

Annual and seasonal changes in mineral contents (Ca, Mg, P, K and Na) of grazed clover-grass mixtures in organic farming

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A grazed field experiment was established in 1995 to evaluate alsike clover (*Trifolium hybridum* L.), red clover (*Trifolium pratense* L.) and white clover (*Trifolium repens* L.) in clover-grass mixtures under organic farming practices. In this study the effect of seed mixture (alsike clover, red clover, white clover, white and alsike clover or grass mixture), year (1997, 1998) and grazing period (5 per grazing season) on the herbage calcium (Ca), magnesium (Mg), potassium (K) phosphorous (P) and sodium (Na) contents was assessed and the relationships between botanical proportions and herbage mineral contents were studied. Herbage Ca and Na contents varied between the seed mixtures, Ca, Mg, P and Na contents between the years and all measured minerals, except Na, between the grazing periods. The white clover mixture resulted in higher Ca and Na contents. The contents of Ca and Mg were positively related with the proportions of clovers and weeds and were higher in 1997. The contents of P and K were higher in the rainy summer of 1998. The seed mixtures resulted in similar mean K/(Ca + Mg) equivalent ratios, but the Ca/P ratio was higher for the white clover mixture. Mineral rations varied between and within grazing seasons. Under organic practices the supply of minerals in the pasture herbage varied temporally and according to the botanical contents and was unable to meet fully the requirements of dairy cows. Additional mineral feeding is recommended for organic farming systems to balance the dietary mineral contents for grazing cows.

Key words: organic farming, dairy cows, pastures, *Trifolium repens*, *Trifolium pratense*, *Trifolium hybridum*, herbage mineral concentrations, calcium, magnesium, phosphorus, potassium, sodium

Introduction

In natural systems animal products can be seen as the result of a biogeochemical cycling of nutrients

through soil, water, air, plants, animals and manure (Tamminga 2003). In agroecosystems the balance is changed by human interventions such as external inputs of energy, fertilizers and feeds from distant areas. The cycles of nutrient elements in graz-

ing systems are complex and interact with each other. Organic farming aims to minimise the use of external inputs and attempts to make the best use of local natural resources such as soil mineralisation nutrient recycling and biological N fixation (Lampkin 1994, IFOAM 2002). Hence the summer feeding of dairy cows should mainly be based on grazing, the most natural feeding system for bovines (CEC 1999, Weller and Cooper 2001). However, when circumstantial limitations on herbage mass, sward structure or herbage nutritive value decrease herbage intake and milk yield, a moderate concentrate supplement is advantageous to early-mid lactating cows (Khalili et al. 2002). It should be noticed that supplementary feeding affects the dietary mineral content.

The mineral contents of pasture herbage depend on the plant species, availability of minerals in the soil, climatic and seasonal conditions and the stage of maturity (Underwood and Suttle 1999). The efficiency of nutrient uptake is found to change during the year, according to variation in the ambient conditions of light, temperature and soil water content, and the physiology of the plant itself (Scholefield and Fisher 2000). Clovers are richer in calcium (Ca) and magnesium (Mg) and many trace elements compared to grasses (Leaver 1985) and several weeds for many minerals (Wilman and Riley 1993). Particularly under extensive grazing systems grasses, clovers and weeds result in clearly different mineral contents (Carcia-Ciudad et al. 1997). Samples collected from the current experimental field during 1996 and pooled on the basis of seed mixture suggested higher mean Ca and Mg contents of the herbage, but similar potassium (K), phosphorus (P) and sodium (Na) concentrations compared with conventional grass pastures (MTT 2004, Kuusela, unpublished data). The botanical proportions of organic pastures are subject to between-season and within-season changes (Kuusela 2004), which may affect the mineral supply for grazing animals. Besides shortage or excess of individual minerals, also mineral imbalances can be detrimental to animal health and welfare (Hovi et al. 2003). Consequently, the necessity of mineral supplements for grazing cows is questioned among organic farmers.

The aim in this study was to assess temporal changes in the mineral contents and ratios of two-three-year-old grazed grass-clover mixtures under organic farming practices. This study is connected to the study 'Annual and seasonal changes in production and composition of grazed clover-grass mixtures in organic farming' (Kuusela 2004). The effect of seed mixture, year and grazing period on the calcium, magnesium, phosphorus, potassium and sodium contents of pre-grazing herbage was studied, the relationships between the botanical proportions and mineral contents were considered and, finally, the implications for dairy cows' mineral feeding are discussed.

Material and methods

Location of experiment field, cultivation history and soil fertility of experimental area

The field study was conducted in 1997–1998 on the Siikasalmi Experimental Farm. The Siikasalmi Farm is situated 62°30'N, 29°30'E in the commune of Liperi, province of North Karelia, which belongs to Finnish milk production zone. Conversion of the entire farm to organic production was started in 1992 and nearly completed in 1996. North Karelia has cold winters and snow cover for 5.5 months per annum. The mean temperature and precipitation sum over the three summer months (June–August) demonstrated that the weather conditions were hot and dry (17.0°C, 129 mm) in 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).

Before beginning to convert to organic farming in 1993, the current area had been cultivated for several years using conventional pasture practices. The soil texture of the experimental area was defined as silty very fine sand (0.02–0.06 mm) and at the end of the experiment the soil was as of medium/good fertility (Ca 1365, P 28, K 175, Mg 177

mg l⁻¹), with an organic matter content between 60–120 g kg⁻¹ dry matter (DM) and a mean pH (water) of 6.1 (Kuusela 2004).

Experimental design, establishment and grazing of experimental area

The field trial was established in spring 1995 using a randomised complete-block design with five seed mixture treatments and four replicates (Kuusela 2004). The size of each plot was 17.50 × 17.50 m. The seed mixtures, containing different clovers and same complementary grasses, were alsike clover (AM), red clover (RM), white clover (WM), white and alsike (1:1) clover (WAM) and a grass (GM) mixture. Complementary grasses consisted of meadow fescue, timothy and smooth-stalked meadow grass. No fertilizers were applied. The effect of the seed mixtures was studied over two years (1997–1998) with five grazing periods (GP1–GP5) per annum.

During the experimental summers the replicates were rotationally (21 day cycle) grazed five times per summer by lactating Ayrshire dairy cows applying a mean stocking rate of 3.5 and 2.9 cows ha⁻¹ for 1997 and 1998, respectively. After GP1–GP4, replicates were topped to a mower height of 10 cm to minimise carry-over effects and to control weed growth.

Measurements and analytical procedures

Pre-grazing herbage samples were taken manually by cutting six randomised areas (74.0 cm × 22.5 cm) to a height of 3 cm above ground level using shears and an aluminium frame (Kuusela 2004). Each homogenised sample was divided for DM determinations (100 g), chemical analysis (200 g) and botanical analysis. The botanical proportions of the pre-grazing herbage mass were estimated by sorting approximately half of each homogenised sample for clovers, grasses and weeds. Herbage quality samples were dried at 60°C, stored at room temperature prior to chemical analyses. The min-

eral contents (Ca, Mg, P, K, Na) were determined for each pre-grazing herbage sample according to Luh Huang and Schulte (1985) by Inductively Coupled Plasma emission spectrophotometry (Thermo Jarrel Ash/Baird, Franklin, USA).

Statistical analysis

During 1997–1998, the effects of the seed mixture (main plot), year (split-plot) and grazing period (split-split-plot) on the mineral content of the pre-grazing herbage were assessed using analysis of variance for repeated measurement over time and a split-plot design for longitudinal data. Differences between treatments were compared using Tukey's test. The relationship between botanical proportions and herbage mineral content was assessed using Spearman correlation.

Results

The botanical and mineral characterisation of the pre-grazing herbage is shown in Table 1. Over the two experimental years (1997–1998), pre-grazing herbage Ca, Mg, P, K and Na concentrations averaged 6.20, 2.08, 4.04, 32.9, 0.09 g kg⁻¹ DM, respectively. The mean values for the K/(Ca+Mg) equivalent ratio and C/P ratio were 1.84 and 1.56, respectively.

In these two-three-year-old grass-clover swards, the seed mixtures were different in respect of the proportion of clovers ($P < 0.001$) and grasses ($P < 0.05$), but not for the amount of weeds in the total herbage (Table 2). The mean clover proportion was highest in WM, followed by WAM, RM, AM and GM ($P < 0.05$). The average proportion of clovers decreased and grasses increased ($P < 0.01$) annually, while the level of weeds was similar between years. The proportion of clovers was lowest at the beginning and highest in the middle of the grazing season ($P < 0.05$). The botanical proportions were affected by interactions between seed mixture, year and grazing period.

Table 1. Description of the botanical and mineral contents of pre-grazing herbage mass during grazing in 1997–1998.

Variable	Mean	Median	Standard deviation	Min	Max
Botanical content, (g kg ⁻¹ DM)					
Grasses	738	759	114	411	956
Clovers	145	125	95.1	7.60	474
Weeds	117	102	68.8	17.5	453
Mineral content, (g kg ⁻¹ DM)					
Potassium	32.9	32.9	3.74	23.3	41.7
Phosphorus	4.04	4.02	0.45	2.90	5.24
Calcium	6.20	5.92	1.57	3.32	11.5
Magnesium	2.08	2.03	0.37	0.91	3.44
Sodium (mg kg ⁻¹ DM)	89.0	79.0	47.7	10.8	233.4
Mineral ratios in pre-grazing herbage					
- K/(Ca + Mg) equivalent ratio	1.84	1.80	0.46	0.86	3.14
- Ca/P ratio	1.56	1.47	0.47	0.76	2.95

Sampling number 200 = 5 seed mixtures, 2 years, 5 grazing periods each summer, 4 replicates
DM = dry matter

The influence of the seed mixture was different on Ca and Na ($P < 0.05$), but not for the other minerals measured. White clover mixture resulted in 15–25% higher Ca content than other mixtures ($P < 0.05$). Two grazing seasons resulted to different herbage Ca, Mg, P and Na concentrations ($P < 0.05$). The content of all minerals measured, except Na, varied between grazing periods ($P < 0.001$). Between years Ca and Mg contents were higher in 1997 and P, K and Na in 1998. On the average Ca and Mg were low at the beginning, P in the middle and K at the end of the grazing season ($P < 0.05$). Herbage mineral concentrations were affected by interactions between seed mixture, year and grazing period. Thus herbage mineral content developed differently during two grazing seasons (Fig. 1).

The seed mixtures resulted in similar K/(Ca+Mg) equivalent ratios, but different Ca/P ratios ($P < 0.05$) (Table 2). In WM herbage the Ca/P ratio was 21% higher than in AM and GM. The effect of year and grazing period was evident for both mineral ratios (Table 2). Between years the K/(Ca+Mg) equivalent ratio was higher in 1998 than in 1997 and vice versa for the Ca/P ratio. Within a grazing season the K/(Ca+Mg) equivalent

ratio was high during GP1 compared to the following grazing periods ($P < 0.05$) (Fig. 2). The Ca/P ratio was low at the beginning of a grazing season and high in the middle ($P < 0.05$).

The botanical proportions were related to the herbage mineral contents. Clovers increased the Ca ($r_s = 0.673$) and Mg ($r_s = 0.493$) concentrations and decreased the P ($r_s = -0.331$) and K ($r_s = -0.140$) concentrations ($P < 0.05$, $n = 200$). Weeds increased the Ca ($r_s = 0.259$) and Mg ($r_s = 0.417$) concentrations and decreased the Na concentrations ($r_s = -0.143$) ($P < 0.05$, $n = 200$). Grasses increased the P ($r_s = 0.303$) concentrations and decreased the Ca ($r_s = -0.705$) and Mg ($r_s = -0.686$) concentrations ($P < 0.001$, $n = 200$).

Discussion

In organic farming systems pasture is the primary mineral resource for dairy cows during summer, but also supplementary feeding affects the dietary mineral content. Herbage mineral concentrations depend on the availability of nutrients, environ-

Table 2. Effect of seed mixture, grazing season and grazing period on the botanical contents, mineral composition and mineral ratios of pre-grazing herbage.

	Proportion of species in herbage g kg ⁻¹ DM			Mineral content in dry matter (DM) g kg ⁻¹ DM						
	Grasses	Clovers	Weeds	Calcium (Ca)	Magnesium (Mg)	Phosphorus (P)	Potassium (K)	Sodium (Na)	K/(Ca+Mg) equivalent ratio	Ca/P ratio
Seed mixture										
Alsike clover mixture	78.4 ^a	99 ^a	116	5.74 ^a	1.92	4.02	32.47	0.082 ^{ab}	1.95	1.45 ^a
Red clover mixture	73.4 ^b	136 ^b	131	6.11 ^{ab}	2.13	4.10	33.55	0.074 ^a	1.84	1.52 ^{ab}
White clover mixture	667 ^c	210 ^d	123	7.16 ^c	2.22	4.12	33.47	0.104 ^c	1.66	1.77 ^c
White-alsike clover mixture	717 ^b	180 ^c	103	6.24 ^b	2.10	3.97	32.89	0.096 ^{bc}	1.83	1.61 ^b
Grass mixture	787 ^a	98 ^a	114	5.76 ^a	2.00	4.02	32.32	0.087 ^{ab}	1.91	1.47 ^a
Grazing season										
1997	704	173	122	6.69	2.18	3.86	32.42	0.056	1.71	1.76
1998	772	116	112	5.72	1.97	4.23	33.47	0.122	1.97	1.36
Grazing period										
1	791 ^a	71 ^a	138 ^a	4.98 ^a	1.92 ^a	4.51 ^a	37.11 ^a	0.082	2.38 ^a	1.11 ^a
2	760 ^a	138 ^b	102 ^{bc}	5.46 ^b	1.92 ^a	3.96 ^b	33.62 ^b	0.098	2.05 ^b	1.38 ^b
3	651 ^c	220 ^d	129 ^{ab}	7.15 ^d	2.21 ^b	3.73 ^c	31.94 ^c	0.090	1.56 ^c	1.94 ^d
4	705 ^b	169 ^c	127 ^{ab}	6.82 ^{cd}	2.15 ^b	3.94 ^b	31.11 ^c	0.094	1.58 ^c	1.74 ^c
5	783 ^a	126 ^b	92 ^c	6.62 ^c	2.18 ^b	4.08 ^b	30.93 ^c	0.082	1.62 ^c	1.65 ^c
Source of variation	P value									
Seed mixture (SM)	0.013*	<0.001***	0.941	0.021*	0.452	0.620	0.335	0.014*	0.209	0.040*
Grazing season (GS)	0.001**	0.001**	0.142	0.003**	<0.001***	<0.001***	0.110	<0.001***	<0.001***	<0.001***
Grazing period (GP)	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	0.088	<0.001***	<0.001***
SM x GS	0.239	0.153	0.371	0.890	0.511	0.462	0.546	0.039*	0.760	0.825
SM x GP	0.051	0.001**	0.458	0.005**	0.143	0.438	0.484	0.703	0.049*	0.144
GS x GP	<0.001***	0.134	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	0.011*	<0.001***	<0.001***
SM x GS x GP	0.577	0.129	0.398	0.597	0.907	0.734	0.603	0.729	0.290	0.512

^{a-d} 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

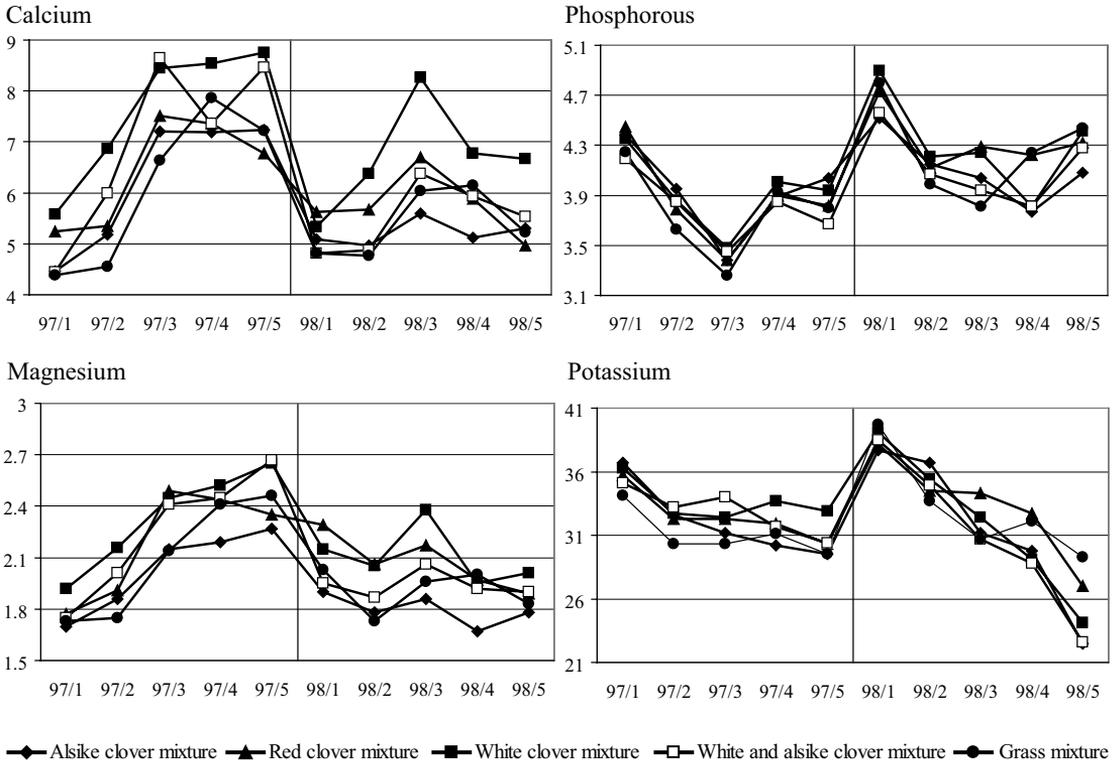


Fig. 1. Temporal variation (year/grazing period) in mineral content of seed mixtures (g kg⁻¹ dry matter).

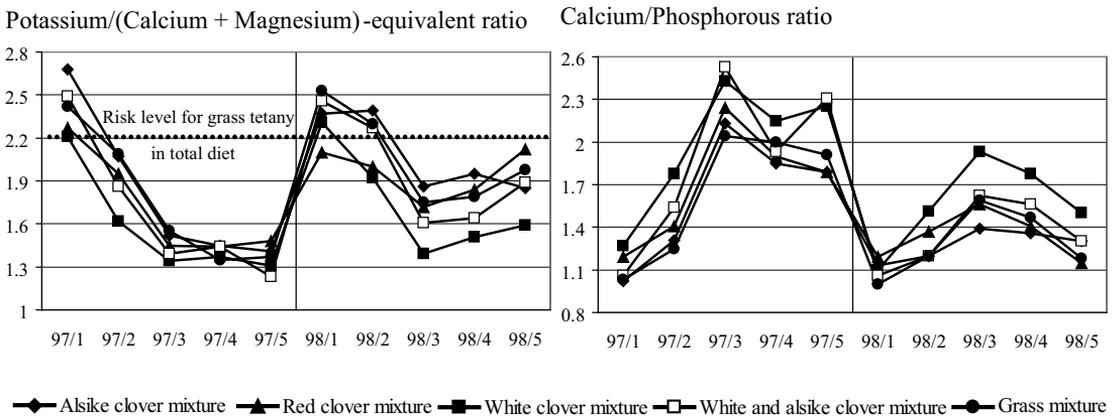


Fig. 2. Temporal variation (year/grazing period) in mineral ratios of pre-grazing herbage.

mental factors, plant species, age of tissues, age of whole shoots, etc. (Reuter and Robison 1986). In the present study, which was conducted in relatively fertile soil conditions, the impacts of the

year and grazing period on the mineral parameters measured were greater than the impacts of the seed mixture, highlighting the importance of temporal considerations. According to Hansen et al. (2002)

herbage and soil parameters are poorly correlated, when the mineral concentrations in shoot material are not below requirements for normal growth. However, complicated interactions between minerals affect the plant uptake in soil. For instance, high K concentrations in soil solutions decrease P, Ca, Mg and Na concentrations in plants (Evans et al. 1986, Underwood and Suttle 1999). High N, K, Ca concentrations in soil decrease Mg uptake (Grunes and Welch 1989). Between species, grasses exhibit significantly lower nutrient contents than legumes and weeds in extensively managed pasture systems (Carcia-Ciudad et al. 1997). According to a preliminary study, weeds collected from this experiment had a Ca and Mg content similar 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 mineral analysis gives the current values of herbage mineral concentrations, shows if plants have been supplied sufficiently and helps to control the dietary mineral contents for grazing animals (Clement and Hopper 1968, Reuter and Robison 1986). However, the complexities of the field environment mean that sampling for plant analysis may occur when growth is limited by water stress, temperature, light, disease, insect attack, abnormal root development or other nutrients (Reuter and Robison 1986). In any case, the mineral feeding cannot be based on a single herbage sample, even one representative at that moment, because of temporal changes in the mineral contents of herbage. Furthermore, the mineral amounts of the offered pasture herbage are not congruent with the minerals actually utilised by the animals, because of selective grazing and differences in mineral absorption and utilisation (Underwood and Suttle 1999). Mineral concentrations, forms, interactions with other minerals and even with vitamins affect mineral availability for animals and the current needs of animals affect the final utilisation of minerals. For instance, adequate P nutrition depends on the chemical forms in which P occurs in the diet, the vitamin D status of diet and animal, food intake, level of performance and the dietary Ca concentration (Underwood and Suttle 1999).

Mineral content of herbage

The experimental site was located in Finnish milk production zone, where rotationally grazed short-term pastures, similar to the current experimental design, are generally used. The good soil fertility, typical of swards, which before converting had been cultivated for several years using intensive conventional pasture practices, could provide relatively high herbage mineral concentrations. They were of the same levels than in a Danish commercial organic dairy farm study (Hansen et al. 2002), but clearly higher than in a Netherlander low-intensive grazing study (Bakker and Heerdt 2005).

The main differences between seed mixtures were related to the proportion of clover in the sward, which affected the Ca content of the herbage. The average Ca content of the herbage (6.20 g kg⁻¹ DM) was 24% higher compared to the standard value for pasture in Finnish feeding tables (MTT 2004), and the mean Ca content of WM (7.16 g kg⁻¹ DM) was 43% higher. An increase in temperature is known to increase the Ca and Mg contents of herbage and the ageing of sward decreases them (Evans et al. 1986, Grunes and Welch 1989). In the present study, within a grazing season the Ca content of the herbage was low at the beginning and high in the middle, concurrent with the proportion of clover and the temperature. Consistently, the Ca content of herbage was 17% higher in 1997 than in 1998, when the clover content and mean temperature were lower and the sward older. In the species samples collected in 1998 the Ca content of clovers, grasses and weeds was 12.4, 3.3 and 10.0 g kg⁻¹ DM, respectively (Kuusela and Hytti 2001). In pasture, an adequate (required for normal growth) Ca level for clover and grass has been suggested to be > 11.0 and 2.5–3.0 g kg⁻¹ DM, respectively (Reuter and Robison 1986).

The average Ca content of 15 kg DM of current herbage would have clearly exceeded the Ca requirement for 25 kg milk yield d⁻¹ and the Ca content of WM requirement for 30 kg milk yield d⁻¹ (MTT 2004). The calcium contents for all the seed mixtures were almost all the time above the recommended (minimum) value of 4.6 g kg⁻¹ DM for 20 kg milk yield d⁻¹ (Underwood and Suttle 1999).

The relative high Ca content of clovers should be noted in clover-grass-based diets, where mineral Ca supplements are often unnecessary. Most of the time excess of dietary Ca is not a problem, because homeostatic mechanisms extensively excrete any excess to faeces (Underwood and Suttle 1999). However, before calving a high Ca content of basic herbage may predispose cows to milk fever by hindering normal Ca transport from bones to milk (ARC 1980, Tauriainen et al. 1998, Underwood and Suttle 1999). According to Breukink (1993), the amount of Ca in feed should not exceed 25 g d⁻¹ during the later dry period. This low level of dietary Ca would be difficult to implement in Nordic clover-grass-based organic dairy farming systems. Also other factors such as age, fatness and dietary cation-anion ratio are involved (Underwood and Suttle 1999, Tauriainen et al. 2003). According to Hovi et al. (2003), the occurrence of milk fever on organic farms is unclear, somewhat higher in Finland, but lower in Norway compared to the overall incidence in the country. However, a clover proportion under 0.40 has been recommended for pasture for another reason, to avoid a risk of legume bloat (Alder et al. 1967). Clover-rich pastures are best suited for high-yielding dairy cows, while pregnant dry cows are better grazed separately on poorer, grass-dominated swards.

The mean Mg content of the pasture herbage (2.08 g kg⁻¹ DM) was 30% higher than the standard value for pastures in Finnish feeding tables (MTT 2004). The herbage Mg content was similar between the seed mixtures and related to the proportions of clovers and weeds. Like Ca, Mg was higher in 1997 than in 1998. During the most active period of grass growth in spring, the Mg level and particularly the amount of available Mg in grass often falls (Grunes and Welch 1989). In the present study the Mg content increased for all the seed mixtures during the grazing season in 1997, but not in 1998, perhaps due the higher grass content or cooler weather then. Consistently in species samples collected in summer 1998, the Mg content of clovers, grasses and weeds was 3.25, 1.42 and 3.11 g kg⁻¹ DM, respectively (Kuusela and Hytti 2001). In pasture, an adequate Mg content for clovers and grasses has been suggested to vary be-

tween 1.8–2.2 and 1.6–2.0 g kg⁻¹ DM, respectively (Reuter and Robison 1986). A fatal Mg deficiency for cows, hypomagnesaemia, is attributed to low blood magnesium levels, and is generally found in grazing animals during early spring (Underwood and Suttle 1999). The average Mg content of 15 kg DM of current herbage would have exceeded the Finnish Mg requirement for 20 kg milk yield d⁻¹ (MTT 2004), but the temporal variation was significant. Hence the Mg content of seed mixtures was often below the recommended value of 2.0 g kg⁻¹ DM for 20 kg milk yield d⁻¹ (Underwood and Suttle 1999). In the context of high herbage K concentrations (> 20 g kg⁻¹ DM), Mg concentrations higher than 2.5 g kg⁻¹ DM are recommended (Grunes and Welch 1989). Therefore an additional Mg supplementation was required also in the present study.

The mean P content of herbage was similar between the seed mixtures (4.04 g kg⁻¹ DM) and similar to the standard value for pasture in Finnish feeding tables (MTT 2004). Like other minerals, herbage P is dependent on the amount of available P in the soil, but also environmental conditions are important. For instance, the P concentration in shoots is decreased by water stress, but recovers when the water stress is relieved (Reuter and Robison 1986). Also in the present study the P content was at lowest in the middle of the dry summer of 1997. The P content of herbage was negatively associated with proportion of clovers and positively with proportion of grasses. Clovers are generally poorer competitors for P than grasses (Hogh-Jensen et al. 2000). In consistent species samples collected during 1998, the P contents of clovers, grasses and weeds were 3.87, 4.00 and 4.04 g kg⁻¹ DM, respectively (Kuusela and Hytti 2001). In a Danish organic farm study the P contents of pasture clovers were similarly lower than grasses (4.4 vs. 5.3 g kg⁻¹ DM), although both relatively high (Hansen et al. 2002). For grazed clovers and grasses the adequate shoot content of P has been suggested to vary between 3.5 – 4.0 g kg⁻¹ DM (Reuter and Robison 1986). The average P content of 15 kg DM of current herbage would have clearly exceeded the P requirement for 20 kg milk yield d⁻¹ according to the current Finnish recommendation

(MTT 2004). The P contents of the seed mixtures were all the time above the recommended concentration of 2.5 g kg⁻¹ DM for 20 kg milk yield d⁻¹ (Underwood and Suttle 1999).

The seed mixture did not affect the herbage K content, which was clearly dependent on the phase of summer (grazing period). The mean K content (32.9 g kg⁻¹ DM) was only slightly lower (6 %) than the standard value for pasture in Finnish feeding tables (MTT 2004). The current result is in agreement with Sormunen-Cristian et al. (1997) who reported similar high K concentrations (35.1–32.4 g kg⁻¹ DM) for conventional clover-grass pastures and grass only pastures. In a Danish organic dairy farm study the K contents of pasture clovers and grasses were 33.0 and 38.0 g kg⁻¹ DM, respectively (Hansen et al. 2002). For maximum DM production the K content of herbage should exceed 20 g kg⁻¹ DM (Clement and Hopper 1968, Reuter and Robison 1986). Grasses are generally stronger competitors for K than clovers, which can improve the success of grasses on low K soils (Dunlop et al. 1979, Hogh-Jensen et al. 2000). If there is a plentiful K available in the soil, most pasture species will take up more than required (luxury uptake). In the present study, the high K values showed that K availability in the current soil was good and luxury uptake occurred, especially in early summer. In this respect grasses, clovers and weeds seemed to be similar. Consistently in species samples collected in summer 1998, the mean K contents of clovers, grasses and weeds were all relatively high (34.3, 29.8 and 37.0 g kg⁻¹ DM, respectively) (Kuusela and Hytti 2001). Soils contain varying total reserves of potassium, depending on the soil mineralogy, but the rate at which potassium becomes available to plants is of primary significance and varies between soils and even between crop rotations (Clement and Hopper 1968). In organic pasture farming, biotic fertilisation might be needed for peat or sandy soils (Baars 2002), although most of the grazed K is directly circulated back to the soil (Leaver 1985). When fertilisation is needed, it should be based on herbage K measurements, which show the true K availability for pasture species (Clement and Hopper 1968). Plants have relatively high K requirements compared to animal

requirements and notably forages, when used as animal feeds, often contain high amounts of K, much higher than the animal can efficiently use (Tamminga 2003). The amount of 15 kg DM of current herbage would have corresponded to more than 5 times the K requirement for 20 kg milk yield d⁻¹ (MTT 2004). The K contents of the seed mixtures were all the time clearly above the recommended value of 7 g kg⁻¹ DM for 20 kg milk yield d⁻¹ (Underwood and Suttle 1999). A high K content in the herbage can predispose animals to grass tetany (Grunes and Welch 1989) and milk fever (Tauriainen et al. 2003) and has been also connected to legume bloat (Majak et al. 1995). Although related to many disorders, a clear surplus of K for cows on grass-based diets is inevitable to ensure grass growth, but unnecessary excess should be minimised.

The mean content of Na (0.09 g kg⁻¹ DM) was at a very low level (Underwood and Suttle 1999), but almost similar to the standard value for pasture in Finnish feeding tables (MTT 2004). The seed mixture affected the herbage Na content, and WM and WAM resulted in slightly higher values. The amount of 15 kg DM of current herbage would have corresponded to only 6% of the Na requirement for 20 kg milk yield d⁻¹ (MTT 2004). The Na contents of the seed mixtures were clearly below the recommended value of 1.2 g kg⁻¹ DM for 20 kg milk yield d⁻¹ (Underwood and Suttle 1999). In conclusion, additional Na supplement is necessary for cows grazing either organic or conventional pastures in Finland.

Dietary mineral contents and herbage mineral ratios

Besides unsatisfied requirements for individual minerals, certain mineral imbalances present in pastures may lead to metabolic disorders of ruminants. In the present study the mean value for the K/(Ca + Mg) equivalent ratio was 1.84. Low Mg concentrations, high K concentrations and K/(Ca + Mg) equivalent ratios above 2.2 have been implicated in the etiology of grass tetany (Kemp and

Hart 1957, Grunes and Welch 1989). Grass tetany or hypomagnesaemia is widespread in countries with cool wet spring weather (Grunes and Welch 1989). Rinne et al. (1978) summarised that the $K/(Ca + Mg)$ ratio in swards is affected by season, plant species, age of ley, soil type, fertilisation and yield level. In conventional farming the average $K/(Ca + Mg)$ equivalent ratio of clover-grass pastures converge to the current result (1.8), while that of nitrogen-fertilized grass swards was clearly higher (2.8) (Sormunen-Cristian et al. 1997). In the present study, the decrease in the proportion of clover during 1998 resulted in lower Ca and Mg contents in herbage and an increased $K/(Ca + Mg)$ equivalent ratio. Besides species composition, the phase of summer is an important consideration for the $K/(Ca + Mg)$ equivalent ratio, because the high K contents and often low Mg and Ca concentrations in early summer push the ratio upwards. Later in summer both a decreased herbage K content and often increased Ca plus Mg contents result in a lower $K/(Ca + Mg)$ equivalent ratio. This study showed that the $K/(Ca + Mg)$ equivalent ratio of organic pastures was adequate most of the summer, but in early summer the risk of grass tetany must be noted and additional Mg is necessary.

In the present study, the average Ca/P ratio (1.56) was higher than in Finnish recommended diets (MTT 2004). The imbalance in the Ca/P ratio of herbage containing clover was a consequence of the high Ca content of clover. However, ruminants can tolerate a wide range of Ca/P when their vitamin D status is adequate and the dietary supply of each mineral is adequate, because animals can radically change extreme dietary ratios by homeostatic control to adequate ratios of absorbed and retained Ca/P (Underwood and Suttle 1999). A diet defined for both Ca and P can have an apparently 'ideal' Ca/P ratio, which is often between 1.1–2.1 (ARC 1980, Underwood and Suttle 1999). Still requirements for Ca and P should be formulated independently, not based on their ratio, which, however, may affect Ca and P utilisation if the supply of one element is limiting and the other is excessive (Underwood and Suttle 1999). A high Ca/P ratio cannot and must not be changed, if the herbage P concentration is adequate. In Nordic organic

farming systems with a short grazing season more concern should be directed to ensuring a sufficient supply of vitamin D around the year.

In non-optimal grazing conditions moderate concentrate feeding supplements are recommended for early-mid lactating cows grazing at organic clover-grass pastures (Khalili et al. 2002). They complement animal nutrition, increase milk yield, decrease demands for additional pasture area and similarly improve the dietary mineral content. Rapeseed meal is rich in P and Mg and cereals are low in Ca and K (MTT 2004). For example, replacing on an energy basis 4.3 kg of 15 kg DM of current herbage (Kuusela 2004) by 2.75 kg barley-oats mixture and 1.25 kg rapeseed meal, would decrease the Ca and K supply by 20 and 22%, respectively, while the Mg supply would be similar and the P supply would increase by 13%. The protein content of diet would remain unchanged.

Conclusions

Organic pasture herbage did not fully correspond to the mineral requirements of grazing dairy cows. The main differences between seed mixtures were connected to the proportion of clover in the sward. The seed mixture resulted in different Ca and Na contents, but similar Mg, P and K concentrations in the herbage. On average the P and Mg contents of the herbage were close to animal requirements, but high K contents, similar to those in conventional farming, influenced the mineral balance and increased the need for Mg supplementation. The temporal changes in mineral contents and mineral ratios were significant. In early summer the risk of grass tetany was actual ($K/(Ca + Mg)$ equivalent ratio > 2.2). Clovers, to some extent also weeds, increased the Ca and Mg contents and the Ca/P ratio of herbage and decreased the risk of grass tetany. Calcium-free or low-Ca mineral feeds containing Na, Mg and occasionally some P, probably complement best the mineral feeding of dairy cows grazing on organic clover-grass swards. However, mineral supplementation must always be adjusted

on current animal requirement (milk yield) and on actual diet mineral content basis.

Acknowledgements. The author is grateful to the Finnish Ministry of Agriculture and Forestry for financial support and acknowledges the assistance of the staff of the Sii-kasalmi Research Farm at the University of Joensuu and the staff of Animal Production Research, MTT Agrifood Research Finland.

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SELOSTUS

Luomulaidunrehun kivennäiskoostumuksen ja kivennäissuhteiden vaihtelu

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Laidunnetussa kenttäkokeessa verrattiin alsikeapilan (*Trifolium hybridum* L.), puna-apilan (*Trifolium pratense* L.) ja valkoapilan (*Trifolium repens* L.) vaikutusta laidunrehun määrään ja laatuun luonnonmukaisessa tuotannossa. Koska kesällä 1996 siemenseoksista otetut näytteet antoivat viitteitä tavanomaisesta tuotannosta poikkeavasta kivennäiskoostumuksesta, mitattiin tässä kokeessa siemenseoksen (alsikeapila-, puna-apila-, valkoapila-, valko-alsikeapila- ja heinäseos), vuoden (1997, 1998) ja laidunkerran (5 laidunkertaa) vaikutusta luomulaidunrehun kalsium-, magnesium-, kalium- fosfori- ja natriumpitoisuuteen. Lisäksi arvioitiin laidunrehun kivennäiskoostumuksen sopivuutta lypsylehmien ruokintaan. Koe toteutettiin satunnaistettujen lohkojen menetelmällä Itä-Suomessa, Liperissä.

Luomulaidunrehun keskimääräiset kalsium- ja magnesiumipitoisuudet olivat tavanomaiseen laidunrehuun verrattuna suurempia, mutta kalium-, fosfori- ja natriumpitoisuudet samaa tasoa. Luomulaidunrehun kivennäiskoostumus vaihteli kuitenkin huomattavasti vuosien, laidunkertojen ja siemenseosten mukaan. Valkoapilaseoksen kalsium- ja natriumpitoisuudet olivat muita

seoksia suurempia. Laidunrehun kasvikoostumus vaikutti sen kivennäiskoostumukseen.

Kun suunnitellaan laidunkauden kivennäisruokintaa, on syytä ottaa huomioon, että apilapitoisella luomulaitumella kalsiumlisä on yleensä tarpeeton. Sen sijaan natriumia laidunrehussa on eläinten tarpeeseen nähden aivan liian vähän. Luomulaidunrehun keskimääräiset fosfori- ja magnesiumipitoisuudet olivat kokeessa lähellä eläinten tarpeita. Kuitenkin magnesiumilisä on myös luomulaitumella yleensä tarpeen, koska tavanomaisen tuotannon kanssa yhtä suuri kaliumipitoisuus voi lisätä poikimahalvausriskiä etenkin laidunkauden alussa. Kalsiumvapaa tai vähän kalsiumia sisältävä kivennäinen, jossa on pääasiassa natriumia ja magnesiumia sekä tarpeen mukaan fosforia, täydentää todennäköisesti parhaiten luomulaidunrehun kivennäiskoostumusta. Sopiva kivennäisrehu tulee valita ottaen huomioon eläimen tarpeet (tuotostaso) ja kaikkien rehujen kivennäiskoostumus. Luomulaidunrehun kivennäiskoostumus on syytä määrittää, koska se voi vaihdella enemmän kuin tavanomaisen laidunrehun.