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Red clover grown in a mixture with grasses: yield, persistence and dynamics of quality characteristics

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Red clover (*Trifolium pratense* L.) was grown in mixtures with timothy and meadow fescue in field experiments at four sites in Finland to broaden knowledge on it's potential as a forage crop. The effects of cutting frequency, nitrogen fertilization in the spring and sward density were investigated. Forage yield quality was analyzed using standard methods. Red clover produced well in all swards during the two first seasons. In the third summer the proportion of red clover was greatly diminished except on sandy soil at the northernmost locality (64˚40'N) where it remained productive. Linear regression adequately described the dependence of crude fibre content and crude protein content in dry matter of the primary growth and regrowth, both of red clover and grass, on accumulated temperature sum. The contents of P, K, Ca and Mg in clover and grass are given as a function of accumulated temperature to describe their changes during crop growth. The results give new knowledge about possibilities to grow red clover in the northern livestock region of Finland. They proved that soil type is more important for good persistence of red clover than latitude.

Key words: cutting frequency, sward density, nitrogen fertilization, chemical composition, digestibility, heat sums, *Trifolium pratense, Phleum pratense, Festuca pratensis*

Introduction

Mixtures of red clover and timothy have been grown as the principal components of hay swards in Finland since the last decades of the nineteenth century when cultivation of grass in rotation with cereals began. In the early 1960s the sward area was at its greatest, 52%, corresponding to 1.4 million hectares: 1.1 million hectares were harvested for dry hay (Official Statistics of Finland 1961) and 74% of seed mixtures sown included red clover (Raatikainen and Raatikainen 1975).

The focus of studies on red clover has been improvement of its persistence. Under Finnish conditions red clover content in a sward decreases rapidly because of abiotic and biotic stresses incurred during winter after the second harvest

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season (Paatela 1953, Ylimäki 1967). A considerable number of studies were directed at breeding (Ravantti 1980, Multamäki and Kaseva 1983) and testing (Valle 1958, Paatela 1962, Mela et al. 1980) new persistent red clover genotypes and improving the hardiness of plant material. Bjursele in particular, a local variety from northern Sweden, and some newer varieties, demonstrated increased persistence in Finland. A Finnish tetraploid variety was durable but had too low a seed yield (Valle 1959, Mela 1969).

Following development of improved methods of harvesting and storage, as well as generation of new knowledge on the benefits of increased N-fertilization on grass yields and protein content, the area allocated to grass-only swards cut for silage began to increase rapidly in the 1960s. Most farmers also stopped growing red clover in their hay fields because it did not fit with mechanized hay drying in the field. Scattering of leaflets resulted in it losing much of its feeding value. As a consequence, the decreased research on red clover was directed at its suitability for intensive methods of cultivation. Red clover-grass mixtures proved to be profitable because they gave higher crude protein yields without N-fertilization than abundantly N-fertilized grass swards, although dry matter yields were lower (Salonen and Hiivola 1963, Hakkola and Nykänen-Kurki 1994). Irrigation, another component of intensive cultivation, increased red clover yields more than yields of grasses, but did not decrease their crude protein content as it did for grasses (Raininko 1968). Thus red clover could have represented a feasible option for producing protein rich feed. However, most farmers opted for N-fertilized pure grass swards that they considered to provide reliable forage yields.

During the last two decades interest has increased in forage legumes. Currently, the area devoted to organic farming in Finland is about 160 000 hectares and red clover is commonly grown in rotation for forage and to provide nitrogen-rich green manure on-farm (Mela 1988). Recent studies on red clover have concentrated on feed quality. The greatest advantage of red clover-grass silage over pure grass silage has proved to be increased intake and enhanced milk yield (Heikkilä et al. 1992, Vanhatalo et al. 1995, Heikkilä et al. 1996). Red clover forage is not associated with bloat or hypomagnesia because of its high magnesium content. Disadvantages are oestrogenically effective compounds in red clover (Kallela 1974) and high liquid loss if not predried (Syrjälä-Qvist et al. 1984).

In spite of occasional increased interest in red clover, large research projects on its cultivation under the range of growth conditions that exist across Finland have not been organized except for official variety trials. This investigation addressed this shortcoming. The effects of cultivation methods on yields, sward development and dynamics of common yield quality characteristics as a function of accumulated temperature sums were studied for red clover-grass mixtures across a range of growth conditions at four research sites in Finland.

Material and methods

The research was performed at four sites of the Agricultural Research Centre of Finland in south and central Finland. These included the Crop Research Department, Jokioinen (60°49'N, 23°30'E), 1990–1995, North Savo Research Station, Maaninka (63°09'N, 27°19'E), 1991–1992, Kainuu Research Station, Sotkamo (64°01'N, 28°22'E), 1990–1992, and North Ostrobothnia Research Station, Ruukki (64°40'N, 25°06'E), 1990–1994.

Mixed swards of red clover (*Trifolium pratense* L.), timothy (*Phleum pratense* L.) and meadow fescue (*Festuca pratensis* Huds.) were established under barley (*Hordeum vulgare* L.) as a cover crop in the spring before the start of the experiments. The varieties and seed quantities in the mixtures were as follows: red clover 'Björn' (Svalöf Weibull Co., Sweden) or in Ruukki 'Bjursele' (Swedish local variety) 10 kg ha^{-1}, timothy 'Tammisto' (Boreal Plant Breeding Co., Finland) 10 kg ha^{-1} and meadow fescue 'Kalevi' (Boreal Plant Breeding Co., Finland) 12 kg ha^{-1}.

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The barley cover crop was cut before maturity to provide sufficient time for the sward to establish before the end of the growing season.

The trials were established as split-split plot designs. Treatments were allocated as follows:

Main plots, cutting time = A: a_1 = two harvests, for hay and regrowth, a_2 = two to three harvests at silage stage, a_3 = three to five harvests at pasture stage,
Split plots, nitrogen fertilization = B: b_1 = 0, b_2 = 30, b_3 = 60, b_4 = 90 kg ha^{-1},
Split-split plots, row distance = C: c_1 = 12.5, c_2 = 25.0 cm.

The area of the subplot was 15 m^2. There were four replicate blocks.

Soil analysis was done at the start of the experiments at all sites, and also at the end in Jokioinen. According to the results P- and K- fertilizers were applied at establishment and during the course of the trials. The barley cover crop was fertilized only with small amounts of nitrogen to preclude lodging. For the split plots, the N-treatment was given once per season in the spring when grass growth had begun.

Plants were harvested from different parts of the subplots of each replicate and combined to provide a sample representing a treatment, but not a replicate. Botanical analysis was done to separate red clover, grasses and weedson a 0.5 kg subsample. In Jokioinen these species fractions were dried and analyzed separately. At the other localities 2 × 100 g subsamples of the original mixed sample were chopped fresh, dried and analyzed. Samples were dried in oven at 105°C for two hours and then at 60°C overnight. Total drying time was 14 to 16 hours.

The amount of reduced nitrogen was measured using a Kjeltec Auto 1030 analyzer (Tecator, Höganäs) and the Kjeldahl procedure (Tecator Kjeltec Auto, 1030 Analyzer Manual, 1987). The crude protein concentration was calculated by multiplying the nitrogen concentration by 6.25. Crude fibre concentration was measured using the Fibertec System M (Tecator, Höganäs) and the Weende method (Tecator Fibertec System and Manual, 1978). Ca, Mg, K and P were analyzed with a Perkin Elmer 2100 flame atom absorption spectrophotometer.

Data on grass yields were analyzed using standard two-way analysis of variance: PROC GLM of SAS. Tukey's Studentized Range Test was used to compare statistically significantly different means among treatments. For regression analysis, t-tests and standard supplementary statistical calculations were used.

Results

Performance of red clover

Red clover comprised the main part of the dry matter yields during the first year's harvest at Jokioinen and Sotkamo (Figures 1–3). In 1990 in the Jokioinen A experiment red clover dominated regrowth and gave as high a yield of regrowth as for the initial harvest (Fig. 1).

The proportion of red clover in the yields of the other experiments during the first year was also high, except for the first harvest of the Jokioinen B experiment. The red clover content of the second year's harvest of Jokioinen A trial, excepting the first cut of sward for pasture, and the second year's harvest at Maaninka were substantial. The red clover contents in the trials at Ruukki were high, not only during the first and second years but also during the third year of harvest, except for the pasture sward in the A trial of the second year.

As a rule red clover content of the initial harvest was smaller than that for regrowth. There are two reasons for this: the first is the innate slower start of growth of red clover than that of grasses in the spring, the second is N-fertilization given before the first growth in the spring, which promoted grass growth but not that of clover.

Red clover survived best in Ruukki B trial, for which red clover content of regrowth of the swards for hay, silage and pasture reached 70 to 80% until the third year. Moreover, the red clover content of regrowth in Ruukki A trial in the

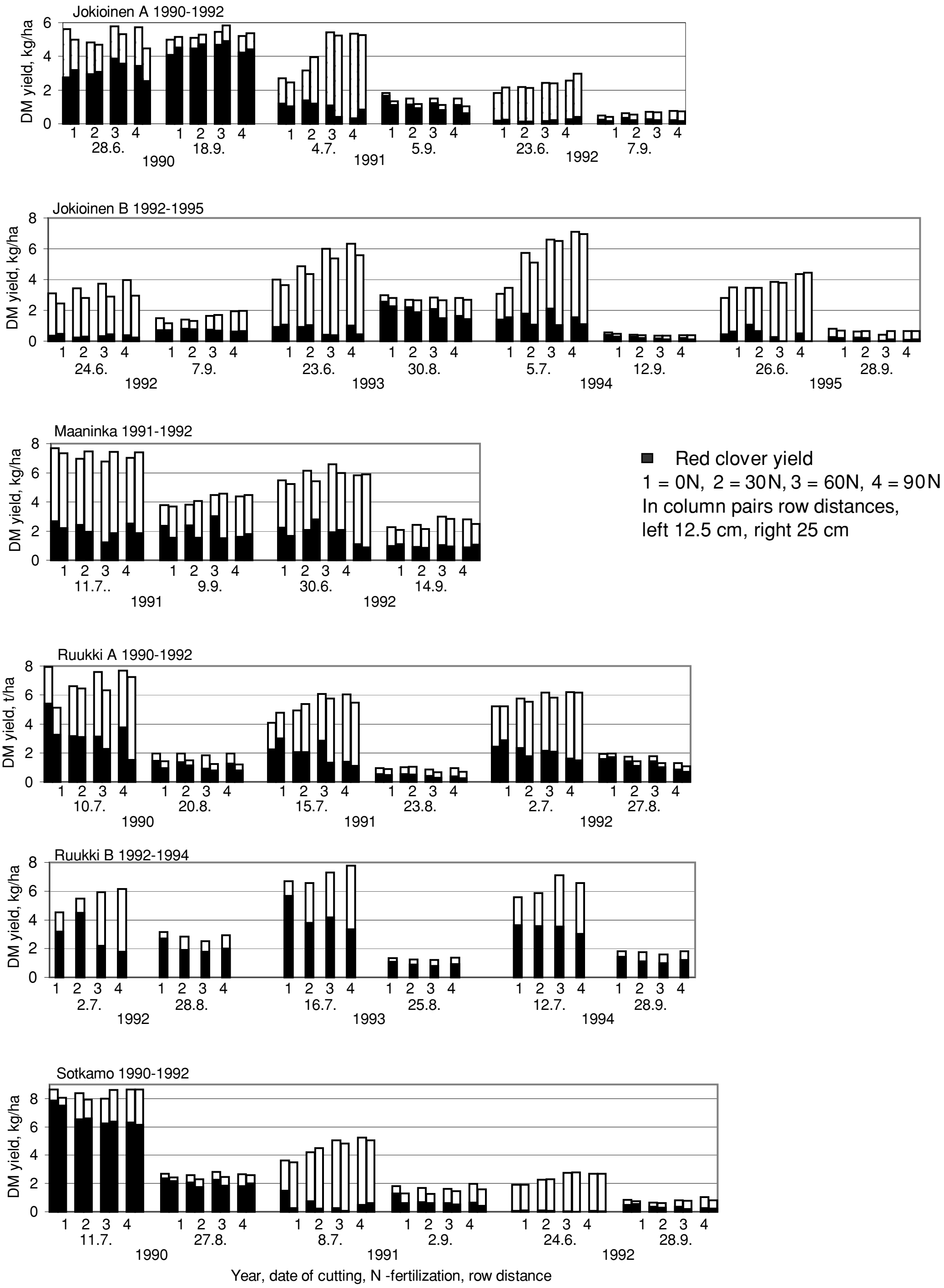

Fig. 1. Development of swards and their red clover content cut for hay and regrowth. Effects of age of sward, date of cutting, N-fertilization in spring and row distance in column pairs. Filled sections of columns indicate proportion of red clover and unfilled sections the proportion of grass.

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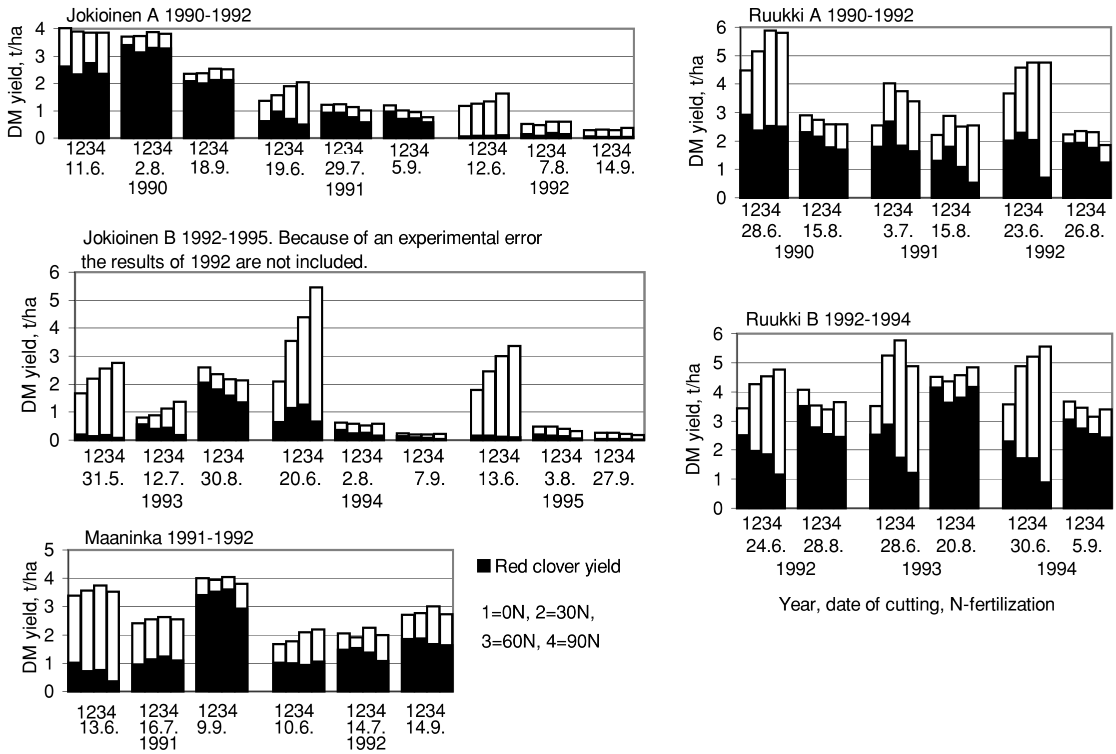

Fig. 2. Development of swards and their red clover content cut for silage. Effects of age of sward, date of cutting and N-fertilization in spring. Results of row distances are combined. Filled sections of columns indicate proportion of red clover and unfilled sections the proportion of grass.

third year was high, reaching 80% in the hay sward, 60% in the silage sward and 70% in the autumn harvest pasture sward.

The red clover content in the Jokioinen A experiment was 80% for the second year autumn regrowth over all cutting treatments. Red clover was low 8 to 20 in the Jokioinen A experiment in the third year autumn regrowth except for in the hay sward, which included about 40% red clover in the regrowth. Similarly as for the Jokioinen trial, red clover was low in the Sotkamo experiment in the third year. Red clover content in the Maaninka experiment was at its peak of 50 to 80% at autumn harvest of regrowth in the first year and decreased by 20% in the second year.

Red clover is not drought hardy. In the spring, soil is wet and water is not a limit to growth, but the amount of precipitation can strongly affect regrowth after a cut for silage or pasture. Thus drought (Table 1) decreased growth in Jokioinen in June 1990, July 1991, July 1994 and August 1994 (Figures 3–4). Abundant rainfall increased growth in Jokioinen in July and August 1993, in Maaninka in July and August 1992 and in Ruukki in July and August 1992.

N-fertilizer applied in the spring markedly decreased the red clover content of the sward; the greater the rate of fertilizer application the greater the decrease. On average, red clover was associated with N- fertilization in the Jokioinen experiments accordingly: (0N) 59a, (30) 54ab, (60) 46c, (90) 43c. The means followed by different lowercase letters differ from each other significantly at $P \leq 0.05$.

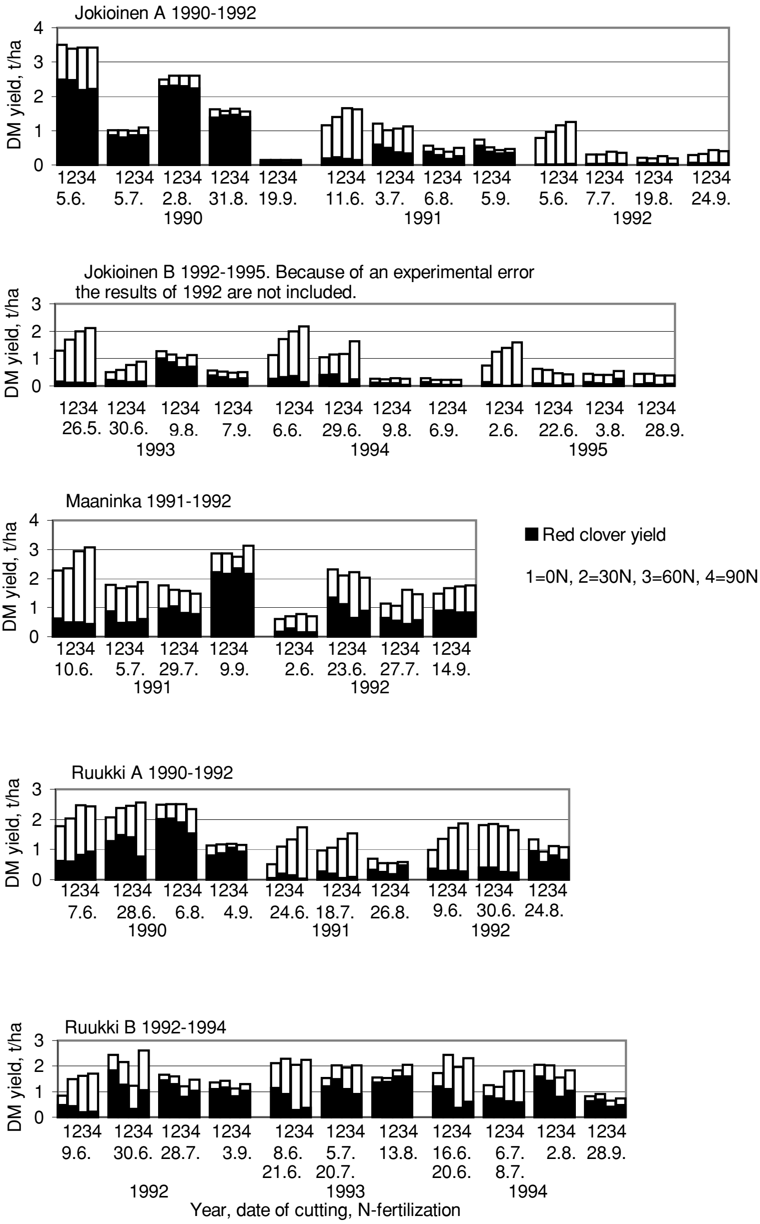

Fig. 3. Development of swards cut for pasture. Effects of age of sward, date of cutting and N-fertilization in spring. Results of row distances are combined. Filled sections of columns indicate proportion of red clover and unfilled sections the proportion of grass.

Heavy clay characterising Jokioinen soil and silt in Sotkamo (Table 2) did not favour the persistence of red clover. In Ruukki well-aerated sandy soil allowed red clover to develop deep and strong roots and form a long-lived sward. pH values for all soils of the trials were satisfactory for red clover and the concentration of minerals was maintained through annual fertilizer application. In Maaninka and Sotkamo heavy and long-lasting snow cover (Table 1) created conditions favouring low-temperature fungal development, which probably killed red clover.

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Table 1. Monthly mean temperature and precipitation for those growing seasons at research stations when trials were performed. Snow cover duration and maximum depth during winter before each growing season are indicated.

Year	Mean temperature, °C					Precipitation, mm						Snow cover
	May	Jun	Jul	Aug	Sep	May	Jun	Jul	Aug	Sep	Sum	days/cm max
						Jokioinen						
1990	9.3	14.4	15.2	15.0	8.0	22	19	85	90	62	279	92/34
1991	7.2	12.1	16.6	16.2	9.1	28	69	55	91	79	324	140/59
1992	11.4	15.6	16.0	14.3	11.2	7	24	47	107	59	245	125/35
1993	13.5	11.4	15.6	12.9	5.7	1	55	107	136	12	312	106/25
1994	7.8	12.1	19.0	15.1	10.0	33	66	1	54	105	260	143/37
1995	8.7	16.7	15.3	15.1	10.3	87	120	53	65	44	370	127/18
1996												162/54
1971–2000	9.5	14.1	16.1	14.5	9.3	35	57	80	80	61	313	
						Maaninka						
1991	6.5	13.0	16.5	15.3	8.4	50	132	57	81	90	412	148/38
1992	10.3	15.7	14.9	12.7	11.3	21	19	108	152	61	363	152/60
1993												170/41
1971–2000	8.5	14.3	16.5	14.0	8.8	42	66	74	84	56	322	
						Sotkamo						
1990	6.9	12.5	15.0	13.7	6.4	4	33	69	131	10	249	137/50
1991	5.4	12.3	15.5	14.7	7.0	61	117	51	80	92	404	159/60
1992	8.8	14.4	13.7	11.7	10.4	15	20	87	150	66	340	168/44
1993												194/44
1971–2000	7.5	13.3	15.8	13.1	7.8	38	61	67	82	56	304	
						Ruukki						
1990	7.2	12.9	15.2	14.1	6.8	7	42	93	59	18	222	120/31
1991	5.4	12.0	15.6	14.7	6.9	54	73	27	68	70	294	134/34
1992	9.3	14.3	13.7	11.8	10.5	35	26	116	138	94	412	138/35
1993	10.2	10.0	15.6	12.5	4.3	10	43	85	76	21	237	166/28
1994	5.7	12.4	16.5	13.8	7.9	15	60	24	35	48	184	166/57
1995												166/58
1971–2000	7.6	13.1	15.5	13.0	7.9	35	52	69	72	49	277	

Data provided by the Finnish Meteorological Institute.

Effect of the number of cuttings and age of sward on yields

In most experiments the highest yield was recorded in the first year (Tables 3–7). Jokioinen A, Maaninka and Sotkamo experiments produced more than 10 t ha^{-1} yield in the first season, in Ruukki yields were somewhat smaller. An exception was the Jokioinen B experiment that failed in 1992. Swards harvested as hay and regrowth yielded most, swards harvested three times per season as silage yielded less and swards harvested three to five times per season as pasture yielded, as a rule, less than grass for silage.

Yields from Jokioinen A trial (Table 3) decreased rapidly over time, to a half in the second and to a fifth to fourth in the third year compared with the yield from the first year. Jokioi-

Table 2. Analysis of soils at trial sites. In Jokioinen samples were collected both in spring when the trial was begun and in autumn when it was finished, at other sites samples were collected only in spring at trial initiation.

		Soil type	pH	Ca	Mg	P	K
					mg l^{-1}		
Jokioinen A	before exp.	heavy clay	6.60	3152	231	33.6	524
	after exp.	heavy clay	6.43	2886	238	33.8	485
Jokioinen B	before exp.	heavy clay	6.27	2163	264	12.0	324
	after exp.	heavy clay	5.87	2139	240	14.2	343
Maaninka	before exp.	fine sand	5.90	1242	151	18.1	208
Sotkamo	– ” –	silt	6.05	1284	214	14.1	213
Ruukki A	– ” –	fine sand	6.20	1873	182	14.8	162
Ruukki B	– ” –	fine sand	6.51	1759	201	19.0	234

nen B experiment (Table 4) yielded most in the second year and remained productive up to the fourth year. In the Sotkamo experiment (Table 5), which included only one cutting treatment, grass cut for hay and regrowth, yields decreased rapidly in subsequent years, similarly as in the Jokioinen A experiment. In Maaninka (Table 5) and Ruukki A (Table 6) experiments yields were quite stable up to the third year. The yields in Ruukki B (Table 7) experiment remained high throughout the trial period.

Effect of nitrogen fertilization on yields

N-fertilization generally increased dry matter yield. However, the effect was small when content of red clover was high, as in the first year swards of Jokioinen A, Maaninka and Sotkamo experiments. N-fertilization given in the spring variously affected the cutting treatments depending on the relative proportions of primary growth and regrowth and their different red clover and grass contents in the sward. This was demon-

Table 3. Dry matter yields (kg ha^{-1}) of red clover grass mixture as influenced by number of cuts and N-fertilization in Jokioinen in 1990–1992.

N, kg ha^{-1}	No. of cuts									
	1990					1991				1992
	2	3	4–5	mean		2	3	4–5	mean	mean
0	10370	9640	8270	9430a		4160	3440	3240	3610a	1990a
30	9940	9340	8070	9120a		4890	3670	3320	3960a	2150a
60	11200	9500	7980	9560a		6650	3840	3580	4690b	2560b
90	10400	9640	8150	9400a		6570	3950	3710	4740b	2740b
mean	10480a	9530ab	8120b			5570a	3730b	3460b		
					(1992)	2960a	2180b	1940b		

Statistical significancies: The different letters indicate significant difference at $P \leq 0.05$
1990 *A***, B*, C***, AxB***, AxC***, BxC NS, AxBxC**
1991 *A***, B***, C***, AxB***, AxC NS, BxC**, AxBxC**
1992 *A***, B***, C NS, AxB NS, AxC NS, BxC NS, AxBxC NS*
A = number of cuts, B = N-fertilization, C = row distance

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Table 4. Dry matter yields (kg ha^{-1}) of red clover grass mixture as influenced by number of cuts and N-fertilization in Jokioinen in 1992–1995.

N, kg ha^{-1}	No. of cuts												
	1992	1993				1994				1995			
	mean	2	3	4	mean	2	3	4	mean	2	3	4	mean
0	4110a	6730	4900	3430	5020a	3790	3040	2390	3070a	3900	2630	2070	2870a
30	4460ab	7290	5220	3790	5430ab	5830	4630	3080	4510b	4110	3150	2550	3270b
60	4980bc	8440	5600	4000	6010bc	6910	5020	3530	5150c	4370	3620	2380	3460b
90	5430c	8710	6130	4410	6420c	7410	5780	4080	5760d	5060	3840	2830	3910c
mean		7790a	5460b	3910b		5990a	4620b	3270c		4360a	3310b	2460c	

Statistical significancies: The different letters indicate significant difference at P ≤ 0.05
1992 B***, C***, BxC NS
1993 A***, B***, C***, AxB***, AxC NS, BxC NS, AxBxC NS
1994 A***, B***, C***, AxB***, AxC**, BxC**, AxBxC***
1995 A***, B***, C NS, AxB***, AxC***, BxC NS, AxBxC NS
A = number of cuts, B = N-fertilization, C = row distance

strated by generation of statistically significant A*B interaction effects.

Effect of growth density on yields

The ability of red clover and grass species to compete with each other and to fill empty space in a sward was tested through the row distance treatment. In nine years out of fifteen, the 12.5 cm inter-row distance promoted a statistically significantly (P ≤ 0.05) larger yield than 25.0 cm. In six other cases the yields were equal. Red clover content of dense swards was higher than that of thin swards. Red clover contents by sward density and degree of N-fertilization were as follows: 12.5cm/25.0cm (0N) 59a/51b, (30) 54a/47a, (60) 46a/40a, (90) 43a/37a. Statistically sig-

Table 5. Dry matter yields (kg ha^{-1}) of red clover grass mixtures as influenced by number of cuts and N-fertilization in Maaninka in 1991–1992 and in Sotkamo in 1990–1992.

N, kg ha^{-1}	No. of cuts					
	Maaninka					Sotkamo
	1991	1992				1991
	mean	2	3	4	mean	mean
0	9830a	7540	6220	5320	6360a	5120a
30	9970a	8060	6310	5570	6650ab	5820ab
60	10260a	9190	6920	6290	7470c	6480bc
90	10280a	8500	6830	5910	7080bc	6930c
mean		8320a	6570b	5770c		(1990 mean 10940)
	(1991)	11410a	9910b	8940c		(1992 mean 3200)

Statistical significancies: The different letters indicate significant difference at P ≤ 0.05
1991 *A***, B**, C NS, AxB NS, AxC NS, BxC NS, AxBxC** — 1990 *B NS, C NS, BxC NS*
1992 *A***, B***, C***, AxB*, AxC*, BxC NS, AxBxC NS* — 1991 *B***, C**, BxC NS*
A = number of cuts, B = N-fertilization, C = row distance — 1992 *B NS, C NS, BxC NS*

Table 6. Dry matter yields (kg ha^{-1}) of red clover grass mixture as influenced by number of cuts and N-fertilization in Ruukki in 1990–1992.

N, kg ha^{-1}	No. of cuts											
	1990				1991				1992			
	2	2	3–4	mean	2	2	3–4	mean	2	2	3–4	mean
0	8210	7130	6650	7330a	5350	4660	2260	4090a	7160	5940	3920	5670a
30	8230	7490	7210	7640a	7670	6180	2670	5510a	7230	6490	4140	5950a
60	8500	8350	7850	8230b	6680	6140	3190	5340a	7550	6580	4560	6230a
90	9020	8220	7920	8390b	6580	5830	3880	5430a	7370	6100	4680	6050a
mean	8490a	7800a	7440b		6570a	5700a	3000b		7330a	6280a	4330b	

Statistical significancies: The different letters indicate significant difference at P ≤ 0.05
1990 *A***, B***, C***, AxB NS, AxC***, BxC*, AxBxC**
1991 *A***, B**, C NS, AxB NS, AxC NS, BxC NS, AxBxC NS*
1992 *A***, B*, C***, AxB NS, AxC NS, BxC NS, AxBxC NS*
A = number cuts, B = N-fertilization, C = row distance

nificant differences (P ≤ 0.05) were apparent only between growth densities of the red clover contents without supplementary nitrogen application. Some statistically significant interactions, A*C and B*C, give an impression that N-fertilization in the spring and late cutting for hay helped a sward to compensate for a sparser stand.

Yield quality

Crude fibre and crude protein contents

Linear regression described well both the crude fibre (CF) and crude protein (CP) contents of red clover and grass yields as a function of accumulated temperature for the Jokioinen experiments

Table 7. Dry matter yields (kg ha^{-1}) of red clover grass mixture as influenced by number of cuts and N-fertilization in Ruukki in 1992–1994.

N, kg ha^{-1}	No. of cuts					
	1992	1993				1994
	mean	2	2	3–4	mean	mean
0	7160a	8010	8030	5220	7090a	6840a
30	7590ab	7800	9600	5840	7740ab	7500b
60	7180a	8510	10340	5360	8070b	7660b
90	8200b	9150	9750	6330	8410b	8000b
mean		8380a	9430b	5690c		

Statistical significancies: The different letters indicate significant difference at P ≤ 0.05
1992 *A***, B*, AxB NS*
1993 *A***, B***, AxB**
1994 *A***, B***, AxB NS*
A = number of cuts, B = row distance

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(Figs 4 and 5). Results of the second harvest were not included in the regression calculations because the number of culms, which increases in a sward after the primary growth, depends much on the time of the harvest and is not possible to predict. These culms have a substantial effect on the quality of the second harvest.

Based on the corresponding regression values reported in Figures 4 and 5, estimates were made of dependence of organic matter digestibility (OMD) and crude protein digestibility (CPD) of red clover and grass on temperature sum. The Kivimäe (1959) function (OMD = 94.3 – 1.01 × CF) was used to calculate OMD values for red clover and the Korva and Tuori (1986) function (OMD = 92.0 – 139.3/CP – 0.01261 × CF^2) to calculate OMD values for grass in Fig. 6. Crude protein digestibility values for both red clover and grass in Fig. 7 were calculated using the Korva and Tuori (1986) function (CPD = 91.8 – 288.4/CP).

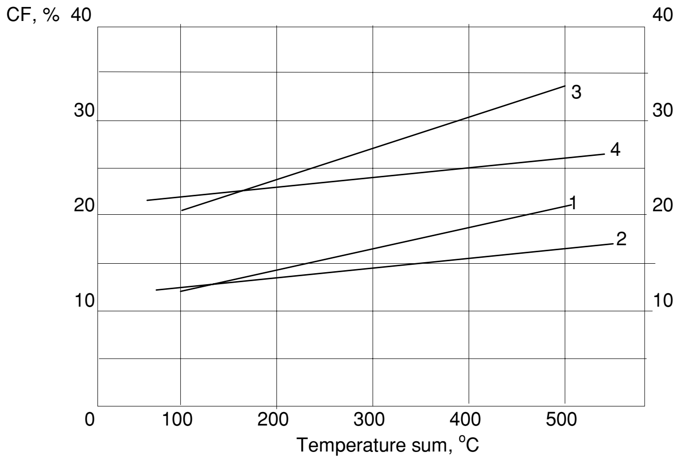


Fig. 4. Crude fibre (CF) content of red clover and grass as a function of temperature sum. Experiments conducted at Jokioinen in 1990–1995.

1 = red clover, 1st cut y = 9.40 + 0.0227x; r = 0.639*** ; SE = 2.95 ; n = 130
2 = red clover, 3rd to 5th cut y = 11.09 + 0.0116x; r = 0.453*** ; SE = 2.67 ; n = 147
3 = grass, 1st cut y =17.26 + 0.0320x; r = 0.619*** ; SE = 4.22 ; n = 176
4 = grass, 3rd to 5th cut y = 20.98 + 0.0102x; r = 0.486*** ; SE = 2.14 ; n = 148

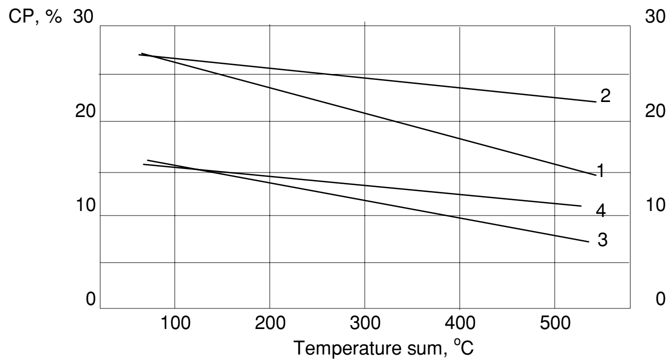
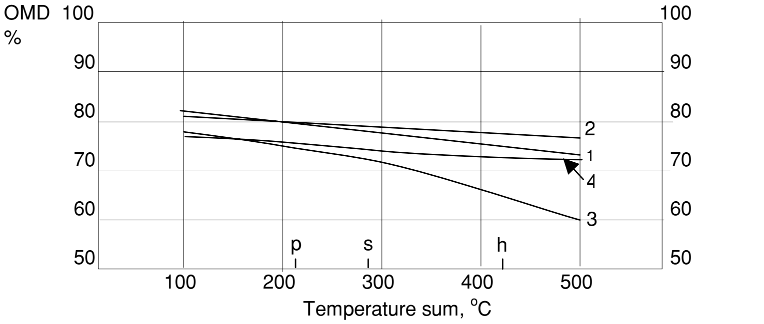


Fig. 5. Crude protein (CP) content of red clover and grass as a function of temperature sum. Experiments conducted at Jokioinen in 1990–1995.

1 = red clover, 1st cut y = 29.45 - 0.0276x ; r = 0.772*** ; SE = 2.40 ; n = 132
2 = red clover, 3rd to 5th cut y = 28.36 - 0.0121x ; r = 0.414*** ; SE = 3.10 ; n = 151
3 = grass, 1st cut y = 17.93 - 0.0205x ; r = 0.653*** ; SE = 2.46 ; n = 176
4 = grass, 3rd to 5th cut y = 16.33 - 0.0098x ; r = 0.426*** ; SE = 1.93 ; n = 172

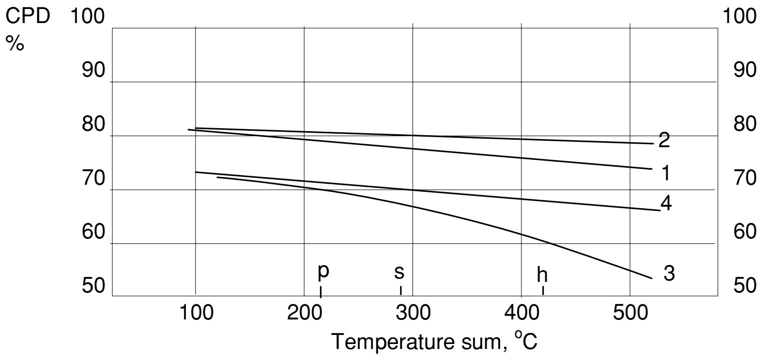


p, s, h = average stages of cutting the experimental swards for pasture, silage and hay

1 = red clover, 1st cut
2 = red clover, 3rd to 5th cut
3 = grass, 1st cut
4 = grass, 3rd to 5th cut

1 & 2 Kivimäe (1959): OMD = 94.3 - 1.01 * CF
3 & 4 Korva and Tuori (1986): OMD = 92.0 - 139.3/CP - 0.0126 * CF^2

Fig. 6. Organic matter digestibility (OMD) of red clover and grass as a function of temperature sum. Based on models developed by Kivimäe (1959) for red clover and Korva and Tuori (1986) for grass, and crude fibre (CF) and crude protein (CP) values from functions indicated in Figures 4 and 5.



p, s, h = average stages of cutting the experimental swards for pasture, silage and hay

1 = red clover, 1st cut
2 = red clover, 3rd to 6th cut
3 = grass, 1st cut
4 = grass, 3rd to 5th cut

Korva and Tuori (1986): CPD = 91.8 - 288.4/CP

Fig. 7. Crude protein digestibility (CPD) of red clover and grass as a function of temperature sum. Based on model developed by Korva and Tuori (1986), and crude protein (CP) values from functions indicated in Fig. 5.

According to the calculations, OMD of red clover and grass primary growth were 80.2% and 74.8%, respectively, and at 200˚C accumulated temperature (AT), which was the average time of the first cut of sward for pasture (Fig. 6). At 400˚C AT, the time just preceding hay harvest, OMD of the primary growth red clover was 75.6% and that of grass 66.3%. OMD of regrowth red clover was 80.7% at 200˚C AT and 78.4% at 400˚C. OMD of regrowth grass was 75.6% at 200˚C and 72.8% at 400˚C AT.

CPD of the primary growth red clover (Fig. 7) was 79.7% at 200˚C AT and 76.1% at 400˚C AT. CPD of the primary growth grass was 70.9%

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Table 8. Mean mineral contents (g kg^{-1}) of primary yield and regrowth of red clover and grass as a function of temperature sum.

Element	Function	Mean$^{t\text{-}test}$	n
Red clover			
Ca, 1st cut	y = 14.89 – 0.0061x; r = 0.408***; SE = 1.27	12.9***	128
Ca, regrowth	y = 16.10 + 0.0022x; r = 0.133*; SE = 3.05	17.0	301
Mg, 1st cut	y = 3.67 – 0.0004x; r = 0.095NS; SE = 0.50	3.5***	128
Mg, regrowth	y = 3.93 – 0.0003x; r = 0.107NS; SE = 0.53	3.8	301
P, 1st cut	y = 3.88 – 0.0054x; r = 0.706***; SE = 0.45	2.8***	128
P, regrowth	y = 3.34 – 0.0017x; r = 0.443***; SE = 0.54	2.6	300
K, 1st cut	y = 33.02 – 0.0156x; r = 0.125NS; SE = 3.89	32.7***	129
K, regrowth	y = 33.78 – 0.0102x; r = 0.420***; SE = 3.54	29.4	301
Grass			
Ca, 1st cut	y = 2.93 + 0.0048x; r = 0.254***; SE = 0.32	3.0***	151
Ca, regrowth	y = 4.74 + 0.0039x; r = 0.117NS; SE = 1.07	4.9	297
Mg, 1st cut	y = 1.04 – 0.0006x; r = 0.043NS; SE = 0.16	1.0***	128
Mg, regrowth	y = 1.68 + 0.0005x; r = 0.262***; SE = 0.31	1.8	293
P, 1st cut	y = 2.77 + 0.0036x; r = 0.181*; SE = 0.61	2.9***	144
P, regrowth	y = 4.37 – 0.00008x; r = 0.003NS; SE = 0.95	4.3	310
K, 1st cut	y = 32.21 – 0.0180x; r = 0.450***; SE = 3.30	26.6***	152
K, regrowth	y = 30.82 – 0.0007x; r = 0.020NS; SE = 6.61	30.5	302

at 200˚C and 62.1% at 400˚C AT. CPD of regrowth red clover was 80.6% at 200˚C AT and 79.5% at 400˚C AT. CPD of regrowth grass was 71.7% at 200˚C and 68.5% at 400˚C AT.

Minerals

Ca content of the primary growth red clover decreased but Ca content of the regrowth increased, when the sward aged (Table 8). Mg content did not change over time. P content of both the primary growth and regrowth as well as K content of regrowth red clover decreased over the growth period. Ca and P content of the primary growth and Mg content of grass regrowth increased and K content of the grass primary growth decreased over time. Contents of other minerals studied were unchanged over time.

N-fertilization decreased Ca content of the spring harvested red clover (y = 13.42 – 0.0115x; r = 0.213*; SE = 1.58; n = 128), but it did not affect Ca content of red clover regrowth or other mineral contents of red clover. N-fertilization increased Ca content (y = 2.93 + 0.0048x; r = 0.254**; SE = 0.56; n = 151), P content (y = 2.77 + 0.0036x; r = 0.181*; SE = 0.64; n = 144) and K content (y = 24.28 + 0.052x; r = 0.388***; SE = 3.48; n = 152) of the first harvest of grass species, and increased Ca content (y = 4.74 + 0.0039x; r = 0.117*; SE = 1.07; n = 297) of regrowth of grass species.

Discussion

According to previous results, red clover survives for only two to three years in the field (Paatela 1953, Williams 1982). This was the case also in the present study. In the Ruukki experiment, one reason for the good survival through three years could have been attributable to the variety grown, Bjursele, which originates from northern Sweden and has been shown to be hardy in variety trials (Mela et al. 1980). Björn, another winter-hardy Swedish variety, was grown in the other experiments of the study. Obviously the most important reason for the good survival at Ruukki was the sandy soil, which was well-aerated and allowed red clover taproots and *Rhizobium* to develop optimally. Furthermore, a thin snow cover is typical for the western coast region of Finland where Ruukki is located, and as a result soil is well frozen in winter, which prevents low-temperature fungi from developing and damaging plants (Mäkelä 1981). Maaninka and Sotkamo are located in the less favourable deep snow region in eastern Finland. The heavy clay soil of Jokioinen fields and the summer dry periods did not favour red clover growth, and explain its lack of persistence there.

The growth of the experimental swards was based very much on red clover as nitrogen fertilizer was applied only in the spring at the start of growth and mainly favoured the growth of grass in the initial harvest. N-fertilizer applied in the spring has only a small effect on regrowth capacity (Agerberg 1943, Julén 1954). Some nitrogen becomes available through mineralization of plant material, harvest litter and dead roots, but it only partly satisfies the need of grasses for nitrogen through the summer (Ingebrigtsen 1959). To increase grass growth significantly, adequate N-fertilizer should be applied for regrowth even in grass-clover mixtures. However, it should not stimulate excessive competition between the grass and red clover.

At the time of this study estimated feed digestibility values were generally based on crude fibre and crude protein analysis, at least when the number of forage samples to be analyzed was large as is usually for field experiments. Other available methods were too expensive. Use of NIR (Near Infrared Reflectance) for organic matter digestibility determinations was developed but the required equipment became generally available in laboratories later during the 1990s (Hellämäki 1992).

Models based on CF and CP values were used for calculating the digestibility of organic matter and crude protein (Kivimäe 1959, Korva and Tuori 1986). In the present study, OMD and CPD contents based on these models are presented as a function of accumulated temperature sum.

The calculated OMD and CPD contents are close to the corresponding values from other studies: for OMD (Salo et al. 1975, Mela and Poutiainen 1975, Sanderson and Wedin 1989, Rinne and Nykänen 2000): for OMD and CPD (Kivimäe 1965, Feed tables and feeding recommendations 2002 by MTT Agrifood Research Finland (Tuori et al. 2002), based on plant material from different sources.

The digestibility of herbage can be predicted through observation of the phenological stage of plants (Kivimäe 1959, Deinum et al. 1968, Mela and Poutiainen 1975, Rinne and Nykänen 2000), accumulation of temperature degrees (present study) and even by determining the proportion of leaves in dry matter (Rinne and Nykänen 2000).

During primary growth the phenological stage of a single species is easily identified from the stage of ear and flower development. However, when there is a mixed sward of different species their relative proportions influence forage quality. Consequently, due to their differential development and growth rates it is difficult to forecast forage quality. Another difficulty is in estimating the digestibility of regrowth after the first cut as it includes a varying number of culms depending on the temperature during primary growth, the growth stage of grass at cutting, grass species and probably genotype.

Regrowth includes tillers at different stages of growth and it is difficult to determine its phenological stage. Regrowth consists mainly of leaf mass, the chemical composition of which changes relatively slowly. Therefore, specific knowledge of the dependence of the quality characteristics on accumulation of temperature degrees combined with botanical analysis can be considered a suitable method to predict the digestibility for practical purposes.

N-fertilization does not affect digestibility much, if at all (Mela and Poutiainen 1975, Fagerberg and Ekbohm 1995, Bélanger and McQueen

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1998), but it affects protein content significantly. Except for N-fertilization there are several factors that affect the protein content of herbage, as the amount of free nitrogen in soil, soil organic matter and its decomposition, it is changes in air and soil temperature and soil aeration that affect the rate of decomposition and control soil N reserves available to plants.

There is close correlation between plant development and protein content. Quality of the tillers at the same phenological stage and established at the same time is similar. On the other hand, tillers at the same stage but established later have lower protein content. This depends on changes in competition in the sward for light and nutrients. Thus, the way a sample for analyses is taken is of great importance (Thorvaldsson 1989). More tillers and leaves develop in a low density sward than in a dense sward, which also affects quality (Wivstad 1997).

Weather conditions affect development of a sward and both quality and yield. A cold period slows down or stops growth and development of both red clover and grass: a large part of a grass stand remained in the node stages and budding of red clover was delayed one to two weeks (Fagerberg 1988b, Thorvaldsson and Fagerberg 1988). After a long dry period precipitation stimulates growth of high quality new stems and leaves (Mela and Youngner 1976). Rising temperature hastens maturity and reduces carbohydrate content and digestibility (Deinum et al. 1968, Ruegg and Nösberger 1977, Fagerberg 1988a). High temperatures increase respiration more than photosynthesis and promote lignification of the cell walls. This results in reduced digestibility.

Similar to other results, those of the present study showed that an increase in N-fertilization increased K and Ca (Hiivola et al. 1974, Rinne et al. 1974). In contrast with previous results N-fertilization increased Mg content and decreased P content of grass. Differences in mineral content of grass among the experiments depend greatly on the various experimental treatments and different soil mineral contents. In the study of Rinne et al. (1974) there was only one cutting treatment, three cuts for silage and N-fertilization treatments ranged from 0 to 600 kg ha^{-1}. The mineral contents in the present study correspond quite well with those of Feed tables and feeding recommendations 2002 (Tuori et al. 2002). The mineral content of plants varies greatly according to soil mineral content (Jokinen 1979).

Advantages of red clover for feeding dairy cattle have been demonstrated in several experiments. Better animal performance is achieved by feeding cattle with red clover-grass silage compared to pure grass silage of similar digestibility. Positive effects of red clover on milk output and composition were evident when silage included 30 to 70% red clover (Heikkilä et al. 1992). Milk output was increased and the protein/fat ratio of milk was improved compared with meadow fescue-timothy grass mixture for silage. Cows consumed more red clover-grass silage than grass silage and milk output was increased (Vanhatalo et al. 1995, Heikkilä et al. 1996). This resulted both from increased microbial N and decreased rumen N degradability for the red clover diet (Vanhatalo et al. 1995). Disadvantages of red clover are marked effluent losses (Syrjälä-Qvist et al. 1984) with high plant oestrogen content (Kallela 1974, Mela et al. 1993) and risk of bloat with cattle on pasture.

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References

Agerberg, L.S. 1943. Slåttertids- och gödslingsförsök i vall. *Sveriges Lantbrukshögskolan, Jordbruksförsöksanstaltet. Meddelande* 9: 1–45.

Bélanger, G. & McQueen, R.E. 1998. Analysis of the nutritive value of timothy grown with varying N nutrition. *Grass and Forage Science* 53: 109–119.

Deinum, B., Van Es, A.I.H. & Van Soest, P.J. 1968. Climate, nitrogen and grass. II. The influence of light intensity, temperature and nitrogen on in vivo digestibility of grass and the prediction of these effects from some chemical procedure. *Netherlands Journal of Agricultural Science* 16: 217–223.

Fagerberg, B. 1988a. Phenological development in timothy, red clover and lucerne. *Acta Agriculturae Scandinavica* 38: 159–170.

Fagerberg, B. 1988b. The change in nutritive value in timothy, red clover and lucerne in relation to phenological stage, cutting time and weather conditions. *Acta Agriculturae Scandinavica* 38: 347–362.

Fagerberg, B. & Ekbohm, G. 1995. Variation in clover content and in nutritional value of grass-clover leys. Swedish University of Agricultural Sciences, Uppsala, Sweden. *CropProduction Science* 23. 46 p.

Hakkola, H. & Nykänen-Kurki, P. 1994. Effect of nitrogen fertilization and cutting time on the quality and variable costs of red clover and timothy herbage production. *Proceedings of the 15th General Meeting of the European Grassland Federation*, Wageningen, the Netherlands, 1992. p. 105–108.

Heikkilä, T., Toivonen, V. & Mela, T. 1992. Comparison of red clover-grass silage with grass silage for milk production. *Proceedings of 14th General Meeting of the European Federation*, Lahti, Finland, June 8–11, 1992. p. 388–391.

Heikkilä, T., Toivonen, V. & Mela, T. 1996. Effects of red clover-grass, grass and annual ryegrass silages with two concentrate protein levels on milk production. *Grassland and Land Use Systems. Proceedings of the 16th General Meeting of the European Grassland Federation*, Grado (Gorizia), Italy, September 15–19, 1996. p. 447–450.

Hellämäki, M. 1992. Estimation of forage digestibility using NIR. *Proceedings of 14th General Meeting of the European Federation*, Lahti, Finland, June 8–11, 1992. p. 405–408.

Hiivola, S.-L., Huokuna, E. & Rinne, S.-L. 1974. The effect of heavy nitrogen fertilization on the quantity and quality of yields of meadow fescue and cocksfoot. *Annales Agriculturae Fenniae* 13: 149–160.

Ingebrigtsen, S. 1959. Gjodsling til kloverrik eng. *Forskning og Forsog i Landbrug* 10: 159–206.

Jokinen, R. 1979. The effect of magnesium, potassium and nitrogen fertilizers on the contents and ratios of nutrients in spring cereals and grassland crops. *Annales Agriculturae Fenniae* 18: 188–202.

Julén, G. 1954. Försök rörande spridningstidens inverkan på kvävegödslingens effekt på avkastning och proteinhalt hos timotej. *Sveriges Utsädesföreningens Tidskrift* 63: 444–468.

Kallela, K. 1974. Estrogenic and anti-estrogenic characteristics of common Finnish fodders. *Nordisk Veterinärmedicin* 26: 97–107.

Kivimäe, A. 1959. Chemical composition and digestibility of some grassland crops with particular reference to changes caused by growth, season and diurnal variation. *Acta Agriculturae Scandinavica*. Supplement 5: 1–142.

Kivimäe, A. 1965. Timotejhöets sammansättning och smältbarhet vid framskridande kördestadier. Sveriges Lantbrukshögskolan. Meddelande Ser. A nr. 37. 23 p.

Korva, J. & Tuori, M. 1986. Prediction of the digestibility of silage and hay from the crude fibre and crude protein content. *Journal of the Agricultural Science in Finland* 58: 175–183.

Mäkelä, K. 1981. Winter damage and low-temperature fungi on leys in North Finland in 1976–1979. *Annales Agriculturae Fenniae* 20: 102–131.

Mela, T. 1969. The effects of N-dimethylaminosuccinamic acid (B-995) on the seed cultivation characteristics of late-flowering red clover. *Acta Agralia Fennica* 115: 1–114.

Mela, T. 1988. Luonnonmukainen peltoviljely Suomessa. Summary: Organic farming in Finland. Cultivation methods, weeds, soil fertility, yields, and yield quality. *University of Helsinki, Department of Crop Husbandry. Publications* No. 16. 220 p.

Mela, T., Huokuna, E., Köylijärvi, J., Rinne, K., Simojoki, P. & Teittinen, P. 1980. Comparisons between Nordic red clover varieties in clover-grass mixtures. *Annales Agriculturae Fenniae* 19: 131–141.

Mela, T., Laakso, I., Mäenpää, T. & Ihamäki, H. 1993. Variation in the isoflavone and pterocarpan contents of red clover. *Proceedings of the 17th International Grassland Congress*. p. 1385–1386.

Mela, T. & Poutiainen, E. 1975. Grass must be cut in time for silage. (Säilörehunurmi on korjattava ajoissa.) *Pellervo* 76: 14–15, 19. (in Finnish).

Mela, T. & Youngner, V.B. 1976. Recovery of three temperate-climate grasses from drought stress. *Annales Agriculturae Fenniae* 15: 309–315.

Multamäki, K. & Kaseva, A. 1983. Kotimaiset lajikkeet. Maatalouden tutkimuskeskus, Tiedote 7/83. 9 p.

Official Statistics of Finland 1961. Suomen virallinen tilasto 1961. p. 56.

Paatela, J. 1953. Maamme heinänurmien botaanisesta koostumuksesta. *Acta Agralia Fennica* 79, 3: 1–128.

Paatela, J. 1962. Characteristics of some diploid and tetraploid varieties of the late red clover *Trifolium pratense v. subdunum* subv. *serotinum. Acta Agralia Fennica* 99, 4: 1–31.

Raatikainen, M. & Raatikainen, T. 1975. Heinänurmien sato, kasvilajikoostumus ja sen muutokset. *Annales Agriculturae Fenniae* 14: 57–191.

Raininko, K. 1968. The effects of nitrogen fertilization, irrigation and number of harvestings upon leys established with various seed mixtures. *Acta Agralia Fennica* 112. p. 1–137.

Ravantti, S. 1980. Winter hardiness and yield of local varieties of Finnish red clover grown in southern Finland at Anttila experimental farm of the Hankkija plant breeding institute in 1962–1966. *Annales Agriculturae Fenniae* 19: 142–155.

Rinne, M. & Nykänen, A. 2000. Timing of primary growth harvest affects the yield and nutritive value of timothy-red clover mixtures. *Agricultural and Food Science in Finland* 9: 121–134.

Rinne, S.-L., Sillanpää, M., Huokuna, E. & Hiivola, S.-L. 1974. Effects of heavy nitrogen fertilization on potassium, calcium, magnesium and phosphorus contents in ley grasses. *Annales Agriculturae Fenniae* 13: 96–108.

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Ruegg, J. & Nösberger, J. 1977. Influence of temperature on the phenological development, dry matter distribution, total nonstructural carbohydrates and crude protein of *Festuca pratensis* Huds. *Angewandte Botanik* 51: 167–177.

Salo, M.-L., Nykänen, A. & Sormunen, R. 1975. Composition, pepsin-HCL solubility and in vitro digestibility of forages at different growth stages. *Journal of the Scientific Agricultural Society of Finland* 47: 480–490.

Salonen, M. & Hiivola, S.-L. 1963. Typpilannoituksen vaikutus puna-apilan ja nurminadan sadon määrään ja laatuun. *Annales Agriculturae Fenniae* 2: 136–152.

Sanderson, M.A. & Wedin, W.F. 1989. Phenological stage and herbage quality relationships in temperature grasses and legumes. *Agronomy Journal* 81: 864–869.

Syrjälä-Qvist, L., Pekkarinen, E., Setälä, J. & Kangasmäki, T. 1984. Effect of red clover/timothy ratio on the protein feeding value and the quality of silage. *Journal of the Agricultural Science in Finland* 56: 183–191.

Thorvaldsson, G. 1989. Phenological development and nutritional value of timothy. *Swedish Journal of Agricultural Research* 19: 73–76.

Thorvaldsson, G. & Fagerberg, B. 1988. Effects of weather on nutritional value and phenological development of timothy. *Swedish Journal of Agricultural Research* 18: 51–59.

Tuori, M., Kaustell, K., Valaja, J., Aimonen, E., Saarisalo, E. & Huhtanen, P. 2002. *Rehutaulukot ja ruokintasuositukset 2002. (Feed tables and feeding recommendations 2002).* MTT Agrifood Research Finland, Jokioinen, Finland. Available on the Internet: http://www.mtt.fi/julkaisut/rehutaulukot//URN:NBN:fife20011096. (in Finnish).

Valle, O. 1958. Experiences with Canadian Altaswede and Swedish commercial red clover in Finland. *Journal of the Scientific Agricultural Society of Finland* 94: 293–299.

Valle, O. 1959. Pollination and seed setting in tetraploid red clover in Finland. *Journal of the Scientific Agricultural Society of Finland* 95, 4: 1–34.

Vanhatalo, A., Heikkilä, T. & Gäddnäs, T. 1995. Microbial protein synthesis in dairy cows fed grass silage or red clover-grass silage. *Proceedings of the 7th International Symposium on Protein Metabolism and Nutrition*, Vale de Santarém, Portugal, May 24–27, 1995. p. 275.

Williams, T.E. 1982. Herbage production: grasses and leguminous forage crops. In: Holmes, W. (ed.). *Grass, its production and utilization*. Oxford, Blackwell. p. 70–124.

Wivstad, M. 1997. Plant morphology and content of nitrogen, cell wall and lignin at different phenological stages of red clover and yellow sweetclover. *Swedish Journal of Agricultural Research* 27: 3–14.

Ylimäki, A. 1967. Root rot as a cause of red clover decline in leys in Finland. *Annales Agriculturae Fenniae* 6. Supplement 1: 1–59.

SELOSTUS

Puna-apilan pysyvyys apila-heinänurmessa sekä seosnurmen satoisuus ja laadun muutokset erilaisissa kasvuoloissa

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Vaikka puna-apilaa on Suomessa tutkittu ajoittain runsaasti, sen menestymistä vaihtelevissa oloissa eri puolilla maata ei ole selvitetty samassa tutkimuksessa. Vain virallisia lajikekokeita on suoritettu samanaikaisesti monella koepaikalla. Nyt kun kiinnostus puna-apilaan on jälleen kasvamassa luonnonmukaisten viljelymenetelmien yleistyessä, tämä tutkimus täydentää tietoa puna-apilan viljelymahdollisuuksista Suomen merkittävillä nurmirehun tuotantoalueilla.

Puna-apilan viljelyä seoksena timotein ja nurminadan kanssa tutkittiin neljällä Maatalouden tutkimuskeskuksen koepaikalla: Kasvintuotannon tutkimuslaitoksella Jokioisissa, Pohjois-Savon tutkimusasemalla Maaningalla, Kainuun tutkimusasemalla Sotkamossa ja Pohjois-Pohjanmaan tutkimusasemalla Ruukissa vuosina 1990–1995. Tutkittu puna-apilalajike oli ruotsalainen Björn kolmella koepaikalla ja ruotsalainen paikallislajike Bjursele Ruukissa. Siemenseoksen kylvömäärä oli 32 kg/ha, josta puna-apilaa 10 kg, timoteitä 10 kg ja nurminataa 12 kg. Kokeiden koejäseninä olivat korjuutapa (heinä-, säilörehu- tai laidunasteen niitto, Sotkamossa vain heinä), typpilannoitus keväällä (0, 30, 60 tai 90 kg/ha) ja kasvuston tiheys (riviväli 12,5 tai 25,0 cm).

Puna-apila muodosti pääosan Jokioisten ensimmäisen kokeen ensimmäisen vuoden heinä-, säilörehu- ja laidunnurmen sadosta sekä Sotkamon ensimmäisen vuoden heinäsadosta. Myös muiden kokeiden ensimmäisen vuoden puna-apilasadot olivat korkeita, Jokioisten toista koetta lukuun ottamatta. Myös Maaningan ja Jokioisten ensimmäisen kokeen toisen vuoden sekä Ruukin kokeiden toisen ja kolmannen vuoden satojen puna-apilapitoisuudet olivat suuria, laidunasteen ensimmäisiä niittoja lukuun ottamatta. Lähes poikkeuksetta kevätsadon puna-apilapitoisuus oli pienempi kuin odelman. Tämä johtui puna-apilan nurmiheiniä hitaammasta kasvuun lähdöstä keväällä ja kevään typpilannoituksesta, joka lisäsi heinien mutta ei apilan kasvua.

Puna-apila säilyi parhaiten pohjoisimmalla koepaikalla Ruukissa, missä eri niittokoejäsenten odelman puna-apilapitoisuus saavutti jopa 80 % vielä kolmantena koevuonna. Puna-apilan hyvä kestävyys Ruukin kokeissa voi johtua kestävästä Bjursele-lajikkeesta ja ilmavasta hietamaasta, jolla apilan juuristo ja typpibakteerit viihtyivät hyvin. Maaningan kokeessa hietamaalla odelmasadon puna-apilapitoisuus oli ensimmäisenä vuonna 50–80 % ja toisena vain 20 %-yksikköä pienempi, mutta siellä apila hävisi toisen vuoden jälkeen. Jokioisten jäykältä savelta puna-apila katosi toisen vuoden jälkeen lähes kokonaan, samoin Sotkamon hiesulta. Typpilannoitus pienensi selvästi nurmen apilapitoisuutta.

Suurimmat vuotuiset kuiva-ainesadot saatiin heinänurmilta ensimmäisenä korjuuvuonna. Jokioisissa, Maaningalla ja Sotkamossa suurin sato oli 10 t/ha, ja Ruukissa pari tonnia pienempi. Säilörehunurmien sadot olivat 67–92 % ja laidunnurmien 46–88 % heinänurmien sadoista. Kevään typpilannoitus lisäsi vuotuisia kokonaissatoja lannoitteen määrästä riippuen jopa 38 %. Yleensä typen vaikutus oli sitä selvempi mitä pienempi oli nurmen apilapitoisuus. Tiheään kylvetty kasvusto antoi useimmiten suuremman sadon kuin harva kasvusto.

Jokioisten kokeiden satonäytteistä eroteltiin puna-apilan ja heinän osuudet. Kun nämä fraktiot analysoitiin erikseen, saatiin tietoa puna-apilan ja heinien laatueroista. Lämpötilasumman noustessa sadon raakakuitupitoisuus suureni ja raakavalkuaispitoisuus pieneni suoraviivaisesti. Raakakuitutulokset muunnettiin kaavoilla orgaanisen aineen sulavuuksiksi ja raakavalkuaistulokset raakavalkuaisen sulavuuksiksi.

Puna-apilan kevätsadon Ca-pitoisuus pieneni, mutta odelmasadon Ca-pitoisuus suureni kasvuston vanhetessa. Mg-pitoisuus ei muuttunut. Kevät- ja odelmasadon P-pitoisuus sekä odelmasadon K-pitoisuus pienenivät kasvun edistyessä. Heinän kevätsadon Ca- ja P-pitoisuudet sekä odelmasadon Mg-pitoisuus suurenivat kasvun edistyessä. Kevätsadon K-pitoisuus pieneni.

Tulosten perusteella puna-apilaa voidaan viljellä menestyksellä myös Pohjois-Suomen nurmiseoksissa, kun viljeltäväksi valitaan näihin oloihin sopiva lajike. Puna-apilan kestävyyteen näyttäisi vaikuttavan pellon maalaji enemmän kuin leveysaste. Hyvin vettä läpäisevä ja tuulettuva maalaji, jolla puna-apilan pääjuuri ja juuristo pääsevät hyvin kehittymään eikä tulvavesi ehkäise juuriston typpibakteerien toimintaa, on tiivistä maalajia parempi puna-apilan viljelyssä.