

Effects of plant species and harvesting system on grassland production in northern Finland

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The dry matter yields and forage quality of seven grassland plant species and mixed stands which included three cutting regimes (pasture 4–5 cuts, silage 2–3 cuts, hay and aftermath) were studied at two locations in northern Finland, Ruukki (64° 40'N) and Rovaniemi (66° 35'N). Increased cutting frequency lowered the total dry matter yields of all plant species. Production of timothy (*Phleum pratense* L.) and smooth brome grass (*Bromus inermis* L.) swards was significantly reduced by taking four or five cuts instead of one or two cuts. Meadow fescue (*Festuca pratensis* Huds.) and meadow grass (*Poa pratensis* L.) showed only a minor interaction with harvesting regimes and were less affected by the cutting frequency. The increased cutting frequency raised the crude protein content, this causing the highest protein yields despite the smaller dry matter yields. The inclusion of red clover in seed mixtures had a favourable effect on the crude protein content of grass swards. Stands of sown plants decreased and the proportion of weeds in yields increased with time, reflecting the suitability of plant species to various cutting regimes. Meadow fescue and meadow grass with rapid regrowth had a positive effect on sward density and also caused less invasion of weeds when the cutting frequency was increased.

Key words: cutting frequency, dry matter, forage quality, botanical composition, *Phleum pratense* L., *Festuca pratensis* Huds., *Poa pratensis* L., *Bromus inermis* L., *Trifolium pratense* L.

Introduction

Agriculture in northern Finland relies heavily on livestock, and nearly 80% of the cultivated area is used for growing grass forage, i.e. hay, silage, and pasture. The plants best suited for cultivation under northern conditions are grasses with abundant vegetative growth, as they grow well in a cool climate and can benefit from the long

day (Landström 1989). The production of grassland plants is, however, impaired and the number of harvests reduced by the shortness of the growing season (Pulli 1982). Moreover the most winterhardy northern varieties grow very rapidly in the middle of the summer, but very slowly in late summer. On the other hand, the number of cuts is determined by the time of the last cut. This has to be chosen to ensure that the gathering of food reserves and hardening can take place be-

fore the onset of the long winter (Hakkola et al. 1987). As the time of harvest is linked to the development stage of the stands, some sort of aftermath crop is also harvested in northernmost Finland.

There is demand for good-quality grass forage for both summer and winter feeding. The most important factor influencing total yields is cutting frequency. Advanced mechanization in modern grassland management for silage-making has resulted in the use of intensive cutting systems. In northern Finland, however, this type of management has caused problems to grassland yields and the viability of some plant species.

In northern Finland, the straw formation of plants and the sharp increase in dry matter content in early summer cause rapid changes in forage quality. Fibrousness increases, and the crude protein content and digestibility decrease (Pulli 1980, Huokuna and Hakkola 1984). On the other hand, low temperatures reduce the fibrousness of the plants in the north. At the same morphological development stage, plants in the north have better digestibility than those in the south (Deinum et al. 1981). In the autumn, stands are leafier and changes occur more slowly.

Strong straw formation and slow regrowth are typical of timothy (*Phleum pratense* L.) and smooth brome grass (*Bromus inermis* L.).

Straw formation in meadow fescue (*Festuca pratensis* Huds.) and meadow grass (*Poa pratensis* L.) is less strong and regrowth is better. Due to its better regrowth ability, meadow fescue thrives better than timothy in pasture and silage swards (Järvi 1976, Grönneröd 1988). Meadow grass, too endures many harvests during the growing period better than timothy (Grönneröd 1972, Landström 1978). Meadow grass has also had a higher yielding regrowth than timothy (Mason and Lachance 1983). Smooth brome grass has been found to thrive even more poorly than timothy in pasture and silage swards (Grönneröd 1972, Järvi 1982), whereas in hay swards, it has given high yields. The total yield of a mixture of timothy and meadow fescue is often higher than that of pure stands

of either plant species alone (Raininko 1968, Hakkola 1988, Jörgensen et al. 1994). Under variable growth and wintering conditions, a mixed sward also tends to be more reliable for cultivation than a pure stand (Nissinen and Hakkola 1989, Jörgensen et al. 1994).

Owing to its good resistance to frost and ice encasement, timothy is most winterhardy in the south and on the coast. The winterhardiness of meadow fescue, which withstands snow scald (*Sclerotinia borealis*) better than timothy, improves the farther north it is cultivated (Landström 1978, Nissinen and Salonen 1972, Årsvoll 1977). In second-year leys, a rapid increase in the proportion of meadow fescue at the expense of timothy has been reported in mixtures of timothy and meadow fescue (Raininko 1968, Hagsand and Landström 1984, Nissinen and Hakkola 1989, Jörgensen et al. 1994). The yield of meadow grass has not markedly decreased with an increase in age (Landström 1978, Hagsand and Landström 1984). According to Andersson (1988), meadow grass is best suited for long-duration pasture swards, and the farther north the better. Moreover, the yield of smooth brome grass has improved with the increasing age of the sward, and thus it is suitable for long-duration hay swards (Järvi 1976). Since red clover (*Trifolium pratense* L.) is not very permanent, the yield of a mixed sward containing clover diminishes more rapidly than that of pure grass mixtures (Hagsand and Landström 1984, Huokuna et al. 1985).

The protein content of meadow fescue is higher than that of timothy at the same developmental stage and at the same harvesting time (Salo et al. 1975). As, however, the yield of meadow fescue is often higher than that of timothy harvested at the same time, the protein content of the yield may be lower in meadow fescue than in timothy. The crude protein content is higher in meadow grass than in timothy (Landström 1978, Hole 1985). Many studies have further shown that the protein content of smooth brome grass is higher than that of timothy at the same development stage, harvesting time and yield level (Olsen 1978, Järvi 1982). Red clover

increases the crude protein content of mixtures. According to the findings of Andersson (1986, 1989), the nitrogen compensating effect of red clover on protein content is greater than the effect on the dry matter yield.

In mixtures of plant species, meadow fescue has been found to increase the fibre content owing to its earliness and red clover to reduce it (Hagsand and Landström 1984, Olsen 1978, Åman and Lindgren 1983). The fibre content of meadow grass is higher than that of timothy. Also, smooth brome grass has been found to contain more fibre in an early harvest than timothy and meadow fescue, but by the hay stage the fibrousness of timothy may be higher (Järvi 1982, Åman and Lindgren 1983). According to Olsen (1978), meadow fescue is more digestible than timothy when harvested at the same time. Correspondingly, timothy has been found to have better digestibility than meadow grass up to the flowering stage (Mason and Lachance 1983). Like meadow fescue, red clover has also improved the digestibility of plant species mixtures (Frankow-Lindberg 1989).

In northern Finland, grass forage accounts for almost 60% of the feed units used per milk cow, and thus grassland production is of very great economic importance to cattle farms. The aim of this trial was to investigate the effect of the harvesting system and cutting frequency on the yield and quality of different grassland plants in

northern Finland. In the field experiments, the superiority and suitability of the most important grass species and mixtures of plant species in pasture, silage and hay swards were compared. The main topics of interest were dry matter yield, forage quality and the persistence of a sown plant species when different cutting frequencies were used in forage management under the conditions of a short growing season and low temperature sum.

Material and methods

The trial was carried out during 1987–1992 at the Agricultural Research Centre of Finland's North Ostrobothnia Research Station in Ruukki (64° 40'N) and Lapland Research Station in Rovaniemi (66° 35'N).

The field experiments were set up using a split-plot method, with three harvesting systems – pasture, silage and hay – as the main plots. Plant species and their mixtures were as the split plots. There were four replicates. The species, seeding and nitrogen rates used in the trial are shown in Tables 1 and 2.

In Ruukki, the soil used was medium fine sand, pH 6.0, Ca 903, K 51, P 15 and Mg 42 mg/l. In Rovaniemi, the soil was fine sandy till, pH 5.95, Ca 1254, K 118, P 13 and Mg 165 mg/l.

The ground-cover percentage of the plot was evaluated visually in autumn and spring to reveal winter damage. Before harvesting, the heights of stands were measured and the maturing phase was evaluated on a scale of 0–100% (100 = all heads or panicles visible).

The swards were harvested by a forage plot harvester (Haldrup). The cuts at pasture stage were carried out when the stands were approximately 30 cm high. There were three to five cuts. For grass species, the first silage crop was harvested when 20% of heads or panicles had appeared. In Ruukki, mixtures containing clover were cut later, at the start of clover flowering. In Rovaniemi, all plant species and mixtures were

Table 1. Plant species, varieties, seed mixtures and seed rates used in the trial.

Plant	Variety	Seed rate kg/ha
Timothy	Iki	20
Meadow fescue	Boris	25
Meadow grass	Jo 0011	20
Smooth brome grass	Kesto	30
Timothy/red clover	Iki/Bjursele	15/5
Timothy/meadow fescue	Iki/Boris	13/13
Timothy/meadow fescue/ red clover	Iki/Boris/ Bjursele	10/10/5

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Table 2. Fertilization of trial plots during years of harvest in 1988–1992.

Harvest system	Locality	Nitrogen/yield				Total		
		1	2	3	4	N	P	K
Pasture	Rovaniemi	80	50	40	40	210	35	140
	Ruukki	90	60	50		200	33	133
Silage	Rovaniemi	110	80			190	32	127
	Ruukki	120	80	50		250	42	167
Hay	Rovaniemi	80	60			140	23	93
	Ruukki	90	70			160	27	107
Mixed stands with red clover (all harvesting systems):								
	Rovaniemi	62				62	60	108
	Ruukki	40				40	60	108

usually harvested at the same time. Each year, two or three silage crops were harvested. Hay swards were harvested when the stands were in full head or panicle and red clover was in full flower. In Ruukki, the last cut was carried out right at the beginning of September, and in Rovaniemi around 20th August.

Botanical composition was determined from combined samples of about 500–1000 g from all replicates of the treatments. In some cases, the botanical composition of the pure stands of timothy, meadow fescue, meadow grass and smooth brome grass was assessed visually as the coverage of sown and unsown species. One representative crop sample from different replicates of each treatment was taken and analysed for dry matter, crude protein and fibre. Dry matter was determined by drying two parallel 200 g samples of the chopped plant, first for two hours at 100°C and then for 14 hours at 60°C. For total nitrogen, the plant samples were analysed with the Kjeldatherm system (Gerhardt, Germany) and for fibre content with the Fibertec system (Tecator, Sweden). The digestibility of the organic matter was tested *in vitro* by the cellulase-enzyme method of Friedel (1990).

The effects of the harvesting systems and species and their interactions were determined

by analyses of variance. For dry matter and crude protein yields the analyses of variance were carried out by the SAS program. The significance of the differences was tested using Tukey's test (LSD $P < 5\%$).

Due to the very different climatic conditions at the two research stations, experimental data were examined separately. Analyses of variance were made only for dry matter and protein yields. The crude protein yields of the replicates of the treatments were calculated by mean crude protein content of dry matter. Because of the lack of replicates, statistically reliable analyses could not be made for the botanical composition and qualitative values of grass forage.

At both trial sites the weather was warmer and rainier than the average during the trial period. In Ruukki, the growing period (daily mean temperature above +5°C) averaged 160 days, the effective temperature sum (degree-days, base +5°C) 1102°C, and the precipitation in May–September 314 mm. In Rovaniemi, the growing period was 132 days, the effective temperature sum 922°C and the precipitation 295 mm. The average number of days with snow cover in Ruukki was 147, and in Rovaniemi 181. In all winters, the soil froze before the permanent snow cover formed.

Results and discussion

Sward overwintering

The effect of harvesting method on the amount of winter damage was relatively slight (Tables 3 and 4). In Ruukki, most winter damage occurred in fourth- and fifth-year swards, and the main causes of damage were frost and ice scorch. In Rovaniemi, an increase in damage due to low-temperature fungi was seen from the second crop year. At both trial sites there was more damage, on average, in swards harvested at the silage stage than in pasture or hay swards. In Ruukki, timothy suffered the least winter damage and meadow fescue the most. In Rovaniemi meadow fescue overwintered as well as timothy. Smooth brome grass had the highest annual variation in winter damage. At both trial sites, there was less winter damage in mixed swards than in pure stands.

According to this trial, timothy thrives considerably better than meadow fescue in Ruukki, which is situated on the coast, where the snow cover is shallow. Meadow fescue was most severely damaged by frost and ice scorch in old swards. Timothy has better resistance to ice encasement and frost than meadow fescue (Gudleifsson 1986). The winter climate in Rovaniemi is stable and the snow cover continuous throughout the long winter. As a result, attacks by snow moulds are a frequent problem. Meadow fescue is more resistant to snow scald (*Sclerotinia borealis*) than timothy (Nissinen and Salonen 1972, Årsvoll 1977). This explains the good overwintering of meadow fescue in Rovaniemi.

In this trial, the poorer overwintering of silage swards than of pasture swards may have been due to the timing of the last cut rather than to the harvesting system. For many years, the last cut was carried out earlier in silage swards than in pasture swards, and the aftermath left for overwintering had time to become more lush before the onset of winter. This increased the incidence of pink snow mould (*Fusarium nivale*)

and of speckled snow mould (*Typhula* sp.) in the swards.

Dry matter yields

According to the statistical examination of dry matter yields, the differences between harvesting systems and plant species, and the interaction of these variables, were significant at both trial sites (Tables 5 and 6).

Increasing the number of cuts reduced the total yield of plant species and mixtures of plant species. The combined yield of dry hay and aftermath was the highest, and the yield of swards cut at the pasture stage was the lowest. The only exceptions to this were meadow fescue in Ruukki, and meadow grass and smooth brome grass in Rovaniemi, which gave the highest yields of dry matter harvested at the silage stage. The effect of harvesting system on dry matter yields was greater in Rovaniemi than in Ruukki. At both trial sites, production dropped sharply in fourth- and fifth-year swards.

In Ruukki, the plant with the highest average yield was smooth brome grass and in Rovaniemi, meadow fescue. Timothy yields were considerably higher in Ruukki than in Rovaniemi. Meadow fescue, in contrast, thrived more poorly than timothy in Ruukki, but in Rovaniemi gave higher yields than timothy. The highest yielding plant species mixture was timothy and meadow fescue and the lowest timothy and red clover.

The total yields of pasture swards in Ruukki were 5500 to 7680 kg/ha in the first- to third-year swards, and 2180 to 4200 kg/ha in the fourth- to fifth-year swards. The yield variations between plant species in Rovaniemi were 3340 to 6310 kg/ha and 1570 to 4900 kg/ha, respectively (Table 6). The highest yielding plants were meadow fescue and meadow grass and the mixture of timothy and meadow fescue. The lowest total yield with four cuts was obtained from smooth brome grass. A comparison of swards of different ages shows that yields of dry matter dropped most rapidly in timothy and in smooth brome grass (Figs. 1 and 2).

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Table 3. Average winter damage and the proportion (%) of sown plant species in first harvest of first- to fifth-year swards in Ruukki in 1988–1992.

Plant species and harvesting system	Winter damage %	Percent sown plants				
		Year of ley				
		1	2	3	4	5
Timothy						
Pasture	3	100	100	100	40	61
Silage	7	100	100	100	100	49
Hay	2	100	100	100	47	31
Meadow fescue						
Pasture	20	100	100	100	100	39
Silage	22	100	100	100	47	21
Hay	11	100	100	100	24	13
Meadow grass						
Pasture	19	73	100	100	100	60
Silage	21	77	100	100	100	50
Hay	9	100	100	100	73	53
Smooth brome grass						
Pasture	21	100	100	39	85	15
Silage	12	100	100	100	100	26
Hay	12	100	100	100	87	93
Timothy/red clover						
Pasture	5					
Timothy		92	82	81	47	56
Red clover		5	18	7	3	12
Silage	6					
Timothy		90	52	57	47	44
Red clover		7	45	30	22	28
Hay	5					
Timothy		87	77	62	55	56
Red clover		13	20	23	2	10
Timothy/meadow fescue						
Pasture	15					
Timothy		73	50	27	25	35
Meadow fescue		25	50	65	40	13
Silage	19					
Timothy		79	35	46	28	41
Meadow fescue		18	53	50	31	16
Hay	6					
Timothy		75	54	30	20	36
Meadow fescue		21	43	63	28	11
Timothy/red clover/meadow fescue						
Pasture	9					
Timothy		63	37	22	25	25
Red clover		3	26	4	1	14
Meadow fescue		32	37	67	50	16
Silage	14					
Timothy		56	41	53	28	35
Red clover		9	29	27	6	19
Meadow fescue		31	28	17	36	20
Hay	8					
Timothy		48	48	36	46	51
Red clover		15	26	10	1	15
Meadow fescue		35	23	41	15	18

Table 4. Average winter damage and proportion (%) of sown plant species in first harvest of first- to fifth-year swards in Rovaniemi in 1988-1992.

Plant species and harvesting system	Winter damage %	Percent sown plants				
		Year of ley				
		1	2	3	4	5
Timothy						
Pasture	7	99	100	90	62	78
Silage	19	95	100	78	64	49
Hay	18	94	100	97	80	71
Meadow fescue						
Pasture	14	98	100	99	97	92
Silage	16	92	100	90	96	73
Hay	14	92	100	99	99	89
Meadow grass						
Pasture	11	99	100	98	99	94
Silage	14	97	100	96	96	77
Hay	14	82	100	92	96	66
Smooth brome grass						
Pasture	22	99	100	85	50	44
Silage	30	99	100	89	79	60
Hay	16	73	95	77	69	18
Timothy/red clover						
Pasture	5					
Timothy		98	30	77	68	58
Red clover		1	67	14	9	12
Silage	22					
Timothy		97	16	66	56	55
Red clover		1	83	21	22	9
Hay	23					
Timothy		98	14	49	45	55
Red clover		1	85	46	41	17
Timothy/meadow fescue						
Pasture	9					
Timothy		89	24	4	4	3
Meadow fescue		10	74	95	92	91
Silage	16					
Timothy		93	7	5	1	3
Meadow fescue		6	92	94	98	68
Hay	10					
Timothy		93	44	10	4	11
Meadow fescue		6	55	89	88	72
Timothy/red clover/meadow fescue						
Pasture	7					
Timothy		92	16	14	7	8
Red clover		1	52	11	16	3
Meadow fescue		6	31	74	76	79
Silage	15					
Timothy		84	15	20	7	1
Red clover		2	75	18	15	5
Meadow fescue		13	9	61	74	71
Hay	8					
Timothy		86	7	9	6	7
Red clover		3	84	29	28	5
Meadow fescue		9	8	61	63	85

In Ruukki, the highest yielding silage plants were smooth brome grass and timothy and in Rovaniemi, meadow fescue and meadow grass. The lowest yields were obtained from mixed swards of timothy and red clover. The total yield of young swards in Ruukki was 7240 to 9620 kg/ha, and in Rovaniemi 5030 to 7330 kg/ha. In old, fourth- to fifth-year swards, the lowest yields in Ruukki were obtained from meadow fescue, 1980 kg/ha, and in Rovaniemi from timothy, 2800 kg/ha. In Ruukki, production of grass for silage was highest with smooth brome grass, 3800 kg/ha, and in Rovaniemi, with meadow fescue, 5980 kg/ha (Table 6).

The yields of hay swards, including aftermath, were generally higher than those of silage swards (Tables 5 and 6). In Ruukki, the highest yielding plant in hay swards was smooth brome grass, which had an average dry matter yield of 10 640 kg/ha in the first- to fifth-year swards. In Rovaniemi, meadow fescue had the highest average yield, 7170 kg/ha. In hay swards, timothy also thrived well at both trial sites. Aftermath

accounted for one-third of the total dry matter yield an average.

It is clear from the trial that the economic use of sown grassland can not be prolonged with the plant species studied in any harvesting system. The yield of pasture and silage swards can, however, be significantly increased with the correct choice of plant species. In the trial, timothy and smooth brome grass were highly unsuitable for harvesting at the pasture stage, which explains well the poor yield production ability of timothy-dominated pasture swards in northern Finland. Meadow fescue and meadow grass also thrived well when there were several harvest cuts during the growing season. The yield formation of meadow grass was more rapid in Rovaniemi than in Ruukki, which supports the view of Andersson (1988) that meadow grass thrives relatively better the farther north it is grown.

In the trials dry matter yields were increased in plants harvested at a later stage of development, as found also by Raininko (1968). The smaller differences between total yields of sil-

Table 5. Average dry matter yields of different harvesting systems and plant species in Ruukki and Rovaniemi in 1988-1992

	A. Harvesting system			B. Plant species							Statistical significance			
	P	S	H	1	2	3	4	5	6	7	A	B	A x B	SE
Ruukki														
1-3 year	6700 ^c	8520 ^b	9190 ^a	8620 ^{ab}	8530 ^{ab}	8240 ^b	9000 ^a	7040 ^c	8210 ^b	7320 ^c	***	***	***	165
4-5 year	3120 ^b	3230 ^b	3920 ^a	2850 ^{cd}	2310 ^d	3830 ^b	5000 ^a	2940 ^{cd}	3560 ^{cb}	3450 ^{cb}	*	***	***	165
1-5 year	5310 ^c	6400 ^b	7080 ^a	6320 ^b	6100 ^{cb}	6510 ^b	7400 ^a	5400 ^d	6350 ^b	5770 ^{cd}	***	***	***	145
Rovaniemi														
1-3 year	5050 ^b	6500 ^a	6610 ^a	5230 ^d	7080 ^a	6490 ^b	5310 ^d	5490 ^{cd}	6910 ^{ab}	5860 ^c	**	***	***	130
4-5 year	3290 ^c	4500 ^b	4940 ^a	2980 ^c	5840 ^a	4520 ^c	2970 ^c	3420 ^d	5380 ^b	4580 ^c	***	***	***	145
1-5 year	4340 ^b	5700 ^a	5940 ^a	4330 ^d	6580 ^a	5700 ^b	4370 ^d	4660 ^d	6300 ^a	5350 ^c	**	***	***	130

* P < 0.05 ** P < 0.01 *** P < 0.001

Means on same line with same superscript do not differ significantly (P < 5%)

P = Pasture 1 = Timothy 5 = Timothy/red clover
 S = Silage 2 = Meadow fescue 6 = Timothy/meadow fescue
 H = Hay 3 = Meadow grass 7 = Timothy/red clover/meadow fescue
 4 = Smooth brome grass

age and hay swards were due to the high second yield of silage swards and the relatively poor aftermath of hay swards. In northern Finland, it is not possible to fully utilize the most rapid growth phase of grass for silage. The first yield

has to be harvested at the beginning of the heading stage, before the crude protein content starts to decline, and the second so early that the swards have enough time to recover and harden before winter, as shown by Hakkola et al. (1987).

Table 6. Effect of harvesting system on dry matter yields in Ruukki and Rovaniemi in 1982–1992.

	Plant species							LSD ¹ (P < 5%)
	1	2	3	4	5	6	7	
Dry matter yields, kg / ha								
Ruukki								
1–3 year								
Pasture	7140	7530	7680	5500	5860	7330	5900	830
Silage	9090	9240	8290	9620	7240	8340	7790	1260
Hay	9650	8830	8750	11870	8040	8950	8270	1580
LSD (P < 5%)	1330	850	1140	1280	930	880	1050	
4–5 year								
Pasture	2940	4200	4020	2400	2180	3170	2950	1410
Silage	3110	1980	3420	3800	3320	3280	3680	1650
Hay	2510	1200	4320	8790	3330	3520	3740	1340
LSD (P < 5%)	570	810	1380	1510	990	2010	990	
1–5 year								
Pasture	5460	6200	6220	4260	4380	5670	4720	790
Silage	6700	6340	6350	7290	5670	6310	6140	960
Hay	6790	5780	6980	10640	6150	6780	6450	1310
LSD (P < 5%)	790	520	900	1290	670	930	960	
Rovaniemi								
1–3 year								
Pasture	4250	6300	6310	3340	4380	5960	4670	890
Silage	5030	7330	7020	6650	5480	7080	6370	1230
Hay	6340	7520	6070	5860	6200	7640	6500	1280
LSD (P < 5%)	330	1120	770	860	960	970	1170	
4–5 year								
Pasture	2290	4900	4010	1570	2330	4660	3290	510
Silage	2800	5980	4790	4010	3620	5580	4740	840
Hay	3880	6650	4780	3330	4340	5890	5730	540
LSD (P < 5%)	420	730	570	500	560	630	410	
1–5 year								
Pasture	3460	5740	5390	2630	3560	5440	4120	580
Silage	4140	6790	6130	5590	4950	6480	5720	960
Hay	5350	7170	5550	4850	5450	6940	6190	760
LSD (P < 5%)	790	510	900	1290	670	930	960	

1 = Timothy

2 = Meadow fescue

3 = Meadow grass

4 = Smooth brome grass

¹LSD = Least significant difference

5 = Timothy/red clover

6 = Timothy/meadow fescue

7 = Timothy/red clover/meadow fescue

Generally, dry matter yields of silage and hay swards were highest in the second crop year. As mentioned by Hagsand and Landström (1984), this is typical of grasses owing to inadequate growing density during the sowing year. With the exception of meadow grass, the dry matter yields of all plants harvested at the pasture stage in Rovaniemi declined after the first crop year, probably owing to the great stress of four cuts (Huokuna et al. 1985).

The increased cutting frequency reduced the yields of shortgrowing grasses, meadow fescue and meadow grass less than those of tall-growing grasses, timothy and smooth brome grass. After cutting, more leaf remains in stands of meadow fescue and meadow grass than in the stubble of timothy and smooth brome grass. As documented by Landström (1992), at the beginning of regrowth after the first cut, the growth rate was higher in meadow fescue than in timothy, reflecting the continuation of leaf growth in meadow fescue.

The timothy and meadow fescue mixture was no more productive than the pure stand of meadow fescue in Rovaniemi and or the pure stand of timothy in Ruukki. However, the production of a mixed stand of timothy and meadow fescue was very high at both trial sites and in all harvest systems, and it would therefore to be the best grass for general use in northern Finland. A mixed stand of grass species is better able to adapt to varying climatic conditions and different cultivation techniques than is a pure culture of a single grass. In the studies of Raininko (1968) and Hakkola (1988), the dry matter yields of a mixed stand of timothy and meadow fescue were higher than those of a pure culture of timothy or meadow fescue.

Botanical composition of yield

In general, as the sward aged, the proportion of sown plant in the yield decreased and that of weeds increased. The less suitable the plant species was for different harvest intensities, the faster the changes occurred (Tables 3 and 4). Win-

ter damage as well as cutting frequency caused gaps where unsown grasses and dicotyledons could become established. However, in both Ruukki and Rovaniemi, the proportion of sown plants was fairly constant in all stands until the third crop year.

The clover content was higher in mixtures of timothy and red clover than in mixtures of timothy, red clover and meadow fescue. Swards harvested at the hay stage contained the most timothy, and swards harvested at the pasture stage the least. In a mixture, timothy thrived better with red clover than with meadow fescue. Smooth brome grass behaved similarly to timothy. In Rovaniemi, stands containing meadow fescue were still very dense even in the fifth-year swards. Likewise, the proportion of weeds in the yields of these stands was small. The proportion of meadow fescue in the mixed stands of plant species increased with cutting frequency. In the trial, meadow fescue supplanted timothy in the very first year. In Rovaniemi, a mixed sward of timothy and meadow fescue became a sward dominated by meadow fescue already in the second crop year. Meadow grass remained clear of weeds with all harvesting methods. In Ruukki, most of the sown plant species were still present in yields of mixed stands of timothy, red clover and meadow fescue in fifth-year swards. In Ruukki, the effect of the harvesting system was greatest on the amount of weeds in smooth brome grass. When harvested at the pasture stage, only 15% of smooth brome grass was present in the yield of the fifth-year sward, whereas in the plots harvested at the hay stage, smooth brome grass accounted for more than 90%.

It was shown here, as elsewhere (Hagsand and Landström 1984, Grönneröd 1988, Jørgensen et al. 1994), that meadow fescue had a positive effect on sward density, both in a pure culture and in mixed stands containing it, even with the most intensive cutting regime, and also that it was well able to compete with weeds. In the mixtures, however, there was also a sharp increase in the proportion of meadow fescue at the expense of timothy and red clover. Initially, timothy made up more of the mixture than the

prescribed 50% mixture, mainly because of the higher number of seeds of timothy than of meadow fescue. However, in the trial, a mixed sward of timothy and meadow fescue turned into a meadow fescue -dominated sward in the second crop year, and most clearly in the swards cut at the pasture stage. The changes in botanical composition can be attributed both to different overwintering abilities and to interspecific competition between meadow fescue and timothy. Due to the strong competitiveness of meadow fescue, there was also less red clover in the mixture of

timothy, meadow fescue and red clover than in the mixture of timothy and red clover. The decrease in clover content in swards was more rapid in Ruukki than in Rovaniemi, partly owing to the winter damage caused by frost and ice scorch.

Quality of grassland yield

Data on the quality of grassland yields are presented in Table 7.

Table 7. Average forage quality of yields harvested at pasture, silage and hay stage in Ruukki and Rovaniemi in 1988–1992.

Harvesting system and plant species	Ruukki		Rovaniemi		OMD ¹⁾ %
	Crude protein %	Crude fibre %	Crude protein %	Crude fibre %	
Pasture (first to fourth cut)					
Timothy	20.4	25.0	18.4	24.0	79.6
Meadow fescue	21.0	26.7	16.7	24.5	82.2
Meadow grass	21.7	27.5	17.4	27.8	79.3
Smooth brome grass	22.7	25.9	19.0	26.3	80.3
Timothy/red clover	18.6	23.8	19.4	22.2	80.1
Timothy/meadow fescue	20.5	26.5	17.1	24.9	80.6
Timothy/red clover/ meadow fescue	17.5	25.3	17.6	23.1	80.4
Silage (first to second cut)					
Timothy	15.6	31.1	14.7	26.5	74.1
Meadow fescue	17.0	30.8	13.8	29.4	75.9
Meadow grass	16.2	29.8	15.6	30.0	72.6
Smooth brome grass	15.9	32.7	13.6	31.4	71.8
Timothy/red clover	14.9	29.3	16.0	25.6	74.2
Timothy/meadow fescue	15.5	31.1	13.6	29.1	75.5
Timothy/red clover/ Meadow fescue	14.2	29.8	14.9	27.6	76.2
Hay (first cut)					
Timothy	11.0	35.2	9.3	34.3	63.5
Meadow fescue	11.4	34.2	8.7	36.2	63.9
Meadow grass	11.8	33.9	10.0	32.7	70.8
Smooth brome grass	10.9	36.6	8.5	31.9	66.9
Timothy/red clover	9.7	34.7	11.9	34.3	62.8
Timothy/meadow fescue	11.1	34.6	9.3	34.8	62.1
Timothy/red clover/ meadow fescue	9.3	35.2	11.3	34.5	62.4

¹⁾ Organic matter digestibility, in vitro (pasture 1988–1992, silage 1991–1992, hay 1992).

Nissinen, O. & Hakkola, H.: Effects of cultivation technique on grassland production

The average crude protein content of forage crops harvested at the pasture stage was 16.7 to 22.7%. In Ruukki, the highest average protein contents were in smooth brome grass and meadow grass and in Rovaniemi, in the timothy and red clover mixture, and in smooth brome grass. At the silage stage in Ruukki, the yields of meadow fescue contained the most protein, 17.0%. In Rovaniemi, the protein content was the highest in the yields of a mixture of timothy and red clover, 16.0%, and in meadow grass, 15.6%. The protein content of hay swards was 8.5 to 11.9%. In Ruukki, protein percentages were lowest in mixtures containing clover but in Rovaniemi, in hay swards containing clover protein contents were highest.

The differences in crude protein yields between plant species and harvesting systems were statistically significant (Tables 8 and 9). In Ruukki, the total protein yield of all plants except smooth brome grass increased when the number of cuts was increased. In Rovaniemi, only meadow fescue and the timothy and meadow fescue mixture gave the highest protein yields in pasture swards. With all other plants, the best pro-

tein yields were obtained from silage swards. In Ruukki, the highest amount of protein kilos in the first- to third-year swards was obtained from meadow grass harvested at the pasture stage, 1580 kg/ha, and in Rovaniemi, from a silage sward, 1070 kg/ha.

The variation in the average crude fibre content of pasture yields was 22.2 to 27.8%. Meadow grass had the most fibre, and the timothy and red clover mixture the least. In most cases meadow fescue had more fibre than timothy. In Rovaniemi, the average fibre content was one percentage unit lower than in Ruukki but the variation between plant species was greater in Rovaniemi than in Ruukki. Meadow fescue had the highest organic matter digestibility, and meadow grass the lowest. The fibre contents of silage crops were 25.6 to 32.7%. Smooth brome grass had the most fibre, and the timothy and red clover mixture the least. In Rovaniemi, the fibre content of timothy was lower than in meadow fescue at the silage stage, too. Meadow fescue and the mixtures containing it had the best average digestibility, and smooth brome grass the poorest. In Ruukki, the lowest crude fibre con-

Table 8. Average crude protein yields of different harvesting systems and plant species in Ruukki and Rovaniemi in 1988–1992.

	A. Harvesting system			B. Plant species							Statistical significance			
	P	S	H	1	2	3	4	5	6	7	A	B	A x B	SE
Ruukki														
1–3 year	1340 ^a	1280 ^a	1070 ^b	1310 ^{ab}	1350 ^a	1330 ^a	1340 ^a	1020 ^c	1240 ^b	1020 ^c	***	***	***	25
4–5 year	540 ^a	570 ^a	520 ^a	470 ^{cd}	420 ^d	690 ^b	790 ^a	430 ^d	560 ^c	440 ^d	NS	***	***	25
1–5 year	1020 ^a	990 ^a	850 ^b	970 ^b	970 ^b	1070 ^a	1120 ^a	790 ^c	970 ^b	790 ^c	**	***	***	20
Rovaniemi														
1–3 year	830 ^a	890 ^a	700 ^b	690 ^b	840 ^a	900 ^a	670 ^b	840 ^a	870 ^a	850 ^a	**	***	***	15
4–5 year	600 ^b	690 ^a	580 ^b	420 ^c	840 ^a	700 ^c	420 ^c	550 ^d	770 ^b	670 ^c	**	***	***	20
1–5 year	740 ^a	810 ^a	650 ^b	580 ^d	840 ^a	820 ^{ab}	710 ^d	720 ^c	830 ^a	780 ^b	**	***	***	15

* P < 0.05 ** P < 0.01 *** P < 0.001

Means on same line with same superscript do not differ significantly (P < 5%)

P = Pasture 1 = Timothy 5 = Timothy/red clover
 S = Silage 2 = Meadow fescue 6 = Timothy/meadow fescue
 H = Hay 3 = Meadow grass 7 = Timothy/red clover/meadow fescue
 4 = Smooth brome grass

tent of hay yields was in meadow grass, 33.9%, and in Rovaniemi, in smooth brome grass, 31.9%.

In any harvest, there has to be a compromise between quantity and quality. The later the date of harvest, the greater is the yield, the lower is

the crude protein content and the poorer is digestibility. Grass forage from pasture alone contains enough protein and energy for a milk yield of 20 kg per day. Animals fed with hay always need supplements to ensure quality. Silage is the basic roughage used by most farms in northern

Table 9. Effect of harvesting system on crude protein yields in Ruukki and Rovaniemi in 1982-1992.

	Plant species							LSD ¹ (P<5%)
	1	2	3	4	5	6	7	
Crude protein yields, kg / ha								
Ruukki								
1-3 year								
Pasture	1410	1510	1580	1180	1130	1470	1090	150
Silage	1370	1490	1260	1490	1040	1220	1060	190
Hay	1150	1030	1130	1340	900	1040	900	190
LSD (P < 5%)	190	120	180	150	140	110	170	
4-5 year								
Pasture	480	720	730	400	350	670	460	230
Silage	550	360	650	720	570	620	510	260
Hay	390	180	690	1250	380	400	350	145
LSD (P < 5%)	76	150	220	220	130	310	130	
1-5 year								
Pasture	1040	1190	1240	870	820	1150	840	140
Silage	1040	1040	1020	1180	850	980	840	150
Hay	840	690	960	1310	690	780	680	150
LSD (P < 5%)	120	90	140	160	90	130	140	
Rovaniemi								
1-3 year								
Pasture	730	940	1000	600	810	950	820	150
Silage	720	890	1070	830	880	870	930	170
Hay	610	690	640	560	830	770	810	120
LSD (P < 5%)	40	130	100	110	80	130	170	
4-5 year								
Pasture	430	860	760	310	460	810	570	90
Silage	430	910	750	600	590	840	730	130
Hay	420	740	590	370	590	670	700	70
LSD (P < 5%)	70	100	90	70	90	100	70	
1-5 year								
Pasture	610	910	900	480	670	900	720	100
Silage	610	900	940	740	760	860	850	130
Hay	540	710	620	480	730	730	760	90
LSD (P < 5%)	30	110	70	80	130	100	100	

1 = Timothy

2 = Meadow fescue

3 = Meadow grass

4 = Smooth brome grass

¹LSD = Least significant difference

5 = Timothy/red clover

6 = Timothy/meadow fescue

7 = Timothy/red clover/meadow fescue

Finland. In making silage, the right timing of the harvest is very important for both the quantity and quality of the yield. The aim is to reach a 15–16% protein content in the dry matter of the grass for ensiling. In our trial, this objective was reached with all plant species and mixtures on average only in Rovaniemi, and even there only in the spring yield. Although the crude protein content decreases less rapidly in aftermath than in spring growth, the mean protein content of the second yield in Rovaniemi was only 12.7%. The protein content of the yield also depends on nitrogen fertilization, yield quantity and the development stage of plants at the time of harvest. In the nitrogen fertilization trials of Andersson (1986), the amount of nitrogen had a greater effect on the protein content of the second harvest than on that of the spring harvest. According to Thorvaldsson (1988), the protein content of the spring harvest is higher than that of the second harvest at the same morphological development stage. The aftermath, has a longer growing time and the quantity of yield with respect to the development stage is higher than in the spring harvest, which, in addition to lower nitrogen fertilization, reduces the protein content.

As well as protein content, crude fiber and digestibility of the organic matter are important indicators of the feeding quality of forage. In grasses, the increase in fibrousness is most rapid at the time of straw growth (Salo et al. 1975). In the trial, when the plants were harvested at the same time, the difference in development stages may explain why meadow fescue had a

higher fibre content (29.4%) than timothy (26.5%). Similar results were obtained in both the spring and aftermath harvests. In the aftermath, the higher fibre content of meadow fescue was probably due to the more rapid growth of meadow fescue than of timothy. In general, fibrousness increases less rapidly in the aftermath than in the spring harvest (Huokuna & Hakkola 1984).

The increase in the fibrousness of plants at the time of straw formation is also connected to the decline in digestibility of the organic matter (Salo et al. 1975, Huokuna & Hakkola 1984). Fibrousness does not necessarily determine digestibility. The amount of protein and its digestibility also play a role. Therefore, despite the higher fibre content, the digestibility of meadow fescue in Rovaniemi was better than that of timothy. On the other hand, the digestibility of fibrous meadow grass was poorer than that of timothy and meadow fescue despite the high protein content of meadow grass. In general, the crude fibre content does not seem to be a primary quality factor with any harvesting system. As Deinum et al. (1981) observed that, at the same morphological developmental stage, organic matter digestibility is higher in northern than in southern latitudes. The low temperature decreases the crude fibre content of dry matter. Another probable cause of better digestibility under northern growing conditions is the increased lignin content of timothy at higher growth temperatures (Ames et al. 1993).

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SELOSTUS

Kasvilajin ja korjuutavan vaikutus nurmen satotasoon Pohjois-Suomessa

Oiva Nissinen ja Heikki Hakkola

Maatalouden tutkimuskeskus

Pohjois-Suomen viljellystä peltoalasta lähes 80 % käytetään nurmirehun tuotantoon. Sadonkorjuun tehostuminen on kuitenkin nopeuttanut timotein katoamista nurmista, alentanut satotasoa ja lyhentänyt nurmien taloudellista käyttöikä.

Vuosina 1988–92 Maatalouden tutkimuskeskuksen Pohjois-Pohjanmaan tutkimusasemalla Ruukissa ja Lapin tutkimusasemalla Rovaniemellä suoritettujen tutkimusten tavoitteena oli selvittää kasvilajin ja niittotiheyden vaikutusta nurmen tuottokykyyn ja rehusadon laatuun. Kenttäkokeissa olivat mukana timotei, nurminata, niittynurmikka ja rehukattara sekä timotei-puna-apila-, timotei-nurminata- ja timotei-puna-apila-nurminataseokset. Nurmet korjattiin laidun-, säilörehu- ja heinäasteella.

Niittotiheyden lisääminen heikensi kokonaissatoa kaikilla kasvilajeilla ja kasvilajiseoksilla. Eniten satotaso aleni ns. korsiheinillä, timoteilla ja rehukattaralla. Lehtiheinillä, niittynurmikalla ja nurminadalla korjuutavan vaikutus satoon oli verraten vähäinen. Näillä heinälajeilla sadonkorjuun jälkeen jää sänkeen aina myös lehtiä, joiden avulla odelman kasvu alkaa nopeasti heti niiton jälkeen. Laidunnurmien kokonaissadot olivat tutkimuksessa keskimäärin 74 % heinäasteella korjattujen nurmien sadosta. Puna-apila ei vaikuttanut rehusadon määrään, mutta paransi sen

ruokinnallista laatua. Sadonkorjuutavasta riippumatta nurmien kuiva-ainesadot alenivat nopeasti kolmanteen satovuodesta lähtien.

Tutkimuksessa timotei menestyi hyvin Ruukissa ja nurminata Rovaniemellä, mikä johtuu lähinnä erilaisista talvehtimisolosuhteista. Ruukissa talvituhojen aiheuttajina olivat etupäässä pakkakanen ja jääpolte, kun taas Rovaniemellä tuhoja aiheuttivat talvituhoisienet. Kuitenkin timotei-nurminataseosnurmi menestyi hyvin molemmilla koepaikoilla ja kaikilla sadonkorjuutavoilla. Kun käytännössä nurmea ei perusteta pelkästään yhtä korjuutapaa ajatellen, tutkimustulosten mukaan timotei-nurminataseos on hyvä yleisnurmi Pohjois-Suomeen.

Myöhäisellä kasvien kehitysasteella tapahtunut sadonkorjuu lisäsi kuiva-ainesatoa, mutta huononsi rehun laatua. Niittotiheyden lisääminen kohotti huomattavasti sadon valkuaispitoisuutta ja useimmissa tapauksissa lisäsi myös valkuaisen määrää pienentyneestä kuiva-ainesadosta huolimatta. Säilörehuasteella korjattaessa useimmilla kasvilajeilla päästiin tavoiteltuun 15–16 % valkuaispitoisuuteen. Tällä valkuaisitasolla tutkimuksen mukaan myös nurmisadon kuituisuus ja sulavuus täyttävät Pohjois-Suomessa hyvin ruokinnan asettamat vaatimukset.