ELSEVIER

Livestock Production Science 85 (2004) 113–127

LIVESTOCK PRODUCTION SCIENCE

www.elsevier.com/locate/livprodsci

Fertilisation, seed mixtures and supplementary feeding for annual legume–grass–cereal pastures in organic milk production systems

Eeva Kuusela[a,*], Hannele Khalili[b], Päivi Nykänen-Kurki[c]

[a] *University of Joensuu, Department of Biology, P.O.Box 111, FIN-80101 Joensuu, Finland*
[b] *MTT Agrifood Research Centre, Animal Production Research, FIN-31600 Jokioinen, Finland*
[c] *MTT Agrifood Research Centre, Ecological Production, FIN-50600 Mikkeli, Finland*

Received 28 May 2002; received in revised form 6 May 2003; accepted 19 May 2003

Abstract

Two field trials were carried out in North Karelia during 1999 in order to evaluate annual legume–grass–cereal mixtures for grazing cows within an organic milk production system. For all mixtures, Italian ryegrass (*Lolium multiforum* Lam.) was used as the source of grass and barley (*Hordeum vulgare* L.) was used as the cereal component. The effect of compost fertilisation (0 and 25 t ha^{-1}) and legume in four mixtures (common vetch (*Vicia sativa* L.), hairy vetch (*Vicia villosa* Roth.), Persian clover (*Trifolium resupinatum* L.) and a mixture of Persian and white clover (*Trifolium repens* L.) based) on botanical composition, herbage mass (HM), nutritive value and postgrazing sward height (SH), were studied in Experiment 1. Experiment 2 assessed the effects of two legume based mixtures (common and hairy vetch or Persian and white clover) and two concentrate feeding regimens (once or twice daily) on milk production. In both experiments, herbage nutritive value was relatively constant during the entire grazing season, despite major changes in sward botanical composition. Compost application had no effect on pregrazing botanical composition, but stimulated increases in both pre- ($P=0.056$) and postgrazing ($P<0.05$) HM and postgrazing SH ($P<0.05$). Use of hairy vetch resulted in higher mean pregrazing HM ($P<0.05$) and a greater proportion of legumes in grazed swards ($P<0.05$) than common vetch. Neither compost nor seed mixture influenced pre- minus postgrazing HM ($P>0.05$). In spite of lower digestibility and sugar content, milk production was similar ($P>0.05$) for cows grazing vetch compared with clover based swards. At the end of grazing season, high proportions of clover in the sward were associated with an increased incidence of bloat. Concentrate feeding regimen had no effect on animal performance ($P>0.05$).

Keywords: Organic dairy farming; Annual pastures; Compost fertilisation; Seed mixtures; *Vicia sativa* L.; *Vicia villosa* Roth.; *Trifolium resupinatum* L; *Trifolium repens* L.; Concentrate feeding regimen

1. Introduction

Grazing is an essential part of organic milk production systems and the cattle feeding should be based on maximum use of pasturage according

* Corresponding author. Tel.: +358-13-251-3683; fax: +358-13-251-3590.
E-mail address: eeva.kuusela@joensuu.fi (E. Kuusela).

0301-6226/$ - see front matter © 2003 Elsevier B.V. All rights reserved.
doi:10.1016/S0301-6226(03)00139-8

to the availability of pastures in the different periods of year (EU 1804/1999; CEC, 1999). Consequently, producers are becoming increasingly interested in the development and implementation of alternative grazing practices and pasture species, with the potential to support efficient grazing and milk production. In Nordic Countries, milk production from grazed grass is limited due to the short grazing season, and in some cases, as a result of low herbage yields from perennial pastures, particularly in the autumn during preparation for overwintering. Winter damages of perennial swards may also require the use of seed mixtures that can be sown in the spring and grazed soon after establishment. Some annual crops, such as Italian ryegrass (*Lolium multiforum* Lam.), have a rapid regrowth after harvest, providing sufficient herbage mass (HM) for several harvests and late summer growth (Nissinen, 1992; Nissinen and Hakkola, 1998). N-Fertilised mixtures of Italian ryegrass and barley *(Hordeum vulgare* L.) have been the most productive annual mixtures in Lapland under conventional conditions (Nissinen, 1992).

In organic farming systems, where soluble fertilisers are not permitted, annual pastures allow more frequent applications of manure/compost than perennial pastures. Even when these materials are applied, legumes that are capable of biological nitrogen fixation are fundamental to successful organic grass based livestock production systems (Weller and Cooper, 2001). Common vetch (*Vicia sativa* L.), hairy vetch (*Vicia villosa* Roth.), Persian clover (*Trifolium resupinatum* L.) and also some white clover varieties (*Trifolium repens* L.) may have potential as annual mixtures under Nordic conditions (Duke, 1981). Mixtures of cereals, grasses and the above-mentioned species could be used in a short occupation rotational grazing system (Kuusela and Khalili, 2002). However, these nominated annual pastures have to provide relatively high yields of herbage of suitable nutritive value throughout the grazing season to support high levels of milk production. Furthermore, grazing management could be simplified by adopting once than twice daily concentrate supplementation regimens.

The current study was conducted to introduce annual legume–grass–cereal mixtures for milk production within organic or other low fertiliser input systems under Nordic conditions. The first study assessed the effect of compost fertilisation (0 and 25 t ha^{-1}) and four seed mixtures (common vetch, hairy vetch, Persian clover or mixture of white and Persian clovers based) on herbage parameters. The second experiment evaluated the effect of seed mixtures (vetch or clover based) and concentrate feeding regimen (4 kg once and 2 kg twice daily) on milk production.

2. Materials and methods

Both experiments were conducted during 1999 at the Siikasalmi experimental farm of the University of Joensuu (62°30′ N, 29°30′ E) in North Karelia, Eastern Finland. The farm was converted to organic farming in 1996. Mean temperature and sum of precipitation from the beginning of June to the end of September indicated that conditions in 1999 were somewhat dryer (13.3 °C, 205 mm) than the long term (1961–1990) regional average (13.3 °C, 285 mm).

2.1. Pastures, experimental design and treatments

2.1.1. Experiment 1, grazing field trial, compost fertilisation and seed mixtures

Existing pasture was ploughed at the end of May 1999 and the area was immediately harrowed prior to the onset of the field trial. The establishment of this trial was conducted as a split-split-plot design. Soil texture was comprised of silty very fine sand (0.02–0.06 mm) of medium fertility with an organic matter content of 60–120 g kg^{-1} DM and pH (water) 6.0.

Treatments with three replicates were as follows:

- Fertilisation (main plot): unfertilised (U), 25 t ha^{-1} farmyard manure compost (C).
- Seed mixture (split-plot): common vetch mixture (CV), hairy vetch mixture (HV), Persian clover mixture (PC), Persian and white clover mixture (PWC).
- Periods of grazing within grazing season (split-split-plot): grazing periods designated 1–5 (GP1–GP5) were started 5, 7, 10, 13 and 16 weeks postseeding, respectively.

Main plots measured 35.00 × 17.50 m with subplots of 17.50 × 8.75 m. Compost fertilisation was applied before harrowing. The ratio of carbon to nitrogen in compost was 18.8. Total nitrogen supplied by compost was 154 kg ha^{-1} and no other fertilisers were applied. The composition of the seed mixtures is presented in Table 1. Seed application kg ha^{-1} of hairy and common vetch was targeted to result in a similar number of seeds per unit area, determined on thousand seed weight and expected germination basis. Lower seedling rates of clovers for PWC compared with PC were selected to advance white clovers expansion. Plots were seeded on 26th of May.

During the grazing season the experimental area was grazed five times replicate by replicate using Finnish Ayrshire dairy cows. The number of animals (5–8) and the duration of each grazing period varied (0.5–1.5 days) according to estimated HM of a fixed area (a replicate). Animals were offered alternative grazing during intervals between grazing periods. Cows were removed from each replicate, when targeted postgrazing SH (10–12 cm) of unfertilised areas were approached. Grazing of the experiment began 29th of June and ended 15th September. The rotation cycle was typically 21 days, but was only 14 days between GPI and GP2. Immediately after grazing each replicate was topped with a mower to a height of 10 cm.

2.1.2. Experiment 2, milk production trial, seed mixtures and concentrate feeding regimen

Three perennial pastures (total 3 ha) were ploughed up at the end of May 1999. Soil comprised of silt (0.02–0.002 mm) to silty very fine sand, an organic matter content of 60–120 g kg^{-1} DM and pH (water) 6.2. No fertilisers were used. After harrowing, pastures (1–3) were divided into two equal areas for seeding. Seed mixtures consisting of vetch (VM) and clover (CM) based mixtures (Table 1), were allocated at random to one of two sides of each pasture and seeded on 24th–25th of May.

Eight lactating (150 ± 36 days in milk) Finnish Ayrshire cows, were used in a milk production trial conducted as two 4 × 4 Latin squares with four 21-day experimental periods, comprised of a 15-day adjustment period and a 6-day recording period. Mean body condition score of animals was 3.1 using a scale from 1 (very thin) to 5 (very fat). Cows were divided into two squares according to milk yield and treatments were randomly assigned to each cow within a square. Four experimental treatments in a 2 × 2 factorial arrangement consisted of two sward mixtures (clover or vetch) and 4.0 kg day^{-1} (on an air-dry basis) of standard concentrate supplement offered once (4 kg) or twice (2 + 2 kg) daily. Concentrate was offered at morning milking for both feeding regimens, and only at the afternoon milking for the twice-daily regimen. Concentrate supplements were formulated (g kg^{-1}) from oats (375), barley (375) and rapeseed meal (250), with calculated ME and CP contents of 10.8 MJ and 170 g kg^{-1}, respectively (Tuori et al., 1996). All cows received 250 g day^{-1} of a mineral supplement that contained (g kg^{-1}) Ca (160), P (64), Mg (80) and Na (90), 20 g of NaCl and ad libitum access to salt licks [(g kg^{-1}) Na (360) and Ca (54)]. Grazing started 22nd June and ended 13th September 1999. Herbage allowance (HA) was 21.5 kg DM (above 3 cm) cow^{-1} day^{-1}. Paddocks were used for between 3 and 4 days, with the area

Table 1
Composition of seed mixtures (cultivars) used in Experiments 1 and 2

Basic seed mixture contained barley (Pohto), 80 kg ha^{-1} and Italian ryegrass (Meroa), 14 kg ha^{-1} accompanied by	
Experiment 1	
Common vetch mixture (CV)	+ Common vetch (Ebena), 40 kg ha^{-1}
Hairy vetch mixture (HV)	+ Hairy vetch (Viola), 30 kg ha^{-1}
Persian clover mixture (PC)	+ Persian clover (Ciro), 14 kg ha^{-1}
Persian and white clover mixture (PWC)	+ Persian clover (Ciro), 6 kg ha^{-1} and white clover (Huia), 1 kg ha^{-1}
Experiment 2	
Clover mixture (CM)	+ Persian clover (Accadia), 12 kg ha^{-1} and White clover (Huia), 2 kg ha^{-1}
Vetch mixture (VM)	+ Common vetch (Ebena), 20 kg ha^{-1} and hairy vetch (Viola), 14 kg ha^{-1}

allocated being determined by HM availability to satisfy HA requirements. Average duration between the beginning of the first and second, second and third, and third and fourth grazing periods was 13, 26 and 30 days, respectively. Experimental cows were simultaneously transferred into the next pasture, while the remainder was grazed by other cows. After grazing, pastures were topped with a mower to a height of 10 cm. Cows were milked indoors at 0600 and 1600 h. During the last experimental period, animals were carefully monitored and housed indoors from late evening (2100 h) until morning milking to reduce the risk of bloat from grazing swards of increased legume content. Animals did not receive any additional feed during this time.

2.2. Measurements and analytical procedures

In both experiments HM before grazing, and after grazing (experiment 1) was measured manually by cutting six randomised areas of 74.0 × 22.5 cm to a height of 3 cm using shears and an aluminium frame. Dry matter (DM) content of herbage was determined by oven drying at 105 °C for 24 h. Intake was estimated in experiment 1, as the difference between pre- and postgrazing HM (pre-postgrazing HM). For experiment 2, the size of each paddock was based on measured HM and HA requirements of 21.5 kg DM (above 3 cm) cow^{-1} day^{-1}. In both experiments, herbage growth during the grazing event was not recorded, and therefore herbage accumulation from treatments was underestimated, but not to a great amount since occupation of paddocks was relatively short (Frame, 1981). Samples used to assess herbage quality was dried at 60 °C and stored at room temperature prior to analysis. All samples in experiment 1, and weekly composite samples in experiment 2 were analysed for organic matter by ashing at 600 °C for 12 h, nitrogen (Kjeldahl N), neutral detergent fibre (NDF) according Van Soest et al. (1991) and in vitro organic matter digestibility (IVOMD) using a cellulase based method (Friedel and Poppe, 1990). The botanical composition of pregrazing HM (above 3 cm) was determined manually before each grazing period in experiment 1, and at three stages (start, middle and end) in experiment 2. Postgrazing SH were measured using a sward stick (Bircham, 1981) and a total of 15 and 40 random measurements were collected (including both eaten and uneaten areas) per split-plot (experiment 1) and paddock (experiment 2), respectively. In experiment 2, herbage samples for soluble carbohydrate determinations were collected from VM and CM paddocks on 20th June and 23rd August. Samples were cut within a 2-h interval along each day (between 0500 and 2100 h) using same method described for other herbage samples, freeze-dried and analysed for water soluble carbohydrate content according to Somogyi (1945).

In experiment 2 milk yield was recorded daily and results are presented based on measurements collected during the last 6 days of each experimental period. Intake from pasture was not estimated. Representative samples of concentrates were collected during the last 6 days of each experimental period and pooled within period. Samples of concentrates were analysed for organic matter (OM), nitrogen and NDF using the same methods described for herbage samples. During each collection period milk samples were collected over six consecutive milking from each cow and each sample was analysed for fat, protein and lactose using an infrared milk analyser (Milcoscan 605) and urea according to McCullough (1967).

2.3. Statistical analysis

In experiment 1, the effects of fertilisation, seed mixture and period of grazing on pre- and postgrazing HM, botanical and chemical composition of herbage and postgrazing SH were assessed by analysis of variance for repeated measures using a spilt-plot model. Differences between seed treatments were compared using Tukey's *t* test. The relationship between pre-post HM and pregrazing HM was evaluated using Pearson correlation coefficients and that between herbage botanical and chemical composition by Spearman rank correlation coeeficients.

In experiment 2, the effect of two seed mixtures on pregrazing HM, postgrazing SH, herbage botanical and chemical composition was evaluated using the paired sample *t*-test, because measurements were obtained simultaneously, from two sides of the same pasture. The effect of experimental period on herbage chemical composition was assessed separately for both seed mixtures using one-way analysis of variance. Milk production data were analysed using the

SAS systems for linear models for a Latin square design according to the following model: $y_{ijlkm} = \mu + S_i + C_J(S_i) + P_k + D_l + PxS_{ki} + DxS_{li} + f_{ijklm}$, where μ is the overall mean, S, C and P are the random effects of square, cow and period, respectively, D is the fixed effect of treatments and f_{ijlkm} is the random error term (Littell et al., 1992). Treatment effects were further separated into single degree of freedom orthogonal contrasts to evaluate the effects of sward mixture, concentrate feeding regimen, and their interaction.

3. Results

3.1. Experiment 1

Mean pregrazing HM of fertilised areas was 18% higher than unfertilised areas ($P = 0.056$, Table 2). The average pregrazing HM of HV was 11% higher than that of CV, whilst the two clover mixtures were not different ($P < 0.05$) to vetch mixtures. Interactions between fertilisation and seed mixture were found to be significant ($P < 0.05$) for pregrazing HM. Mean incremental increases in pregrazing HM in responses to fertilisation were 502, 333, 236 and 47 kg DM ha^{-1}, for PC, PWC, CV and HV, respectively. Pregrazing HM was significantly different ($P < 0.01$) between grazing periods, being highest during GP1 and 2. Interactions between seed mixture and grazing period were significant ($P < 0.001$) for pregrazing HM. At the end of the grazing season, pregrazing HM in CV was lowest across both fertilisation treatments (Fig. 1).

Compared with unfertilised areas, compost applications resulted in 27% higher ($P < 0.05$) postgrazing HM and 13% increases in postgrazing SH. Interactions between fertilisation and grazing period had a significant ($P < 0.05$) effect on postgrazing HM, such that the effect of fertilisation was diminished with advances in grazing season (Fig. 2). Postgrazing HM was also influenced by interactions between seed mixture and grazing period, such that postgrazing HM in CV decreased linearly during grazing season, whilst variations in other mixtures was less systematic (Fig. 2). Pre – postgrazing HM was not affected ($P > 0.05$) by fertilisation or seed mixture, but was correlated positively with pregrazing HM ($r = 0.613$, $P < 0.001$, $n = 112$). Further examination of this relationship indicated a closer association for pregrazing HM of unfertilised ($r = 0.783$, $P < 0.001$, $n = 56$) than fertilised areas ($r = 0.566$, $P < 0.001$, $n = 56$).

Fertilisation had no effect ($P > 0.05$) on the proportion of barley, grass or legumes in the sward (Table 2). There was a tendency ($P = 0.055$) for fertilisation to increase the proportion of weeds. Seed mixture had no effects ($P > 0.05$) on the mean proportion of barley. The average proportion of grasses was nearly 20% higher for CV and PWC than for PC and HV ($P < 0.05$). Mean proportions of legumes in the sward were clearly higher for HV and PC compared with PWC or CV ($P < 0.05$). Grazing period altered ($P < 0.01$) the proportion of barley, grasses, legumes and weeds in the sward, such that barley predominated early in the growing season, but was rapidly displaced by other species, whilst grasses became increasing dominant during late summer. Interactions between seed mixtures and grazing periods had a significant effect on the proportion of legumes ($P < 0.001$). In both clover mixtures proportion of clover was relatively low at the beginning of grazing season, increased rapidly, but remained constant during GP 3–5 (Fig. 3). For both vetch mixtures, the proportion of vetch in swards was similar during GP1, but the decline in CV vetch was more rapid than for HV.

Mean CP content of pregrazing HM was slightly higher for unfertilised compared with fertilised areas ($P < 0.05$), whilst fertilisation had no effect on IVOMD. The average CP content of HV was higher ($P < 0.001$) and IVOMD was lower ($P < 0.01$), compared with PC, PWC and CV. Herbage NDF content was not affected ($P > 0.05$) by fertilisation or seed mixture. Herbage NDF, CP and ash content decreased with advances in grazing season, while the reverse was true for IVOMD ($P < 0.05$). Relationships between chemical and botanical characteristics of pregrazing HM are presented in Table 3. Herbage IVOMD was inversely related with barley and positively correlated with the proportion of grass in the sward ($P < 0.001$). Herbage CP content was positively correlated with the proportions of barley and legumes and negatively associated with increases in the proportion of grasses and weeds ($P < 0.05$). Herbage NDF content was positively influenced by the pro-

Table 2
Effect of compost fertilisation (FE), seed mixture (SM) and grazing period (GP) on pre- and postgrazing herbage mass, postgrazing sward height and botanical and chemical composition of pregrazing herbage mass (Experiment 1)

	Herbage mass (kg DM ha^{-1})			Post-	Proportion of species in DM				Chemical content in DM (g kg^{-1} DM)			In vitro
	Pre-grazing	Post-grazing	Pre – post grazing	grazing sward height	Barley	Grasses	Legumes	Weeds	Ash	CP	NDF	digestibility of organic matter
Fertilisation												
No compost	1584	1014	571	11.0	0.192	0.490	0.230	0.088	11.3	209	427	0.755
Compost	1863	1291	538	12.4	0.211	0.478	0.207	0.104	12.4	202	438	0.751
S.E.M.	30.7	29.1	39.7	0.256	0.006	0.011	0.008	0.005	0.109	2.32	2.62	0.002
Seed mixture												
Common vetch	1645^{a}	1109^{a}	519^{a}	11.1^{a}	0.187^{a}	0.550^{b}	0.153^{a}	0.110^{b}	11.5^{a}	193^{a}	444^{a}	0.756^{a}
Hairy vetch	1821^{b}	1221^{a}	593^{a}	12.1^{a}	0.183^{a}	0.440^{a}	0.300 c	0.077^{a}	12.2^{b}	229^{b}	434^{ab}	0.727^{b}
Persian clover	1758^{ab}	1105^{a}	611^{a}	11.7^{a}	0.204^{ab}	0.444^{a}	0.255^{b}	0.096^{ab}	11.9^{ab}	204^{a}	424^{b}	0.764^{a}
Persian and white clover	1670^{ab}	1142^{a}	512^{a}	11.7^{a}	0.231^{b}	0.502^{b}	0.165^{a}	0.102^{ab}	11.9^{ab}	195^{a}	430^{ab}	0.759^{a}
S.E.M.	43.4	41.2	56.9	0.362	0.009	0.015	0.011	0.007	0.154	3.28	3.70	0.003
Grazing period												
1	1442^{a}	1178^{b}	264^{a}	13.0^{a}	0.539^{d}	0.268^{a}	0.136^{a}	0.056^{a}	13.5^{c}	240^{c}	497^{a}	0.731^{a}
2	1993^{b}	1281^{b}	719 c	11.9^{ab}	0.343^{c}	0.361^{b}	0.197^{b}	0.099^{bc}	12.6^{b}	206^{b}	445^{b}	0.735^{a}
3	1986^{b}	1140^{ab}	846 c	11.7^{ab}	0.081^{b}	0.500^{c}	0.273^{c}	0.147^{d}	11.9^{b}	197^{ab}	422^{c}	0.743^{a}
4	1618^{a}	1194^{b}	425^{ab}	11.5^{ab}	0.044^{b}	0.591^{d}	0.258^{c}	0.106^{c}	11.0^{a}	196^{ab}	399^{d}	0.762^{b}
5	1577^{a}	977^{a}	600^{bc}	10.3^{b}	0.000^{a}	0.699^{e}	0.228^{bc}	0.072^{ab}	10.4^{a}	190^{a}	401^{d}	0.784^{c}
S.E.M.	48.6	44.5	60.6	0.391	0.010	0.017	0.013	0.008	1.60	3.66	4.14	0.004
Source of variation	*P* value											
FE	0.056	0.047*	0.727	0.025*	0.679	0.697	0.316	0.055	0.153	0.048*	0.122	0.179
SM	0.058	0.381*	0.598	0.578	0.185	0.045*	0.006**	0.404	0.075	< 0.001***	0.076	0.004**
GP	0.008**	0.057	0.001**	0.499	< 0.001***	< 0.001***	0.004**	< 0.001***	0.024*	0.001**	< 0.001***	0.017*
FE × SM	0.024*	0.402	0.077	0.795	0.430	0.595	0.326	0.906	0.260	0.769	0.881	0.991
FE × GP	0.991	0.013*	0.137	0.710	0.929	0.598	0.575	0.244	0.004**	0.916	0.745	0.915
SM × GP	< 0.001***	0.005**	0.319	0.104	0.186	0.071	< 0.001***	0.605	0.570	0.226	0.123	0.124
FE × SM × GP	0.081	0.105	0.806	0.499	0.740	0.547	0.074	0.815	0.406	0.533	0.798	0.983

$^{a-e}$Means within the same column and variable not sharing a common superscript letter are significantly different (Tukey, $P < 0.05$).
Statistical significance of treatments determined using split-split-plot ANOVA, *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$; S.E.M., Standard error of mean.

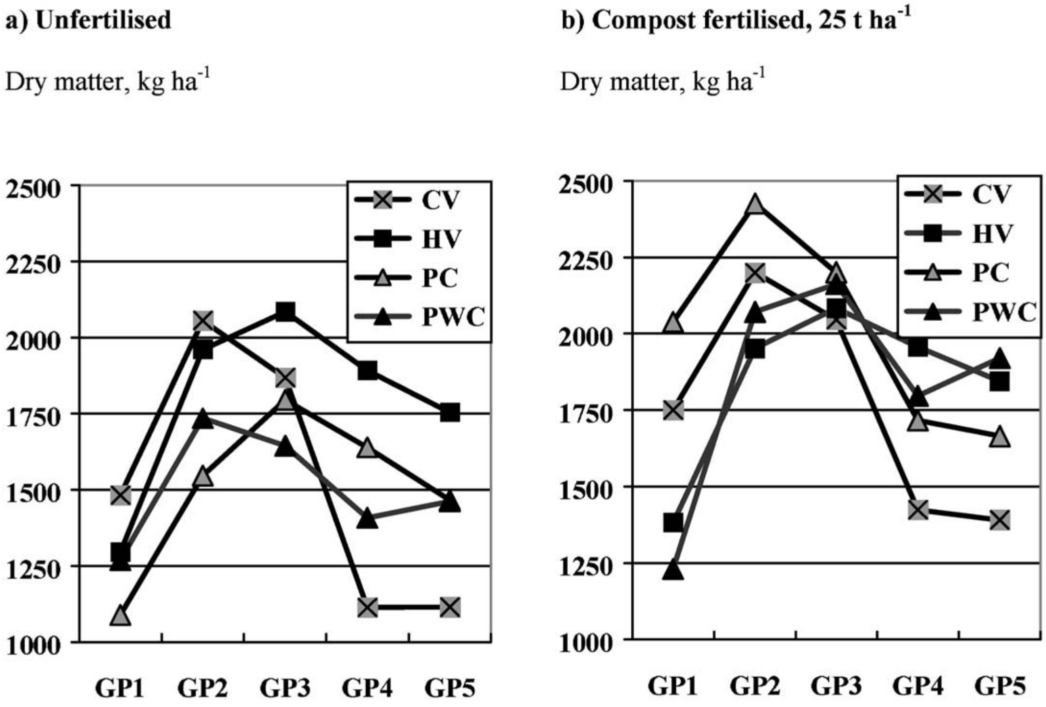

Fig. 1. Effect of fertilisation on pregrazing herbage mass in common vetch mixture (CV), hairy vetch mixture (HV), Persian clover mixture (PC) and Persian and white clover mixture (PWC) during five consecutive periods of grazing (GP1 – GP5) (Experiment 1).

portion of barley in the sward and reduced by the proportion of grass and legumes ($P<0.001$).

3.2. Experiment 2

Mean pregrazing HM of CM paddocks was 16% higher ($P<0.05$) than VM paddocks, while post-grazing SH was 15% higher ($P<0.05$) for CM than VM (Table 4). The average proportion of legumes was marginally higher ($P>0.05$) for CM than VM. Seed mixture had no effect ($P<0.05$) on the mean proportion of barley, grass and weeds. However, herbage from the clover based mixture had a higher ($P<0.05$) mean IVOMD, but similar ($P>0.05$) CP and NDF content compared with the vetch-based mixture.

By applying a flexible grazing cycle, the amount of pregrazing HM was relatively high, except at the beginning of the experiment (Fig. 4). Advances in grazing season altered the botanical composition of pregrazing HM (Fig. 5). As the experiment progressed the proportion of clovers increased from 0.060 to 0.675 and the proportion of vetches from 0.134 to 0.534. During the last experimental period cows grazing CM experienced temporary problems with bloating. Advances in the grazing season had no effects ($P>0.05$) on herbage CP or IVDOM of either mixture. In contrast, NDF concentrations in CM and the ash content in VM were affected ($P<0.05$, Table 5).

Mean HM sugar concentration was 57% higher ($P<0.001$) for CM than VM herbage, sampled during the main daily grazing h (0500–2100 h) of 20th June and 23rd August (Table 4). On average, herbage mass sugar concentration was lowest after morning milking (0900 h 78.9 g kg DM^{-1}), but increased during the day and remained higher after afternoon milking (1700–2100 h 120 g kg DM^{-1}) compared with morning milking.

Milk production and composition was similar ($P>0.05$) for cows grazing clover and vetch based mixtures, with the exception that urea concentrations were higher ($P<0.001$) in milk produced from vetch-based mixture (Table 6). Concentrate feeding

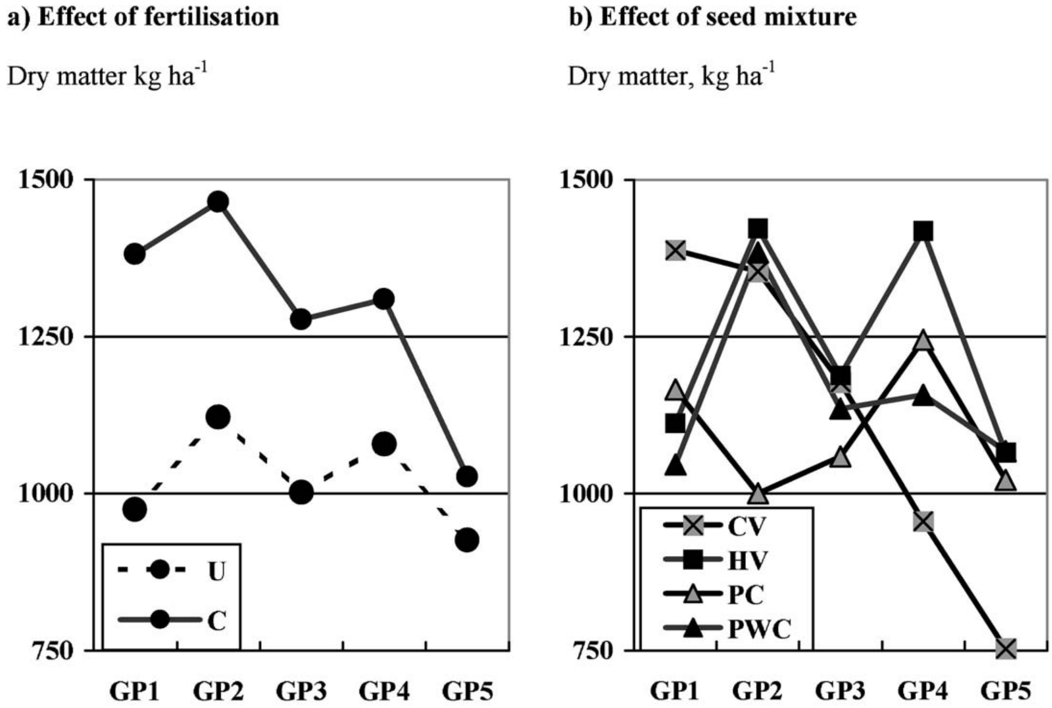

Fig. 2. Effect of fertilisation (unfertilised (U), 25 t ha^{-1} farmyard manure compost (C)) and seed mixture (common vetch mixture (CV), hairy vetch mixture (HV), Persian clover mixture (PC), Persian and white clover (PWC)) on postgrazing herbage mass during 5 consecutive periods of grazing (GP1–GP5) (Experiment 1).

regimen had no effect ($P > 0.05$) on milk yield or composition.

4. Discussion

4.1. Herbage production

Annual leguminous mixtures have typically been advocated for green manuring (Poutala and Hannukkala, 1995; Abdin et al., 1998), and therefore data concerning the potential for grazing is limited (Abd Et Moneim et al., 1990; Assefa and Ledin, 2001). In rotational grazing of perennial pastures, HA, nutritive characteristics, species composition, sward structure, the proportion of green and dead material, in addition to the amount of pregrazing HM are important determinants. In experiment 1, positive correlations between pre-post grazing HM and pregrazing HM suggests that low HM can limit herbage intake from annual mixtures, as is the case for conventional grass swards (Peyraud et al., 1996; Wales et al., 1998; Parga et al., 2000). This relationship was stronger with unfertilised (lower pregrazing HM) than fertilised areas (higher pregrazing HM), where the preference appeared to be more influenced by other factors.

Positive linear effects of N fertilisation on HM production of grass swards, and the reduction in the proportion of clovers in mixed swards is well established (Holmes, 1968; Leaver, 1985). Application of nitrogen fertiliser also decreased the proportion of vetch in vetch and oat (*Avena sativa* L.) mixtures (Assefa and Ledin, 2001). In this study, fertilisation through the application of compost clearly increased pregrazing HM, but had no effect on botanical composition, indicating that slow release of nitrogen from compost has only minor effects on inter-species competition. However, associated increases in HM were not realised as improvements in HM intake (pre – post grazing HM), that may reflect imposed management strategy, animal selection, or both.

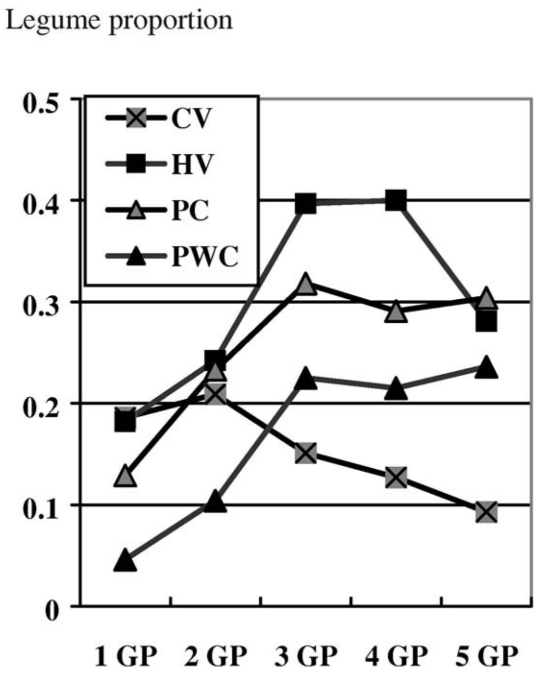

Fig. 3. Legume proportions of pregrazing herbage mass in common vetch mixture (CV), hairy vetch mixture (HV), Persian clover mixture (PC) and Persian and white clover (PWC) during 5 consecutive periods of grazing (GP1–GP5) (Experiment 1).

The adverse effects of cattle excreta on pasture have long been recognised. Marten and Donker (1964) showed that this rejection is a response to the offensive properties, odour or some other factors, associated directly with animal manures and not due to inherent forage properties. Both the odour of fresh faeces and decomposition products will result in herbage rejection that can persist for several months (Wilkins and Garwood, 1986). As a secondary effect of faecal fouling, the nutritive value of rejected pasture decreases due to advances in maturation. The adverse effect of faeces has also been recognised with manure fertilisation. For example, Laws et al. (1996) reported that cattle will select clean rather than slurry fertilised herbage and express a preference for herbage fertilised by soil injection than surface-spread manure applications. Animal selection based on olfactory examination became more prevalent as the animals grazed down through the sward, when switching to alternative swards and towards the end of meals. In agreement with Laws et al. (1996) current postgrazing HM and SH of compost fertilised areas was higher than corresponding unfertilised areas. The reduction can be attributed to off-odours even though the soil was harrowed after compost spreading. Differences in herbage chemical composition were minor. It appears that the reduction in postgrazing HM between fertilisation treatments with advances in growing season in this experiment can be explained as a gradual reduction in compost smell and animal adaptation to fertilised herbage (Laws et al., 1996).

The choice of legume in seed mixtures influenced the average amount of available pregrazing HM and legume persistence during the grazing season. Hairy vetch was more suitable than common vetch, based on a 11% improvement in mean pregrazing HM (Experiment1). This is consistent with findings that the maximum DM yield of hairy vetch *Varia Dasycarpa* was attained at an earlier state of maturity relative to common vetch (Abd Et Moneim et al., 1990). In experiment 2, the clover based mixture had higher (16%) pregrazing HM than the vetch-based mixture, which contained both the low yielding common vetch and more productive hairy vetch. One argument for using annual pastures, which cannot fully utilise favourable growing conditions in early summer, is to extend the grazing season in autumn. Current results suggest that annual legume–grass–cereal mix-

Table 3
Spearman rank correlation coefficients between herbage chemical composition and botanical proportions (Experiment 1)

	Barley	Grasses	Legumes	Weeds
In vitro digestibility of organic matter	– 0.548***	0.570***	– 0.050	0.044
Crude protein content (g kg^{-1} DM)	0.431***	– 0.556***	0.211*	– 0.445***
Neutral detergent fibre content (g kg^{-1} DM)	0.747***	– 0.602***	– 0.397***	– 0.102

Statistical significance: *, $P<0.05$; **, $P<0.01$; ***, $P<0.001$.

Table 4
Effect of seed mixture on pregrazing herbage mass, postgrazing sward height and botanical and chemical composition of pregrazing herbage mass (Experiment 2)

Variable	Seed mixture		n	S.E.M.	Significance
	Clover	Vetch			
Pregrazing herbage mass (kg DM ha^{-1})	1990	1717	22	101.3	0.014*
Postgrazing sward height (cm)	11.8	10.3	22	0.581	0.016*
Proportion of species in DM					
Barley	0.266	0.206	9	0.051	0.275
Italian rye grass	0.243	0.317	9	0.051	0.185
Weeds	0.093	0.133	9	0.028	0.184
Legumes	0.399	0.434	9	0.059	0.370
Chemical content in DM (g kg^{-1} DM)					
Ash	11.6	12.0	12	0.52	0.541
Crude protein	212	223	12	8.07	0.219
Neutral detergent fibre	381	401	12	14.7	0.191
In vitro digestibility of organic matter	0.778	0.742	12	0.08	0.001**
Sugar concentration in DM (g kg^{-1} DM)	136	86.4	18	9.37	< 0.001***

n, Number of samples. Samples for herbage mass estimation were taken in 3–4 days intervals. Samples for chemical content determination were pooled weekly. Samples for botanical analysis were taken at start, middle and end state of experiment. Sugar concentration samples were taken on 20th June and 23rd August. Statistical significance between treatments determined using paired sample t-test, *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$; S.E.M., Standard error of mean.

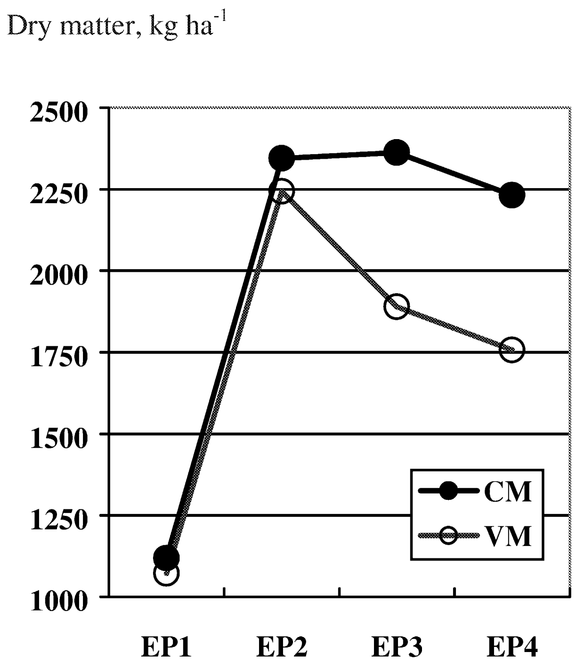

Fig. 4. Pregrazing herbage mass of clover (CM) and vetch based mixture (VM) during four consecutive experimental periods (EP1–EP4) (Experiment 2).

tures, with the exception of CV mixtures, can support grazing in the autumn.

4.2. Botanical and chemical composition

Nutritive value of herbage and HA determine the intake and nutrient supply in grazing cows (Leaver, 1985; Mayne et al., 1999). For any given grazing system, pasture species, application of fertilisers, growing conditions, stage of maturity and stocking rate all affect nutritive value of herbage (Leaver, 1985; Delagarde et al., 1997; Wales et al., 1998). On average, CP, NDF and IVOMD content of annual pastures were relatively high. Seasonal changes in these parameters were related to changes in botanical composition, but these effects had only a minor influence on overall nutritive value. Herbage botanical composition was markedly different between experiments. It is likely that variations in the onset of grazing, grazing cycle, occupation, grazing pressure and legume composition, contributed to between-experiment differences. Fertilisation had no effect on botanical composition, but resulted in a marginal decrease in herbage CP content. Fertiliser application decreased the CP content of oat–vetch mixtures, that unlike the current study, was associated with a de-

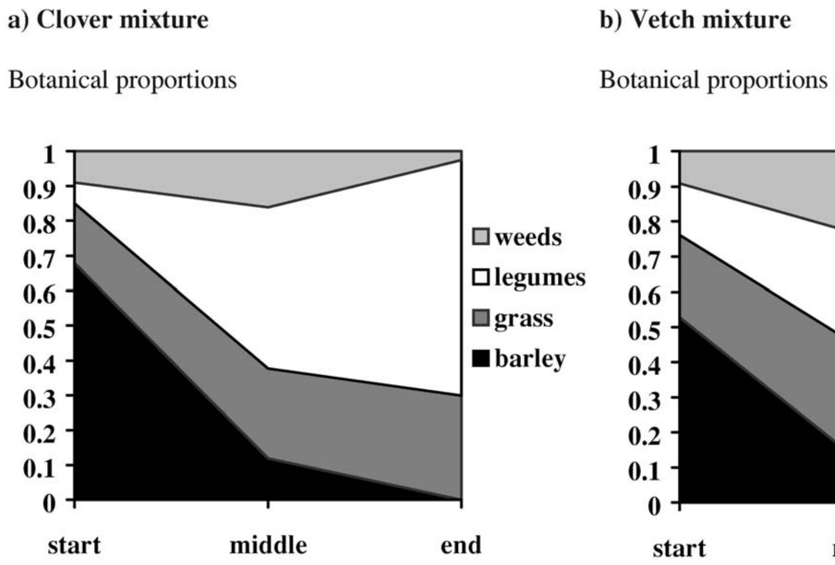

Fig. 5. Pregrazing botanical proportions of clover and vetch based mixtures at three stages during experiment 2.

crease in the proportion of legumes in the sward (Assefa and Ledin, 2001).

A high CP content of herbage is indicative of substantial biological N fixation, partly realised as higher herbage production, partly as improved sward N status and finally as improved soil fertility. For dairy cows, high herbage CP concentrations are undesirable due to the poor utilisation of dietary N for milk production (Tamminga, 1992). Mixtures containing hairy vetch had higher CP contents and lower digestibility than other mixtures, a finding that held true for both experiments. Current results are in line with Assefa and Ledin (2001), reporting that herbage harvested from pure hairy vetch at the 20% flowering stage of maturity contained relatively high amounts of CP (243 g kg^{-1}DM) but were of moderate IVOMD (0.655).

For low input systems, the beneficial effects of legumes on animal nutrition and soil fertility and associated effects on the incidence of bloat are well

Table 5
Ash, crude protein (CP) and neutral detergent fibre (NDF) content and in vitro digestibility of organic matter (IVDOM) of pregrazing herbage mass during feeding periods (Experiment 2)

	Content (g kg^{-1} DM)							
	Clover mixture				Vetch mixture			
	Ash	CP	NDF	IVDOM	Ash	CP	NDF	IVDOM
Experimental periods								
Weeks 1–3	11.5[a]	220[a]	452[a]	0.776[a]	14.1[a]	251[a]	418[a]	0.778[a]
Weeks 4–6	11.8[a]	196[a]	403[ab]	0.762[a]	10.9[b]	199[a]	416[a]	0.730[a]
Weeks 7–9	11.6[a]	226[a]	327[b]	0.791[a]	11.2[b]	219[a]	381[a]	0.737[a]
Weeks 10–12	11.4[a]	201[a]	343[ab]	0.785[a]	11.8[ab]	222[a]	376[a]	0.739[a]
S.E.M.	0.324	8.27	12.2	0.007	0.307	7.79	8.00	0.006
P value	0.974	0.531	0.027*	0.559	0.023*	0.238	0.188	0.096

Means within the same column not sharing a common superscript letter are significantly different (Tukey, $P<0.05$).
Statistical significance of treatments determined using one-way ANOVA, *, $P<0.05$; **, $P<0.01$; ***, $P<0.001$; S.E.M., Standard error of mean.

Table 6
Effect of pasture seed mixture and concentrate feeding regimen (4 kg day^{-1} at morning milking (Once), 2 kg day^{-1} at morning and 2 kg day^{-1} at afternoon milking (Twice)) on milk production (Experiment 2)

	Clover mixture		Vetch mixture		S.E.M.	Significance of effect	
	Twice	Once	Twice	Once		Mixture	Concentrate
Yield							
Milk (kg day^{-1})	21.8	22.0	22.0	20.6	0.61	Ns	Ns
Fat (g day^{-1})	892	892	907	859	29.3	Ns	Ns
Protein (g day^{-1})	733	735	739	682	22.5	Ns	Ns
Lactose (g day^{-1})	1029	1045	1040	975	31.0	Ns	Ns
Composition							
Fat (g kg^{-1})	40.9	40.5	41.2	41.9	0.87	Ns	Ns
Protein (g kg^{-1})	34.2	33.4	33.8	33.3	0.44	Ns	Ns
Lactose (g kg^{-1})	46.9	47.5	47.3	47.3	0.31	Ns	Ns
Urea (mg kg^{-1})	321	317	406	380	18.8	***	Ns

Number of observations per each treatment was eight. Statistical significance of treatments. *, $P<0.05$; **, $P<0.01$; ***, $P<0.001$; S.E.M., Standard error of mean.

documented (Leaver, 1985; Assefa and Ledin, 2001). Cows grazing CM experienced temporary bloat problems during the last grazing period, as a result of increases in sward legume content. Relatively few legumes such as birdsfoot trefoil (*Lotus corniculatus)* are thought to be nonbloating, but clovers and vetches are known to cause bloat (Piper et al., 1923; Duke, 1981; Majak et al., 1995). Birdsfoot trefoil has relative high levels of condensed tannins, which are thought to prevent bloat through decreases in ruminal protein degradation (Tamminga and Suderkum, 2000). General recommendations of preventing grazing on legume rich pastures are difficult to adhere to under organic conditions. Majak et al. (1995) suggested that bloat associated with lucerne (*Medicago sativa* L.) could be reduced by grazing more mature swards, transferring cattle onto a new pasture in the afternoon, through continuous grazing and use of bloat preventing agents. In essence, grazing systems that promote continuous and rapid ruminal clearance of digesta, are most likely to reduce the incidence of bloat. Balanced animal nutrition is targeted, but preemptive medications are not permitted within organic production systems (EU 1804/1999; CEC, 1999). In this study, grazing management and concentrate feeding was similar for both seed mixtures, and therefore the incidence of bloating is most likely to be explained by differences in the proportion of legumes in the sward and inherent differences in digestibility (Hall et al., 1994).

4.3. Milk production

Within organic milk production systems, cows generally graze perennial pastures supplemented with concentrates (Khalili et al., 2002; Kuusela and Khalili, 2002). The present study showed that annual pastures have potential in organic farming systems. A lack of difference in the yield of milk or milk constituents indicates that both vetch and clover mixtures can be used. It appears that total nutrient intakes were similar between clover and vetch based mixtures and that HA was near optimal for both. Mean milk urea concentrations (319 mg kg^{-1}) of cows grazing the clover mixture, suggests that the supply of protein and energy was less imbalanced for clover than vetch (393 mg kg^{-1}) that is most convincingly explained as a consequence of a higher digestibility and lower CP content. Concentrations of urea in milk from vetch based swards are comparable to levels present in milk produced from conventional grass swards (Khalili and Sairanen, 2000).

Postgrazing SH is a practical management tool for perennial swards (Le Du et al., 1979). Low postgrazing SH indicative of overgrazing will decrease animal performance and protract sward regrowths. High postgrazing SH due to undergrazing decrease pasture utilisation and reduce nutritive value of herbage, if swards are not appropriately mananged. Targeting postgrazing SH is depending on species, fertilisation, sward structure and grazing system (Le Du et al., 1979; Parga et al., 2000; Kuusela and Khalili, 2002). Relatively high postgrazing SH targets implemented in the current study appeared to be suitable for annual cereal–grass–legume mixtures, containing atypical pasture species. Despite similar HA and milk yield, postgrazing SH was lower for VM than CM, when HA was maintained through HM based adjustments of allocated grazing areas. This suggests that cows compensated for the reduced digestibility and lower sugar content of vetch through higher intakes. Differences in pregrazing HM and variations in sward structure may also have contributed to the difference in postgrazing SH between seed mixtures (Parga et al., 2000).

In the present study concentrate feeding regimen had no effect on milk production consistent with previous studies (Johnson, 1979; Dhiman et al., 2002). Gibson (1984) on the basis of 35 experiments concluded that the effect of frequency of feeding had only minor beneficial effects on milk yield (proportionate increases of 0.027) and that cows producing milk with commercially acceptable fat concentrations were also unlikely to benefit from increases in feeding frequency. In some cases increases in feeding frequency can improve intake. At higher levels of concentrate supplementation, more frequent feeding can facilitate higher levels of intake without decreasing rumen pH (Kaufmann, 1976). Since milk production was not affected, reducing the frequency of feeding moderate levels of concentrate could afford decreases in labour costs and simplify management practices. Concentrate supplementation of grazing cows should also consider related to increases in herbage sugar content during the day. Simpson et al. (2000) proposed that feeding concentrates as a single meal in the morning would permit higher herbage intakes as a result of increases in sugar content, a suggestion not supported by current data.

5. Conclusions

Mean productivity and chemical composition of annual pastures was relatively good. Changes in measured chemical parameters during the grazing season were minor compared with changes in botanical composition. Even though annuals are unable to capitalise on favourable growing conditions during early summer, this is compensated for by autumnal growth. Application of compost fertilisation increased pregrazing herbage mass, but not herbage utilisation, when animals were able to select. Annual legumes are not equally suited for grazing. The potential of common vetch mixture was compromised by regular cutting, while hairy vetch mixture was best suited for extended grazing. Milk production was similar with clover and vetch based mixtures. Production of herbage mass was higher for clover than vetch based mixtures, but the high proportion of clover at the end of grazing season was associated an increased incidence of bloat. Moderate levels of concentrate can be offered once daily.

Acknowledgements

The Finnish Ministry of Agriculture and Forestry are acknowledged for financial support of the ‘Key elements to develop ecological grassland farming’ research programme and also the Finnish Cultural Foundation for support of this study. The authors wish to thank the staff of the Siikasalmi research farm at the University of Joensuu and the staff of Animal Production Research at MTT Agrifood Research Centre.

References

Assefa, G., Ledin, I., 2001. Effect of variety, soil type and fertiliser on the establishment, growth, forage yield, quality and voluntary intake by cattle of oats and vetches cultivated in pure stands and mixtures. Anim. Feed Sci. Technol. 92, 95–111.

Abd Et Moneim, A.M., Khair, M.A., Cocks, P.S., 1990. Growth analysis, herbage and seed yield of certain forage legume species under rainfed conditions. J. Agron. Crop Sci. 164, 34–41.

Abdin, O., Coulman, B.E., Cloutier, D., Faris, M.A., Zhou, X., Smith, D.L., 1998. Yield and yield components of corn interseeded with cover crops. Agron. J. 90, 63–68.

Bircham, J.S., 1981. Herbage growth and utilisation under continuous management. Ph.D. Thesis, University of Edinburgh, UK.

CEC, 1999. Council regulation No 1804/1999 supplementing regulation No 2092/91on organic production. Official journal of the European Communities L222, 1–28.

Delagarde, R., Peyraud, J.L., Delaby, L., 1997. The effect of nitrogen fertilisation level and protein supplementation on herbage intake, feeding behaviour and digestion in grazing dairy cows. Anim. Feed Sci. Technol. 66, 165–180.

Dhiman, T.R., Zaman, M.S., MacQueen, I.S., Boman, R.L., 2002. Influence of corn processing and frequency of feeding on cow performance. J. Dairy Sci. 85, 217–226.

Duke, J.A., 1981. Handbook of Legumes of World Economic Importance. Plenum Press, New York and London.

Frame, J., 1981. Herbage mass. In: Hodgson, J., Baker, R.D., Davies, A., Laidlaw, A.S., Leaver, J.D. (Eds.), Sward Measurement Handbook. British Grassland Society, pp. 39–70.

Friedel, K., Poppe, S., 1990. Ein modifiziertes Zellulase-Verfahren als Methode zur Schätzung der Verdaulichkeit von Grobfutter. G-4-Bericht, Wilhelm-Pieck Universität Rostock, WB Tjereährung.

Gibson, J.P., 1984. The effects of frequency of feeding on milk production of dairy cattle: an analysis of published results. Anim. Prod. 38, 181–189.

Hall, J.W., Majak, W., Stout, D.G., Cheng, K.-J., Goplen, B.P., Howart, R.E., 1994. Bloat in cattle fed alfalfa selected for a low initial rate of digestion. Can. J. Anim. Sci. 74, 451–456.

Holmes, J., 1968. The use of nitrogen in the management of pastures for cattle. Herb. Abstr. 38, 265–277.

Johnson, C.L., 1979. The effect of level and frequency of concentrate feeding on the performance of dairy cows of different yield potential. J. Agric. Sci. Camb. 92, 743–751.

Kaufmann, W., 1976. Influence of the composition of the ration and the feeding frequency on pH-regulation in the rumen and on feed intake in ruminants. Lives. Prod. Sci. 3, 103–114.

Khalili, H., Sairanen, A., 2000. Effect of concentrate type on rumen fermentation and milk production of cows at pasture. Anim. Feed Sci. Technol. 84, 199–212.

Khalili, H., Kuusela, E., Suvitie, M., Huhtanen, P., 2002. Effect of protein and energy supplements on organic milk production. Anim. Feed Sci. Technol. 98, 103–119.

Kuusela, E., Khalili, H., 2002. Effect of grazing method and herbage allowance on the grazing efficiency of milk production in organic farming. Anim. Feed Sci. Technol. 98, 87–101.

Laws, J.A., Rook, A.J., Pain, B.F., 1996. Diet selection by cattle offered a choice between swards treated or untreated with slurry: effects of application method and time since application. Appl. Anim. Behav. Sci. 48, 131–142.

Leaver, J.D., 1985. Milk production from grazed temperature grassland. J. Dairy Res. 52, 313–344.

Littell, R.C., Freund, R.J., Spector, P.C., 1992. SAS system for linear models. In: 3rd Edition. SAS Series in Statistical Applications, p. 329.

Le Du, Y.L.P., Combellas, J., Hodgson, J., Baker, R.D., 1979. Herbage intake and milk production by grazing dairy cows. Part 2. The effect of winter feeding and daily herbage allowance. Grass Forage Sci. 34, 249–260.

Majak, W., Hall, J.W., McGaughey, W.P., 1995. Pasture management strategies for reducing the risk of legume bloat in cattle. J. Animal Sci. 73, 1493–1498.

Marten, G.C., Donker, J.D., 1964. Animal excrement as a factor influencing acceptability of grazed forage. In: Proceedings of 10th international Grassland Congress. Helsinki, pp. 359–361.

Mayne, C.S., Wright, I.A., Fisher, G.E.J., 1999. Grassland management under grazing and animal response. In: Hopkins, A. (Ed.), Grass Its Production and Utilization. Blackwell Science.

McCullough, H., 1967. The determination of ammonia in whole blood by a direct colorimetric method. Clin. Chem. Acta 17, 297–304.

Nissinen, O., 1992. The suitability of green forage plants for grazing in northern finland. In: Proceedings of 14th General Meeting of the European Grassland Federation. Lahti, Finland, pp. 329–331.

Nissinen, O., Hakkola, H., 1998. Herbage production of annual ryegrass in northern Finland. In: Proceedings of 17th General Meeting of the European Grassland Federation. Debrecen, Hungary May 18–21, pp. 803–805.

Parga, J., Peyraud J.L Delagarde, R., 2000. Effects of sward structure and herbage allowance on herbage intake and digestion by strip-grazing dairy cows. In: Rook, A.J., Penning, P.D. (Eds.), Grazing management. British Grassland Society Occasional Symposium, No. 34, pp. 61–66.

Peyraud, J.L., Comeron, E.A., Wade, M.H., Lemaire, G., 1996. The effect of daily herbage allowance, herbage mass and animal factors upon herbage intake by grazing dairy cows. Ann. Zootech. 45, 201–217.

Piper, C.V., McKee, R., Hillman, F.H., 1923. Vetches. In: Farmers Bulletin. No. 515. American Botanist and New Farm Magazine. US Department of Agriculture, Washington, DC.

Poutala, R.T., Hannukkala, A., 1995. The effect of the method of incorporation of *Trifolium resupinatum* L. and *Vicia villosa* Roth residues in the soil on the performance of succeeding cereal crop. Acta Agric. Scand. Sect. B, Soil Plant Sci. 45, 251–257.

Simpson, R.J., Dove, H., Luery, B.J., Sims, I.M., 2000. Diurnal changes in the concentration of water soluble carbohydrates in *Phalaris aquatica* L. pasture in spring, and the effect of short term shading. Aust. J. Agric. Res. 51, 749–756.

Somogyi, M., 1945. A new reagent for determination of sugars. J. Biol. Chem. 160, 61–68.

Tamminga, S., 1992. Nutrition management of dairy cows as a contribution to pollution control. J. Dairy Sci. 75, 345–357.

Tamminga, S., Suderkum, K.-H., 2000. Optimise feeding value of forage protein. In: Proceedings of 18th General Meeting of the European Grassland Federation. Aalborg, Denmark, May 22–25, pp. 143–156.

Tuori, M., Kaustell, K., Valaja, J., Aimonen, E., Saarisalo, E., Huhtanen P., 1996. Rehutaulukot ja ruokintasuositukset (Feed tables and feeding recommendations), 2nd Edition. Helsinki.

Van Soest, P.J., Robertson, J.B., Lewis, B.A., 1991. Methods for dietary fiber, neutral detergent fiber and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74, 3583–3597.

Wales, W.J., Doyle, P.T., Dellow, D.W., 1998. Dry matter intake and nutrient selection by lactating cows grazing irrigated pastures at different pasture allowances in summer and autumn. Aust. J. Exp. Agric. 38, 451–460.

Weller, R.F., Cooper, A., 2001. Seasonal changes in the crude protein concentration of mixed swards of white clover/perennial ryegrass grown without fertilizer N in an organic farming system in the United Kingdom. Grass Forage Sci. 56, 92–95.

Wilkins, R.J., Garwood, E.A., 1986. Effects of treading, poaching and fouling on grassland production and utilisation. In: Frame, J. (Ed.), Proceedings of grazing conference, Malvern, Worcestershire, November 5–57, 1985, pp. 19–31.