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Sward quality affected by different grazing pressures on dairy systems

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Abstract

The objective of the experiment was to examine the effects of different stocking densities (3.7, 4.6, and 5.5 cows ha^{-1}) on tiller density, botanical composition, and chemical (crude protein [CP], acid detergent fiber [ADF], Ca, P, K, and Mg) quality of pasture and the seasonal (before flowering [spring], after flowering [summer], and autumn) distribution of these parameters. Percentages of sown [perennial ryegrass (*Lolium perenne* L. cv `Brigantia'*)* and white clover (*Trifolium repens* L. cv `Huia'*)*] and volunteer species were not significantly affected by stocking density, although as stocking density increased, tiller density also increased. This effect was more pronounced for volunteer species than sown species. Density was significantly higher before flowering than after flowering or autumn. Stocking density affected the chemical quality of herbage with ADF, CP, P, K, and Mg higher at high stocking density. The Ca/P relationship was lower at high stocking density, but the K/(Ca+Mg) relationship was not significantly affected by stocking density. Chemical quality of the pasture was higher before flowering than after flowering or autumn. The Ca/P ratio exceeded the upper limit recommended for dairy cows, but no osteomalacia was found in the present experiment. Low values of the K/(Ca+Mg)ratio were found in the spring. Therefore, on these pasture types it is advisable to use concentrates high in Mg or Mg supplements in the spring in order to avoid hypomagnesemia.

Key Words: *Lolium*, stocking rate, *Trifolium*

Resumen

El objetivo de este experimento fue evaluar el efecto de diferentes cargas ganaderas (3.7, 4.6 y 5.5 vacas ha^{-1}) sobre la densidad, composición botánica y calidad química (proteína bruta (PB), fibra ácido detergente (FAD), Ca, P, K y Mg) del pasto y la distribución estacional (antes de la floración [primavera], después de la floración [verano], y otoño) de estos parámetros. Los porcentajes de las especies sembradas [raigrás inglés (*Lolium perenne* L. var "Brigantia") y trébol (*Trifolium repens* L. var 'Huia")] y espontáneas no se vieron significativamente afectados por la carga ganadera, sin embargo a medida que la carga ganadera aumentó, la densidad del pasto se incrementó. Este efecto fue más pronunciado para las especies espontáneas que para las sembradas.

La densidad fue significativamente mayor antes de la floración que después de la floración o en otoño. La carga ganadera afectó a la calidad química de la hierba, resultando los contenidos en FAD, PB, P, K, y Mg mayores con las cargas más altas. La relación Ca/P fue menor en las cargas altas, sin embargo la relación K/(Ca+Mg) no fue significativamente afectada por este parámetro. La calidad química del pasto fue mayor antes de la floración que después de este período o en otoño. A pesar de que la relación Ca/P fue mayor que el límite superior recomendado para vacas de leche, no se encontraron casos de osteomalacia en este experimento. Se encontraron valores bajos de la relación K/(Ca+Mg) en la primavera. Por lo tanto en este tipo de pastos es recomendable utilizar concentrados ricos en Mg o complementados con Mg en primavera para evitar problemas de hipomagnesemia.

Pasture production and its seasonal distribution are important variables which determine animal production. However, it is important to know other characteristics relating to the sward such as density (number of tillers per square meter) and botanical composition, which can affect pasture production and herbage intake. Density and botanical composition are usually affected by management decisions, such as stocking rate or density (Curll and Wilkins 1985, Baker and Leaver 1986).

Forage intake is dependent on the availability of forage, on the chemical and physical composition of the forage, and on the nutritional requirements of the animal (Minson 1982). Therefore, herbage quality is an important factor which affects animal production, and knowledge about its seasonal distribution is necessary to make management decisions such as use of supplements or calving dates.

Chemical analysis of pasture is an indirect method of determining availability of an element to an animal. It is important to know the mineral contents of pastures which are grazed because there are some important differences with ungrazed pastures (Frame and Hunt 1971). Mineral content, that exceeds or falls short of the optimal requirements of grazing animals can cause health and production problems. Milk fever or hypocalcaemia (Pickard 1986, Grace 1983a, Minson 1990) is a pathology related to a deficit of calcium in dairy diet and can lead to occasional bone disorders. Hypomagnesaemia or grass tentany is produced when magnesium is not given in adequate proportion in the diet and causes mainly a reduction on milk production and fertility of

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cows (Pickard 1986, Minson 1990, Grace 1983a). Deficiency of potassium is not usual as pasture has substantial percentage of this element, but if it is in excess then it will cause problems with magnesium absorption and therefore precipitate hypomagnesaemia (Minson 1990).

Protein content and ADF of pasture are related to intake (Mott 1983, Minson 1982) and are affected by climatic conditions (Munro and Walters 1985, Metson and Saunders 1978b, Roberts 1987, Stehr and Kirchgessner, 1976).

Our objective was to determine the effect of differing stocking densities on botanical composition, density, and chemical characteristics (ADF, CP, and mineral content) of dairy system pastures in Spain, as well as the seasonal distribution of these parameters.

Materials and Methods

The experiment was carried out in Mabegondo (Galicia region)(43º15' N, 8º18'W) during 3 years of a dairy systems study. In the study, 3 treatments were established: Treatment A was pasture only and Treatment B was a pasture plus corn+rye (*Zea mays* L.+ *Secale cereale* L.) for silage. Both Treatments A and B had an overall stocking rate of 2.5 cows ha^{-1}. Treatment C was also a pasture plus corn+rye silage system, but the overall stocking rate was 3 cows ha^{-1}. Due to the different overall stocking rates and land area allocated for grazing vs. corn+rye or forage-based silage production, the effective stocking densities for the pasture component of each treatment differed during the year and are shown in Table 1. The average stocking density for the grazing component of the treatments was 3.7, 4.6, and 5.5 cows ha^{-1} for A, B, and C, respectively. The effect of the 3 stocking rates on animal production and on pasture production had been evaluated by Mosquera and González (1998, 1999).

Table 1. Stocking rates (cow ha^{-1}) for each treatment and period pre-flowering (pre), post flowering (post) and autumn for 1989, 1990, and 1991.

		Treatment A	B	C
		- - - - - (cows ha^{-1})		- - - - -
1989	pre	4.93	5.00	5.55
	post	4.32	4.58	5.74
	autumn	2.47	4.17	5.65
1990	pre	4.93	5.00	5.55
	post	2.87	4.56	5.72
	autumn	2.73	4.72	5.65
1991	pre	4.93	5.00	5.55
	post	2.78	3.92	5.09
	autumn	3.57	4.69	5.47

The total area for the systems studied was 8.1, 8.0, and 6.7 ha for treatments A, B, and C, respectively. Each treatment was grazed with Friesian breed dairy cows with live weights of approximately 500 kg.

For all treatments, the pasture area was sown with a mixture of 22 kg ha^{-1} perennial ryegrass cv. Brigantia and 4 kg ha^{-1} white clover cv. Huia. On average, the swards were 5 years old and they contained about 60% sown species (mostly perennial ryegrass) at the start of the experiment.

Grazing management

Cows were rotationally grazed across paddocks from March until the forage supply was limited by drought. The average number of grazing days per paddock was around 1.9 and the average regrowth period was 25 days. Areas reserved for grass silage production were all cut before flowering (15 May) and then integrated into the grazing cycle if necessary in the autumn. During the summer, cows were usually fed silage until autumn growth provided enough herbage to graze. Cows resumed grazing in the autumn after sufficient herbage mass had accumulated after the summer drought and continued grazing until herbage production was limited by cold temperatures.

While grazing, cows were offered a similar daily herbage allowance (around 15 kg cow^{-1} day^{-1}). This was achieved by changing regrowth period and grazing days.

Measurements

In each paddock, 5 random samples of available herbage were taken just before grazing (0.33 x 0.33 m area cut to 2.5 cm above ground level). Samples were taken every time that cows were moved into a paddock in each rotation. Samples were stored at 4ºC until processing (never more than 5 days). Samples were dried (70ºC for 24 hours) and weighed. Acid detergent fiber was determined by the method of Goering and Van Soest (1970). A micro-Kjeldahl digestion technique, modified auto-analyzer, was used to determine simultaneously total N (%) and P (%) concentration (Castro et al., 1990). Calcium (%), K (%,) and Mg (%) were determined by atomic absorption spectrophotometry by using a Perkin-Elmer 460 spectrophotometer. The relationships Ca/P (%) and K/(Ca+Mg)(meq/meq) were calculated.

To determine botanical composition, in 1990 and 1991, a 100 g subsample of fresh herbage was collected from each paddock just before grazing by cutting five, 1 m^2 areas to 2.5 cm above ground level. Subsamples of 100 g were taken at random and species were hand-separated, dried (70ºC for 24 hours) and weighed individually for estimating composition based on dry weight. Tiller density was determined in 1991 by taking forty, 5-cm diameter cores from each grass paddock just before grazing to measure tiller population densi-

Table 2. Percentage of sown *Lolium perenne* L. and *Trifolium* sp., dead matter (dead) and volunteer species in spring (before flowering), summer (after flowering) and autumn in 1990 and 1991 in each treatment.

Species	Treatment A	B	C	Sig.	Period Spring	Summer	Autumn	Sig.
	- - - - - - - - - - - - - - - - - - -	(%)	- - - - - - - - - - - - - - - - - - -		- - - - - - - - - - - - - - - -	(%)	- - - - - - - - - - - - - - -	
1990:								
Sown	27.37±21.8	32.09±13.7	34.84±13.8	ns	48.85a±3.6	28.22b±9.6	17.23b±4.4	**
Lolium perenne	26.04±20.8	30.27±12.2	32.77±12.8	ns	46.03a±4.0	26.25b±9.0	16.81b±4.1	*
Trifolium sp	1.32±1.1	1.82± 1.5	2.06± 1.0	ns	2.82a±0.4	1.97b±0.5	0.42c±0.3	**
Volunteer	63.11±15.0	58.91±12.1	57.87±9.9	ns	49.81b±3.0	57.25a±9.7	72.83a±3.8	*
Dead Material	9.51±8.3	8.99±6.9	7.29±5.1	ns	1.33a±0.6	14.52b±3.4	9.94b±0.8	***
1991:								
Sown	23.35±8.2	27.55±2.6	30.49±3.4	ns	29.03±5.8	24.12±7.6	28.24±3.3	ns
L olium perenne	19.55±5.5	25.31±3.2	26.39±5.5	ns	27.22±5.5	22.41±7.1	21.62±1.6	ns
Trifolium sp	3.80±3.5	2.24±0.8	4.10±2.1	bs	1.81a±0.4	2.50b±0.9	5.83b±2.4	*
Volunteer	72.18±10.2	69.87±2.4	67.07±3.0	ns	69.26 ±5.6	71.98±7.4	67.88±6.2	ns
Dead material	4.46±2.6	2.58±1.8	2.43±0.7	ns	1.70±0.4	3.89±0.7	3.87±2.9	ns

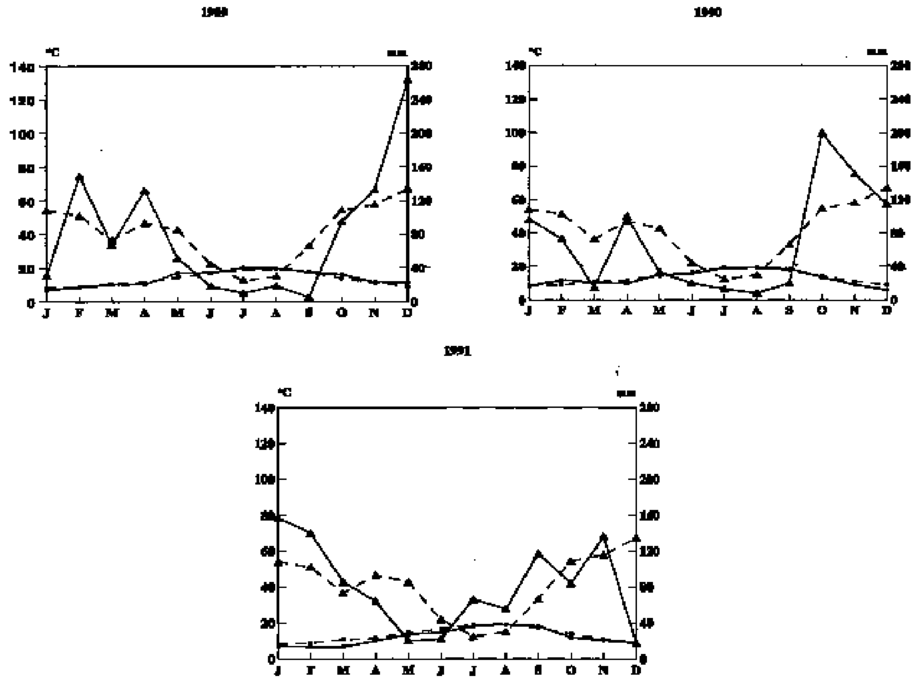

Fig. 1. Monthly rainfall (mm) and average temperatures (°C) for each studied year (continuous line and monthly rainfall mean of the last 20 years (1978–1998) and average temperature of the last 12 years (1986–1998) (discontinuous line).

ty in each treatment. Visual estimations of dead matter and bare ground were made on each core as were tillers (every shoot and root was one tiller).

The treatment and period effect on botanical composition, tiller density, ADF, CP, and mineral content of pasture were statistically analyzed with a two-way ANOVA. Treatment was considered as random factor and period as fixed factor as described in Little and Hills (1987) and Stockdale and King (1980). Three periods were established: before and after flowering (date of flowering is considered to be on 10 May) and autumn (starting on 10 October). Means were separated by using L.S.D. test.

Results

Climatic conditions

Monthly rainfall and average temperatures for each year are presented in Figure 1. Herbage growth was usually restricted by dry conditions from July to October. In 1991, there was a dry period between May and June and an unusually wet summer (mainly July and August).

Table 3. Sward density of different species in each treatment during 1991 (tillers m^{-2})

Species	Treatment A	Treatment B	Treatment C	Sig.
Total	8198a±1329	13735b±7086	16974b±11677	*
Sown:				
Lolium perenne	1755± 441	2433±1437	2221±1159	ns
Trifolium repens	180± 00	1210± 300	766± 680	ns
Total	1955± 484	3643±2379	2977± 495	ns
Volunteer:				
Plantago lanceolata	944± 196	996± 530	1277± 785	ns
Holcus lanatus	2016±1602	2124±1375	2079±1452	ns
Agristus tebyus	2968± 878	2989± 545	2402±1046	ns
Dactylis glomerata	204± 142	203± 251	153± 21	ns
Bellis perennis	62± 21	200± 40	4088±6851	ns
Poa sp	465± 388	2674±3696	1277±1404	ns
Geranium molle	24± 10	131b± 143	1877±3242	ns
Total	6242a± 846	10091b±4728	13997b±11500	*
Dead matter (%)	8.68 ±2.48	3.21±6.66	8.68±4.96	ns
Bare soil (%)	49 ±7.27	55 ±21.6	38 ±3.83	ns

ns:not significant; *:p<0.05

Botanical composition

Percentages of volunteer and sown species in each treatment and period are presented in Table 2. The percentages of sown and volunteer species were not significantly affected by the stocking density, but there was a tendency towards a higher percentage of sown species at the 2 higher stocking densities in 1990 and 1991.

In 1990, the percentage of volunteer species was higher in the summer and autumn than in spring, and the amount of dead material was lower in the spring. However, no differences were found for these parameters in 1991. White clover content was lower in autumn in 1990, compared to autumn 1991. In that year white clover content was higher in autumn than the other seasons. These results could be explained by the wet summer in 1991, which permitted the recovery of white clover plants along whith a lesser amount of dead tissue. Perennial ryegrass was significantly lower in summer and autumn in 1990 but did not vary due to season in 1991.

Tiller density is shown in Table 3. Increased stocking density increased tiller density of the sward. Total tiller density of Treatment C was double that of Treatment A. The effect of stocking density was more pronounced for volunteer than sown species.

Of the volunteer species, *Agrostis tenuis* Sibth., *Poa pratensis* L., *Holcus lanatus* L., and *Plantago lanceolata* L. comprised about 67, 63, and 41% of total volunteer species in Treatments A, B, and C, respectively. Density of these individual species was not affected by the treatment. Increased plant density at the higher stocking density was due to the increased presence of *Bellis perennis* L. and *Geranium molle* L., which represented 30 and 12%, respectively, of the volunteer species in Treatment C. These species were present at only low numbers in the other treatments.

The density per grazing period is shown in Table 4. Densities of both volunteer and sown species were generally higher before flowering than for the other 2 periods although this varied among species.

Numbers of tillers m^{-2} of perennial ryegrass, white clover, *H. lanatus*, and *P. pratensis* were lower in autumn and summer than in spring. However, *P. lanceolata* had a higher percentage of tillers in autumn than in the summer or spring.

Species percentages obtained by weighing differed from that found by counting the number of tillers. Based on tiller numbers, the total volunteer species percentage was higher (82%) at the high stocking density (Treatment C) than in Treatments A (76%) or B (73%). However based on

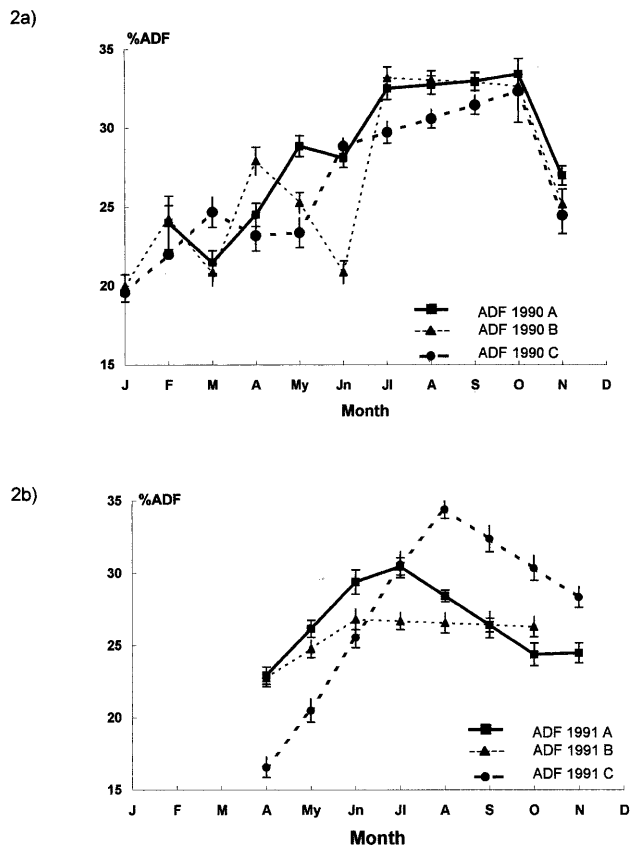

Fig. 2. Seasonal distribution of ADF for the treatments A, B, and C, in 1990 and 1991.

weight, percentage of volunteer species was lower in Treatment C (59%) than either Treatment A (73%) or B (71%). This was because, although more numerous, the prostrate growth habit of the volunteer species made very little contribution to herbage mass.

Protein, ADF, and mineral composition of pasture

Two year average for sward CP, ADF, and mineral concentration and ratios for the three stocking density treatments and pre-flowering, post-flowering, and autumn periods are shown in Table 5. Acid detergent fiber was not affected by the increase of stocking density and averaged 26%. Seasonal variation in ADF for 1990 and 1991 for each stocking density is presented in Figure 2a and 2b. Information from 1989 was omitted because it was very similar to 1990. Both years, ADF was lowest in the spring before flowering and highest in the summer.

Crude protein (Table 5) concentration was lowest at the lowest stocking density, Treatment A. But, because forage availability was 68 and 211 kg ha^{-1} more in 1990 and 1991, respectively, on treatment A than on treatments B and C, the kilograms of protein offered to cows were similar for all 3 treatments (244.14, 246.02, and 247.30 kg ha^{-1} for Treatments A, B, and C, respectively). Seasonal variation in CP concentration was similar for all treatments (Fig. 3a and 3b), starting off high in the spring, declining in the summer with a minimum around August, and increased again in the autumn. Average CP concentration in the summer of 1991 was higher (13%) than in 1989 or 1990 (10%) because of the wetter growing conditions that summer which promoted growth.

Average P and K concentrations increased with increasing stocking density (Table 5). Similar to CP levels, P and K were also high in the spring, decreased in the summer, and increased in the autumn (Fig. 4a, 4b, 5a, and 5b). Also similar to CP, P, and K levels were higher during the summer in 1991 compared to 1990 due to the better growing conditions that year.

Concentration of Mg was highest at the high stocking density (Table 5). Unlike P and K, levels of Mg were highest in the fall and lower during the spring, but the variation during the year was small (Fig. 6a and 6b).

Calcium concentration was lower at the intermediate stocking density (Table 5). The lowest value of Ca was in the spring (Fig. 7a and 7b).

The Ca/P ratio increased as stocking density declined (Table 5) and was lowest in the spring (Fig. 8a and 8b). It was highest in the summer mainly due to declines in P concentration during this period. The K/(Ca+Mg) relationship did not show significant differences among treatments (Table 5). There was a seasonal effect on the K/(Ca+Mg) ratio, which was higher in the spring and lower in the summer (Fig. 9a and 9b).

Discussion and Conclusions

Seasonal variation in tiller density was similar to the pattern described by Tallowin (1981) for areas with wet summers. It was

Table 4. Sward density (tillers m^{-2}) in spring (before flowering), summer (after flowering) and autumn in 1991.

Species	Species			
	Spring	Summer	C	Sig.
	---------------------------(Tillers m^{-2}) ---------------------------			
Total	2058a±10485	10067b ±1673	8254b±1297	**
Sown:				
Lolium perenne	2907a± 771	2502a ± 542	1010b± 242	*
Trifolium repens	1046 ± 1321	283 ± 194	827 ± 686	ns
Total	3954a± 2036	2785ab± 730	183b± 508	ns
Volunteer:				
Plantago lanceolata	923ab± 110	651a ± 159	1595b± 509	*
Holcus lanatus	3207a ± 122	2678b ± 146	434c± 226	***
Dactylis glomerata	340 ± 164	123 ± 24	96 ± 72	ns
Agrostis sp	1659 ± 753	2801 ± 782	3011 ± 180	ns
Bellis sp	4075 ± 6862	119 ± 47	156 ± 96	ns
Poa sp	3567a ± 3085	573b ± 192	275b± 187	*
Geranium molle	1918 ± 3207	103 ± 160	10 ± 10	ns
Total	16631a±10122	7281b ± 979	6417b± 866	*
Dead matter (%)	13.33a± 2.42	12.15a ±5.34	5.07b± 1.26	*
Bare soil (%)	53.67±23.0	44.51 ±3.91	44.42 ±11.21	ns

ns:not significant; *:p<0.05; **:p<0.01; *** p<0.001

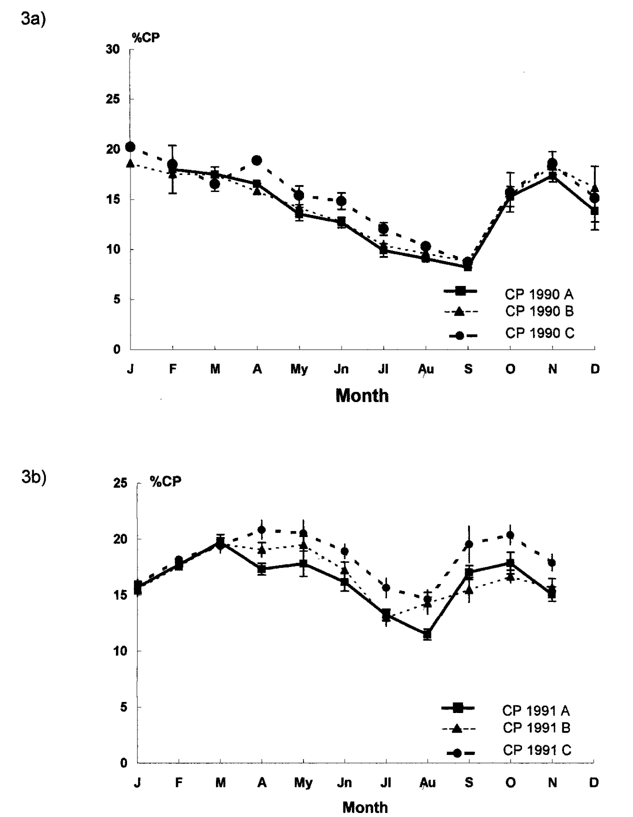

Fig. 3. Seasonal distribution of crude protein (CP) for the treatments A, B, and C, in 1990 and 1991.

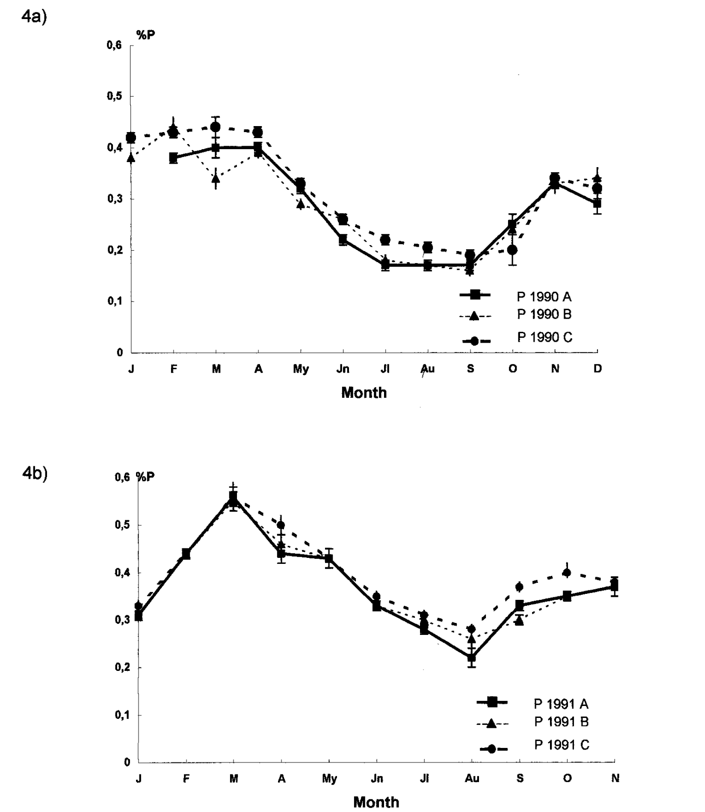

Fig. 4. Seasonal distribution of P for the treatments A, B, and C, in 1990 and 1991.

high in the spring and decreased in the summer and autumn. Patterns in seasonal variation in tiller density depend on species present (Hume and Lucas 1987, Garwood 1969, Takasaki et al. 1989). The majority of the species present in our study had their highest tiller density in spring (*L. perenne, T. repens, H. lanatus, D. glomerata, B. perenne, P. annua and G. molle*). Although others, such as *P. lanceolata*, were higher in the fall.

Similar to that described by previous authors (Curll and Wilkins 1985, Baker and Leaver 1986, Hunt 1989, Tallowin 1981, L' Huillier 1987, Xia et al. 1990), increasing stocking density resulted in increased tiller density.

Reductions in ADF values as stocking density increased in this study are similar to what has been found in other studies (Stockdale and King 1980, Freer 1960, Gordon 1973, Castle et al. 1968, Mayne et al. 1987, Kristensen 1988, Rugambwa et al.1990). This was a function of reduced flowering and lowering of the stem to green leaf ratio in the herbage (Munro and Walters 1985, Holmes 1989, Mott 1983).

Little dead material was accumulated in any season and treatment in this experiment due to the relatively high grazing intensity found at all stocking density treatments. This accounts for the similar ADF values for stocking density treatments.

Seasonal variation in ADF is dependent on the development state of pasture species. Generally, as plants mature ADF increases (Minson 1982, Demarquilly 1989, Holmes 1987, Munro and Walters 1985, Corral 1974, Valdés et al. 1991). This accounts for the higher ADF values after flowering.

Protein content found was within the typical range for temperate-type grassland vegetation (Demarquilly 1989). Crude protein levels increased as stocking densi-

Table 5. Acid detergent fiber (ADF), crude protein (CP), calcium (Ca), potassium (K) and magnesium (Mg) pasture content average and relationships Ca/P (%) and K/(Ca + Mg) (miliequivalents/milliequivalents) of 3 years in each treatment and period (1:before flowering, 2:after flowering and 3:autumn) with their standard deviation.

Variable	Treatment			Sig.	Period			Sig.
	A	B	C		1	2	3	
	(%)				(%)			
ADF	26.26 ±3.84	26.13±3.97	25.64±4.59	ns	23.05b±2.69	28.28a±4.09	27.16a±3.30	***
CP	14.99b±3.82	15.66b±4.03	17.44a±4.75	***	18.38a±3.40	14.47b±4.09	17.89a±4.08	***
P	0.32b±0.10	0.32b±0.10	0.35a±0.10	***	0.44a±0.09	0.28b±0.08	0.33c±0.06	***
Ca	0.98a±0.31	0.92b±0.29	0.96ab±0.30	*	0.90a±0.32	0.92a±0.25	1.06b±0.34	***
K	2.23b±0.74	2.31b±0.82	2.51a±0.81	***	2.79a±0.75	2.07b±0.77	2.49c±0.76	***
Mg	0.17b±0.05	0.17b±0.04	0.18a±0.04	**	0.17b±0.03	0.18a±0.04	0.19a±0.05	***
Ca/P	3.49a±1.65	3.17b±1.51	2.90c±2.96	***	2.16a±0.88	3.59b±1.51	3.33c±1.26	***
K/(Ca+Mg)	0.98 ±0.47	1.03±0.45	1.08±0.47	ns	1.33a±0.55	0.91b±0.38	0.99c±0.39	***

Sig: significance; ns:not significant; *:p<0.05; **:p<0.01; *** p<0.001

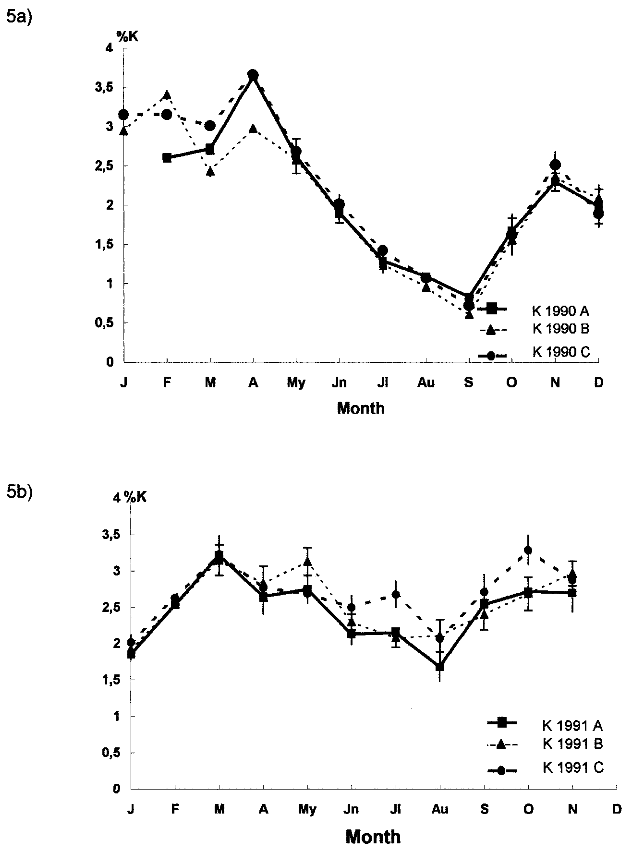

Fig. 5. Seasonal distribution of K for the treatments A, B, and C, in 1990 and 1991.

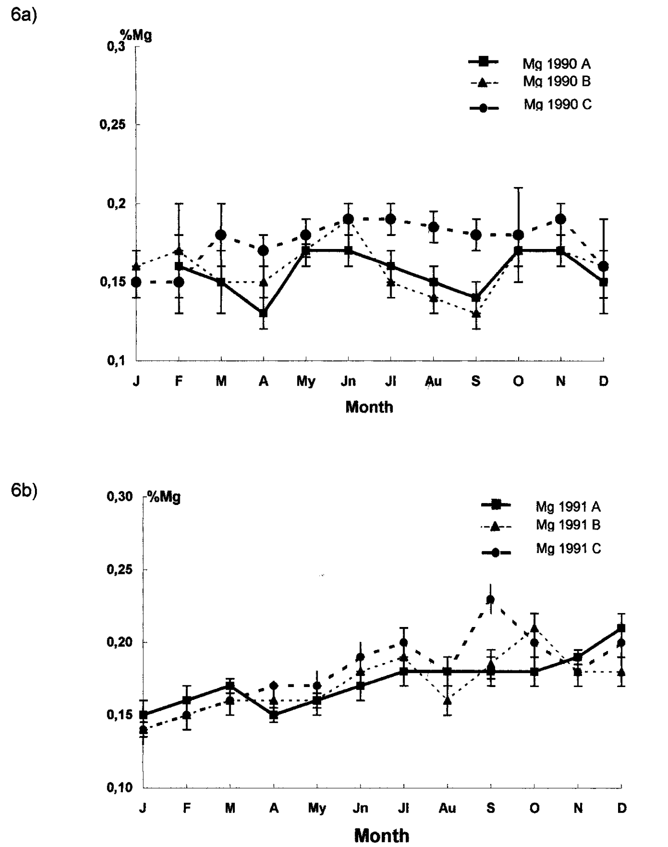

Fig. 6. Seasonal distribution of Mg for the treatments A, B, and C, in 1990 and 1991.

ty increased. Short re-growth intervals and high grazing intensity, that is to say high stocking density, increase the protein content in the pastures, because flowering is reduced. This increases the leaf to stem ratio in herbage (Stockdale and King 1980, Overman and Wilkinson 1990, Castle et al. 1968). Since the protein content of leaves is greater than that in stem (Norton 1982, Demarquilly 1989), average protein content of the forage increases. However, the protein offered to cows did not differ among treatments, because Treatment A had higher amounts of forage on offer than Treatments B or C.

Crude protein levels were highest in spring and lowest in summer because post-flowering plants had less protein content than pre-flowering plants (Munro and Walters 1985, Metson and Saunders 1978b, Roberts 1987, Stehr and Kirchgessner 1976).

Herbage mineral content found was within the typical range for temperate type grassland vegetation (Grace 1983a, 1983b, 1983c, Pickard 1986), and mineral levels of grassland were always above the minimum limits recommended for dairy cows (NRC 1989, ARC 1991). Increasing stock-

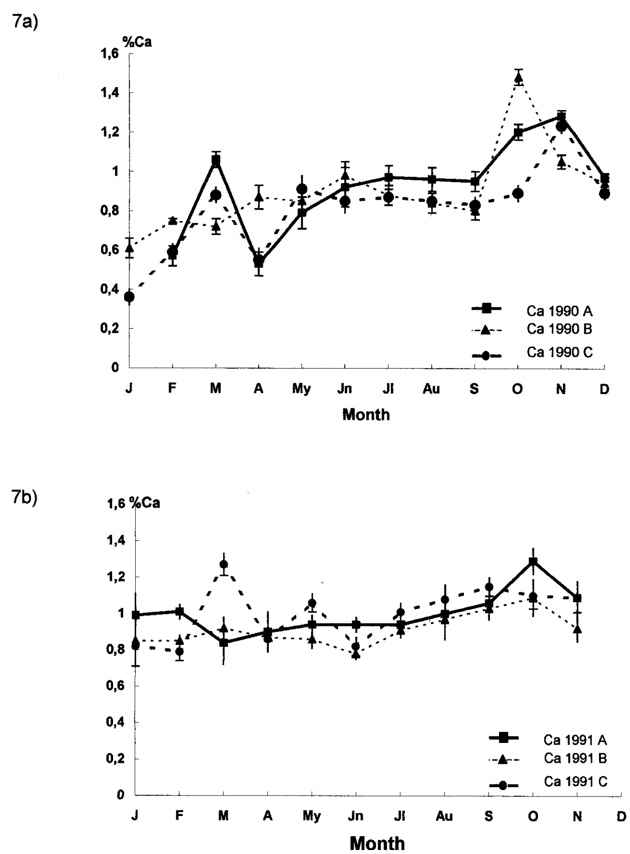

Fig. 7. Seasonal distribution of Ca for the treatments A, B, and C, in 1990 and 1991.

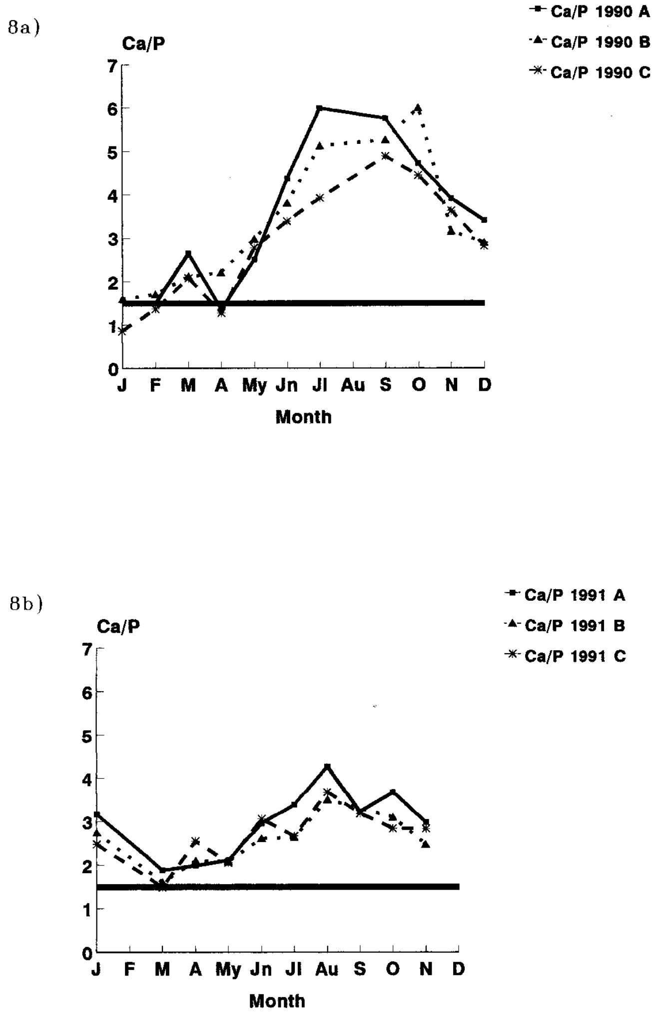

Fig. 8. Seasonal distribution of Ca/P for the treatments A, B, and C, in 1990 and 1991. Solid line indicates adequate value for animal intake described by Grunes and Allaway (1985).

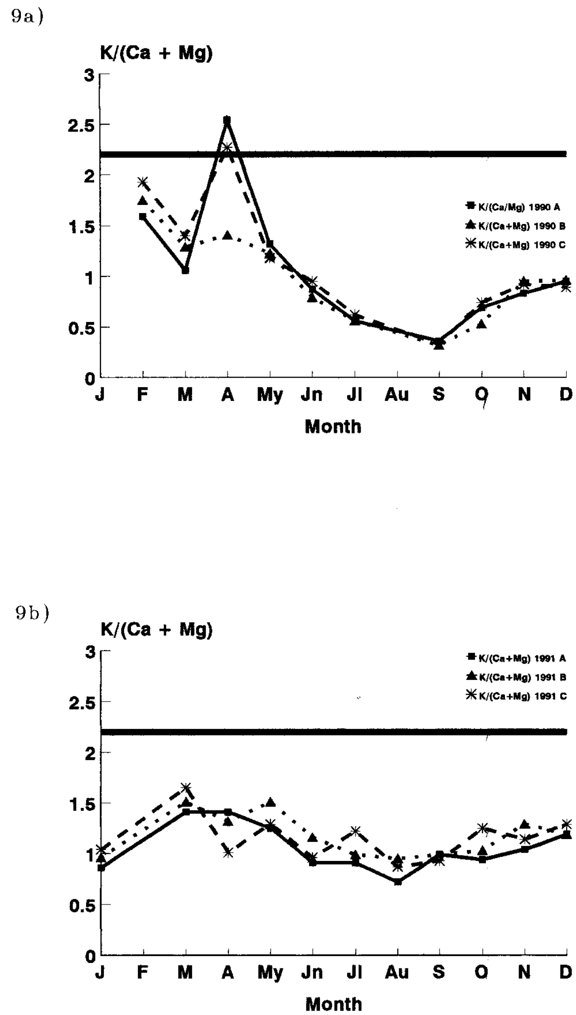

Fig. 9. Seasonal distribution of K/(Ca+Mg) for the treatments A, B, and C, in 1990 and 1991.

ing density did increase the mineral content of pasture, because as for ADF and CP, development stage and age of pasture species affects mineral content of the herbage. More intensive management as higher stocking rates also introduced more quantity of nitrogen and mineral elements (eg. potassium) in the soil mainly through faeces, which ususally increase soil contamination and recycling of nutrients. In the present experiment, P and K concentration decreased during the spring period as the plants approached flowering, as found by Andrieu et al. (1989), Norton (1982), Stockdale and King (1980) and Roberts (1987). In the summer P and K concentration were lower than in the other periods due to high temperatures and low rainfall which originated no leafy pasture and therefore an old pasture as found (Willman et al. 1994).

Magnesium and Ca varied little during the year as described by Roberts (1987), Metson and Saunders (1978a) and Golob and Cop (1990). Although, Mg and Ca levels were significantly lower in the spring than in the autumn.

Older recommendations indicate that the Ca/P for grazing animals should be around 1.5 and within a range of 1–2 (Grunes and Allaway 1985, Gallego 1986). In the present experiment, the upper limit was exceeded throughout the year but no osteomalacia found (Grunes and Allaway 1985). The latest A.R.C. review ARC (1991) said that concerns with upper limits were incorrect, because ruminants tolerate a great variation of Ca/P ratios.

The K/(Ca+Mg) ratio is indicative of pasture tetany. If this ratio is higher than 2.2, problems of hypomagnesemia could appear (Kemp and T´Hart 1957, Butler 1963, Metson et al. 1966). In the present experiment, most of the time this relationship was not exceeded except in the spring of 1990, but no case of hypomagnesemia was found. This was probably because the animals were being fed concentrates (2.5 kg cow day^{-1}) during the spring.

Previous small plot studies carried out in Galicia indicated that the K/(Ca+Mg) ratio was always below 1.5 (Garcia et al. 1986) and that hypomagnesemia should not be a problem. Later surveys of dairy pastures showed that this recommended value could be exceeded during the spring, but that the feeding of concentrates rich in magnesium would be sufficient to correct the imbalance in the animals diet.

In our experiment (with medium level of soil fertility), stocking density had an important effect on tiller density but did not affect the botanical composition of the pastures. Higher stocking density increased the chemical quality of herbage. The Ca/P relationship was not a good indicator of osteomalacia, because even when the recommended values were exceeded no problems occurred. It was possible to prevent hypomagnesemia problems by feeding Mg rich concentrates to the cows during the spring.

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