Applied Animal Behaviour Science 117 (2009) 137–143

Contents lists available at ScienceDirect

Applied Animal Behaviour Science

journal homepage: www.elsevier.com/locate/applanim

Behavioural patterns of heifers under intensive and extensive continuous grazing on species-rich pasture in the Czech Republic

Pavla Hejcmanová [a,*], Michaela Stejskalová [a], Vilém Pavlů [b,c], Michal Hejcman [b,c]

[a] Institute of Tropics and Subtropics, Czech University of Life Sciences, Kamýcká 129, Prague 6 - Suchdol 165 21, Czech Republic
[b] Crop Research Institute, Prague-Ruzyně, Department of Plant Ecology and Weed Science, Grassland Research Station Liberec, Rolnická 6, 460 01 Liberec, Czech Republic
[c] Department of Ecology, Czech University of Life Sciences, Kamýcká 1176, Prague 6 - Suchdol 165 21, Czech Republic

ARTICLE INFO

Article history:
Accepted 19 January 2009
Available online 13 February 2009

Keywords:
Stocking rate
Ingestive behaviour
Semi-natural grassland
Cattle
Forage availability

ABSTRACT

This study examines the effects of season and of two grazing intensities, namely extensive grazing (EG) and intensive grazing (IG), on the grazing behaviour of heifers on species-rich upland pasture in the Czech Republic. Ten or eight (IG), and six or four (EG) heifers were continuously stocked in two completely randomized blocks from June to late September in 1998, 1999, 2000, 2006 and 2007. Swards were maintained at a target height of 5 and 10 cm, respectively. Grazing, ruminating, resting, and other activities were monitored during 24 h observations, and grazing, chewing and ruminating rates (per minute) were recorded. Daily behavioural patterns and the time budgets for particular activities were not significantly different between IG and EG heifers. However, IG heifers did spend more time grazing and slightly less time ruminating and resting than EG heifers. Other activity such as drinking, salt licking, comfort behaviour or social interaction was stable and there was no difference between the two treatments. Grazing rates were found significantly higher for IG heifers. Grazing was negatively affected by increase in air temperature at the expense of resting. Grazing time increased as the season progressed in the both IG and EG treatments, while resting showed a reverse trend. Concurrently, the ruminating time of IG heifers decreased and was variable for EG heifers. As the season progressed further, grazing rates then showed a decreasing trend. Considering that the differences in behavioural patterns between IG and EG were not conspicuous, our results indicate that the target sward of 5 cm commonly used in animal husbandry practices in the Czech Republic does offer enough forage to animals. Furthermore, the seasonal patterns of ingestive behaviour showed that the heifers under both grazing intensities balanced their intake by increase of grazing time along with decrease of grazing rates as the season progressed. These findings suggest that the herbage on species-rich pasture was sufficiently available to livestock at both the investigated grazing intensities.

1. Introduction

A key aim of animal husbandry is to optimize the livestock production systems and grassland management (Rook et al., 2004; Tallowin et al., 2005; Pavlů et al., 2007). The ingestive behaviour on which production closely depends has consistently remained at the centre of grassland management interest. Forage intake is determined as the function of bite size, biting rate and total grazing time (Allden and Whittaker, 1970; Hodgson, 1985; Forbes, 1988).

Cattle have a distinct diurnal grazing pattern with a grazing time which ranges from 6 h to nearly 13 h a day

* Corresponding author. Tel.: +420 22438 2509; fax: +420 23438 1829.
E-mail address: hejcmanova@its.czu.cz (P. Hejcmanová).

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doi:10.1016/j.applanim.2009.01.003

(Krysl and Hess, 1993). Fatigue limit was assumed to be 12 h (Stobbs, 1975). Total daily grazing time tends to be relatively stable in order to meet animals' nutritional requirements at the circadian level (Linnane et al., 2001). Grazing time can, however, be constrained by availability of time for grazing imposed by the management system or stocking rate. For instance, animals facing limited time for grazing may adapt by seeking forage of a higher quality (Ginane and Petit, 2005). Under moderate grazing pressure the total grazing time was longer than under lower pressure (Huber et al., 1995), while a heavy stocking rate reduced grazing time (Hepworth et al., 1991) because of time spent searching. Grazing intensity, as one of components determining availability of forage of particular quality, affects the trade-off animals make between forage quantity and quality (Wallis de Vries and Daleboudt, 1994; Newman et al., 1995). In fact, cattle retain their preference for more abundant forage regardless of its quality and compensate for fluctuations of forage accessibility by matching grazing time and biting rate. However, when accessibility of forage decreases under a certain limit, animals switch their dietary choice to better quality forage (Ginane et al., 2003). This behavioural adaptation is valid throughout the grazing season; animals increase their grazing time and biting rate in response to the changing parameters of the sward (e.g. Funston et al., 1991; Realini et al., 1999).

Time for grazing is limited by the performing of other, mutually exclusive, activities. The second most important activity after grazing in ruminants is chewing the cud (Arnold and Dudzinski, 1978; Realini et al., 1999). Ruminating time and ruminating rate vary according to the diet. Cattle ruminate for longer as fibre content increases in the forage and for less time with decreasing forage particle size (Albright, 1993).

Understanding livestock behaviour in relation to varying environmental conditions and forage dynamics is paramount in designing management strategies for livestock production (Demment et al., 1986). Management systems for livestock on pasture have increasingly become an important domain of livestock production as well as a tool for biodiversity conservation over the last decades (Watkinson and Ormerod, 2001). Therefore, we aim to evaluate heifers' behavioural pattern on species-rich semi-natural pasture under a continuous grazing regime as this is currently the most extensive management system employed in Central Europe (Isselstein et al., 2005).

Our objective was to investigate how heifers cope with various grazing intensities and the ongoing seasons in terms of grazing time and rate of biting. Specific questions addressed were: (1) is there any effect of grazing intensity on the daily activity pattern of heifers? (2) Is there any effect of grazing intensity on the biting rate of heifers? and (3) Is there any effect of grazing season on heifers' grazing behaviour?

2. Material and methods

The study was performed on an experimental upland pasture in the Jizerské Mountains (50° 49′N, 15°02′E. The altitude is 420 m.a.s.l., annual rainfall 803 mm, mean annual temperature 7.2 °C) The land belongs to the Crop Research Institute, Prague, the Czech Republic. The experiment was conducted for 5 years (1998, 1999, 2000, 2006, and 2007).

2.1. Design of the experiment and animals studied

The experiment was arranged in two treatments composed of two completely randomized blocks consisting of two paddocks of intensive grazing (IG1, IG2) and two paddocks of extensive grazing (EG1, EG2). Each grazed paddock was approximately 0.35 ha. The pasture was continuously stocked with growing heifers (1998, 2006—Czech Simmental × Charolais, 1999, 2000, and 2007—Holstein) of 150–220 kg in initial live weight. The animals were of the same age and came from the same breeding conditions. In 1998, 1999 and 2000, IG and EG paddocks were grazed by five and three heifers each, respectively, while in 2006 and 2007 they were grazed by four and two heifers each, respectively. The grazing season lasted from early May to the end of October. The stocking density during the grazing season in both of the groups was adapted to a target sward height of 5 cm (IG) or 10 cm (EG), respectively. This was maintained by manipulating areas of the respective paddocks according to biomass growth rate. Sward height was measured weekly using the first contact method (modified point quadrat method) between 1998 and 2000, and by the rising plate meter method between 2006 and 2007 (Pavlů et al., 2007). The mean sward heights were 5.10 ± 0.11 cm and 9.62 ± 0.23 cm (mean ± S.E.) for IG and EG treatments, respectively. Predominant species in the sward were *Aegopodium podagraria* L., *Agrostis capillaris* L., *Alopecurus pratensis* L., *Festuca rubra agg.* L., *Galium album* Mill., *Trifolium repens* L., and *Taraxacum* spp. Wigg. The mean forage yields were 3.57 (±S.E. 0.20) t ha^{-1} and 2.81 (±S.E. 0.17) t ha^{-1} under IG and EG, respectively. Total crude protein content and forage digestibility were both higher under IG, and the content of crude fibre consequently showed a reverse effect. Sward quality parameters showed seasonal changes, namely decrease of biomass growth rate and increase in crude fibre content as the season progressed (Pavlů et al., 2006).

2.2. Animal behaviour and bite rate recording

Behavioural pattern data were collected between June and September once a month at a regular interval for each year. Principal activities were recorded by scan-sampling each heifer at 15-min intervals from 06.00 h to 21.00 h and at 1-h intervals during the night (between 21.00 h and 06.00 h), all together making up 24 h of observation. The principle activities of heifers on pasture included grazing, ruminating, resting as well as other behaviour. Grazing was defined as biting, chewing or swallowing herbage, or walking with the muzzle close to the sward. Ruminating was defined as chewing the cud, resting as lying or standing without any activity and 'other behaviour' included activities such as drinking, salt licking, comfort behaviour and social interaction, etc. Actual weather conditions, air temperature and other circumstances (if any) were recorded at 1-h interval.

Table 1
Mean behaviour patterns of heifers expressed as percentage of the observation time per 24 h (in %) in the study years.

Month	Behavioural pattern							
	Percentage of observation time (in %)							
	Intensive grazing				Extensive grazing			
	Grazing	Ruminating	Resting	Other	Grazing	Ruminating	Resting	Other
June	49	22	26	3	50	18	30	2
July	49	20	28	3	47	22	28	3
August	58	18	22	2	53	23	23	1
September	61	18	19	2	58	18	21	3
Average	54	19.5	24	2.5	52	20	25	3

The biting rate was investigated by comparison of forage ingestion by heifers from both of the two grazing intensities (IG, EG). We recorded three types of bite: grazing, chewing, and ruminating. Grazing was defined as a wrenching of the vegetation sward, chewing as biting and grinding of forage in the muzzle (for better swallowing) and rumination as chewing the cud. All these type of bites were recorded in the form of biting rate (number of bites per minute). We made ten records for each type of biting behaviour (grazing, chewing, and rumination) in each paddock.

2.3. Statistical analyses

All of the data were analyzed using the STATISTICA 8.0 package (StatSoft, 1995).

We used General Linear Model (GLM) procedures for repeated (within-subject) measures. The behavioural variables were time spent grazing, ruminating, resting, and other behaviour as a percentage of the observed 24-h cycle. All these variables showed normal distribution (all tested by Kolmogorov–Smirnov test had $P > 0.2$). We tested the effects and interactions of the treatment (IG/EG) (categorical predictor) and year, month and temperature (continuous variables) on behavioural variables. For statistical analyses of intensity of biting (grazing, chewing, and ruminating rates), the same General Linear Models procedures were carried out for categorical predictor treatment (IG/EG) and continuous variables for year, month, and sward height. We performed linear regressions to reveal relations between temperature and grazing time and relations between sward height and grazing rate.

3. Results

3.1. General activity pattern

The time budget for particular activities of heifers during the 24-h cycle was not different between IG and EG treatments (Table 1). Results revealed that the grazing intensity had no significant effect on any activity (Table 2). However, heifers on intensively grazed pasture spent generally more time grazing than heifers on extensively grazed pasture (Fig. 1a). In addition, grazing time became significantly longer as the vegetation season progressed (effect of month) for both treatments (Table 2). Furthermore, grazing behaviour was a negative function of temperature (Fig. 2); in the range of 11–28 °C, time spent grazing decreased at the rate of 1.2% per 1 °C.

Treatment and month had no effect on rumination but the effect of treatment was affected by month ($P = 0.06$). There were some variations in the time budget allotted to ruminating activity between IG and EG treatments with the ongoing season, and only heifers on intensively grazed pasture showed a continuously decreasing trend in time spent ruminating (Fig. 1b). Ruminating activity also tended to be affected ($P = 0.077$) by temperature.

Resting was affected by season, temperature and year (Table 2). The differences between IG and EG were not significant. However, on average heifers from EG spent more time resting than heifers from IG (Fig. 1c). In both treatments the animals showed a decreasing trend in resting in the course of season (Fig. 1c).

Other activities such as drinking, salt licking, comfort behaviour or social interactions were affected neither by the season, nor by temperature (Table 2). The time allotted to these activities was stable for the IG as well as EG treatment (Fig. 1d).

Table 2
Results of GLM analyses of different effects on behaviour during 24-h cycle.

Behaviour	Effect	DF	*F*	*P*-value
Grazing	Year	1	1.21	0.277
	Temperature	**1**	**16.84**	**<0.001**
	Month	**3**	**5.96**	**0.001**
	Treatment	1	2.15	0.148
	Month × treatment	3	0.66	0.577
Ruminating	Year	1	1.227	0.273
	Temperature	1	3.248	0.077
	Month	3	0.342	0.795
	Treatment	1	0.687	0.411
	Month × treatment	3	2.604	0.060
Resting	Year	**1**	**5.43**	**0.023**
	Temperature	**1**	**10.16**	**0.002**
	Month	**3**	**4.16**	**0.010**
	Treatment	1	1.47	0.230
	Month × treatment	3	0.37	0.777
Other	Year	1	0.118	0.733
	Temperature	1	0.254	0.616
	Month	3	0.091	0.965
	Treatment	1	0.232	0.632
	Month × treatment	3	0.365	0.779

DF: degree of freedom; *F*: *F*-statistics.
Effects in bold characters were significant at the level $p < 0.05$.

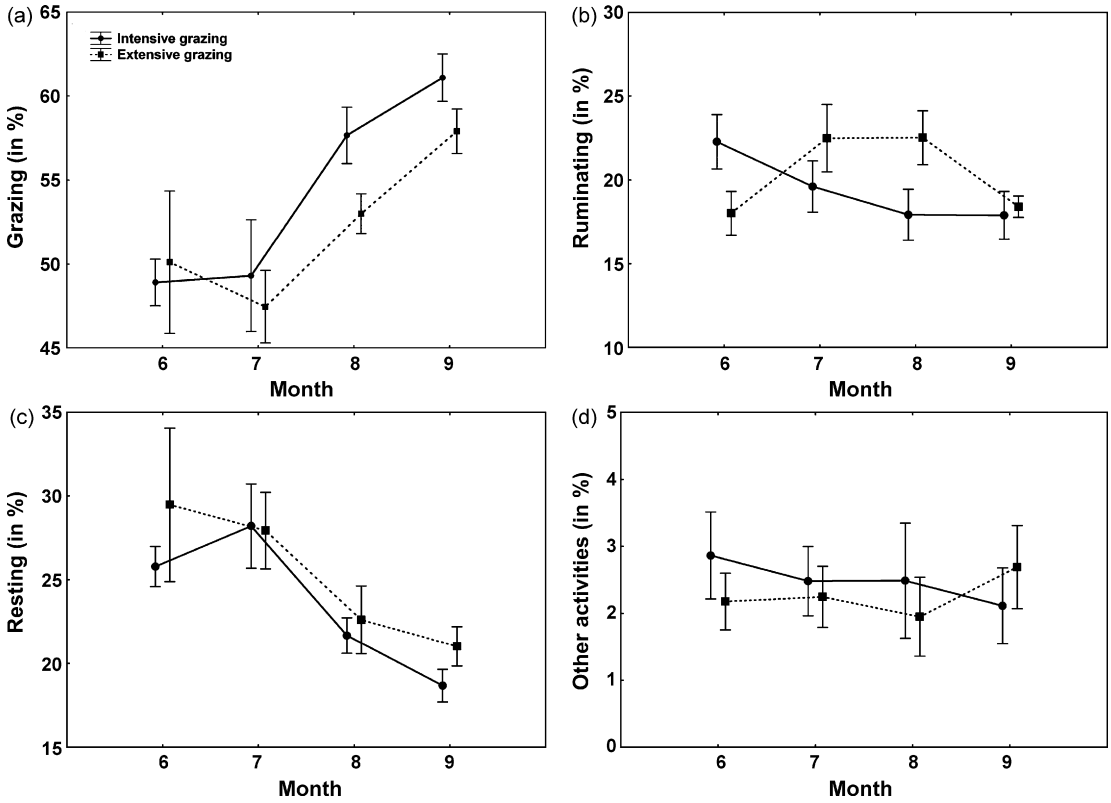

Fig. 1. Development of time budget for grazing (a), ruminating (b), resting (c), and other activities (d) of heifers with the progressing season on intensively and extensively grazed pasture (S.E. are indicated by vertical lines).

3.2. Biting rates

Biting rates significantly differed between IG and EG treatments and showed dependence upon the ongoing season (Table 3). In both treatments the animals showed a decreasing trend in grazing rate (Fig. 3a). The grazing rate increased by two bites per minute for each 1 cm decrease in sward height (Fig. 4). On the other hand, ruminating rate was affected by the ongoing season with only a slight difference in trend between the treatments (Table 3 and Fig. 3c).

4. Discussion

4.1. Effect of grazing intensity

The present study did not reveal significant differences in the daily activity patterns of heifers between two

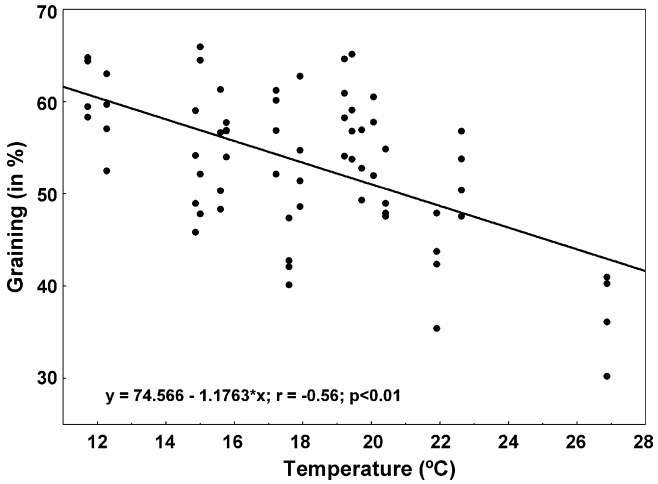

Fig. 2. Effect of actual daily temperature on grazing activity of heifers (in percentage of 24-h cycle).

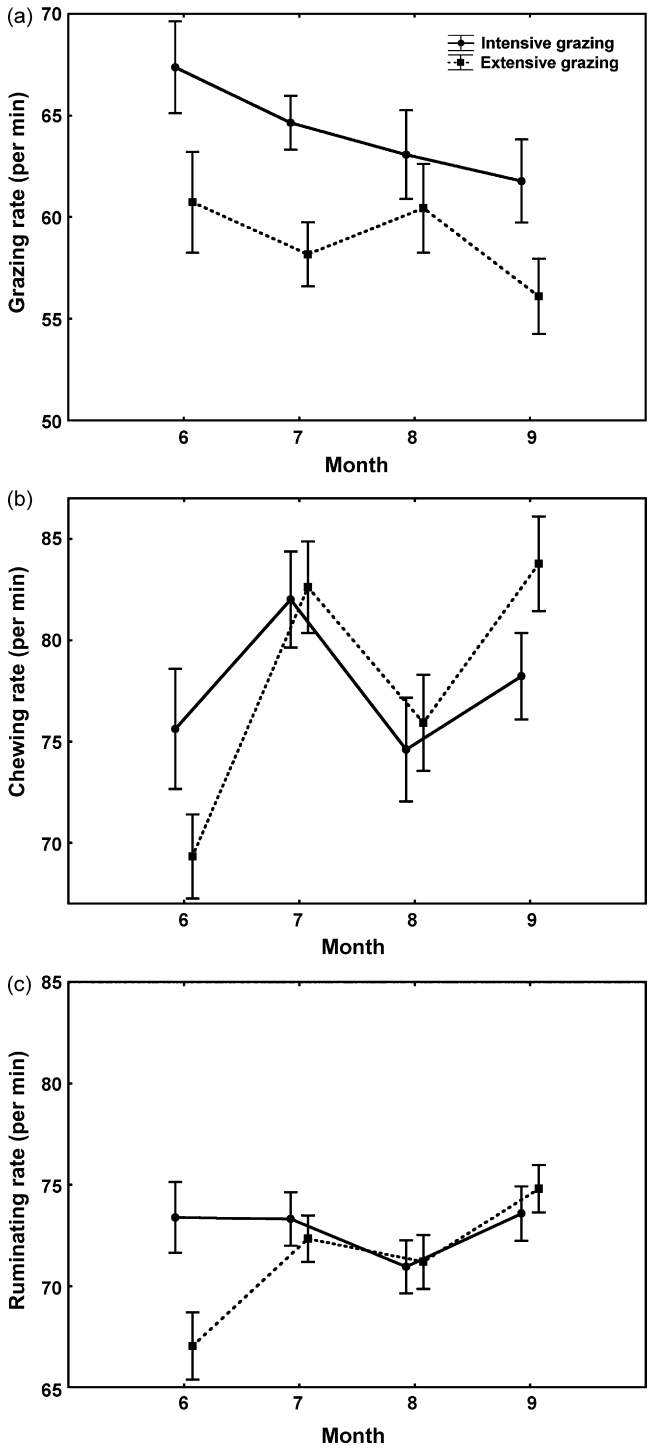

Fig. 3. Grazing rate (a), chewing rate (b), and ruminating rate (c) of heifers with the ongoing season on intensively and extensively grazed pasture (S.E. are indicated by vertical lines).

grazing intensities which were similar to species-rich natural pastures (Huber et al., 1995; Dumont et al., 2007). However, animals did display some differences in their behaviour that were more likely to consist of the frequencies of particular activities during the day. The major grazing periods persisted (described also by Linnane et al., 2001), but EG heifers often interrupted their grazing by ruminating, whilst IG heifers grazed for longer and more continuously, which corresponds with Arnold and Dudzinski (1978). As daily intake is to be maintained (Penning

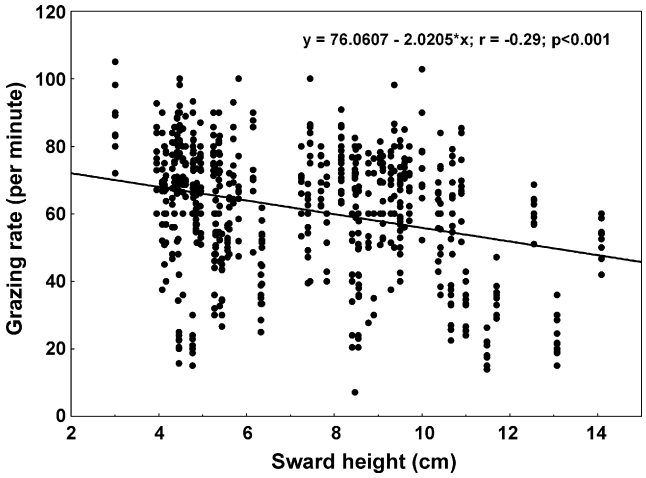

Fig. 4. Effect of the actual sward height on grazing rate (per minute) of heifers.

et al., 1991; Morris et al., 1993; Rutter et al., 2002) and the heifers in the IG treatment were exposed to a shorter sward, the IG heifers compensated for less available forage by increasing their grazing time (Jamieson and Hodgson, 1979; Allison, 1985; Penning et al., 1991; Ginane et al., 2003). However, the total length of time spent grazing per day may have a relatively small impact upon daily herbage intake (Wade and Carvalho, 2000). Thus, it was in order to meet a necessary daily forage quantity that this additional increase of grazing rate in the IG treatment occurred, which is consistent with the findings of Forbes (1988). It is in accordance with the fact that on lower sward, the quantity of herbage per bite is lower (Allden and Whittaker, 1970; Forbes, 1988). Hence, the chewing rate was higher for the EG treatment where longer particles of herbage probably caused longer periods of mastication before swallowing.

Longer ruminating time (except in June) of EG heifers, and variations in ruminating rate as consequence of higher fibre and lower crude protein content in the EG sward were consistent with the findings of Albright (1993) or Realini et al. (1999). However, the differences were not significant and this is probably due to more variable sward heights encountered by the EG treatment: the EG heifers fed on the both taller and shorter patches with both quality parameters. Consequently, the effect of grazing intensity diminished.

Table 3
Results of GLM analyses of different effects on different types of bite.

Type of intake	Effect	DF	*F*	*P*-value
Grazing per minute	Year	1	1.34	0.247
	Sward height	**1**	**98.43**	**<0.001**
	Month	**3**	**4.28**	**0.005**
	Treatment	**1**	**48.84**	**<0.001**
	Month × treatment	**3**	**2.86**	**0.036**
Chewing per minute	Year	**1**	**12.39**	**<0.001**
	Sward height	**1**	**8.28**	**0.004**
	Month	**3**	**7.43**	**<0.001**
	Treatment	**1**	**6.96**	**0.008**
	Month × treatment	3	2.20	0.086
Ruminating per minute	Year	1	2.92	0.087
	Sward height	1	1.87	0.171
	Month	**3**	**3.04**	**0.028**
	Treatment	1	3.60	0.058
	Month × treatment	3	2.03	0.10

DF: degree of freedom; *F*: *F*-statistics.
Effects in bold characters were significant at the level $p < 0.05$.

4.2. Effect of season

The grazing season on our upland semi-natural pasture lasted from May to the end of September. Seasonal changes in forage quality parameters were reflected in adaptations of behavioural processes. Time budget of principle activities changed as the season progressed in the both IG and EG treatments, with more or less the same trends. Grazing time increased with the month as expected, following the consistently decreasing biomass growth rate. The same findings were noted e.g. by Stricklin et al. (1976), Funston et al. (1991), Huber et al. (1995), or Realini et al. (1999). Resting exhibited a reverse trend, whereas ruminating varied in relation to treatment and month, and other activities did not show any important trends. At the same time, grazing rate showed a clear decreasing trend although parameters of forage quality, namely crude protein and crude fibre content, did not display any continuous trend (Pavlů et al., 2006). This is in contrast with the results of, for instance, Realini et al. (1999) or Ginane and Petit (2005) who recorded an increase in biting rate over the investigated periods. The increase in grazing time together with the increase in biting rate usually occurs under conditions of less available forage (e.g. Chacon and Stobbs, 1976; Penning et al., 1991; Linnane et al., 2004). In our study, however, maintaining the target sward height across the whole vegetation season had the effect of providing an adequate availability of forage on both of the treatments. Consequently, there was no restriction of forage accessibility and the heifers could balance their daily intake through a decrease in grazing rate, similarly to as described by Funston et al. (1991).

The only point when the seasonal trend in grazing and resting time was interrupted appeared in July when high

temperatures (particularly excessive in July 2006) caused a sharp decline in grazing and ruminating activities in favour of resting. Changes in temperature induce changes in behavioural patterns (Seath and Miller, 1946; Arnold and Dudzinski, 1978; Beverlin et al., 1989). Particularly hot weather imposed a long rest period on the heifers during a great part of the day which can be perceived as a constraint of shorter time for grazing (Ginane and Petit, 2005).

5. Conclusion

There was a clear trend towards longer grazing time and higher grazing rate, and less time for ruminating and resting found among heifers under higher grazing intensity, and hence with less availability of forage on the shorter sward. On the other hand, inconspicuous differences could be caused under conditions of sufficient forage availability to both groups during the course of grazing season. In fact, stocking rates as well as other grazing management conditions of pasture in our experiment were designed to correspond to the conditions of animal husbandry practices in the Czech Republic. This affected, furthermore, the seasonal patterns of ingestive behaviour. As the season progressed, the heifers under both grazing intensities increased their grazing time along with the decrease in their grazing rates. This suggests that the herbage on species-rich pasture was sufficiently available to livestock at both the investigated grazing intensities.

Acknowledgements

We are grateful to N. Al Hakimová, V. Černý, J. Gaisler, P. Kopřiva, F. Paška, V. Podhájecká, A. Urban and H. Zemanová for their assistance with the experiment. The investigation was supported by the grant from the Czech Science Foundation 523/06/P422; V. Pavlů and M. Hejcman were separately supported by the grant SP 203/179/07.

References

Albright, J.L., 1993. Nutrition, feeding, and calves—feeding behavior of dairy cattle. J. Dairy Sci. 76, 485–498.

Allden, W.G., Whittaker, I.A.McD., 1970. The determinants of herbage intake by grazing sheep: the interrelationship of factors influencing herbage intake and availability. Aust. J. Agric. Res. 21, 755–766.

Allison, C.D., 1985. Factors affecting forage intake by range ruminants: a review. J. Range Manage. 38, 305–311.

Arnold, G.W., Dudzinski, M.L., 1978. Ethology of free-ranging domestic animals. Developments in Animals and Veterinary Sciences, vol. 2. Elsevier, Netherlands, 198 pp.

Beverlin, S.K., Havstad, K.M., Ayers, E.L., Peterson, M.K., 1989. Forage intake responses to winter cold exposure of free ranging beef cows. Appl. Anim. Behav. Sci. 23, 75–85.

Chacon, E., Stobbs, T.H., 1976. Influence of progressive defoliation of a grass sward on the eating behavior of cattle. Aust. J. Agric. Res. 27, 709–727.

Demment, M.W., Laca, E.A., Greenwood, G.B., 1986. Intake in grazing ruminants: a conceptual framework. In: Owens, F.N. (Ed.), Feed Intake by Beef Cattle, pp. 208–225. Oklahoma Agric. Exp. Sta., MP-121.

Dumont, B., Rook, A.J., Coran, Ch., Röver, K.-U., 2007. Effects of livestock breed and grazing intensity on biodiversity and production in grazing systems. 2. Diet selection. Grass Forage Sci. 62, 159–171.

Forbes, T.D.A., 1988. Researching the plant–animal interface: the investigation of ingestive behaviour in grazing animals. J. Anim. Sci. 66, 2369–2379.

Funston, R.N., Kress, D.D., Havstad, K.M., Doornbos, D.E., 1991. Grazing behaviour of rangeland beef cattle differing in biological type. J. Anim. Sci. 69, 1435–1442.

Ginane, C., Petit, M., 2005. Constraining the time available to graze reinforces heifers' preference for sward of high quality despite low availability. Appl. Anim. Behav. Sci. 94, 1–14.

Ginane, C., Petit, M., D'Hour, P., 2003. How do heifers choose between maturing reproductive and tall or short vegetative swards? Appl. Anim. Behav. Sci. 83, 15–27.

Hepworth, K.W., Test, P.S., Hart, R.H., Waggoner Jr., J.W., Smith, M.A., 1991. Grazing systems, stocking rates, and cattle behavior in southeastern Wyoming. J. Range Manage. 44, 259–262.

Hodgson, J., 1985. The control of herbage intake in the grazing ruminant. Proc. Nutr. Soc. 44, 339–346.

Huber, S.A., Judkins, M.B., Krysl, L.J., Švejcar, T.J., Hess, B.W., Holcombe, D.W., 1995. Cattle grazing a riparian mountain meadow: effects of low and moderate stocking density on nutrition, behavior, diet selection, and plant growth response. J. Anim. Sci. 73, 3752–3765.

Isselstein, J., Jeangros, B., Pavlu, V., 2005. Agronomic aspects of biodiversity targeted management of temperate grasslands in Europe—a review. Agron. Res. 3, 139–151.

Jamieson, W.S., Hodgson, J., 1979. The effects of variation in sward characteristics upon the ingestive behaviour and herbage intake of calves and lambs under a continuous stocking management. Grass Forage Sci. 34, 273–282.

Krysl, L.J., Hess, B.W., 1993. Influence of supplementation on behavior of grazing cattle. J Anim. Sci. 71, 2546–2555.

Linnane, M.I., Brereton, A.J., Giller, P.S., 2001. Seasonal changes in circadian grazing patterns of Kerry cows (*Bos taurus*) in semi-feral conditions in Killarney National Park, Co. Kerry, Ireland. Appl. Anim. Behav. Sci. 71, 277–292.

Linnane, M.I., Horan, B., Connolly, J., O'Connor, P., Buckley, F., Dillon, P., 2004. The effect of strain of Holstein-Friesian and feeding system on grazing behaviour, herbage intake and productivity in the first lactation. Anim. Sci. 78, 169–178.

Morris, S.T., Hirschberg, S.W., Michel, A., Parker, W.J., McCutcheon, S.N., 1993. Herbage intake and live weight gain of bulls and steers continuously stocked at fixed sward heights during autumn and spring. Grass Forage Sci. 48, 109–117.

Newman, J.A., Parsons, A.J., Thornley, J.H.M., Penning, P.D., Krebs, J.R., 1995. Optimal diet selection by a generalist grazing herbivore. Funct. Ecol. 9, 255–268.

Pavlů, V., Hejcman, M., Pavlů, L., Gaisler, J., 2007. Restoration of grazing management and its effect on vegetation in an upland grassland. Appl. Veget. Sci. 10, 375–382.

Pavlů, V., Hejcman, M., Pavlů, L., Gaisler, J., Nežerková, P., 2006. Effect of continuous grazing on forage quality, quantity, and animals' performance. Agr. Ecosyst. Environ. 113, 349–355.

Penning, P.D., Parsons, A.J., Orr, R.J., Treacher, T.T., 1991. Intake and behaviour responses by sheep to changes in sward characteristics under continuous stocking. Grass Forage Sci. 46, 15–28.

Realini, C.E., Hodgson, J., Morris, S.T., Purchas, R.W., 1999. Effect of sward surface height on herbage intake and performance of finishing beef cattle. New Zealand J. Agric. Res. 42, 155–164.

Rook, A.J., Dumont, B., Isselstein, J., Osoro, K., WallisDeVries, M.F., Parente, G., Mills, J., 2004. Matching type of livestock to desired biodiversity outcomes in pastures—a review. Biol. Conserv. 119, 137–150.

Rutter, S.M., Orr, R.J., Penning, P.D., Yarrow, N.H., Champion, R.A., 2002. Ingestive behaviour of heifers grazing monocultures of ryegrass or white clover. Appl. Anim. Behav. Sci. 76, 1–9.

Seath, D.M., Miller, G.D., 1946. Effect of warm weather on grazing performance of milking cows. J. Dairy Sci. 29, 199–206.

StatSoft, 1995. Statistica for Windows. StatSoft, Tulsa, USA.

Stobbs, T.H., 1975. Factors limiting the nutritional value of grazed tropical pastures for beef and milk production. Trop. Grasslands 9, 141–150.

Stricklin, W.R., Wilson, L.L., Graves, H.B., 1976. Feeding behaviour of Angus and Charolais–Angus cows during summer and winter. J. Anim. Sci. 43, 721–732.

Tallowin, J.R.B., Rook, A.J., Rutter, S.M., 2005. Impact of grazing management on biodiversity of grasslands. Anim. Sci. 81, 193–198.

Wade, M.H., Carvalho, de F., 2000. Defoliation patterns and herbage intake on pastures. In: Lemaire, G., Hodgson, J., de Moraes, A., Nabinger, C., Carvalho, de, F. (Eds.), Grassland Ecophysiology and Grazing Ecology. CAB International, pp. 233–248.

Wallis de Vries, M.F., Daleboudt, C., 1994. Foraging strategy of cattle in patchy grassland. Oecologia 100, 98–106.

Watkinson, A.R., Ormerod, S.J., 2001. Grasslands, grazing and biodiversity: editors' introduction. J. Appl. Ecol. 38, 233–237.