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Annual and seasonal changes in production and composition of grazed clover-grass mixtures in organic farming

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A grazed field experiment based on a randomised block design was conducted in Eastern Finland to evaluate the potential of alsike clover (*Trifoliun hybridum* L.), red clover (*Trifolium pratense* L.) and white clover (*Trifolium repens* L.) to support herbage production from clover-grass mixtures under organic farming practices. The effect of seed mixture (alsike clover, red clover, white clover, white and alsike clover or grass mixture), year (1996, 1997 and 1998) and grazing period (5 per grazing season) on pre- and post-grazing herbage mass (HM), botanical and chemical composition of pre-grazing HM and post-grazing sward height was assessed. The nutritive value of herbage for milk production was also considered. Seed mixtures resulted in different pre-grazing HM and post-grazing sward heights, but similar pre- minus post-grazing HM. Compared with other mixtures, the proportion of clover was higher for white clover based mixtures. The white clover mixture had the highest crude protein content and lowest concentrations of cellulose and hemicellulose. In addition to seed mixture, the effect of year and grazing period on measured parameters was significant, highlighting the importance of grazing management. Moderate pasture herbage production of relative high nutritive value was achieved under organic practices, but the supply and nutritive value of herbage was variable and, in some cases, unable to meet the requirements of lactating dairy cows. The proportion of clover in all seed mixtures decreased year on year, and was subject to seasonal variations that altered the nutritional value of herbage. White clover was the most suitable perennial clover for pastures in Eastern Finland.

Key words: organic dairy farming, pastures, *Trifolium repens*, *Trifolium pratense*, *Trifoliun hybridum*, nutritive value

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Introduction

Current changes in European environmental policies have imposed additional constraints on agricultural practices, causing to consider further decreases in external inputs. Grazing is a natural and relative inexpensive source of nutrients for ruminant animals. In organic farming systems, feeding of dairy cows during the summer has to be based on grazing, where possible (EU 1804/1999, CEC 1999). To achieve high intakes and milk production from pasture, cows should have access to adequate herbage of high nutritive value throughout the grazing season. For pastures, both the development of herbage mass (HM) and herbage quality are related to the duration of the grazing cycle (stage of maturity), pasture species and prevalent growth factors. Under organic practices soluble fertilisers are not permitted, and therefore the typical primary factor determining sward growth is nitrogen (N) that is related to the proportion of biological N-fixing legumes in the sward (Weller and Cooper 2001). However, under Nordic conditions, the long and severe over-wintering conditions have a detrimental impact on sward vegetation and cause significant losses in clover legumes (Nissinen and Hakkola 1995, Linden et al. 1999).

Red clover (*Trifolium pratense* L.) has been used as the primary legume within Finnish organic farming systems owing to a high yield potential and relatively good winter hardiness. However, it is not well suited to multiple-cut systems or close grazing (Nissinen and Hakkola 1995, Taylor and Quesenberry 1996, Clark and Kanneganti 1998). According to a preliminary farm study (14 organic farms, 1994) in North Karelia, red clover was the most prevalent pasture legume, but its use was associated with a rapid decline in the proportion of clover in the sward and herbage yield (Kuusela, unpublished data). Red clover could be replaced with white clover (*Trifolium repens* L.) or alsike clover (*Trifoliun hybridum* L.). White clover is the most important pasture legume in several regions of Europe (Frame and Newbould 1986, Schils et al. 1999). It has a higher tolerance to frequent close grazing than red or alsike clover because growing points on the stolons are located close to the soil surface and are well protected from grazing (Frame and Newbould 1986). Some recently introduced white clover cultivars in Finland, for example 'Jögeva4', have proved to be reasonably resistant to frost (Nykänen-Kurki and Kivijärvi 1996, Sormunen-Cristian and Nykänen-Kurki 2000). Alsike clover has been recommended rather than red clover for unfavourable soils. It could also be used as an alternative to red clover for short-term pastures. However, applying a mixture of white and alsike clover may decrease temporal changes in the proportion of clover in the sward due to different growth cycles between clover species (Heikinheimo 1948).

The aim of this study was to evaluate the potential of white, red and alsike clovers to support the production and quality of herbage from clover-grass mixtures under organic or other low input farming systems in Finland. The effect of seed mixture, year and grazing period on pre-grazing (PRE) and post-grazing (POST) HM, post-grazing sward height (POST SH), botanical and chemical composition of PRE HM was assessed and the implications with respect to milk production are discussed.

Material and methods

Location of experiment field

The field experiment was conducted (1996–1998) at the Siikasalmi Research Farm of the University of Joensuu (62°30'N, 29°30'E) situated in North Karelia. Converting Siikasalmi farm to organic farming system was started in 1992, when the University began managing the farm, and was virtually completed in 1996. North Karelia has cold winters and snow cover for 5.5 months per annum. Mean temperature and sum of precipitation over three summer months (June–August) demonstrated that weather con-

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ditions were warm (15.6˚C, 164 mm) during establishment in the summer of 1995, typical (15.0˚C, 204 mm) for 1996, hot and dry (17.0˚C, 129 mm) for 1997 and rainy (14.6˚C, 307 mm) in 1998 compared with the long term (1961–1990) average for the region (14.9˚C, 220 mm).

Cultivation history and soil fertility of experimental area

Before converting to organic farming, the grazing area had been cultivated using conventional pasture practices for several years. Soil texture of the experimental area was defined in autumn 1993 as silty very find sand (0.02–0.06 mm) of medium fertility (Ca 1360, P 16, K 165, Mg 196 mg l^{-1}) with an organic matter (OM) content of 30–60 g kg^{-1} dry matter (DM) and pH (water) of 6.1 (Soil Analysis Service Ltd, Vuorinen and Mäkitie 1955). In spring 1993, at the beginning of conversion to organic farming, the area received farmyard manure (36 t ha^{-1}) and was seeded with a mixture of lucerne (*Medicago sativa* L.), meadow fescue (*Festuca pratensis* Huds.), timothy (*Phleum pratense* L.) and smooth-stalked meadow grass (*Poa pratensis* L.). Lucerne survival was compromised by grazing and over-wintering. Therefore the area received applications of diluted silage effluent (20 t ha^{-1}) and urine (20 t ha^{-1}) during the summer of 1994. At the end of May 1995, the two-year legume-grass ley was ploughed over and the area was harrowed prior to seeding.

Experimental design and establishment of field experiment

The field trial was initiated in spring 1995 according to a randomised complete-block design with five seed mixture treatments and four replicates. The size of each plot was 17.50 x 17.50 m. Seed mixtures consisted of alsike clover (AM), red clover (RM), white clover (WM), white-alsike (1:1) clover (WAM) and mixture of grasses (GM) (Table 1). Complementary grasses consisted of meadow fescue, timothy and smooth-stalked meadow grass. Before mixing, clover seeds were inoculated with *Rhizobium trifolii*. Seed mixtures (25 kg ha $^{-1}$) were seeded six days after a cover crop of oats (*Avena sativa* L., 'Veli', 90 kg ha^{-1}). Winter hardy cultivars were used: red clover Bjursele, white clover Jögeva4 and alsike clover Frida. Grasses included the cultivars: timothy Botnia, meadow fescue Boris and smooth-stalked meadow grass Baron. No fertilisers were applied. The effect of seed mixtures was studied over three years (1996–1998) during five grazing periods (GP1–GP5) per annum.

Table 1. Composition of seed mixtures.

Seed mixtures	Composition of seed mixtures
Alsike clover mixture	alsike clover (7.50 kg ha^{-1}); timothy (7.50 kg ha^{-1}); meadow fescue (8.75 kg ha^{-1}); smooth meadow grass (1.25 kg ha^{-1})
Red clover mixture	red clover (7.50 kg ha^{-1}); timothy (7.50 kg ha^{-1}); meadow fescue (8.75 kg ha^{-1}); smooth meadow grass (1.25 kg ha^{-1})
White clover mixture	white clover (7.50 kg ha^{-1}); timothy (7.50 kg ha^{-1}); meadow fescue (8.75 kg ha^{-1}); smooth meadow grass (1.25 kg ha^{-1})
White-alsike clover mixture	white clover (3.25 kg ha^{-1}); alsike clover (3.25 kg ha^{-1}); timothy (7.50 kg ha^{-1}); meadow fescue (8.75 kg ha^{-1}); smooth meadow grass (1.25 kg ha^{-1})
Grass mixture	timothy (12.50 kg ha^{-1}); meadow fescue (10.75 kg ha^{-1}); smooth meadow grass (1.75 kg ha^{-1})

Grazing of experimental area

During sward establishment, in summer 1995, 16 lactating Ayrshire dairy cows grazed the area three times. For the next three summers, each replicate was rotationally (21 days cycle) grazed five times per summer for 0.5–3.5 (mean 1.5) days by 7 to 18 (mean 11) lactating Ayrshire dairy cows. Mean stocking rates during the grazing seasons were 4.6, 3.5 and 2.9 cow ha^{-1} for 1996, 1997 and 1998, respectively. Grazing pressure was decreased year by year to allow selective grazing. After GP1–GP4, replicates were topped with a mower to a height of 10 cm to minimise carry over effects and control weed growth. Cows received a low level of 0–6 kg concentrate supplementation (EU 1804/1999, CEC 1999) allocated according to milk yield.

Measurements and analytical procedures

In the beginning of August 1995 during sward establishment, a sample of herbage from each plot was collected by cutting six randomised areas (74.0 cm x 22.5 cm) to a height of 3 cm above ground level using shears and an aluminium frame. Each homogenised sample was divided for dry matter (DM) determinations (100g), chemical analysis (200 g) and botanical analysis. Botanical proportions were estimated by hand sorting approximately half of each sample for clover, grass and weed content. Dry matter content of samples and species separated by botanical analysis was determined by oven drying at 105˚C for 24 h. Herbage quality samples were dried at 60˚C and stored at room temperature prior to chemical analysis. Herbage N content was measured by Kjeldahl analysis.

During summers 1996–1998, PRE HM and POST HM samples were collected before and after each GP using same sampling methods described previously. Botanical composition of PRE HM and DM contents of PRE HM and POST HM were determined using the same methods for herbage collected at the start of the study. Herbage growth during grazing episodes was not measured. Herbage quality samples dried at 60˚C, were stored at room temperature prior to chemical analyses. Organic matter was determined by ashing at 600˚C for 12 h, nitrogen N by the Kjeldahl method, neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin according to Van Soest et al. (1991). *In vitro* organic matter digestibility (IVOMD) was assessed by a cellulase based method (Friedel and Poppe 1990). During summers of 1997 and 1998, POST SH was estimated using a sward stick (Bircham 1981) and a total of 20 measurements per plot were recorded. Mineral content (Ca, Mg, P, K) of herbage samples was determined in samples composited by seed mixture in 1996 and for individual samples during 1997 and 1998 according to Luh Huang and Schulte (1985) using Inductively Coupled Plasma (ICP) emission spectrophotometry (Thermo Jarrel Ash/Baird, Franklin, USA). The average mineral content of herbage was estimated based on sub-samples (1996) and means of years (1997 and 1998). After the experiment, in autumn 1998, pooled soil samples (400 g per replicate, 10 part-samples) were collected and analysed according to standard procedures (Soil Analysis Service Ltd, Vuorinen and Mäkitie 1955).

Statistical analysis

During the sward establishment, the effect of seed mixture on the proportion of clover in the sward and crude protein (CP) content of grasses, clovers and weeds were determined by Analysis of variance for randomised block design. For the main experiment, the effects of seed mixture (main plot) year (split-plot) and grazing period (split-split-plot) on PRE HM and POST HM, botanical and chemical composition of PRE HM and POST SH were assessed by Analysis of variance for repeated measurement over time using a split-plot model for longitudinal data. Differences between treatments were compared using the Tukey test. Relationships between PRE HM, clover proportion and chemical parameters were determined using Spearman correlation coefficients. Linear regression models were derived to evalu-

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ate the relationship between POST HM and POST SH for the estimation of sward bulk density.

Results

During the establishment period in August (1995) the proportion of clover in the sward was high for all clover mixtures (WM 0.504, AM 0.450, WAM 0.410, RM 0.393), but low (0.046) for GM ($P < 0.001$). Naturally occurring white clover was detected in GM plots. Mean CP content of clovers, grasses and weeds were markedly different (246, 167 and 181 g kg^{-1} DM, respectively, $P < 0.01$). The CP content of clovers or weeds did not differ between seed mixtures, concentration of CP in grasses was different ($P < 0.05$) between seed mixtures, being lowest for grass in the GM herbage (144 g kg^{-1} DM).

During experimental summers (1996–1998) the average PRE HM per grazing period (5 GP per summer) was 1830 kg DM ha^{-1} and POST HM 1090 kg DM ha^{-1} (above 3 cm, Table 2), including a mean estimate of utilised HM of 3700 kg DM ha^{-1} per annum. Botanical and chemical characterisation of PRE HM is shown in Table 2. Across the three experimental years (1996–1998), PRE HM Ca, Mg, P and K concentrations averaged 7.1, 2.2, 4.3 and 36.2 g kg^{-1} DM, respectively. Soil samples collected at the end of the experiment contained on average 1365, 28, 175 and 177 mg l^{-1} of Ca, P, K, Mg, respectively, an OM content of 60–120 g kg^{-1} DM and a mean pH (water) of 6.1.

Table 2. Measured herbage parameters during grazing between 1996–1998 (5 grazing periods per each summer).

Variable	Mean	Median	Sample number	Standard deviation	Min	Max
Pre-grazing herbage mass (kg DM ha^{-1}) per grazing period	1830	1720	300	592	674	3500
Post-grazing herbage mass (kg DM ha^{-1}) per grazing period	1090	974	300	575	210	3510
Botanical content of pre-grazing herbage mass						
– Grasses (g kg^{-1} DM)	666	707	300	167	210	956
– Clovers (g kg^{-1} DM)	191	170	300	130	7.60	677
– Weeds (g kg^{-1} DM)	143	119	300	89.7	17.0	531
Chemical content of pre-grazing herbage mass						
– Organic matter (g kg^{-1} DM)	904	905	286	13.0	867	930
– Crude protein (g kg^{-1} DM)	184	179	288	33.0	116	309
– Neutral detergent fibre (g kg^{-1} DM)	510	509	288	47.0	365	633
– Acid detergent fibre (g kg^{-1} DM)	264	267	288	28.1	186	336
– Lignin (g kg^{-1} DM)	37.8	37.1	288	11.9	13.2	77.8
– Cellulose (g kg^{-1} DM)	226	230	288	25.6	147	292
– Hemicellulose (g kg^{-1} DM)	246	247	288	26.7	158	310
In vitro organic matter digestibility	0.754	0.751	283	0.036	0.620	0.840
Feeding unit [1]	0.931	0.926	283	0.044	0.760	1.05
Metabolizable energy (MJ kg^{-1} DM) [1]	10.9	10.8	283	0.519	8.87	12.33
Post-grazing sward height (cm) [2]	12.7	12.0	195	4.31	4.25	30.2

DM= dry matter

[1] Values were predicted according to Tuori et al. (2002).

[2] Post-grazing sward heights were only determined during 1997 and 1998.

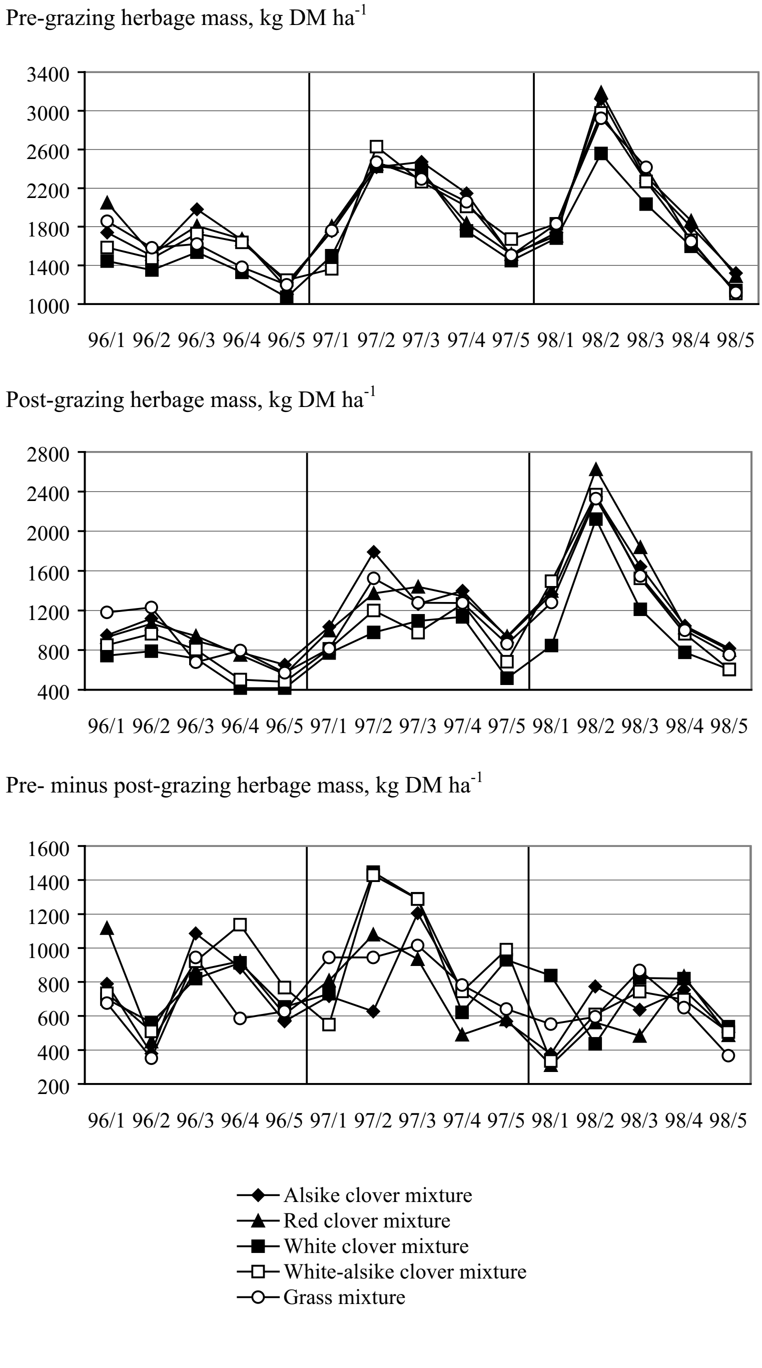

Fig. 1. Temporal variation (year/grazing period) in pre- and post-grazing herbage mass of seed mixtures.

Seed mixture altered several herbage parameters, but the impact of year and grazing period was also evident (Table 3). Interactions between seed mixture, year and grazing period were significant for certain parameters. Seed mixtures differed in PRE HM ($P < 0.05$) and POST SH ($P = 0.053$). There was a trend for lower PRE HM ($P < 0.05$) and POST HM for WM compared with

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Table 3. Effect of seed mixture (SM), grazing season (GS) and grazing period (GP) on pre- and post-grazing herbage mass, post-grazing sward height and botanical and chemical composition of pre-grazing herbage mass.

	Herbage mass kg DM ha^{-1}			Post-grazing sward height [2]	Proportion of species in DM g kg^{-1} DM			Chemical content in DM g kg^{-1} DM							*In vitro* organic matter digestibility
	Pre-grazing	Post-grazing	Pre- minus post-grazing	cm	Grasses	Legumes	Weeds	Organic matter	Crude protein	Neutral detergent fibre	Acid detergent fibre	Lignin	Cellulose	Hemi-cellulose	
Seed mixture [1]															
– AM	1910 ^{b}	1202 ^{c}	708	13.5 ^{b}	711 ^{c}	148 ^{ab}	141	905	178 ^{a}	518 ^{c}	269 ^{b}	38.8	230 ^{cd}	249 ^{bc}	0.749
– RM	1903 ^{b}	1202 ^{c}	702	13.7 ^{b}	658 ^{b}	182 ^{b}	160	903	186 ^{b}	519 ^{c}	267 ^{b}	39.9	227 ^{bc}	252 ^{cd}	0.750
– WM	1684 ^{a}	876 ^{a}	808	11.3 ^{a}	584 ^{a}	264 ^{c}	152	901	195 ^{c}	482 ^{a}	253 ^{a}	37.5	215 ^{a}	229 ^{a}	0.762
– WAM	1830 ^{ab}	1033 ^{ab}	797	11.8 ^{a}	637 ^{b}	235 ^{c}	128	904	189 ^{bc}	499 ^{b}	258 ^{a}	35.6	222 ^{b}	241 ^{b}	0.758
– GM	1844 ^{ab}	1141 ^{bc}	703	13.5 ^{b}	740 ^{c}	126 ^{a}	133	905	172 ^{a}	533 ^{d}	274 ^{b}	37.3	236 ^{d}	260 ^{d}	0.750
Grazing season															
–1996	1534 ^{a}	791 ^{a}	743 ^{ab}		522 ^{a}	284 ^{a}	194 ^{a}	890 ^{a}	213 ^{a}	502 ^{a}	262 ^{a}	46.8 ^{a}	215 ^{a}	240 ^{a}	0.767 ^{a}
–1997	1992 ^{b}	1108 ^{b}	884 ^{b}	12.6	704 ^{b}	174 ^{b}	122 ^{b}	915 ^{c}	163 ^{c}	515 ^{b}	264 ^{a}	38.3 ^{b}	226 ^{b}	251 ^{b}	0.742 ^{c}
–1998	1977 ^{b}	1373 ^{c}	604 ^{a}	13.0	772 ^{c}	116 ^{c}	112 ^{b}	904 ^{b}	179 ^{b}	513 ^{b}	266 ^{a}	29.5 ^{c}	236 ^{c}	247 ^{b}	0.754 ^{b}
Grazing period															
– 1	1709 ^{b}	1031 ^{bc}	678 ^{a}	13.6 ^{c}	731 ^{c}	112 ^{a}	157 ^{a}	912 ^{a}	198 ^{a}	460 ^{a}	223 ^{a}	27.0 ^{a}	196 ^{a}	237 ^{a}	0.808 ^{a}
– 2	2305 ^{d}	1589 ^{d}	716 ^{ab}	18.6 ^{d}	663 ^{b}	192 ^{bc}	146 ^{a}	907 ^{b}	172 ^{c}	533 ^{c}	275 ^{c}	39.3 ^{c}	236 ^{c}	258 ^{c}	0.746 ^{b}
– 3	2118 ^{c}	1190 ^{b}	928 ^{b}	11.6 ^{b}	580 ^{a}	257 ^{d}	163 ^{a}	904 ^{b}	173 ^{c}	512 ^{b}	273 ^{c}	43.3 ^{d}	229 ^{bc}	239 ^{a}	0.737 ^{c}
– 4	1737 ^{b}	965 ^{b}	772 ^{ab}	10.0 ^{a}	638 ^{b}	217 ^{c}	145 ^{a}	900 ^{c}	184 ^{b}	522 ^{bc}	278 ^{c}	41.6 ^{cd}	236 ^{c}	244 ^{ab}	0.740 ^{b}
– 5	1301 ^{a}	679 ^{a}	622 ^{a}	10.1 ^{a}	718 ^{c}	179 ^{b}	103 ^{b}	897 ^{d}	195 ^{a}	514 ^{b}	263 ^{b}	35.8 ^{b}	228 ^{b}	250 ^{bc}	0.747 ^{b}
Source of variation	***P-value***														
SM	0.045^{*}	0.088	0.609	0.053	0.007^{**}	$<0.001^{***}$	0.914	0.125	0.008^{**}	0.003^{**}	0.004^{**}	0.797	0.009^{**}	0.027^{*}	0.232
GS	$<0.001^{***}$	$<0.001^{***}$	$<0.001^{***}$	0.332	$<0.001^{***}$	$<0.001^{***}$	$<0.001^{***}$	$<0.001^{***}$	$<0.001^{***}$	0.080	0.115	$<0.001^{***}$	$<0.001^{***}$	0.108	$<0.001^{***}$
GP	$<0.001^{***}$	$<0.001^{***}$	0.004^{**}	$<0.001^{***}$	$<0.001^{***}$	$<0.001^{***}$	$<0.001^{***}$	$<0.001^{***}$	$<0.001^{***}$	$<0.001^{***}$	$<0.001^{***}$	$<0.001^{***}$	$<0.001^{***}$	$<0.001^{***}$	$<0.001^{***}$
SM x GS	0.972	0.845	0.551	0.708	0.300	0.390	0.930	0.578	0.237	0.714	0.559	0.374	0.844	0.334	0.434
SM x GP	0.985	0.994	0.967	0.551	0.046^{*}	0.002^{**}	0.530	0.131	0.006^{**}	0.012^{*}	0.020^{*}	0.187	0.003^{**}	0.148	0.204
GS x GP	$<0.001^{***}$	$<0.001^{***}$	0.003^{**}	$<0.001^{***}$	$<0.001^{***}$	0.388	$<0.001^{***}$	$<0.001^{***}$	$<0.001^{***}$	$<0.001^{***}$	$<0.001^{***}$	$<0.001^{***}$	$<0.001^{***}$	$<0.001^{***}$	$<0.001^{***}$
SM x GS x GP	0.973	0.994	0.980	0.932	0.957	0.879	0.811	0.728	0.059	0.963	0.401	$<0.001^{***}$	0.822	0.929	0.668

[1] Seed mixtures were Alsike clover mixture (AM); Red clover mixture (RM); White clover mixture (WM); White-alsike clover mixture (WAM) and Grass mixture (GM).

[2] Post grazing sward height was only determined for 1997 and 1998.

[a-e] Means within the same column and the same variable not sharing a common letter differ significantly (Tukey, $P< 0.05$).

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

AM or RM, but the differences in PRE minus POST HM were not significant ($P > 0.05$). Between-year variation in PRE HM, POST HM and PRE minus POST HM is shown in Fig. 1. For white clover based mixtures POST SH (measured in 1997 and 1998) was on average 2 cm lower than the other mixtures ($P < 0.05$). Year, grazing period and their interactions had significant effects ($P < 0.001$) on PRE and POST HM. In 1996 PRE HM was 23% lower than for 1997 or 1998, an effect that was also reflected by the lowest ($P < 0.05$) POST HM. On average PRE HM and POST HM were highest ($P < 0.05$) during GP2 and lowest ($P < 0.05$) during GP5, with the exception of PRE HM in 1996 (Fig. 1). Post-grazing sward height (measured in 1997–1998) was also influenced by grazing period ($P < 0.001$), and was greater during GP2 and lower during CP4 and GP5 ($P < 0.05$).

Seed mixtures were different ($P < 0.01$) in relation to the proportion of clovers and grasses, but not for the amount of weeds in pre-grazing herbage (Table 3). Mean proportions of clover for WM and WAM was higher ($P < 0.05$) than that of other seed mixtures. The average proportion of grasses increased ($P < 0.05$) annually, while the levels of weeds were highest in 1996. Temporal variations in the proportion of grasses, weeds and clovers of herbage are presented in Fig. 2. The proportion of clover in clover based seed mixtures decreased annually and was consistently higher in the middle of each summer.

Seed mixtures differed ($P < 0.01$) in CP, NDF and ADF, cellulose and hemicellulose ($P < 0.05$) content in PRE HM samples, but IVOMD, OM or lignin concentrations were unaffected (Table 3). White clover based mixtures had higher CP and lower ADF concentrations than other mixtures ($P < 0.05$). The white clover mixture was distinctive in containing low amounts of NDF, cellulose and hemicellulose ($P < 0.05$) compared with other seed mixtures. Both year and grazing period had significant ($P < 0.001$) effects on IVOMD, CP and OM content. Organic matter digestibility was marginally higher ($P < 0.05$) in 1996 than for subsequent years. Across grazing periods, IVOMD was higher ($P < 0.05$) during GP1. Crude protein content was 30% higher ($P < 0.05$) in 1996 compared with 1997. Within-season variation in NDF and ADF contents were significant ($P>0.001$), but not between years. Temporal variation in herbage NDF, CP, hemicellulose and IVOMD content are shown in Fig. 3.

The proportion of clover in the sward was not related to PRE HM ($P > 0.05$). Botanical composition altered herbage nutritive value. The amount of clover in herbage was positively associated with total herbage CP ($r_s = 0.30$) and lignin ($r_s = 0.51$) concentration, but negatively correlated with herbage NDF ($r_s = -0.20$), cellulose ($r_s = -0.21$) and hemicellulose ($r_s = -0.33$) content ($P < 0.001$, $n = 288$). Use of data collected between 1997 and 1998 indicated that POST HM could be predicted as: POST HM = 22.7 + 96.4 x POST SH ($r^2 = 0.45$, $P < 0.001$, $n = 195$).

Discussion

In this study, the effect of year and grazing period on most of the measured herbage parameters was greater than the effect of seed mixture. The main differences between seed mixtures were related to the proportion of clover in the sward, which altered the chemical composition of herbage. White clover mixtures contained relatively high proportions of clover in the sward, but by the end of the experiment, the amount of clover in all clover mixtures decreased. In a recent review Sundrum (2001) proposed, that organic livestock farming increases the demands on the producer due to the preference for home-grown feed stuffs and limitations in the choice of approved bought-in feed stuffs, that can result in wide and unintended variation in the nutritional content of animal diets. Consequently, optimising the balance between nutrient supply and requirements can be more difficult under organic than conventional farming systems (Hovi et al.

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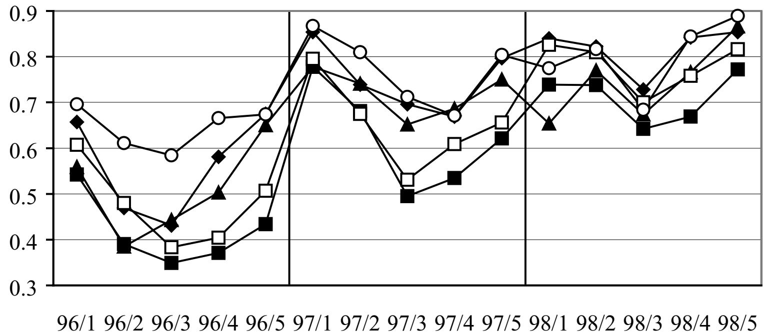
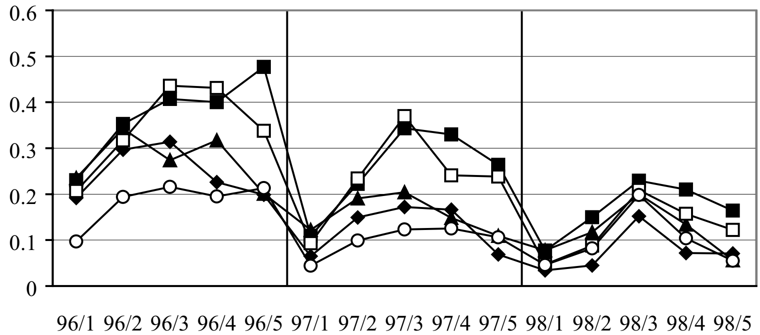
Proportion of grasses in pre-grazing herbage dry matter



Proportion of clovers in pre-grazing herbage dry matter



Proportion of weeds in pre-grazing herbage dry matter

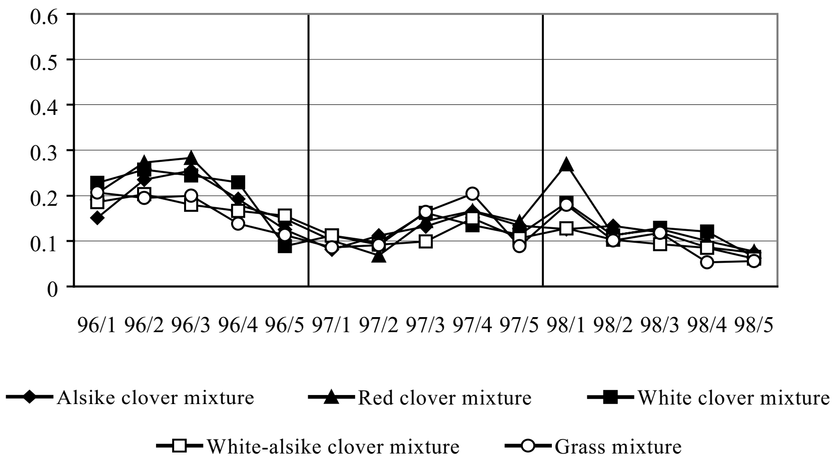


Fig. 2. Temporal (year/grazing period) variation in botanical composition of seed mixtures.

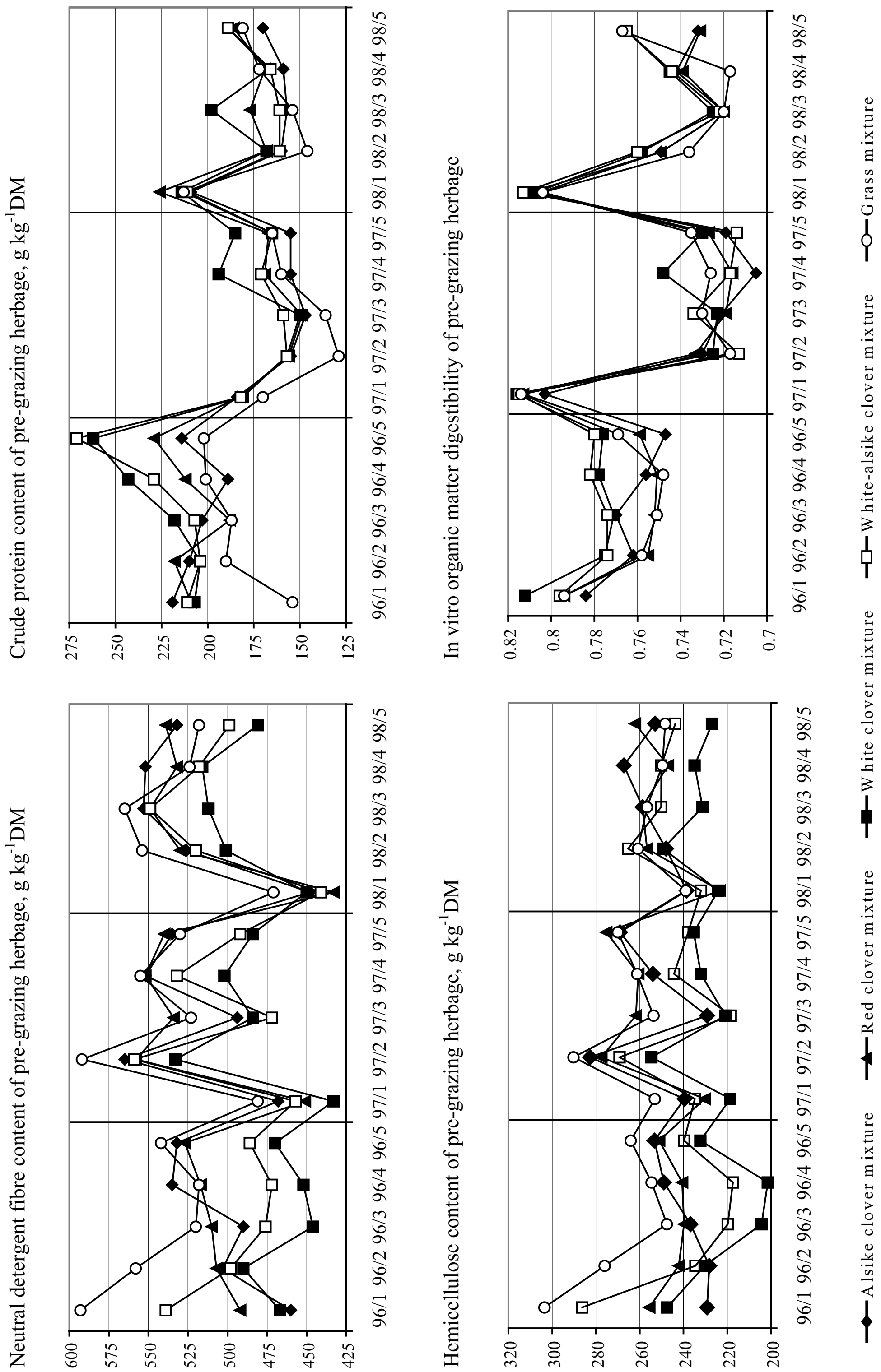


Fig. 3. Temporal variation (year/grazing period) in chemical content of seed mixtures.

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2003). On pasture the nutritive value of herbage is essential.

Herbage production

Within organic farming systems herbage production is dependent on biological N fixation, soil mineralisation and nutrient recycling (Lampkin 1994). The major factor is related to the establishment and maintenance of N-fixing legumes in the sward (Weller and Cooper 2001). Unfertilised white clover rich swards have been estimated to achieve DM yields in excess of proportionally 0.80 of those attained with conventionally managed N fertilised grass swards (Bax and Thomas 1992). In New Zealand and Australia, white clover and other pasture legumes are the primary source of N for many conventional pastures (Lane et al. 2000). According Ledgard and Steele (1992) the level of biological N fixation should match N losses from the pastoral system. On pasture fixed N is mainly transferred to grasses by animal excreta and by decomposition of legume roots and plant materials (Ledgard 1991). Environmental stress, for instance compromised water supply or grazing intensity, increases clover turnover, decomposition and N availability to other plants (Ledgard and Steele 1992). In the present study, the beneficial role of clovers was shown during sward establishment, when the CP of grasses was markedly lower for GM than clover based mixtures. Overall, WM appeared to have the most positive effect on soil N status based on measurements of botanical composition and CP content of PRE HM (Table 3, Kristensen et al. 1995).

During grazing herbage N is removed from total pasture area but 75–90% is returned via faeces and urine to small areas at high concentrations (Afzal and Adams 1992, Ledgard and Steele 1992). Typically legume poor, organic and other low N input pastures are visually constructed in a uniform mosaic appearance with visible green patches of legume rich areas, urination spots and zones around faeces. Biological N fixation of contaminated areas dramatically declines and the available N stimulates the growth of grass species promoting grass-legume competition (Ledgard and Steele 1992). Under these conditions, the proportion of clover is not necessary correlated with the amount of biologically fixed N (Hansen et al. 2002). In this experiment, the proportion of clover and PRE HM were not related, reflecting spatial variation in soil conditions. Compared to other clovers, the stoloniferously progressive white clover appeared to adjust to these changes more easily. It is possible that a large amount of the variation in sward bulk density affected the relationship between POST HM and POST SH ($r^2 = 0.45$). In contrast, Virkajärvi and Matilainen (1995) reported a strong linear relationship ($r^2 = 0.95$) between POST HM and POST SH as measured by disk meter for conventional grazed timothy swards.

Besides N other plant nutrients are also important. Well established pastures can support good soil fertility and herbage production as the majority of grazed nutrients have been directly returned via faeces and urinary excretion by grazing animals (Holmes 1968, Leaver 1985). For grazed clover and grass the adequate shoot content of K and P has been summarised to vary between 20.0–25.0 and 3.5–4.0, respectively (Reuter and Robison 1986). When the concentrations of K and P in shoot material are not below requirements, herbage and soil parameters are poorly correlated (Hansen et al. 2002). In the current study, mean K and P contents of PRE HM were above these values. The average annual PRE HM (9150 kg DM ha^{-1}, above 3 cm) was relatively high, particularly when sward topping after GP1–GP4 is taken into account. Despite year on year decreases in the proportion of clover in the sward, mean PRE HM did not decrease. This probably reflects, previous cultivation history, soil containing relatively high amounts of OM and recycling of nutrients from herbage to soil. Ploughing in spring 1995 rather the preceding autumn also decreases soil N losses (Känkänen et al. 1998). Based on comparisons of analysis in 1993 and 1998, soil fertility was maintained during the conversion to organic farming.

Grazed HM is the only DM harvested from pasture. Pasture utilisation is often limited due to failures in grazing management. Over-grazing will decrease animal performance and protract sward regrowths, while under-grazing will decrease pasture utilisation and have detrimental effects on herbage nutritive value, if the sward is not topped. The present study clearly demonstrated the effect of grazing pressure on PRE minus POST HM, although the cumulative effect of differences in grazing pressure were minimised by cutting the sward after GP1–GP4. Both mean PRE and POST HM were lower in the summer of 1996 than during subsequent summers (Table 3). For 1997, mean PRE minus POST HM was 19% higher than in 1996 and 46% greater than for 1998. Applying a mean nutritional value of herbage and estimates of intake from pasture suggest these benefits correspond to 1490 and 2960 kg ha^{-1} increase in energy corrected milk during the summer of 1997 compared with 1996 and 1998 (Tuori et al. 2002). Average stocking rate and POST HM in the summer 1997 was intermediate compared with 1996 and 1998. These findings emphasise the importance of circumstantial and flexible grazing management. An average stocking rate of 3.5 cows ha^{-1}, POST HM of 1.1 t ha^{-1} and POST SH of 12 cm during 1997 were close to optimal values, but PRE minus POST HM was only 44% from the offered PRE HM (above 3 cm), suggesting depressed canoby structure typical for unfertilised swards (Delagarde et al.1997). In 1996, POST HM was below recommended levels, particularly for WM and WAM (Fig. 1). Post-grazing sward height was not measured, but estimates based on HM suggest, that this was below 10 cm. A POST SH of 10–12 cm has recently been recommended for organic legume-grass pastures in Finland (Kuusela and Khalili 2002).

Botanical proportions of herbage

Organic pasture herbage consists of three divergent botanical groups: grasses, legumes and dicot weeds. Herbage nutritive value, CP content and mineral content in particular, diverge more between these groups under extensive or organic than conditions for conventional grazing systems (Carcia-Ciudad et al. 1997, Kuusela and Hytti 2001). Cows are known to express a preference for plants and plant components of high digestibility and CP content and low NDF concentration (Dalley et al. 1999). In this study, seed mixtures clearly differed in the amount of clover in the sward, but had no effect ($P > 0.05$) on the amount of PRE minus POST HM (Table 3). The lack of a preference between seed mixtures was due to comparable annual declines in the proportion of clover in the sward, use of the same basal grasses and the consistent amount of weeds in all seed mixtures. However in 1997, a trend towards a preference for WM was observed (Fig. 1).

The optimum proportion of clover in the sward is a compromise between the amount of biological fixed N, herbage yield, animal performance, nutrient losses and bloat risk (Alder et al. 1967, Pflimlin 1993, Kristensen et al. 1995, Lane et al. 2000) and varies between 0.20–0.50 (Frame and Newbould 1986, Pflimlin 1993, Taylor and Quesenberry 1996). In the long term, a relatively high and stable proportion of clover in grazed swards is difficult to maintain. Despite of different proportion of clover in the beginning, the amount of clover in swards tends to convergent under similar grazing system conditions (Wilkins et al. 1994). In the present study, rotational grazing system was used to promote clover growth (Leaver 1985), but the average proportion of clover was relative low (mean 0.191, median 0.170). For clover based mixtures, the proportion of clover in the sward decreased annually, being higher than required during establishment but lower than recommended levels at the end. Annual declines in clover were primarily due to hard over-wintering conditions, as reflected by the low proportion of clover in the sward following over-wintering (Fig. 2). During the summer, the proportion of clover increased particularly for WM and WAM, that was probably related to extensive stoloniferous dispersion of white clover. This resulted in higher mean

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proportions of clover for WM (0.264) and WAM (0.235) compared with other clover other mixtures (Table 3). The average clover proportion of WAM was similar to WM, but 59% higher than that of AM. Combining alsike and white clover mixtures did not decrease the temporal changes in proportion of clover in the sward.

The average proportion of dicot weeds was relatively low (mean 0.143, median 0.119) and unaffected by seed mixture, but was highest during the first year after establishment (Fig. 2, Table 3). Frequent grazing and cutting after each grazing session proved an adequate method for controlling weed growth. However, the median proportion of weeds approached 80% of that for clovers. Hence the influence of weeds on PRE HM and herbage nutritive value can not be ignored. Under conventional grassland management practices weeds are undesirable because they compete with crop plants, can potentially reduce herbage intake, and may be nutrient deficient or toxic. For organic farming and other low input systems, weeds can have a beneficial role in improving biodiversity and mineral supply (Lampkin 1994, Kallah et al. 2000). Weeds collected from this experiment had a similar Ca and Mg content relative to clovers, but 3.1 times more Ca and 2.6 times more Mg than grasses, while most weeds had higher P and K concentrations than grasses or clovers (Kuusela and Hytti 2001).

Herbage chemical content

Digestibility is the most important parameter for predicting the energy content and intake potential of grazed grass, and linear intake responses on pasture have been attained up to a digestibility of 0.820 (Leaver 1985). Digestibility depends mainly on the stage on forage maturity, but also pasture species and growing conditions have an effect (Buxton 1996). In organic farming systems, the optimum length of rotation cycle is often a compromise between digestibility and regrowth as measured by PRE HM (Kuusela and Khalili 2002). Earlier studies have reported mean IVOMD in organic legume-grass swards of 0.724–0.785 (Kuusela and Khalili 2002). In this experiment the overall mean IVOMD of herbage (above 3 cm) was 0.754 and independent of seed mixture type, but was significantly affected by annual and seasonal variations (Table 3, Fig. 3). Increases in ambient temperature are known to decrease OM digestibility (Buxton 1996). In the present study the highest mean temperature of summer 1997 was associated with the lowest IVOMD. Ruminants consume more clover than grass of the same digestibility due to their lower structural carbohydrate content, increased rate of OM degradation and lower retention time in the rumen (Thompson 1984, Leaver 1985). In this study, seed mixtures differed in the proportion of clover, resulting in variations in NDF, ADF, cellulose and hemicellulose content (Table 3). Although mean NDF values of the seed mixtures were different (488–533 g NDF kg^{-1} DM), all values were relatively high. Earlier work showed the NDF content of organic legume-grass pasture to vary between 438–556 g NDF kg^{-1} DM (Kuusela and Khalili 2002). In Finland conventionally grazed grasses have a 5–15% higher NDF content (Khalili and Sairanen 2000, Virkajärvi et al. 2002). Generally diets containing 400 g NDF kg^{-1} DM are recommended (Buxton 1996, Dalley et al. 1999).

Herbage CP content is an important consideration for formulating diets and environmental N emissions (Tamminga 1992, Kebreab et al. 2002). In the present study, the mean CP content of herbage was 184 g kg^{-1} DM, but varied widely being higher in 1996 (high clover proportion) and lower in 1997 (dry and hot summer) (Table 3, Fig. 3). Crude protein content and the proportion of clover in the sward were related. Seed mixtures resulted in different mean CP contents (178, 186, 195, 189, 172 g kg^{-1}DM for AM, RM, WM, WAM, GM, respectively). The current results are consistent with previous work indicating that the mean CP content of organic pastures varied between 167–188 g kg^{-1}DM (Kuusela and Khalili 2002). In contrast, Finnish N fertilised grass pastures usually have a higher mean CP content, often above 200 g kg^{-1}DM (Khalili and Sairanen 2000, Virkajärvi et al. 2002). The high CP of grass is poorly utilised by grazing animals (Tamminga 1992). In contrast, the CP content of unfertilised grass can be very low. Delagarde et al. (1997) reported that the CP content of unfertilised perennial ryegrass pasture was only 106 g kg^{-1} DM, compared with 193 g kg^{-1} DM for comparable N fertilised swards. For unfertilised grass-clover swards CP content is primarily dependent on botanical composition (Kristensen et al. 1995). The CP content of N unfertilised ryegrass-white clover mixtures are low (83–129 g kg^{-1} DM), when the levels of clover in the sward are low (0.01–0.20) (Wilkins et al. 1994). Weller and Cooper (2001) reported a CP content of organic perennial ryegrass in grass-clover mixtures of 163 (112–240) g kg^{-1} DM, but a higher value for white clover 266 (220–316) g kg^{-1} DM. These mean values were of the same magnitude measured for clover-grass mixtures during sward establishment. Weller and Cooper (2001) concluded that the CP content of mixed swards grown without fertiliser N might satisfy the minimum N requirement of dairy cows. In this experiment, CP content and the proportion of clover were highest for white clover mixtures. Although some very high CP concentrations were recorded, CP of all clover mixtures did occasionally approach 150 g kg^{-1} DM and CP content of GM approach 125 g kg^{-1} DM (Fig. 3).

Herbage nutritive value

Nutritive value and the availability of herbage determine the intake and nutrient supply of dairy cows. On grass based diets, a maximum milk yield of 20 kg d^{-1} has been assumed to be the highest level of production that can be achieved at pasture. Recent studies, with high genetic merit cows, have shown that a milk yield of 30 kg d^{-1} on grass (DM intake of 17 kg) can be achieved under good grazing conditions (Kennedy et al. 2003). A low herbage allowance is known to limit intake (Leaver 1985), but also low PRE HM associated with an unfavourable canoby structure can restrict intake even when herbage allowance is relatively high (Delagarde et al. 1997, Khalili et al. 2002).

Herbage intake was not measured in this study, but based on an average stocking rate and PRE minus POST HM, the estimated mean intake was 12.3 kg DM. Intakes were highest for 1997, and on average, cows consumed 15 kg herbage DM per day. This amount of herbage represents a level of intake, which could be attained if herbage allowance, PRE HM or herbage quality is not critical. Based on measurements of herbage composition, it can be estimated that a 15 kg DM intake would, without supplementation, support 20.4 kg (14.5–24.6 kg) of energy corrected milk per day for a cow of 550 kg live-weight (Tuori et al. 2002). An 15 kg DM intake for AM, RM, WM, WAM and GM can be estimated to support 20.2, 20.2, 20.7, 20.6 and 20.3 kg of energy corrected milk per day, respectively. In 9% of all measurements, energy content of herbage (15 kg DM) was at least 5% lower (corresponding to 0.7 kg of barley, Tuori et al. 2002) than requirements for the production of 20.4 kg energy corrected milk. Deficiencies in energy supply would occur less frequently for WM and WAM. Based on digestibility and CP measurements, the mean adsorbed amino acid content (AAT) would account for almost all (97%) of the amino acid requirements for daily milk production of 20.4 kg milk (Tuori et al. 2002). However, for 38% of all measurements, protein supply was at least 5% below requirements, that corresponds to daily supplements of 0.5 kg of rapeseed meal (Tuori et al. 2002).

Current results and estimations are in agreement with a recent study concluding that a concentrate supplement including additional protein was advantageous for milk production from cows grazing grass-clover swards grown under organic farming conditions (Khalili et al. 2002). Because most of the supplementary protein is excreted in urine, only small amounts of high quality protein such as rape seed meal in the diet are recommended for grazing cows (Tamminga 1992, Kebreab et al. 2002, Khalili et al. 2002).

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Conclusions

It is possible to achieve moderate levels of herbage production of relatively high nutritive value from pasture under organic farming practices. However, the nutrient requirements of lactating dairy cows were not consistently satisfied for grass only diets. In addition to seed mixture, the influence of year and grazing period on measured parameters was significant, suggesting the importance of circumstantial and flexible grazing management systems. White clover was the most suitable perennial pasture clover for Eastern Finland, but the proportion of clover in swards for all seed mixtures declined annually and varied within each grazing season altering herbage nutritive value.

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SELOSTUS

Alsike-, puna- ja valkoapilan vaikutus laitumen tuottoon luonnonmukaisessa tuotannossa

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Laidunnetussa kenttäkokeessa verrattiin alsikeapilan (*Trifoliun hybridum* L.), puna-apilan (*Trifolium pratense* L.) ja valkoapilan (*Trifolium repens* L.) vaikutusta laitumen tuottoon luonnonmukaisessa tuotannossa. Koe toteutettiin satunnaistettujen lohkojen menetelmänä Itä-Suomessa, Liperissä. Verratut siemenseokset olivat alsikeapila-, puna-apila-, valkoapila-, valko-alsikeapila- ja heinäseos. Kokeessa mitattiin siemenseoksen, vuoden (1996, 1997, 1998) ja laidunkerran (5 laidunkertaa) vaikutusta laidunrehun määrään ennen ja jälkeen laidunnuksen, laidunrehun botaaniseen ja kemialliseen koostumukseen sekä laiduntamisen lopetuskorkeuteen. Lisäksi arvioitiin laidunrehun ruokinnallista arvoa.

Siemenseos vaikutti laidunrehun määrään ennen laidunnusta ja laiduntamisen lopetuskorkeuteen, mutta ei laskennallisen syödyn laidunrehun määrään. Molempien valkoapilaa sisältäneiden seosten apilapitoisuus oli muita seoksia suurempi ja lopetuskorkeus matalampi. Valkoapilaseoksen raakavalkuaispitoisuus oli muita seoksia suurempi ja selluloosa- sekä hemiselluloosapitoisuudet muita pienempiä. Siemenseoksen ohella vuosi ja laidunkerta vaikuttivat mitattuihin tekijöihin. Laiduntaminen tulee aina sopeuttaa vallitseviin olosuhteisiin.

Luonnonmukaisen laitumen sato oli keskimäärin kohtuullinen ja rehu hyvälaatuista, vaikkakaan ei täysin vastannut korkeatuottoisen lehmän ravinnontarvetta. Valkoapila osoittautui sopivimmaksi laidunpalkokasviksi Itä-Suomessa. Kaikkien apilaseosten apilapitoisuus vaihteli laidunkerroittain ja laski kokeen aikana, mikä vaikutti laidunrehun laatuun.