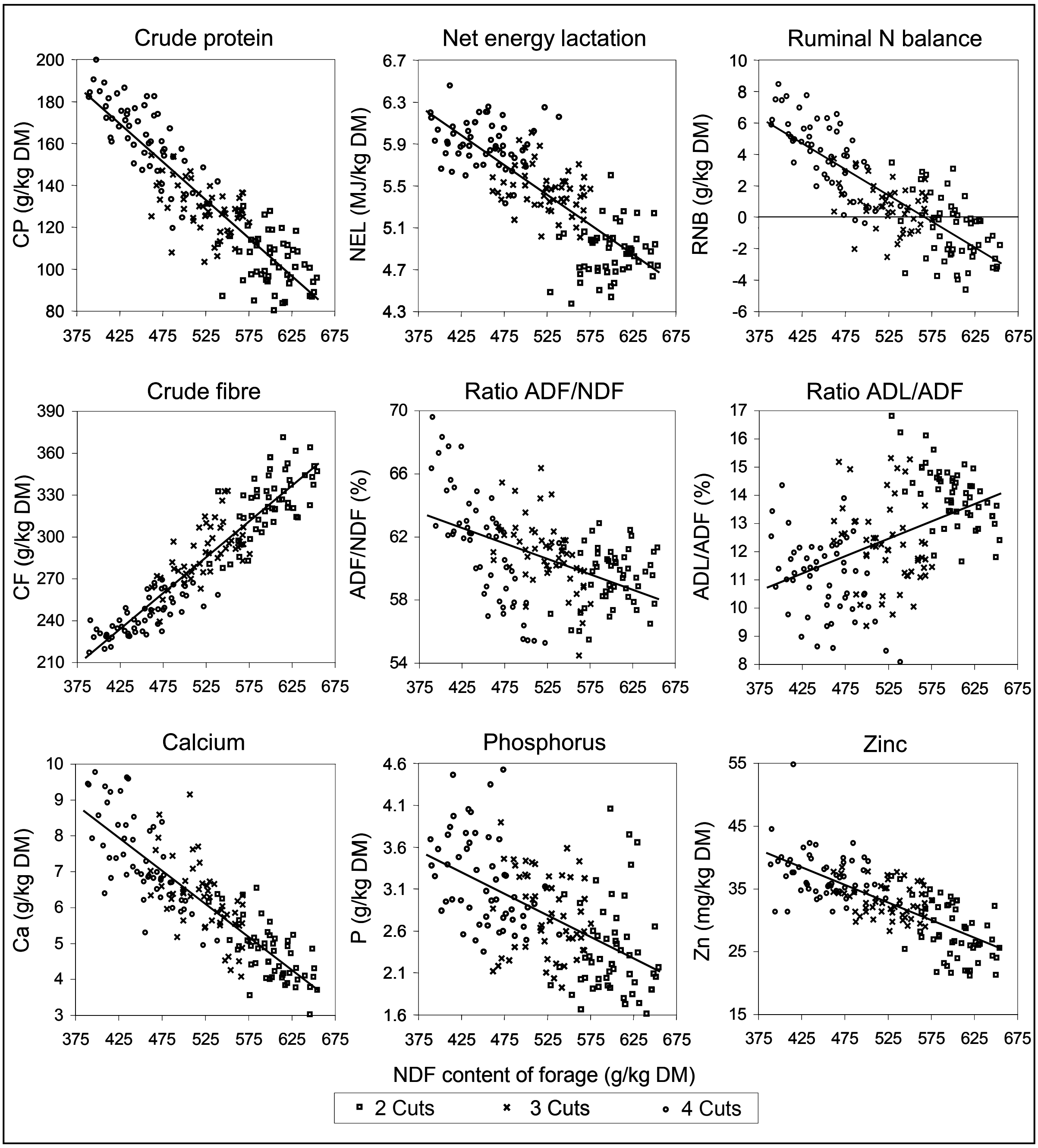

Figure 1: Relationship between the cell wall content and nutrients as well as minerals

3.2 In situ ruminal DM degradation

The results of the *in situ* ruminal DM degradation are presented in Tables 8 – 9 and Figure 2. Cutting frequency exhibited a highly significant impact on each of the DM degradation parameters ($P < 0.000$). This is in line with the data of cell wall content, digestibility and the energy content (Tables 6 – 7). The soluble fraction (a) amounted to 28, 31 and 34 %, the insoluble potentially degradable fraction (b) was 42, 45 and 48 %, resulting in potential degradability (a + b) of 69, 76 and 82 %. This corresponds well to the degradation values at an incubation time of 96 hours. Effective degradability at an assumed rate of passage k_p = 0.05 was 44, 54 and 61% at cutting frequency 2, 3, and 4, respectively. There were also great differences in the rate of DM degradation (c), the values being 3.7, 5.8 and 6.7 % per hour. Valk et al. (1996) concluded from their experiments with fresh grass fertilized with different amounts of nitrogen that the digestibility was more influenced by differences in stage of maturity than by differences in N fertilizer. A decrease of ruminal degradation of grass with maturition was stated by many workers (Cote et al., 1983; Carro et al., 1991; Balde et al., 1993, Huhtanen & Jaakola, 1994; Alert & Eckardt, 1996; Stefanon et al., 1996; Cone et al., 1999; Aufrere et al., 2003; Spanghero et al., 2003; Chaves et al., 2006).

There were only minor effects of N fertilisation on the degradation parameters. They reached the level of significance only in case of effective degradability at k_p = 0.02 (ED2). In tendency, degradability was slightly decreased with fertilisation. The harvest dates were the same in all levels of fertilisation. It can be expected that N fertilisation enhances plant growth, which results in higher physiological age and therefore lower nutrient availability for the digestive system.

Besides cutting frequency, the location of the experiment (i.e. the summative effect of the several meadows) showed a marked influence on the degradation parameters. Among other reasons, this can be explained by different botanical composition of the sites. No interactions were detected, neither between cutting frequency and fertilisation nor meadow or year in the essential degradation parameters a, b, c and ED (Table 9).

Table 8: In situ ruminal DM degradation of forages depending on main effects (cutting frequency and fertilisation)

Parameters	Cutting frequency			Fertilisation			RSD	P values				R^2
	2	3	4	L	M	H		C	F	M	Y	
DM degradation												
00 h %	25.5^{a}	30.2^{b}	32.9^{c}	29.8	29.8	29.1	2.3	0.000	0.437	0.168	0.018	0.783
03 h %	28.8^{a}	37.1^{b}	42.0^{c}	35.9	36.9	35.1	3.6	0.000	0.243	0.088	0.925	0.805
06 h %	33.3^{a}	43.4^{b}	50.4^{c}	42.6	43.4	41.0	4.2	0.000	0.146	0.033	0.865	0.836
10 h %	38.1^{a}	49.6^{b}	57.2^{c}	48.6	49.3	46.9	3.6	0.000	0.053	0.005	0.146	0.893
14 h %	41.8^{a}	54.6^{b}	61.0^{c}	52.8	53.2	51.4	3.2	0.000	0.129	0.000	0.027	0.918
24 h %	50.9^{a}	64.5^{b}	71.0^{c}	62.6^{a}	62.9^{a}	60.9^{b}	3.0	0.000	0.039	0.000	0.462	0.931
34 h %	57.3^{a}	69.8^{b}	77.1^{c}	68.4	68.8	67.0	2.9	0.000	0.067	0.000	0.024	0.932
72 h %	65.1^{a}	73.7^{b}	80.5^{c}	73.6	73.4	72.3	3.3	0.000	0.287	0.006	0.858	0.872
96 h %	66.8^{a}	76.3^{b}	82.6^{c}	76.0^{a}	75.6^{ab}	74.2^{b}	2.7	0.000	0.045	0.000	0.829	0.915
Model coefficients												
a %	27.6^{a}	30.8^{b}	33.6^{c}	30.9	30.8	30.3	2.0	0.000	0.551	0.040	0.559	0.753
b %	41.5^{a}	45.2^{b}	48.4^{c}	45.5	45.1	44.5	2.0	0.000	0.551	0.040	0.559	0.753
c rate per h	0.037^{a}	0.058^{b}	0.067^{c}	0.053	0.057	0.052	0.012	0.000	0.551	0.040	0.559	0.753
lagtime h	1.83^{a}	0.32^{b}	0.09^{c}	0.70	0.56	0.98	0.61	0.000	0.059	0.022	0.040	0.792
Degradability												
(a + b) %	69.1^{a}	75.9^{b}	82.1^{c}	76.4	75.9	74.8	2.7	0.000	0.099	0.003	0.774	0.877
ED2 %	53.4^{a}	63.9^{b}	70.4^{c}	63.1^{a}	63.2^{a}	61.5^{b}	2.4	0.000	0.022	0.000	0.715	0.938
ED5 %	43.6^{a}	54.4^{b}	60.8^{c}	53.3	53.6	51.8	2.8	0.000	0.057	0.000	0.518	0.919
ED8 %	38.9^{a}	49.0^{b}	55.1^{c}	48.0	48.4	46.7	2.9	0.000	0.088	0.001	0.514	0.903

Cutting frequency: 2, 3, 4 cuts per year
Fertilisation level: L, M, H; 80, 160, 240 kg N per hectare
Main effects: C = cutting frequency, F = fertilisation level, M = meadow, Y = year

Model coefficients: a = soluble fraction, b = insoluble potentially deg. fraction, c = rate constant of degradation (Ørskov & McDonald, 1979)
(a + b) = potential degradability; ED2, ED5, ED8 = effective degradability at rates of passage of k_p = 0.02, 0.05, 0.08

Different letters in a row indicate that the means are significantly (P ≤ 0.05) different between the treatments (Student-Newman-Keuls test)

Table 9: In situ ruminal DM degradation of forages depending on interaction (cutting frequency × fertilisation)

		Fertilization L			Fertilization M			Fertilization H			P values		
Cutting frequency		**2**	**3**	**4**	**2**	**3**	**4**	**2**	**3**	**4**	**C×F**	**C×M**	**C×Y**
DM degradation													
00 h	%	26.2	30.3	32.9	25.8	30.2	33.2	24.4	30.1	32.7	0.821	0.577	0.743
03 h	%	29.9	36.6	41.3	29.6	37.9	43.2	26.9	36.8	41.6	0.639	0.866	0.475
06 h	%	34.0	43.7	50.2	34.2	44.0	51.8	31.7	42.4	49.1	0.979	0.935	0.106
10 h	%	39.0	50.0	57.0	38.9	50.4	58.7	36.5	48.3	55.8	0.961	0.584	0.144
14 h	%	43.3	55.0	60.2	42.7	55.2	61.7	39.5	53.7	61.1	0.321	0.360	0.485
24 h	%	52.3	65.1	70.5	51.4	65.1	72.1	49.0	63.2	70.4	0.563	0.826	0.154
34 h	%	57.6	70.7	77.0	58.2	70.0	78.3	56.2	68.7	76.0	0.920	0.474	0.286
72 h	%	65.0	74.5	81.4	65.9	74.2	80.1	64.5	72.4	80.1	0.825	0.005	0.440
96 h	%	67.3	77.5	83.0	67.0	76.9	83.0	66.2	74.6	81.7	0.835	0.017	0.032
Model coefficients													
a	%	28.2	30.7	33.6	27.7	30.9	33.9	26.9	30.7	33.4	0.892	0.456	0.530
b	%	41.3	46.3	49.0	41.6	45.4	48.3	41.8	43.7	48.0	0.892	0.456	0.530
c	rate per h	0.038	0.057	0.063	0.038	0.059	0.073	0.035	0.057	0.066	0.892	0.456	0.530
lagtime	h	1.67	0.34	0.10	1.43	0.22	0.03	2.38	0.39	0.15	0.237	0.281	0.065
Degradability													
(a + b)	%	69.5	77.1	82.7	69.3	76.4	82.2	68.6	74.4	81.4	0.877	0.005	0.299
ED2	%	54.1	64.6	70.5	54.1	64.4	71.1	52.1	62.6	69.7	0.929	0.406	0.286
ED5	%	44.5	54.8	60.5	44.3	54.9	61.7	42.1	53.4	60.1	0.857	0.940	0.255
ED8	%	39.8	49.3	54.8	39.6	49.6	56.2	37.3	48.2	54.5	0.829	0.909	0.246

Cutting frequency: 2, 3, 4 cuts per year
Fertilisation level: L, M, H; 80, 160, 240 kg N per hectare
Main effects: C = cutting frequency, F = fertilisation level, M = meadow, Y = year

Model coefficients: a = soluble fraction, b = insoluble potentially deg. fraction, c = rate constant of degradation (Ørskov & McDonald, 1979)
(a + b) = potential degradability; ED2, ED5, ED8 = effective degradability at rates of passage of k_p = 0.02, 0.05, 0.08

In Figure 2 it is pointed out that cutting frequency has a marked influence on both the extent and the rate of degradation.

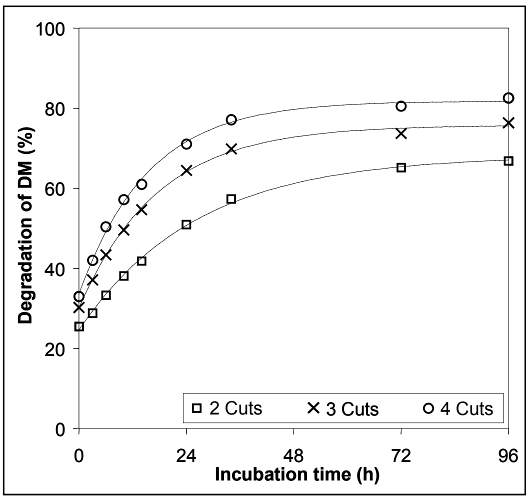

Figure 2: In situ ruminal DM degradation of forages depending on cutting frequency

3.3 Grassland yield

The grassland yield regarding dry matter, net energy and protein is summarized in Table 10 for the main effects "Cutting frequency" and "Fertilisation" and in Table 11 for their interaction. DM yield was highest at medium cutting frequency (11198 kg DM with 3 cuts per year), but differences were not great, although significant. DM yields in cutting regime 2 und 4 were equal (10717 and 10756 kg DM, respectively), the difference to cutting regime 3 being 481 and 442 kg. Besides, the impact of the effect of "Year" and "Meadow" was highly significant. Regarding NEL and protein, highest yields were determined by highest cutting frequency, i.e. the increase of nutrient content was more effective than the decrease of DM yield (52.03, 61.17, 63.57 GJ NEL per ha; 1132, 1461, 1770 kg CP per ha with cutting regime 2, 3 and 4).

There was a significant interaction between cutting frequency and fertilisation regarding the yield of DM as well as nutrients (Table 11). Whereas DM yield decreased with cutting frequency at fertilisation levels L and M, DM yield was highest at the high N fertilisation level with cutting frequency 3 (Figure 3).

There is clear evidence that DM yield decreases if cutting exceeds the optimum frequency without increasing the level of fertilization (Klapp, 1951; Mott, 1962; Vetter & Kuba, 1963; Bommer, 1964; Wilman et al., 1976; Wilhelmy et al., 1991; Buchgraber & Pötsch, 1994; Wachendorf et al., 1995). According to Vetter & Kuba (1963), the reduction of grassland DM yield associated with cutting frequency is due to a range of factors. The main reasons are that the development of the plants is interrupted before the maximum daily growth is reached and that the development of the roots (Klapp, 1951) and the storage of nutrient reserves are lower and botanical composition changes. Generally speaking, there are two main reasons for the reduction of DM yield: (1) Shortening of the time of growth of the primary growth, which has a higher growth rate than the regrowths; (2) More lag-phases due to more cuttings (sigmoidal shape of growth curve). The depressing effect of cutting can be compensated for by higher N fertilization rates (Vetter & Kuba, 1963; Bommer, 1964; Buchgraber & Pötsch, 1994).

Applying 80, 160 and 240 kg N increased DM yield from 10106 to 10751 and 11815 kg per hectare, respectively, i.e. N fertilization efficiency was 8.1 kg DM per kg additional N from nitrogen level L to M and 13.3 kg DM from the level M to H. Under similar growing conditions Jo & Schechtner (1990) determined N fertilization efficiencies of 8 – 16 kg DM per kg N and in long-term experiments Müller (1985) found out that the N response is negatively correlated with the growth potential of the site (8.7, 9.4, 13.2 and 22.1 kg DM per kg N on meadows yielding 9780, 8640, 6410 and 4400 kg DM per ha). In Switzerland, Künzli (1968) found the N fertilization efficiency being 12.9 kg DM per kg N (mean of 5 years and 4 sites). At very high fertilization levels (300 – 400 kg mineral N per ha) Rieder (1973) determined an increase in DM yield of 9.4 kg per kg N.

Table 10: Yield of DM and nutrients depending on main effects
(cutting frequency and fertilisation)

Parameters		Cutting frequency			Fertilisation			RSD	P values				R^2
		2	3	4	L	M	H		C	F	M	Y	
DM	kg/ha	10717 [a]	11198 [b]	10756 [a]	10106 [a]	10751 [b]	11815 [c]	729	0.001	0.000	0.000	0.000	0.914
NEL	GJ/ha	52.03 [a]	61.17 [b]	63.57 [c]	54.87 [a]	58.25 [b]	63.65 [c]	4.52	0.000	0.000	0.000	0.000	0.903
CP	kg/ha	1132 [a]	1461 [b]	1770 [c]	1313 [a]	1388 [b]	1662 [c]	136	0.000	0.000	0.000	0.000	0.932
nXP	kg/ha	1184 [a]	1395 [b]	1484 [c]	1252 [a]	1329 [b]	1482 [c]	99	0.000	0.000	0.000	0.000	0.918

Cutting frequency: 2, 3, 4 cuts per year
Fertilisation level: L, M, H; 80, 160, 240 kg N per hectare (ha)
Main effects: C = cutting frequency, F = fertilisation level, M = meadow, Y = year

DM = dry matter

NEL = net energy lactation , CP = crude protein, nXP = utilizable protein at duodenum (GfE, 2001)

Different letters in a row indicate that the means are significantly (P ≤ 0.05) different between the treatments (Student-Newman-Keuls test)

Table 11: Yield of DM and nutrients depending on interaction (cutting frequency × fertilisation)

Cutting frequency	Fertilisation L			Fertilisation M			Fertilisation H			P values					
	2	3	4	2	3	4	2	3	4	C×F	C×M	C×Y	F×M	F×Y	M×Y
DM kg/ha	10119	10871	11162	10304	10902	12390	9897	10479	11893	0.002	0.036	0.000	0.034	0.328	0.000
NEL GJ/ha	49.46	52.59	54.06	56.88	59.85	66.78	58.27	62.32	70.13	0.006	0.003	0.001	0.040	0.596	0.000
CP kg/ha	969	1118	1310	1348	1354	1680	1623	1692	1996	0.144	0.000	0.000	0.031	0.628	0.000
nXP kg/ha	1103	1192	1257	1293	1349	1544	1361	1445	1645	0.014	0.001	0.000	0.032	0.544	0.000

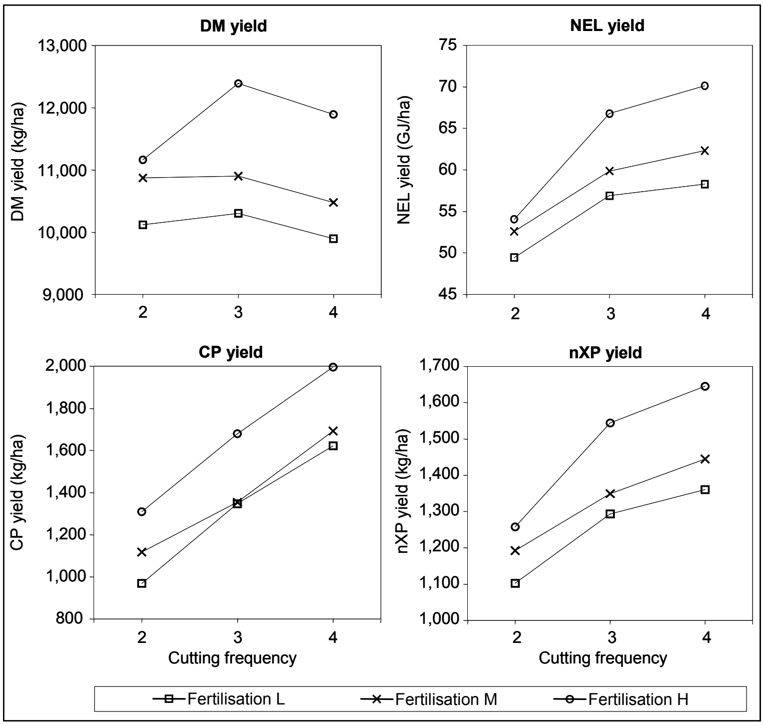

Figure 3: Yield of DM, NEL and protein depending on cutting frequency and fertilization

3.4 Modelling of feed intake, milk yield and nutrient excretion

The results of the model calculations regarding cutting frequency are presented in Table 12 and those regarding fertilisation in Table 13.

Starting from the gross DM yield of grassland, 20% harvest and conservation losses were taken into account. The model calculations were carried out both for a feeding regime without concentrate and a concentrate supply when feeding according to the nutrient and energy requirements (GfE, 2001). Due to digestibility, forage intake increased with cutting frequency (14.5, 15.4 and 16.0 kg DM) in case of feeding no concentrates. This influence was more pronounced (10.6, 13.1 and 15.2 kg DM) when concentrates were fed according to requirements since a high forage substitution rate occurs at high concentrate levels (Kirchgessner & Schwarz, 1984; INRA, 1989). The main results of this first step of model calculations are that there is only a minor effect of forage quality at a low level of concentrate and a very significant one at a normal concentrate regime, combined with high needs for concentrate (38, 23 and 11 % of DMI in cutting frequency 2, 3 and 4). As a consequence there is a wide range of possible stocking rates per hectare, 1.62, 1.60 and 1.47 cows per hectare without feeding concentrates, but 2.21, 1.87 and 1.55 animals in case of concentrate feeding (Figure 4).

This results in great influences on both the milk productivity and nutrient excretion considered on farm level (i.e. calculated per hectare). At a low level of concentrate feeding, milk production and N excretion increases significantly with cutting frequency (4654, 7049 and 8310 kg milk per ha; 127, 149 and 181 kg N per ha forage area). On the other hand, the opposite occurs with normal concentrate feeding, milk productivity being highest at low cutting frequency (14207, 12003 and 10118 kg milk per ha), however the N excretion is highest, but to a minor degree (207, 183 and 189 kg N per ha forage area). These modelling data are in line with experimental results of Gruber et al. (1999, 2000). In their 4-year-study using a total of 216 cows a significant interaction between cutting frequency and concentrate level was found regarding milk production and nutrient excretion per forage area, too. Milk productivity (3651, 6041, 6689 kg) and N excretion (139, 145, 145 kg per hectare forage area) was highest with high cutting frequency (2, 3, 4 cuts per year) at a low level of concentrate and lowest at high concentrate levels (11326, 10619, 9082 kg milk; 183, 179, 171 kg N per hectare forage area).

It should be taken into consideration that a high amount of concentrate is needed to compensate for low forage quality. There are physiological limitations of concentrate feeding since ruminal pH decreases below a critical value where cellulolytic bacteria cannot ferment cell walls in an optimal way. This has negative consequences both on the degradation of fibre carbohydrates and on forage intake (Ørskov, 1986; Van Soest, 1994). Additionally, the area required for production of concentrates must be considered, too. Per hectare of forage, an area of 0.88, 0.45 and 0.17 ha is needed in cutting frequency 2, 3 and 4 to produce the concentrate for supplementing the forage. When relating the milk production and N excretion data to the total area (for production of forage and concentrates) there are only small differences in milk productivity. It shows higher values at high cutting frequency (7559, 8260 and 8651 kg milk per total area). The N excretion per total area is also reversed, with highest values at cutting frequency 4 (110, 126, 162 kg N per ha total area).

Table 12: Calculated feed intake, milk yield and nutrient excretion depending on cutting frequency

		No concentrate			**Conc. acc. standards**		
Cutting frequency		**2**	**3**	**4**	**2**	**3**	**4**
Milk productivity							
DM yield grassland (gross)	kg/ha	10,717	11,198	10,756	10,717	11,198	10,756
DM yield grassland (20% losses)	kg/ha	8,574	8,959	8,605	8,574	8,959	8,605
Forage intake per day	kg DM	14.47	15.35	16.02	10.64	13.13	15.19
Forage intake per year	kg DM	5,283	5,601	5,846	3,884	4,794	5,545
Concentrate intake per year	kg DM	74	74	80	2,383	1,450	654
Total feed intake	kg DM	5,357	5,675	5,925	6,267	6,244	6,199
Concentrate proportion (total year)	% of DMI	1.4	1.3	1.3	38.0	23.2	10.5
Stocking rate	n per ha	1.62	1.60	1.47	2.21	1.87	1.55
Milk production potential forage	kg per year	2,868	4,407	5,645	742	3,028	5,090
Milk production potential total ration	kg per year	2,868	4,407	5,645	6,435	6,422	6,520
Milk production forage per forage area	kg per ha	4,654	7,049	8,310	1,638	5,659	7,899
Milk production total ration per forage area	kg per year	4,654	7,049	8,310	14,207	12,003	10,118
Area requirement for concentrate	hectare	0.02	0.02	0.02	0.88	0.45	0.17
Area requirement for forage & concentrate	hectare	1.02	1.02	1.02	1.88	1.45	1.17
Milk production total ration per total area	kg per ha	4,563	6,913	8,150	7,559	8,260	8,651
N excretion							
Protein content total ration	g/kg DM	112	131	164	130	134	160
N intake	kg per year	95.6	119.1	155.5	130.5	134.2	158.8
N excretion per cow	kg per year	78.3	93.4	123.2	93.9	97.7	121.8
N excretion per forage area	kg per ha	127.0	149.4	181.3	207.4	182.5	189.0
N excretion per total area	kg per ha	124.5	146.5	177.8	110.3	125.6	161.6

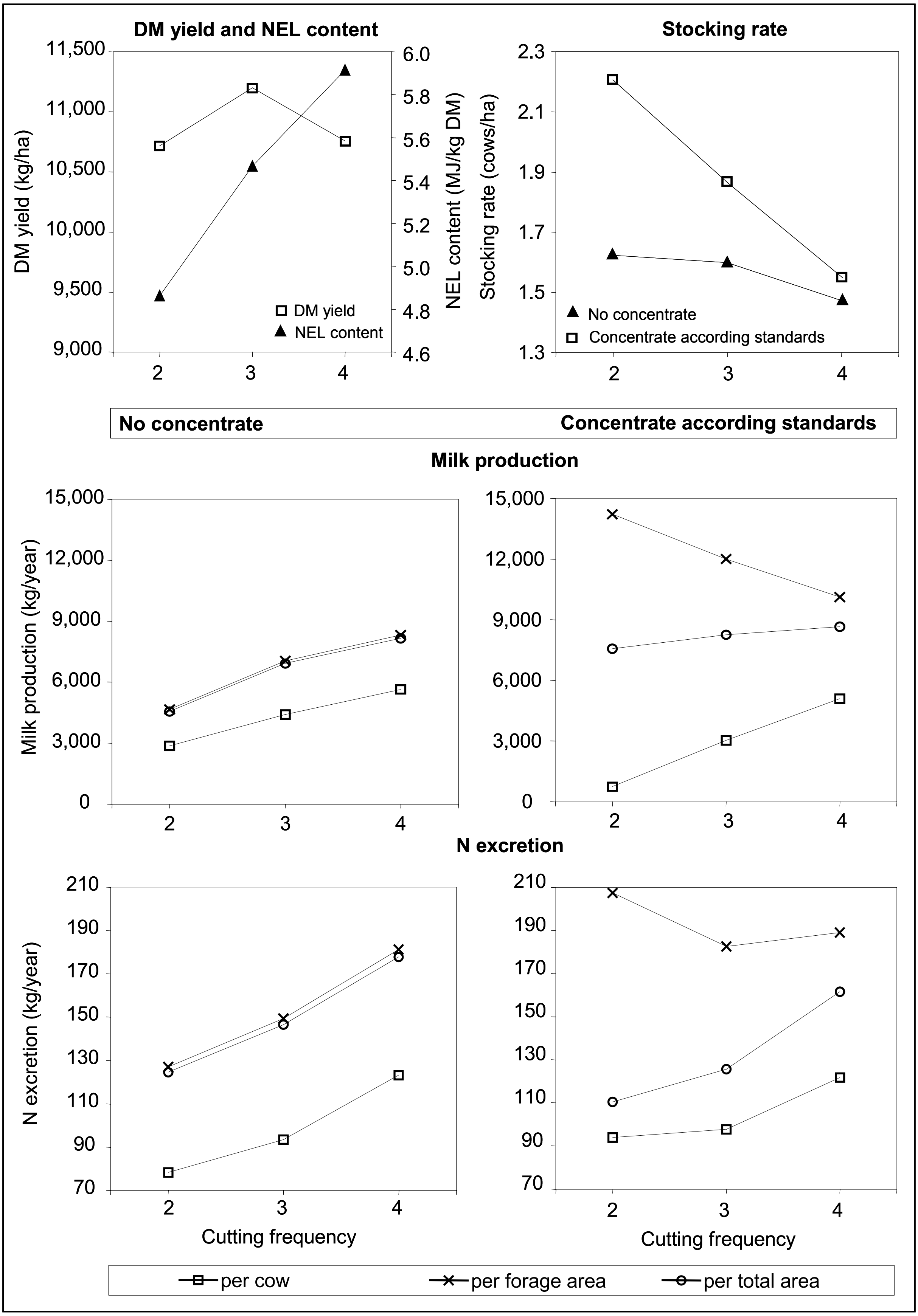

Figure 4: Impact of cutting frequency on DM yield and NEL content of grassland, on stocking rate as well as on milk productivity and N excretion at animal and area level

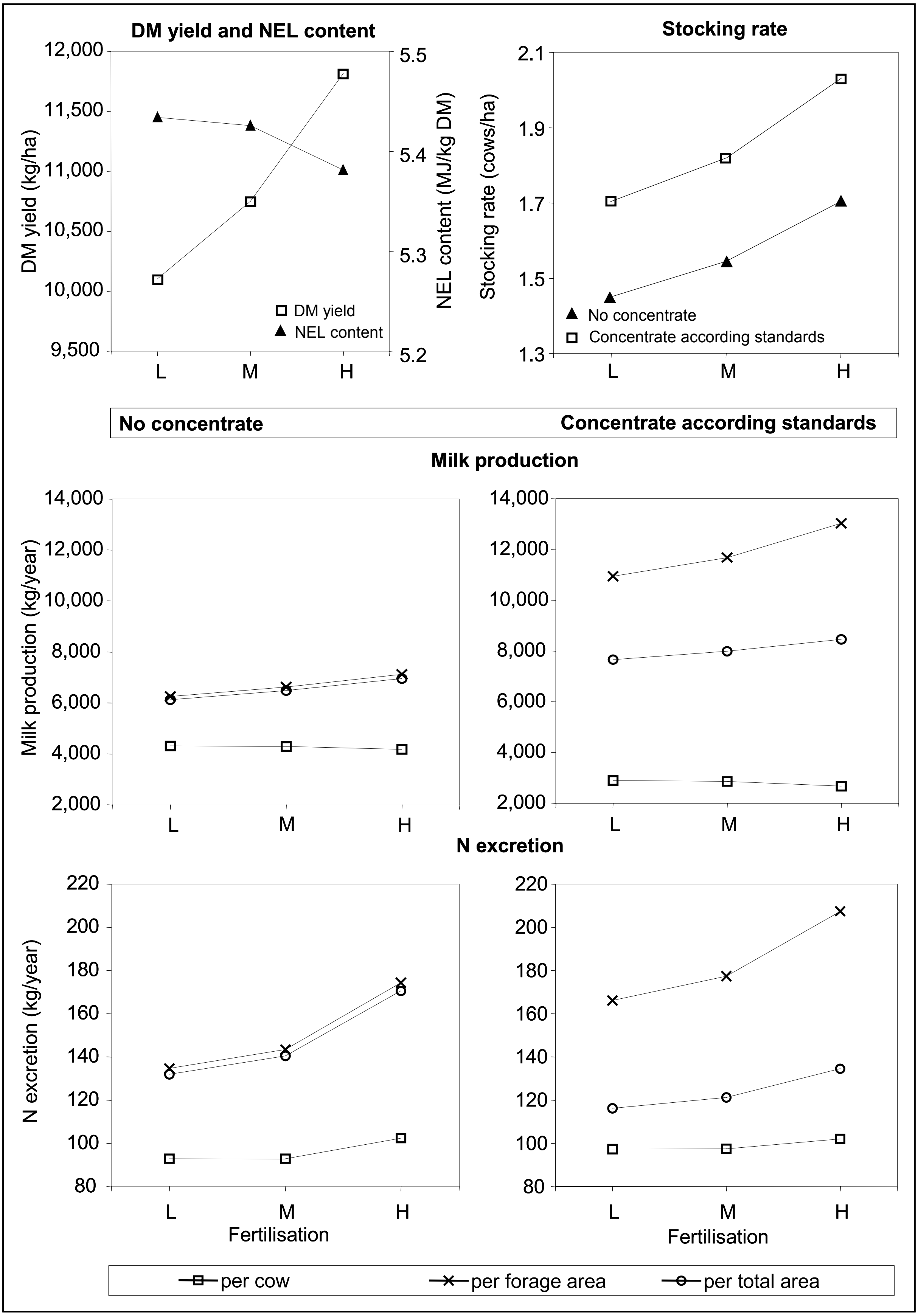

Figure 5: Impact of fertilization level on DM yield and NEL content of grassland, on stocking rate as well as on milk productivity and N excretion at animal and area level

The impact of N fertilisation is mainly due to its effect on DM yield of grassland and to a minor extent due to its effect on nutrient content (increase of protein content and decrease of digestibility). As a consequence, the stocking rate amounts to 1.45, 1.54 and 1.70 cows per hectare with concentrate level zero and to 1.70, 1.82 and 2.03 in fertilisation levels L, M and H (mean cutting frequency), when feeding concentrates according to feeding standards (Table 13, Figure 5). Due to N fertilisation, milk productivity per hectare forage area increases from 6253 to 6624 and 7112 kg (concentrate zero) and 4934, 5200 and 5424 kg milk productivity per hectare forage area (concentrates according to feeding standards) in fertilisation levels L, M and H. As expected, N excretion increases with fertilisation, especially on an area level. Additionally, the concentrate level increases N excretion, too. The 180 kg additional N fertilizer enhanced the N excretion by 40 kg per ha forage area, the influence of 1460 kg concentrate was around 33 kg N per ha forage area.

Table 13: Calculated feed intake, milk yield and nutrient excretion depending on fertilisation level

		No concentrate			Conc. acc. standards		
Fertilisation level		**L**	**M**	**H**	**L**	**M**	**H**
Milk productivity							
DM yield grassland (gross)	kg/ha	10,106	10,751	11,815	10,106	10,751	11,815
DM yield grassland (20% losses)	kg/ha	8,085	8,601	9,452	8,085	8,601	9,452
Forage intake per day	kg DM	15.28	15.27	15.21	12.99	12.96	12.76
Forage intake per year	kg DM	5,578	5,574	5,552	4,742	4,729	4,656
Concentrate intake per year	kg DM	86	81	80	1,505	1,519	1,595
Total feed intake	kg DM	5,664	5,656	5,631	6,247	6,248	6,251
Concentrate proportion (total year)	% of DMI	1.5	1.4	1.4	24.1	24.3	25.5
Stocking rate	n per ha	1.45	1.54	1.70	1.70	1.82	2.03
Milk production potential forage	kg per year	4,314	4,293	4,177	2,894	2,859	2,672
Milk production potential total ration	kg per year	4,314	4,293	4,177	6,423	6,422	6,423
Milk production forage per forage area	kg per ha	6,253	6,624	7,112	4,934	5,200	5,424
Milk production total ration per forage area	kg per year	6,253	6,624	7,112	10,950	11,681	13,037
Area requirement for concentrate	hectare	0.02	0.02	0.02	0.43	0.46	0.54
Area requirement for forage & concentrate	hectare	1.02	1.02	1.02	1.43	1.46	1.54
Milk production total ration per total area	kg per ha	6,126	6,488	6,955	7,663	7,990	8,459
N excretion							
Protein content total ration	g/kg DM	130	130	141	134	134	139
N intake	kg per year	118.1	118.0	126.9	133.9	134.0	138.7
N excretion per cow	kg per year	92.9	93.0	102.4	97.4	97.5	102.2
N excretion per forage area	kg per ha	134.7	143.5	174.4	166.1	177.3	207.4
N excretion per total area	kg per ha	132.0	140.5	170.6	116.2	121.3	134.5

4 Implications

As expected, feed quality (protein and mineral content, digestibility, rumen degradability etc.) was increased significantly by cutting frequency of permanent grassland. Its impact on DM yield was not high, although significant. There is clear evidence in literature that DM yield decreases if cutting exceeds an optimum frequency without increasing the level of fertilization, mainly because of two reasons: (1) Shortening of the time of growth of the primary growth, which has a higher growth rate than the regrowths; (2) More lag-phases due to more cuttings (sigmoidal shape of growth curve).

When applying these results to farm level, the impact of forage quality on feed intake is of major consequence. By higher forage intake – accompanied with lower DM yield of grassland – the possible stocking rate is significantly reduced with cutting frequency. From this it follows that the improved feed intake (and therefore milk yield) on animal level does not necessarily result in higher milk productivity on area level (i.e. milk yield per hectare or farm). The same is true for N excretion. Furthermore, there is a significant interaction between cutting frequency of grassland and concentrate level in dairy cow feeding. At low concentrate levels, the increase of individual milk yield and N excretion with high cutting frequency exceeds the effect of the reduced stocking rate, resulting in higher milk yield and N excretion per hectare forage area. The opposite is true for concentrate levels necessary to fulfill nutrient requirements of the cows. The highest milk yield and N excretion per hectare forage area can be expected at low cutting frequency. However, when the results are related to the total area necessary for milk production (i.e. forage plus concentrates), the highest milk yield and N excretion is achieved with high cutting frequency of grassland.

As a conclusion, optimal cutting frequency of permanent grassland on the one hand has to consider a sustainable grassland management aiming at a stable botanical composition, nutrient content, DM yield and dense swards. From the point of view of dairy cow nutrition it has to be stated that the forage quality required to feed dairy cows has to be enhanced in proportion with the intended and expected milk yield. Otherwise, great amounts of concentrates are necessary to compensate for the low forage nutrient content, which can lead to rumen acidosis of the cows and lead to high nutrient imports to the farm resulting in unbalanced nutrient budgets and environmental problems.

5 References

ALERT, H.-J. – ECKARDT, T. 1996. Nährstoffgehalt und in situ-Abbau der organischen Substanz im Pansen von Weißklee und Gräsern in Abhängigkeit vom Nutzungszeitpunkt. In: *Das Wirtschaftseigene Futter*, Vol. 42, 1996, p. 179-188.

ALVA (Arbeitsgemeinschaft landwirtschaftlicher Versuchsanstalten) 1983. Österreichisches Methodenbuch für die Untersuchung von Futtermitteln, Futterzusatzstoffen und Schadstoffen. Wien, 1983. Loose-leaf edition.

AUFRERE, J. – GRAVIOU, D. – DEMARQUILLY, C. 2003. Ruminal degradation of protein of cocksfoot and perennial ryegrass as affected by various stages of growth and conservation methods. In: *Anim. Res*., Vol. 52, 2003, p. 245-261.

BALDE, A.T. – VANDERSALL, J.H. – ERDMAN, R.A. – REEVES III, J.B. – GLENN, B.P. 1993. Effect of stage of maturity of alfalfa and orchardgrasss on in situ dry matter and crude protein degradability and amino acid composition. In: *Anim. Feed Sci. Technol*., Vol. 44, 1993, p. 29-43.

BMLF (Bundesministerium für Land- und Forstwirtschaft – Fachbeirat für Bodenfruchtbarkeit und Bodenschutz) 1996. Richtlinien für die sachgerechte Düngung. Beratungsunterlage, 5. Auflage, 31 pp.

BMLFUW (Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft) 2002. Standarddeckungsbeiträge und Daten für die Betriebsberatung 2002/2003. Landwirtschaftliche und forstwirtschaftliche Beratung. Herausgeber BMLFUW, 227 pp.

BMLFUW (Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft) 2005. Grüner Bericht 2005. 320 pp. www.gruenerbericht.at.

BMLFUW (Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft) 2006. Milchproduktion 2005. Ergebnisse und Konsequenzen der Betriebszweigsauswertung aus den Arbeitskreisen in Österreich. Landwirtschaftliche und forstwirtschaftliche Beratung. Herausgeber BMLFUW, 57 pp.

BOMMER, D. 1964. Zur Frage von Stickstoffdüngung und Schnitthäufigkeit auf der Wiese. In: *Landw. Forschung*, Vol. 17, 1964, p. 252-259.

BUCHGRABER, K. – PÖTSCH, E.M. 1994. Grundlagen der Grünlandnutzung – Auswirkungen auf Ertrag, Pflanzenbestand und Futterqualität. Abschlußbericht 1964, Bundesanstalt für alpenländische Landwirtschaft Gumpenstein, 8952 Irdning.

CARRO, M.D. – LOPEZ, S. – GONZALEZ, J.S. – OVEJERO, F.J. 1991. The use of the rumen degradation characteristics of hay as predictors of its voluntary intake by sheep. In: *Anim. Prod*., Vol. 52, 1991, p. 133-139.

CHAVES, A.V. – WAGHORN, G.C. – BROOKES, I.M. – WOODFIELD, D.R. 2006. Effect of maturation and initial harvest dates on the nutritive characteristics of ryegrass (*Lolium perenne* L.). In: *Anim. Feed Sci. Technol*., Vol. 127, 2006, p. 293-318.

CONE, J.W. – Van GELDER, A.H. – SOLIMAN, I.A. – De VISSER, H. – Van VURREN, A.M. 1999. Different techniques to study rumen fermentation characteristics of maturing grass and grass silage. In: *J. Dairy Sci*., Vol. 82, 1999, p. 957-966.

COTE, M. – SEOANE, J.R. – GERVAIS, P. 1983. Evaluation la degradation de la matiere seche des fourrages dans le rumen des bovins et des ovins par la methode des sachets de nylon. In : *Can. J. Anim. Sci*., Vol. 63, 1983, p. 367-371.

DACCORD, R. 1992. Grenzen der Milchleistung. In: *Landfreund*, 1992 (No. 52), p. 11-13.

De BOEVER, J.L. – COTTYN, B.G. – BUYSSE, F.X. – WAINMAN, F.W. – VANACKER, L.M. 1986. The use of an enzymatic technique to predict digestibility, metabolizable and net energy of compound feedstuffs. In: *Anim. Feed Sci. Technol*., Vol. 14, 1986, p. 203-214.

DLG (Deutsche Landwirtschaftsgesellschaft) 1973. DLG-Futterwerttabellen. Mineralstoffgehalte in Futtermitteln. 2nd edition. DLG-Verlag, Frankfurt (Main), 1973, 199 pp.

EUROPEAN COMMUNITIES 2002. Nitrogen Equivalents in Livestock Manure. Luxembourg, 25 pp.

FORBES, J.M. 1995. Voluntary Food Intake and Diet Selection in Farm Animals. CABI, UK, 532 pp.
GfE (Society of Nutrition Physiology – Ausschuss für Bedarfsnormen) 1998. Formeln zur Schätzung des Gehaltes an umsetzbarer Energie in Futtermitteln aus Aufwüchsen des Dauergrünlandes und Mais-Ganzpflanzen. In: *Proceedings of the Society of Nutrition Physiology*, Vol. 7, 1998, DLG-Verlag Frankfurt/Main, p. 141-150.
GfE (Society of Nutrition Physiology – Ausschuss für Bedarfsnormen) 2001. *Energie- und Nährstoffbedarf landwirtschaftlicher Nutztiere*, No. 8: Empfehlungen zur Energie- und Nährstoffversorgung der Milchkühe und Aufzuchtrinder. DLG-Verlag Frankfurt/Main, 2001, 135 pp. ISBN 3-7690-0591-0.
GRUBER, L. – WIEDNER, G. – VOGEL, A. – GUGGENBERGER, T. 1994. Nähr- und Mineralstoffgehalt von Grundfuttermitteln in Österreich. Auswertung und Interpretation der Grundfutteranalysen des Futtermittellabors Rosenau der Nö. Landes-Landwirtschaftskammer. In: *Die Bodenkultur*, Vol. 45, 1994, p. 57-73.
GRUBER, L. – STEINWENDER, R. – BAUMGARTNER, W. 1995. Einfluss von Grundfutterqualität und Kraftfutterniveau auf Leistung, Stoffwechsel und Wirtschaftlichkeit. In: *Bericht 22. Tierzuchttagung BAL Gumpenstein*, Irdning, 9 - 10 May 1995, p. 1-49.
GRUBER, L. – STEINWIDDER, A. 1996. Einfluß der Fütterung auf die Stickstoff- und Phosphorausscheidung landwirtschaftlicher Nutztiere – Modellkalkulationen auf Basis einer Literaturübersicht. In: *Die Bodenkultur*, Vol. 47, 1996, p. 255-277.
GRUBER, L. – STEINWIDDER, A. – STEFANON, B. – STEINER, B. – STEINWENDER, R. 1999. Influence of grassland management in Alpine regions and concentrate level on N excretion and milk yield of dairy cows. In: *Livest. Prod. Sci.*, Vol. 61, 1999, p. 155-170.
GRUBER, L. – STEINWIDDER, A. – GUGGENBERGER, T. – SCHAUER, A. – HÄUSLER, J. – STEINWENDER, R. – STEINER, B. 2000. Einfluss der Grünlandbewirtschaftung auf Ertrag, Futterwert, Milcherzeugung und Nährstoffausscheidung. In: *Bericht 27. Viehwirtschaftliche Fachtagung BAL Gumpenstein*, Irdning, 6 - 8 June 2000, p. 41-88.
GRUBER, L. – GUGGENBERGER, T. – STEINWIDDER, A. – SCHAUER, A. – HÄUSLER, J. 2001. Prediction of feed intake of dairy cows by statistical models using animal and nutritional factors. In: *Proc. Soc. Nutr. Physiol.*, Vol. 10, 2001, p. 125.
GRUBER, L. – STÖGMÜLLER, G. – TAFERNER, K. – HABERL, L. – MAIERHOFER, G. – STEINER, B. – STEINWIDDER, A. – SCHAUER, A. – KNAUS, W. 2005. Protein and carbohydrate fractions of the cornell net carbohydrate and protein system as well as ruminal nutrient degradation in situ of energy and protein concentrates. In: *Übers Tierern.*, Vol. 33, 2005, p. 129-143.
HARVEY, W.R. 1987. User's guide for mixed model least squares and maximum likelihood computer program PC-1 version. Columbus. Ohio State University Press, 1987. 59 pp.
HUHTANEN, P. – JAAKKOLA, S. 1994. Influence of grass maturity and diet on ruminal dry matter and neutral detergent fibre digestion kinetics. In: *Arch. Anim. Nutr.*, Vol. 47, 1994, p. 153-167.
HUNTINGTON, J.A. – GIVENS, D.I. 1995. The in situ technique for studying the rumen degradation of feeds: A review of the procedure. In: *Nutrition Abstracts & Reviews* (Series B), Vol. 65, 1995, p. 63-93.
INRA (Institut National de la Recherche Agronomique) 1989. Ruminant Nutrition, Recommended Allowances and Feed Tables. John Libbey Eurotext, 389 pp.
JO, I.H. – SCHECHTNER, G. 1990. Efficiency of mineral nitrogen fertilization on yield and botanical composition of grassland. I. Dry matter yield and economical mineral nitrogen application of grassland. In: *J. Korean Grassl. Sci.*, Vol. 10, 1990, p. 102-109.
JUNG, H.G. – ALLEN, M.S. 1995. Characteristics of plant cell walls affecting intake and digestibility of forages by ruminants. In: *J. Anim. Sci.*, Vol. 73, 1995, p. 2774-2790.
KIRCHGESSNER, M. – SCHWARZ, F.J.1984. Einflussfaktoren auf die Grundfutteraufnahme bei Milchkühen. In: *Übers. Tierernährg.*, Vol. 12, 1984, p.187-214.
KLAPP, E. 1951. Leistung, Bewurzelung und Nachwuchs einer Grasnarbe unter verschieden häufiger Mahd und Beweidung. *Z. f. Acker- und Pflanzenbau*, Vol. 93, 1951, p. 269-286.
KRISTENSEN, V.F. – SKOVBORG, E.B. – ANDERSEN, P.E. 1979. The influence of stage of cutting and amount of concentrate on intake of grass silage and milk production in dairy cows. 30th EAAP Meeting, 23-26 July 1979, Harrogate, England, N1.7, 4 pp.
KÜHBAUCH, W. 1987. Veränderung der Qualität von Grünlandfutter unter dem Einfluß von Standort und Bewirtschaftung. In: *Kali-Briefe* (Büntehof), Vol. 18, 1987, p. 485-510.
KÜNZLI, W. 1968. Pflanzenbestand und Ertrag der Fromentalwiese in Abhängigkeit von Standort und Düngung. In: *Arbeiten aus dem Gebiete des Futterbaues*, 10. Juni 1968, p. 9-27.
MADSEN, J. – HVELPLUND, T. 1994. Prediction of in situ protein degradability in the rumen. Results of a European ringtest. In: *Livestock Production Science*, Vol. 39, 1994, p. 201-212.
MERTENS, D.R. 2005. Rate and extent of digestion. In: *Quantitative Aspects of Ruminant Digestion and Metabolism*. Eds. J. Dijkstra, J.M. Forbes and J. France, CABI Publishing UK, 2005, 2nd edition, p. 13-47. ISBN 0-85199-8143.
McDONALD, I. 1981. A revised model for the estimation of protein degradability in the rumen. In: *J. Agric. Sci. (Camb.)*, Vol. 96, 1981, p. 251-252.
MICHALET-DOREAU, B. – VERITE, R. – CHAPOUTOT, P. 1987. Méthodologie de mesure de la dégradabilité in sacco de l'azote des aliments dans le rumen. In: *Bull. Tech. C.R.Z.V.*, Theix, INRA Vol. 69, 1987, p. 5-7.
MINSON, D.J.,1990. Forage in Ruminant Nutrition. Academic Press, 483 pp.
MOTT, N. 1962. Der Einfluß der Schnitthäufigkeit auf Ertrag und Pflanzenbestand der Fuchsschwanzwiese bei unterschiedlicher N- und PK-Düngung. In: *Bayer. Landw. Jahrb.*, Vol. 39, 1962, p. 311-336.
MÜLLER, A. 1985. Auswirkungen langjähriger PK- und NPK-Düngung auf Pflanzenbestand und Ertrag in Abhängigkeit vom Standort. In: *Das wirtschaftseig. Futter*, Vol. 31, 1985, p. 150-164.

NRC (National Research Council) 2001. Nutrient Requirements of Dairy Cattle. 7th Ed. Washington, D.C.. National Academy Press, 2001. 381 pp. ISBN 0-309-06997-1.

ØRSKOV, E.R. – McDONALD, I. 1979. The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. In: *Journal of Agricultural Science (Cambridge)*, Vol. 92, 1979, p. 499-503.

ØRSKOV, E.R. – HOVELL, F.D. – MOULD, F. 1980. The use of the nylon bag technique for the evaluation of feedstuffs. In: *Tropical Animal Production*, Vol. 5, 1980, p. 195-213.

ØRSKOV, E.R. 1986. Starch digestion and utilization in ruminants. In: *J. Anim. Sci*., Vol. 63, 1986, p. 1624-1633.

RIEDER, J.B. 1973. Einfluß der Steigerung mineralischer Stickstoffdüngung auf Bestandesentwicklung, Ertrag und Qualität des Dauergrünlandes. In: *Bayer. Land. Jahrbuch*, Vol. 50, 1973, p. 606-612.

SCHECHTNER, G. et al. 1991. Wirtschaftsdünger – Richtige Gewinnung und Anwendung. Sonderausgabe der Zeitschrift "Förderungsdienst". BMLF, Fachbeirat für Bodenfruchtbarkeit und Bodenschutz, 1991, 118 pp.

SCHECHTNER, G. 1993. Kalkulationsgrundlagen der Gumpensteiner Normen für die Düngung des Dauergrünlandes. Unpublished results.

SPAHR, S.L. – KESLER, E.M. – BRATZLER, J.W. – WASHKO, J.B. 1961. Effect of stage of maturity at first cutting on quality of forages.In: *J. Dairy Sci.*, Vol. 44, 1961, p. 503-510.

SPANGHERO, M. – BOCCALON, S. – GRACCO, L. – GRUBER, L. 2003. NDF degradability of hays measured in situ and in vitro. In: *Anim. Feed Sci. Technol*., Vol. 104, 2003, p. 201-208.

STATGRAPHICS Plus 5, 2000. Manugistics Leveraged Intelligence. User Manual. Maryland, USA.

STEFANON, B. – PELL, A.N. – SCHOFIELD, P. 1996. Effect of maturity on digestion kinetics of water-soluble and water-insoluble fractions of alfalfa and brome hay. In: *J. Anim. Sci*., Vol. 74, 1996, p. 1104-1115.

SÜDEKUM, K.H. – OESTMANN, A. – STANGASSINGER, M. 1995. Zur Rolle von Lignin und phenolischen Monomeren in Futtermitteln für Wiederkäuer – 2. Einfluß auf die Verdauung pflanzlicher Gerüstsubstanzen. In: *Übers. Tierern*., Vol. 23, 1995, p. 229-260.

SÜDEKUM, K.-H. 2005. Möglichkeiten und Grenzen einer Standardisierung der *in situ*-Methodik zur Schätzung des ruminalen Nährstoffabbaus. In: *Übers. Tierernährg*., Vol. 33, 2005, p. 71-86.

THOMET, P. 1999. Internationale Milchwirtschaft – Konsequenzen für die Alpenländer. In: *Wintertagung 1999*. Ökosoziales Forum Österreich und BAL Gumpenstein, p. 174-183.

VALK, H. – KAPPERS, I.E. – TAMMINGA, S. 1996. In sacco degradation of organic matter, neutral detergent fibre and crude protein of fresh grass fertilized with different amounts of nitrogen. In: *Anim. Feed Sci. Technol*., Vol. 63, 1996, p. 63-87.

Van SOEST, P.J. – ROBERTSON, J.B. – LEWIS, B.A. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. In: *J. Dairy Sci.*, Vol. 74, 1991, p. 3583-3597.

Van SOEST, P.J. 1994. *Nutritional Ecology of the Ruminant*. 2nd Ed. Ithaca and London. Cornell University Press, 1994, 476 pp. ISBN 0-8014-2772-X.

VDLUFA (Verband deutscher landwirtschaftlicher Untersuchungs- und Forschungsanstalten) 1976 including supplements 1983, 1988, 1993, 1997. Methodenbuch Band III – Die chemische Untersuchung von Futtermitteln. 3rd Ed. Darmstadt, 1997. Loose-leaf edition. ISBN 3-922712-14-2.

VETTER, H. – KUBA, F. 1963. Trockensubstanz- und Nährstofferträge bei gesteigerter Nutzungshäufigkeit und Stickstoff-düngung in Weiden und Wiesenversuchen in Hohenschulen. In: *Z. f. Acker- und Pflanzenbau*, Vol. 116, 1963, p. 372-394.

WACHENDORF, M. – KORNHER, A. – TAUBE, F. – TETEN, J.-H. 1995. Ertragsbildung und Qualitätsentwicklung von Rotklee und Rotklee-Gras-Gemengen, simuliert mit witterungs-basierten Modellen. In: *Schriftenreihe der Agrarwissen-schaftlichen Fakultät der Universität Kiel*, No. 78, Vorträge zur Hochschultagung 1995, p. 55-61.

WANGSNESS, P.J. – MULLER, L.D. 1981. Maximum forage for dairy cows. In: *J. Dairy Sci.*, Vol. 64, 1981, p. 1-13.

WILHELMY, B. – KORNHER, A. – TAUBE, F. 1991. Leistungsfähigkeit weißkleebasierter Produktionssysteme auf dem Dauergrünland in Abhängigkeit von der Nutzungshäufigkeit und der Stickstoffdüngung. In: *Jahrestagung der Arbeits-gemeinschaft Grünland und Futterbau*, Bad Hersfeld.

WILMAN, D. – KOOCHEKI, A. – LWOGA, A.B. 1976. The effect of interval between harvests and nitrogen application on the proportion and yield of crop fractions and on the digestibility and digestible yield and nitrogen content and yield of two perennial ryegrass varieties in the second harvest year. In: *J. agric. Sci. (Camb.)*, Vol. 87, 1976, p. 59-74.

WINDISCH, W. – KIRCHGESSNER, M. – KREUZER, M. 1991. Güllemenge bei laktierenden Milchkühen in Abhängigkeit von der Leistungsintsität. In: *Agribiol. Res.*, Vol. 44, 1991, p.170-181.

ZAR (Zentrale Arbeitsgemeinschaft österreichischer Rinderzüchter) 2006. Die österreichische Rinderzucht 2006. ZAR, 1200 Wien, 125 pp.

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