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Frequency and intensity of grazing in winter: their effects on herbage accumulation and nutritive value of *Lolium perenne* L. dominant swards

Frecuencia e intensidad de pastoreo en invierno: efecto en la producción de fitomasa y calidad nutritiva de praderas dominadas por *Lolium perenne* L.

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ABSTRACT

A study was conducted in southern Chile with the objective of determining the effect of two frequencies and two intensities of grazing, measured as herbage mass, on production and nutritive value of a permanent sward dominated by *Lolium perenne* L. during winter season. Additionally the residual effect of the treatments applied in winter was evaluated on the same variables in the following spring. Two pre-grazing herbage mass (kg DM ha^{-1}): low frequency (1,800), high frequency (1,500) and two post-grazing herbage mass: low intensity (1,300), high intensity (1,000), were evaluated. Plots of 145.7 m^2 were grazed by dairy cows. The same plots were grazed in the subsequent spring to a frequency of 2,400 kg DM ha^{-1} and intensity of 1,400 kg DM ha^{-1}. There was no significant effect of the frequency of grazing on herbage mass and growth rate during the first winter. However, in the second winter a greater production with low frequency was obtained. In the two winter seasons, a significant effect of the intensity was obtained, with greater production in high intensity. The most frequently grazed treatments showed higher crude protein and lower soluble carbohydrates. Also, there was a residual effect in the spring generated by frequency and intensity of grazing in the first year, and only for the intensity the second year. It can be concluded that frequency and intensity of grazing applied in winter generate changes in herbage mass production and nutritive value of the sward and also a residual effect in the following spring.

RESUMEN

Se realizó un estudio en el sur de Chile, con el objetivo de determinar el efecto de dos frecuencias y dos intensidades de pastoreo sobre la producción y valor nutritivo de una pradera dominada por *Lolium perenne* L. en invierno. Se evaluó el efecto residual de los tratamientos aplicados en invierno en la primavera siguiente. Se evaluaron dos niveles de fitomasa pre-pastoreo (kg MS ha^{-1}): baja frecuencia (1.800) y alta frecuencia (1.500) y dos niveles de fitomasa post-pastoreo: baja (1.300) y alta (1.000). Se usaron parcelas de 145,7 m^2 pastoreadas por vacas en lactancia. Las mismas parcelas fueron pastoreadas en la primavera siguiente a una frecuencia de 2.400 kg MS ha^{-1} y una intensidad de 1.400 kg MS ha^{-1}. No hubo efecto de la frecuencia en la producción de fitomasa y tasa de crecimiento en el primer invierno. Sin embargo, en el segundo invierno existió una mayor producción de fitomasa con baja frecuencia. En las dos temporadas invernales, se obtuvo un efecto de la intensidad, con una mayor producción de fitomasa con alta intensidad de pastoreo. El pastoreo más frecuente mostró un mayor contenido de proteína cruda y menor de carbohidratos solubles. Hubo un efecto residual en la primavera generado por la frecuencia y la intensidad de pastoreo en el primer año y sólo por la intensidad en el segundo año. Se concluye que la frecuencia e intensidad de pastoreo en invierno genera cambios en la producción de fitomasa y valor nutritivo y un efecto residual en la primavera siguiente.

Palabras clave: Ballica perenne, fitomasa.

INTRODUCTION

The permanent sward constitutes the principal feed resource in cattle production systems for temperate climates such as the south of Chile. *Lolium perenne* L. (perennial ryegrass) is the most used specie in seeded permanent swards, and is generally used as a mix with *Trifolium repens* L. (white clover).

In southern Chile, the annual growth curve of the pastures is characterized by a marked seasonality where winter production comprises about 10% of the total annual production. This is due to meteorological conditions of low temperatures and lower levels of radiation than the other seasons. The transition from autumn to winter has a greater effect on *T. repens* than on *L. perenne* given a decrease in the rate of photosynthesis, which a lesser number of live leaves per plant, and a lower area and weight of individual leaves (Woledge *et al.*, 1990). Winter is a season with forage deficit, in which the sward represents about one third of the diet of lactation cows, but it contributes with high nutritive quality (Parga *et al.,* 2007). In winter, grazing management is of vital importance for the sustainability of grazing based systems. Due to excessive soil humidity, trading can damage the surface of the soil and also the plants themselves, especially in soils with a heavy texture (Holmes *et al.,* 2002). In addition, in many cases grazing is restricted or is differed during this season in order to conserve the pasture until spring. However, Hodgson (1990) shows that the growth rate and senescence are balanced during this period, therefore growth cannot be accumulated, and the pasture should be grazed.

Two variables in grazing management tools that are relevant to the attributes of the pasture are the frequency and the intensity of grazing. These two variables can be determined by different criteria, one of them being herbage mass which is defined by Hodgson (1990) as the weight of the dry material per unit of area (kg DM ha^{-1}) measured at ground level. In relation to the frequency of grazing, Parga *et al.* (2007) show that pre-grazing herbage mass in winter should not be more than 2,000 kg DM ha^{-1} in order to avoid the accumulation of dead leaves at the base of the vegetation. Also, depending on the climate, the rest period between grazings should vary between 40 to 60 days. Belton (1990) demonstrated that the total accumulation of dry matter in winter adapts to a wide range of defoliation intervals and that significant reductions occur only when the defoliation interval is extremely short, in this case 14 days. Grazings that are too frequent have a negative effect on the growth of the pasture, reducing the recuperation time (Ferraro and Oesterheld, 2002). With regards to grazing intensity, Holmes *et al.* (2002) recommends intense grazing, leaving residues of 1,100 kg DM ha^{-1}, in the case of the pastures of New Zealand, in order to avoid shading in the lower strata and reduce the quantity of dead material that is lost due to senescence and decomposition. A grazing that is too intense will affect negatively the quantity of basal reserves necessary to initiate new growth and the amount of residual leaves that photosynthesize after grazing (Ruiz, 1988). Grazings that are too frequent at a high intensity reduce growth rates and the density of tillers in *Arrhenatherum elatius* L. (D'Angelo *et al.,* 2005) and the accumulation of herbage mass in *Dactylis glomerata* L. (Garcia *et al.,* 2003). Similar results were obtained by Bryan *et al*. (2000) in a mixed *Poa pratensis* L./*T. repens* pasture, concluding that infrequent grazing at a low intensity also reduce the growth rate, without interaction between treatments and seasons. Donaghy *et al*. (1997) mentioned that the season of the year in which *L. perenne* plants are most sensitive to changes in the soluble carbohydrate reserves is in winter, principally at the end of the season. Considering that the accumulation of soluble carbohydrate reserves is influenced mainly by the frequency of defoliation (Fulkerson and Donaghy, 2001), management during winter should have a large impact on pasture growth in the subsequent spring, and on the persistence of the species. An adequate management during winter involves maintaining the pasture in good condition and allowing rapid growth in the spring, which is the season that registers the highest percentage of annual production.

The objective of the study was to determine the effect of pre and post-grazing herbage mass on dry matter production and nutritive quality of a *L. perenne* dominated sward in winter, and the residual effect on the pasture characteristics in the following spring.

MATERIALS AND METHODS

The study was carried out at the Vista Alegre Experimental Station, Universidad Austral de Chile, Valdivia (39°47' S, 73°13' W, elevation 12 m above sea level). The soil corresponded to volcanic ash soil of the Valdivia Series (Typic Hapludand). Table 1 shows the climatic data for the two winter seasons evaluated. The study was conducted during the winter (three grazing events per season) and the evaluation period was extended for 6 months each season, being divided into two stages: from the 21st of June to the 21st of September, to evaluate the treatments applied in winter; and from the 21st of September to the 21st of December, to evaluate the the residual effects from winter treatments.

A *L. perenne* (Quartet AR1)/*T. repens* (Huia) mix pasture was utilized. It was established for direct drilling, with a Frankhauser machine model F-3118 (Tuparendi, Rio Grande do Sul, Brazil). The seed rates were 25 kg ha^{-1} of *L. perenne* and 4 kg ha^{-1} of *T. repens*. At establishment 160 kg of P_2O_5, 60 kg of K_2O and 30 kg of N ha^{-1} were applied. Additionally, 45 kg of N ha^{-1} was applied at the beginning of each season.

Two pre-grazing herbage mass were evaluated (kg DM ha^{-1}): low frequency (LF): 1,800; high frequency (HF): 1,500. Two post-grazing herbage mass were also evaluated: low intensity (LI): 1,300 and high intensity (HI) 1,000. This generated four treatments, assigned to a randomized complete block design, with a factorial arrangement, where each experimental unit corresponded to plots with an area of 145.7 m^2 (23.5 m × 6.2 m), limited by electric fences at heights of 30 and 50 cm.

Post-grazing herbage mass of 1,000 and 1,300 kg DM ha^{-1} were fixed through an initial grazing carried out on the 21st of June of each year. The stoking density was 275 cows ha^{-1} (4 cows per plot). This same stoking density was utilized for all grazing. After fixing the initial post-grazing herbage mass, a rising plate meter (Jenquip, Palmerston North, New Zealand) was used to monitor pasture growth. Grazing was conducted when herbage mass reached 1,500 or 1,800 kg DM ha^{-1}, according to the treatment. The period of evaluation ended the 21st of September, grazing all experimental

Table 1. Minimum and maximum temperatures, precipitation, global radiation, and relative humidity registered in Valdivia during the study.

Cuadro 1. Temperaturas mínimas y máximas, precipitación, radiación global, y humedad relativa registrada en Valdivia durante el estudio.

	Temperature (°C)		Precipitation (mm)	Global radiation (cal cm^{-2} $día^{-1}$)	Relative humidity (%)
	Minimum	Maximum			
2005					
June	5.7 (5.7)*	10.3 (11.3)	485.4 (391.5)	41.9 (44.0)	93.4 (89.7)
July	5.9 (5.0)	11.2 (11.1)	337.2 (376.4)	57.0 (51.2)	90.6 (88.7)
August	5.8 (5.2)	12.5 (12.6)	391.8 (305.7)	91.3 (85.8)	84.0 (85.1)
September	4.7 (5.6)	16.6 (14.6)	148.6 (188.1)	162.6 (140.1)	79.4 (79.2)
2006					
June	7.9 (5.7)	12.8 (11.3)	614.0 (391.5)	48.7 (44.0)	94.2 (89.7)
July	6.1 (5.0)	12.5 (11.1)	527.8 (376.4)	60.1 (51.2)	89.6 (88.7)
August	5.1 (5.2)	13.4 (12.6)	317.4 (305.7)	102.7 (85.8)	84.9 (85.1)
September	5.5 (5.6)	15.1 (14.6)	183.1 (188.1)	144.1 (140.1)	81.9 (79.2)

Meteorological Station Isla Teja – Valdivia, Geosciences Institute, Universidad Austral de Chile, 2008.
* Historical averages appear in parentheses

plots, independent of the available herbage mass, but leaving the post-grazing residuals of 1,000 and 1,300 kg DM ha^{-1}, according to the treatment.

The estimation of the herbage mass pre and post-grazing was carried out using a rising plate meter. One hundred and fifty measurements were taken at each paddock at the beginning and at the end of each grazing. The average value was used for predicting herbage mass. The equation was calibrated periodically by double sampling technique, taking five samples pre and post-grazing (0.1 m^2). The samples were cut at ground level using an electric mower, then they were dried at 60°C for 48 hours and weighed, transforming the result into kg DM ha^{-1}. Data pairs of the compressed height (½ cm) and the herbage mass (kg DM ha^{-1}) were graphed and then the respective linear equations of the type $y = a + bx$ were generated, where y was the herbage mass, a was the intercept, b was the increase in herbage mass for each ½ cm of compressed height, and x was the compressed height of the pasture expressed in ½ cm.

Variables evaluated

Undisturbed height (UH). The average value was obtained from 25 measurements per plot, using a sward stick (Jenquip, New Zealand). Measurements taken were before (pre-grazing UH) and after (post-grazing UH) each grazing.

Compressed height (CH). The average of 150 measurements for each plot was registered, being carried out with a rising plate meter. The measurements were taken before (pre-grazing CH) and after (post-grazing CH) each grazing.

Herbage mass production (HMP). The production of herbage mass was calculated through the sum of the growth between grazings during the entire winter season. Pasture growth between grazings was determined by the difference between pre-and post-grazing herbage mass and the residual herbage mass from the previous grazing.

Apparent growth rate (AGR). Apparent growth rate, defined as the daily weight gain of dry matter per hectare, was calculated for each grazing period as follows:

$$AGR = (PGMg_n – RMg_{n-1}) / N$$

Where: $PGMg_n$ was the pre-grazing herbage mass in the grazing n, RMg_{n-1} was the residual herbage mass of the prior grazing and N was the number of days between two successive grazing events.

The average growth rate for each treatment during the winter season was calculated through the pondered average of all of the growth rates registered between grazings.

Grazing time. All of the experimental grazing events started at 08:00 AM and the time was registered in each plot, until reaching the target residual herbage mass.

Total dry matter intake. Total winter dry matter intake was calculated through the sum of the apparent intake in each grazing. Apparent intake is the difference between the pre and post-grazing herbage mass.

Rate of intake. It was expressed as kg DM cow^{-1} hr^{-1} and was calculated dividing the apparent intake by the grazing time and by the number of cows.

Chemical analysis. Previous to each grazing, ten pasture samples were randomly cut from each plot at 4 cm height. Thereafter, sub-samples of 400 g each were sent to the Animal Nutrition Laboratory at the Universidad Austral de Chile to determine the following: crude protein (CP; Bateman, 1970), neutral detergent fiber (NDF; Van Soest *et al*., 1991), acid detergent fiber (ADF; AOAC, 1995), D value (DOM; Tilley and Terry, 1963), and soluble carbohydrates (SC; MAFF, 1985). The metabolizable energy (ME) was calculated from the DOM using the equation of Garrido and Mann (1981): ME (Mcal/kg DM) = 0.279 + 0.0325 × DOM.

The nutritive quality was calculated for each variable as a pondered average using the following calculation (example of soluble protein, SP):

Pondered average SP = ((%SP p_1 × Pr. p_1) + (% SP p_2× Pr. p_2)....+ (%SP p_n × Pr. p_n)) × HMP

Where: p_1, p_2,...p_n are the grazings events carried out in the season, Pr. is the production of herbage mass (kg DM ha^{-1}) in each grazing, and HMP is the total production of herbage mass in the season.

Botanical Composition. It was determined at the beginning and at the end of each winter season. Eight sub-samples were cut at ground level in each plot in a quadrant of 25 × 25 cm. Each sample was manually separated in the Forage Laboratory at the Universidad Austral de Chile. The samples were separated into *L. perenne, T. repens*, other grasses, broadleaf species, and dead material (>50% dead), dried in a forced-air oven at 60° C for 48 hours, weighed, and the species components were expressed as a percentage in relation to the total dry material.

Grass tillers, T. repens growing points, and broadleaf plants density. After winter grazing, eight soil cores were taken at random per each plot with a 10 cm diameter corer. Tillers were cut at ground level and were separated into tillers of *L. perenne*, tillers of other grasses, *T. repens* growing points, and broadleaf plants. Each component was registered numerically and later dried in a forced-air oven at 60° C for 48 h, and then weighed. Each component was expressed through an individual number and weight.

Determination of the residual effect of winter grazing in spring. During the spring season, the 12 plots where the winter grazing treatment was applied, were grazed at the same frequency (2,400 kg DM ha^{-1}) and the same intensity (1,400 kg DM ha^{-1}), with the objective of comparing the residual effects using the same base. On the 21st of December, the last grazing was carried out, independent of the available pre-grazing herbage mass (season change). Variables evaluated in spring were HMP and AGR, as well as variables of nutritive quality: ash, CP, SP, ME, NDF, ADF and SC. These evaluations were carried out using the same methodology described for the winter evaluations.

Statistical analysis. A complete randomized block design with four treatments in a factorial arrangement of two frequencies and two intensities of grazing, was used. Data were analyzed using SAS version 9.2 (SAS Inst. Inc., Cary, NC, United States). The results for each variable were submitted to a normality test and an analysis of variance, in concordance with the experimental design. The LSD test was used for multiple comparisons between means.

RESULTS

Pasture height, production and consumption of herbage mass

Table 2 shows the results of the variables evaluated during both winter seasons in relation to pasture height, production and consumption of herbage mass by dairy cows. In both winter seasons, grazing frequency had a significant effect ($P \leq 0.05$) on pre-grazing UH. Grazing intensity had the same effect on the post-grazing UH. The pre-grazing UH in LF was greater than HF and the post-grazing UH greater in LI and lesser in HI. The same response pattern was recorded for pre-grazing CH and post-grazing CH. Grazing frequency did not affect significantly HMP nor AGR in the first winter evaluated. In the second season a higher HMP was recorded ($P \leq 0.01$) in LF. In both winter seasons, grazing intensity had a highly significant effect on HMP and AGR, with greater herbage mass production in HI. Grazing frequency and grazing intensity had a significant effect ($P \leq 0.05$) on grazing time in both seasons, being higher in LF and HI and lower in HF and LI.

The total DM intake during the season was not significantly modified by the grazing frequency in the first winter, however in the second season, the intake was higher ($P \leq 0.05$) in the LF treatments and lower in HF. The effect of grazing intensity in total DM intake was highly significant ($P \leq 0.01$) in both seasons, which was higher in HI and lower in LI. Grazing frequency did not affect ($P > 0.05$) the rate of consumption in the first winter, nonetheless, in the second winter it was significantly higher ($P \leq 0.05$) in HF. The effect of grazing intensity was highly significant ($P \leq 0.01$) with higher consumption rates of DM in LI.

Table 2. Effect of the two grazing frequencies and intensities on grass height, herbage mass and consumption of dairy cows during two winter seasons.

Cuadro 2. Efecto de dos frecuencias e intensidades de pastoreo en la altura de la pradera, producción y consumo de vacas lecheras durante dos periodos invernales.

	Frequency (F) (kg DM ha^{-1})		Intensity (I) (kg DM ha^{-1})		Significance		
	1,800	1,500	1,300	1,000	F	I	F × I
Winter year 1							
Undisturbed pre-grazing height (cm)	14.9	12.2	13.3	13.9	**	n.s.	n.s.
Undisturbed post-grazing height (cm)	7.98	7.85	9.00	6.86	n.s.	**	n.s.
Compressed pre-grazing height (cm)	6.59	5.11	5.69	6.00	**	n.s.	n.s.
Compressed post-grazing height (cm)	4.29	4.24	4.77	3.76	n.s.	**	n.s
Herbage mass production (kg DM ha^{-1})	1,143	1,144	900	1,387	n.s.	**	n.s.
Apparent Growth rate (kg DM day^{-1})	12.7	12.7	10.0	15.4	n.s.	**	n.s.
Grazing time (hours)	3.15	2.39	1.37	4.17	*	**	n.s.
Total intake (kg DM ha^{-1})	1,149	1,149	903	1,395	n.s.	**	n.s.
Intake rate (kg DM cow hour^{-1})	0.79	0.79	1.11	0.47	n.s.	**	n.s.
Winter year 2							
Undisturbed pre-grazing height (cm)	15.9	13.6	15.5	13.9	**	*	n.s.
Undisturbed post-grazing height (cm)	9.25	9.16	10.1	8.31	n.s.	*	n.s.
Compressed pre-grazing height (cm)	8.26	6.19	7.06	7.39	**	n.s.	n.s.
Compressed post-grazing height (cm)	4.85	4.73	5.48	4.10	n.s.	**	n.s.
Herbage mass production (kg MS ha^{-1})	1,151	1,079	922	1,308	**	**	n.s
Growth rate (kg MS day^{-1})	12.8	12.0	10.2	14.5	**	**	n.s.
Grazing time (hour)	4.07	2.15	1.37	4.85	**	**	*
Total intake (kg MS ha^{-1})	1,136	1,066	915	1,287	*	**	n.s.
Intake rate (kg MS cow hour^{-1})	0.84	1.03	1.25	0.62	*	**	n.s.

* = $P \leq 0.05$, ** = $P \leq 0.01$, n.s. = $P > 0.05$

Nutritive quality in the forage offered

The nutritive quality evaluated during both winter seasons is presented in Table 3. In both seasons, grazing frequency had a significant effect ($P \leq 0.05$) on the percentage of CP and also on the SC. The percentage of CP was higher ($P \leq 0.05$) in HF. On the other hand, the SC content was higher in LF.

In the second winter, grazing frequency and intensity had a highly significant ($P \leq 0.01$) effect on ash; the HF and HI treatments showed a higher ($P \leq 0.05$) concentration of ash compared to LF and LI, respectively. The treatments did not affect ($P > 0.05$) other nutritive quality variables.

Number and weight of grass tillers, *T. repens* growing points, and broadleaf plants density

Table 4 shows the results of the number and weight of the grass tillers, points of growth in *T. repens*, and broadleaf plants at the end of the winter seasons. In the first winter, grazing intensity did not register a significant effect in the number of tillers of *L. perenne* and other grasses. However, grazing frequency had a significant effect ($P \leq 0.05$) in *L. perenne* tiller weight, with higher values in LF and lower in HF. Grazing intensity had a highly significant effect ($P \leq 0.01$) on the individual weight of tillers of other grasses, with higher weights in LI.

In the second winter grazing frequency showed a significant effect ($P \leq 0.05$) on the number of tillers of *L. perenne*, higher in the LF treatments. Grazing intensity had a significant effect ($P \leq 0.05$) on the individual weight of tillers of *L. perenne* with higher LI values.

Grazing frequency and intensity did not have a significant effect on the number of tillers of other grasses. However grazing intensity did affect ($P \leq 0.01$) the individual weight of the tillers, reflected in a higher weight in LI. There was not effect ($P > 0.05$) observed in growth points of the white clover and the number of broadleaf plants at the end of the winter.

Table 3. Grazing frequency and intensity effects on the nutritive quality of the forage in the two winter seasons.

Cuadro 3. Efectos de la frecuencia e intensidad de pastoreo en la calidad nutritiva del forraje y consumo aparente en dos estaciones invernales.

	Frequency (F) (kg DM ha^{-1})		Intensity (I) (kg DM ha^{-1})		Significance		
	1,800	**1,500**	**1,300**	**1,000**	**F**	**I**	**F × I**
Winter year 1							
Ash (%)	8.37	8.65	8.43	8.60	n.s.	n.s.	n.s.
Crude protein (%)	25.1	26.4	25.6	25.8	*	n.s.	n.s.
Metabolizable energy (Mcal kg^{-1})	2.89	2.85	2.87	2.87	n.s.	n.s.	n.s.
Neutral detergent fiber (%)	40.7	41.8	41.5	41.0	n.s.	n.s.	n.s.
Acid detergent fiber (%)	20.9	21.3	21.1	21.1	n.s.	n.s.	n.s.
Soluble carbohydrates (g kg^{-1})	101	90.6	97.7	93.7	*	n.s.	n.s.
Soluble protein (%)	10.6	11.1	10.8	10.9	n.s.	n.s.	n.s.
Winter year 2							
Ash (%)	7.77	9.06	7.80	9.03	**	**	*
Crude protein (%)	20.0	21.4	20.8	20.7	*	n.s.	n.s.
Metabolizable energy (Mcal kg^{-1})	2.71	2.74	2.72	2.74	n.s.	n.s.	n.s
Neutral detergent fiber (%)	36.7	37.9	37.4	37.1	n.s.	n.s.	n.s.
Acid detergent fiber (%)	22.1	23.1	22.3	22.8	n.s.	n.s.	n.s.
Soluble carbohydrates (g kg^{-1})	108	95.4	103	100	**	n.s.	n.s.
Soluble protein (%)	9.32	9.82	9.37	9.76	n.s.	n.s.	n.s.

* = $P \leq 0.05$, ** = $P \leq 0.01$, n.s. = $P > 0.05$

Table 4. Effect of grazing frequency and intensity on tiller number and weight, growth points in *Trifolium repens* and number of broadleaf plants, at the end of both winter seasons.

Cuadro 4. Efecto de la frecuencia e intensidad de pastoreo en el número y peso de macollos, puntos de crecimiento en *Trifolium repens* y número de plantas de hoja ancha, al final de ambas estaciones invernales.

	Frequency (F) (kg DM ha^{-1})		Intensity (I) (kg DM ha^{-1})		Significance		
	1,800	**1,500**	**1,300**	**1,000**	**F**	**I**	**F × I**
End winter 1							
Lolium perenne (tillers m^{-2})	3,873	4,539	4,263	4,149	n.s.	n.s.	n.s.
Lolium perenne (mg tillers^{-1})	1.53	1.30	1.40	1.43	*	n.s.	n.s.
Other grasses (tillers m^{-2})	2,714	2,690	2,578	2,825	n.s.	n.s.	n.s.
Other grasses (mg tiller^{-1})	1.16	1.06	1.23	0.99	n.s.	**	n.s.
Trifolium repens (points m^{-2})	11	13	13	11	n.s.	n.s.	*
Broadleaf plants (plants m^{-2})	19	19	19	19	n.s.	n.s.	n.s.
End winter 2							
Lolium perenne (tillers m^{-2})	6,112	4,194	5,085	5,220	*	n.s.	n.s.
Lolium perenne (mg tillers^{-1})	1.45	1.34	1.51	1.29	n.s.	*	n.s.
Other grasses (tillers m^{-2})	2,202	2,783	2,451	2,533	n.s.	n.s.	n.s.
Other grasses (mg tiller^{-1})	1.74	1.47	1.82	1.39	n.s.	**	n.s.
Trifolium repens (points m^{-2})	0	5	5	0	n.s.	n.s.	n.s.
Broadleaf plants (plants m^{-2})	24	35	29	29	n.s.	n.s.	n.s.

* = $P \leq 0.05$, ** = $P \leq 0.01$, n.s. = $P > 0.05$

Botanical composition

The botanical composition of the pasture at the beginning and the end of the winter seasons is presented in Table 5. The starting botanical composition in both seasons did not show differences ($P > 0.05$) in the evaluated treatments.

At the end of the first winter, grazing intensity had a significant effect ($P \leq 0.05$) on the percentage of *L. perenne*, with higher percentage in HI. Also, grazing frequency registered a significant effect ($P \leq 0.05$) on the percentage of dead material, where the HF treatments showed a higher percentage. There was not a significant effect on the percentages of other grasses, *T. repens* and broadleaf species. At the end of the second winter, the frequency and intensity of the grazing did not register a significant effect on the percentages of *L. perenne* and other grasses. The contribution of broadleaf plants species was significantly affected by the treatments, with higher values in LF and LI, and lower in HF and HI, respectively, although the overall contribution to the pasture was very low. Grazing intensity did have a significant effect on the percentage of dead material, with lower values in the HI treatments.

Residual effect of the winter treatments in spring

Table 6 shows the results of the residual effects of the grazing treatments applied in winter on the characteristics of the pasture in the spring for the two seasons evaluated. In the first season frequency and intensity of grazing had a significant residual effect ($P \leq 0.05$). Pastures that received treatments with LF and HI of grazing during winter registered higher HMP and

Table 5. Botanical composition of the pasture at the beginning and end of the winter seasons.
Cuadro 5. Composición botánica de la pradera al comienzo y final de las estaciones invernales.

	Frequency (F) (kg DM ha^{-1})		Intensity (I) (kg DM ha^{-1})		Significance		
	1,800	1,500	1,300	1,000	F	I	F × I
Beginning winter 1							
Lolium perenne (%)	56.4	66.7	58.6	64.5	n.s.	n.s.	n.s.
Other grasses (%)	20.5	10.2	16.1	14.6	n.s.	n.s.	n.s.
Trifolium repens (%)	0.10	0.09	0.19	0.00	n.s.	n.s.	n.s.
Broadleaf plants (%)	0.32	0.20	0.31	0.22	n.s.	n.s.	n.s.
Dead material (%)	22.7	22.9	24.8	20.8	n.s.	n.s.	n.s.
End winter 1							
Lolium perenne (%)	55.4	54.7	47.0	63.1	n.s.	*	n.s.
Other grasses (%)	31.8	24.8	34.4	22.2	n.s.	n.s.	n.s.
Trifolium repens (%)	0.04	0.10	0.04	0.10	n.s.	n.s.	n.s.
Broadleaf plants (%)	0.51	0.88	1.08	0.30	n.s.	n.s.	n.s.
Dead material (%)	12.3	19.5	17.5	14.3	*	n.s.	n.s.
Beginning winter 2							
Lolium perenne (%)	37.4	31.0	29.4	39.0	n.s.	n.s.	n.s.
Other grasses (%)	23.3	29.7	30.2	22.7	n.s.	n.s.	n.s.
Trifolium repens (%)	0.05	0.17	0.12	0.10	n.s.	n.s.	n.s.
Broadleaf plants (%)	2.40	2.41	3.07	1.74	n.s.	n.s.	n.s.
Dead material (%)	36.9	36.7	37.2	36.5	n.s.	n.s.	n.s.
End winter 2							
Lolium perenne (%)	44.2	43.9	40.2	47.8	n.s.	n.s.	n.s.
Other grasses (%)	33.9	35.3	36.0	33.2	n.s.	n.s.	n.s.
Trifolium repens (%)	0.05	0.04	0.02	0.07	n.s.	n.s.	n.s.
Broadleaf plants (%)	1.45	0.26	1.41	0.30	**	*	n.s.
Dead material (%)	20.5	20.5	22.3	18.7	n.s.	*	n.s.

* = $P \leq 0.05$, ** = $P \leq 0.01$, n.s. = $P > 0.05$

AGR during spring, in comparison with the HF and LI treatments, respectively. In the second season grazing intensity had a significant residual effect ($P \leq 0.05$) on HMP and AGR, with higher values at HI. With respect to grazing frequency, even though it showed a higher HMP in the LF treatments, this difference did not prove to be statistically significant ($P = 0.18$).

Residual effect on nutritive quality in spring

Table 7 presents the residual effects of the frequency and intensity of grazing applied in winter on the nutritive quality of the forage offered in spring. In the first and second spring, the grazing treatments modified the ME values ($P \leq 0.05$) for the frequency and intensity of

Table 6. Residual effects of two grazing frequencies and intensities applied during two winter seasons on herbage mass production and pasture growth rate in spring.

Cuadro 6. Efecto residual de dos frecuencias e intensidades de pastoreo aplicadas en dos estaciones invernales sobre la producción de materia seca y tasa de crecimiento de la pradera durante primavera.

	Frequency (F) (kg DM ha^{-1})		Intensity (I) (kg DM ha^{-1})		Significance		
	1,800	1,500	1,300	1,000	F	I	F × I
			Residual effects winter 1				
Herbage mass production (kg DM ha^{-1})	2,965	2,673	2,611	3,027	*	*	n.s.
Growth rate (kg DM day^{-1})	26.1	19.3	19.4	26.0	*	*	n.s.
			Residual effects winter 2				
Herbage mass production (kg DM ha^{-1})	3,304	3,140	3,023	3,421	n.s.	*	n.s.
Growth rate (kg DM day^{-1})	39.7	37.8	36.3	41.2	n.s.	*	n.s.

* = $P \leq 0.05$, ** = $P \leq 0.01$, n.s. = $P > 0.05$

Table 7. Residual effects of the two grazing frequencies and intensities applied during two winter seasons on the nutritive quality of the forage consumed in the following spring.

Cuadro 7. Efecto residual de dos frecuencias e intensidades de pastoreo aplicadas en dos estaciones invernales sobre la calidad nutritiva del forraje consumido en la primavera siguiente.

	Frequency (F) (kg DM ha^{-1})		Intensity (I) (kg DM ha^{-1})		Significance		
	1,800	1,500	1,300	1,000	F	I	F × I
Residual effect winter year 1							
Ash (%)	8.56	8.21	8.32	8.45	n.s.	n.s.	n.s.
Crude protein (%)	20.8	20.0	20.5	20.2	n.s.	n.s.	n.s.
Metabolizable energy (Mcal kg^{-1})	2.68	2.73	2.70	2.72	**	*	n.s.
Neutral detergent fiber (%)	45.4	45.1	45.2	45.4	n.s.	n.s.	n.s.
Acid detergent fiber (%)	26.4	26.9	26.6	26.7	n.s.	n.s.	n.s.
Soluble carbohydrates (g kg^{-1})	75.3	79.3	78.3	76.4	n.s.	n.s.	n.s.
Soluble protein (%)	9.45	9.30	9.54	9.20	n.s.	n.s.	n.s.
Residual effect winter year 2							
Ash (%)	7.68	7.39	7.47	7.60	n.s.	n.s.	n.s.
Crude protein (%)	17.8	18.3	17.3	18.7	n.s.	n.s.	n.s.
Metabolizable energy (Mcal kg^{-1})	2.71	2.74	2.68	2.76	*	**	n.s.
Neutral detergent fiber (%)	47.0	45.4	47.7	44.6	n.s.	**	n.s.
Acid detergent fiber (%)	28.6	27.9	29.5	27.0	*	**	n.s.
Soluble carbohydrates (g kg^{-1})	97.3	97.9	96.7	98.4	n.s.	n.s.	n.s.
Soluble protein (%)	8.35	8.49	8.26	8.58	n.s.	n.s.	n.s.

* = $P \leq 0.05$, ** = $P \leq 0.01$, n.s. = $P > 0.05$

grazing. The HF and HI treatments reached higher ME contents in the LF and LI treatments, respectively. In the first season, in the rest of the variables, the effects of the frequency and intensity of the grazing were not statistically significant. In the second spring evaluated, grazing frequency had a significant effect ($P \leq 0.05$) on the percentage of ADF, with a higher concentration in the LF treatments. The intensity of the grazing had a highly significant effect ($P \leq 0.01$) on the variables NDF and ADF, with higher percentages in LI and lower percentages in HI.

DISCUSSION

In the two winter seasons, low frequency of grazing increased pre-grazing UH and CH, and high intensity of grazing decreased post-grazing UH and CH. These data confirm the direct relationship that exists between grass height and herbage mass availability. The effect of grazing intensity on the pre-grazing UH in the second season would be reflecting the greater difficulty in reaching the objective height when starting from lower pasture heights.

In both seasons, the HMP was greater for high-intensity grazing. These results coincide with Fulkerson and Slack (2003) in a pasture of *L. perenne* where the herbage mass production was found to be 21% higher when more intense grazing were carried out during winter. A low intensity of grazing has a negative effect on the accumulation of herbage mass upon reducing the photosynthesis due to a loss of leaf area index therefore favouring pseudostem growth, and for a decreased photosynthesis per surface area (Hernández-Garay *et al*., 1999).

There was an effect of grazing frequency in the second winter, where a greater AGR and HMP were recorded upon lowering the frequency of grazing. Fulkerson and Donaghy (2001) show that the frequency of defoliation is the main factor that determines the concentration of soluble carbohydrates, necessary for plants to initiate new growth. When frequent grazing is carried out, the time between grazings will be insufficient to restore carbohydrate reserves, affecting regrowth and long term persistence. Lower accumulation of herbage mass when frequent grazing take place is caused by the short regrowth period in which the herbage mass is relatively slow and never fully reaching the phase of active growth (Dale *et al.,* 2008).

Similar results were obtained by Lee *et al.* (2009), who increased the regrowth of a *L. perenne* pasture in winter through the increase of grazing intervals until the three-leaf state and severe defoliations up to 20 to 40 mm of post grazing height. Data obtained by Lee *et al*. (2009) confirmed that during winter it is possible to graze the pasture more severely than the 50 mm recommended by Fulkerson *et al*. (1994) without negatively effecting regrowth.

Nutritive value of forage offered was similar to the data obtained by Anrique *et al*. (2008) for pastures in the southern region of Chile in winter, and referred to average values of 2.85 Mcal kg^{-1} of ME, 26.7% de CP, 23.0% ADF, and 48.9% FDN. Related to grazing frequency, Turner *et al*. (2006b) concluded that an increase in the defoliation interval produces a decrease in concentration of ME as a result of the decrease in digestibility. However, within the range of frequencies and intensities used in this study, there was not an effect in ME content or in the digestibility of the forage. Generally, the best determinant for animal performance is associated with the consumption of usable energy, expressed in terms of ME. The concentration of ME is closely related to the digestibility of organic material and this digestibility has an important influence on the quantity of forage consumed (Hodgson, 1990). The increase in the SC content and the decrease in the percentage of raw protein upon decreasing grazing frequency was expected due to the inverse relationship that exists between the concentration of CP and the state of maturity (Rawnsley *et al.,* 2002; Donaghy *et al.,* 2008) and the positive relation between the regrowth and the accumulation of SC (Fulkerson *et al*., 1998). Abraham *et al*. (2009), in a study carried out with *D. glomerata* also obtained higher concentrations of CP when the frequency of grazing in winter was increased; furthermore they observed a decreasing in NDF and ADF, effects that were not seen in the present study.

The intensity of grazing did not affect the nutritive quality of the forage offered, which was contrary to the results obtained by Lee *et al*. (2007) who registered a higher digestibility, SC, and ME and lower percentages of fiber when more intense grazing took place in *L. perenne* pastures during winter. This difference in results could be attributed to the fact that in the cited study residual herbage mass of 1,200 and 1,800 kg DM ha^{-1} were used, which establishes a range of 600 kg DM ha^{-1} between both intensities, a value which represents double the range used in the present study (300 kg DM ha^{-1}).

The absence of effects of frequency and intensity of grazing in tiller density of *L. perenne* and other grasses during the first year is contrary to the results of Hernández-Garay *et al*. (1999) where more frequent and intense grazing increased the density of *L. perenne* tillers. In the second year of this study, a higher density of tillers was registered with less frequent grazing, which coincides with the results obtained by D'Angelo *et al*. (2005) in pastures of *A. elatius*. This effect could be due to the longer growth period in a stage with lower growth rates, and as a consequence the leaf area index could be closer to an optimal value.

In general, a greater individual tiller weight was registered in treatments grazed less intensely, which agrees with the results of Turner *et al*. (2006a) and Velasco-Zebadúa *et al*. (2007) who showed that tiller density increases along with grazing intensity. This effect is known as size-density compensation (Hernández-Garay *et al*., 1999).

With regards to the botanical composition at the end of the season, during the first year an increase in the percentage of *L. perenne* was observed under a more intense grazing, which with Lee *et al*. (2007) who utilized more intense grazing in the winter in order to increase the proportion of *L. perenne*.

In the first year, contrary to what was expected, a higher accumulation of dead material was registered at the end of the winter when a high frequency of grazing was applied. A possible explanation for this effect could be that with a little growth achieved during the winter the dead material located at the base of the pasture represents a greater proportion of the total harvested herbage mass when compared to a pasture with a greater growth where the dead material represents a lower proportion of the total. The accumulation of dead material was higher in the second year when a lower intensity of grazing was applied, which could be due to an increase of senescent and decomposing material at the base of the pasture when low intensity grazing were applying (Holmes *et al*., 2002).

It is important to mention the low percentage of *T. repens* that was observed in both evaluated seasons. This species was seeded projecting a 30% contribution to the total DM production, but *T. repens* tended to disappear with time which represented a poor adaption to the soil conditions, climate, and management present in the south of Chile.

Higher growth rates and accumulation of herbage mass were registered when less frequent and less intense grazing was carried out in the winter, although the effect of the frequency was not significant in the second season. The effect of the frequency could be related to a higher tiller density at the end of the winter in the treatments of low grazing frequency, which would demonstrate that the tiller produced during winter have a great relevance to the growth of the pasture in spring. Fulkerson and Michell (1987) demonstrated that tillers produced during autumn and winter contributed to more than 60% of the growth of *L. perenne* during spring. In both seasons under evaluation, intense grazing in winter increased the growth rate and the accumulation of herbage mass in spring. This is contrary to the reports of Hodgson (1990) where pastures that are grazed severely in winter will take longer to reach a complete photosynthetic efficiency at the beginning of spring. Hennessy *et al*. (2006) showed, however, that with a low intensity of grazing in winter, a larger quantity of material is accumulated with a more advanced state of maturity which possesses a lower photosynthetic efficiency, and this decreases the potential for growth of the pasture during spring.

There was a residual effect on the nutritive quality of the forage consumed in spring, which was reflected in the higher ME content and lower NDF and ADF percentages in treatments that received more frequent and more intense grazing during winter. This effect might be caused by a better leaf-sheath proportion of the pasture in spring, when frequent and intense grazing was applied during winter.

CONCLUSIONS

The frequency and intensity of grazing applied in winter had a relevant effect on the variables of production and nutritive quality in a permanent pasture, and furthermore there was a residual effect on the same variables in the spring. Less frequent and more intense grazing in winter increased the accumulation of herbage mass in the season, and also showed a positive residual effect on spring production.

A more frequent grazing increased the percentage of CP and decreased the content of soluble carbohydrates. Frequent and intense grazing decreased the individual weight of *L. perenne* tillers and other grasses tillers, but did not modify the density at the end of the winter. Intense grazing increased the percentage of *L. perenne*, but this effect was manifested only during the first season. Frequent and intense grazing in winter increased the ME content and decreased the percentages of NDF and ADF from the forage produced in spring.

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