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Effects of cattle grazing on herbage quality in a herbaceous Mediterranean rangeland

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Abstract

The main objective of this study was to determine to what extent grazing pressure and timing modulate the seasonal progression of herbage quality in hilly Mediterranean grassland systems. The study was conducted during six consecutive years between 2003 and 2008 at the Karei Deshe experimental farm, in eastern Galilee, Israel, dominated by rich hemicryptophytic grassland. Treatments included two different grazing intensities, heavy and moderate, with 1·1 and 0·55 cows ha^{-1}, respectively, and management that included a continuous and a seasonal stocking system that was divided at both intensities into early and late grazing. Herbage samples were analysed for digestibility, crude protein, neutral detergent fibre and acid detergent fibre contents. Significant differences in herbage quality were found between seasons and years. Herbage quality was significantly higher in paddocks grazed continuously or early in the season. Herbage quality increased with increasing grazing intensity as younger herbage and continued re-growth were maintained during the green season. The greater difference between herbage qualities was found at the peak of the growing season. The significant differences found in herbage quality emphasize the importance of the decision-making process aimed at improving cattle grazing management in Mediterranean rangelands and its consequences for the sustainability of the system.

Keywords: acid detergent fibre, digestibility, grazing system, neutral detergent fibre, near-infrared reflectance spectroscopy, protein, stocking rate

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Introduction

The nutritional value of herbage plays an important role in cattle productivity and is an important consideration in the design and implementation of grazing systems (Briske *et al.*, 2008). Diet quality and herbage availability directly affect the selection of feeding areas (Hirata *et al.*, 2008; Ganskopp and Bohnert, 2009) and animal condition. Long-term grazing history was found to be important, while past grazing interacts with current grazing treatment in determining nitrogen and energy availability to consumers (Milchunas *et al.*, 1995). Large increases in liveweight gain were demonstrated in oversown pastures compared with native pastures (Ash and McIvor, 1998). In addition, it was shown that cows that grazed on high-quality pastures consumed significantly more dry matter than cows that grazed on low-quality pastures; they gained more weight and weaned heavier calves (Holloway *et al.*, 1979).

Rainfall seasonality in relation to temperature has a strong modifying effect on plant growth dynamics (Noy-Meir, 1973). Mediterranean ecosystems are distinguished by high seasonality in resource availability (Sternberg *et al.*, 2000).This implies that free-grazing beef cattle may face a reduction in the nutritional quality of forage because of its chemical ingredients, digestibility and metabolized energy during the hot and dry season characteristics of Mediterranean grasslands (Aharoni *et al.*, 2004; Brosh *et al.*, 2004, 2006a). As a

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result, cows spend less time grazing during summer, when herbage is dry and its quality is low, in comparison with winter and spring (Brosh *et al.*, 2006b; Henkin *et al.*, 2007). High stocking rates may also affect forage quality and biomass production (Gutman *et al.*, 1990, 1999). Low quality of the pasture during the hot and dry season and low availability, at high stocking rates, may have a negative impact on animal health. Low-protein availability can decrease energy expenditure, increase stress and cause a variety of metabolic disturbances, impair the immune system (Langley-Evans *et al.*, 1994, 1997) and restrict offspring growth (Dahri *et al.*, 1991).

Herbage quality in rangelands varies for different reasons and is influenced by the length of both grazing periods and rest periods between subsequent grazing events (Briske *et al.*, 2008). Studies that evaluated the effects of cutting treatments on the nutritive value of herbage showed that defoliation produced forage of relatively good and higher quality (Donkor *et al.*, 2003; De Santis *et al.*, 2004). But as plants mature and total forage dry matter accumulates, a reduction is found in the leaf/stem ratio and consequently a reduction in herbage quality (Nelson *et al.*, 1989). The timing of grazing can also influence quality, as early grazing may be important to maintain younger herbage of relatively high quality. Different studies compared the nutrient intake of cattle and the quantity of available forage under continuous and rotational grazing treatments. Heitschmidt *et al.* (1987) found that crude protein concentration and organic matter digestibility were generally greater in the rotational grazing system, but according to Mckown *et al.* (1991), differences between treatments were attributed primarily to differences in stocking rate rather than the grazing system. Wang *et al.* (2009), who compared herbage biomass, organic matter digestibility and intake and liveweight gain of sheep between rotational and continuous grazing systems in an Inner Mongolian steppe, found that organic matter digestibility increased during continuous grazing.

Optimizing for higher performance of animal production and for rangeland sustainability is a crucial goal in grazing management. Herbage quality is one of the most important parameters in evaluating this action. The aim of this research was to determine to what extent grazing pressure and timing modulate the seasonal progression of herbage quality in hilly Mediterranean grassland systems in order to improve cattle management.

Materials and methods

Study site and experimental design

The study was conducted at the Karei Deshe experimental farm, located in the eastern Galilee in the north-east of Israel (long. 35°35′E; lat. 32°55′N; altitude 60–250 m a.s.l.) (Gutman *et al.*, 1990, 1999). The topography is hilly, with slopes generally <20° (Seligman *et al.*, 1989) covered with basaltic rocks with an average cover of 30% (Gutman and Seligman, 1979). The soil is a fertile brown basaltic protogrumosol of variable depth, but seldom deeper than 60 cm. The area has a Mediterranean climate, characterized by wet, mild winters with mean minimum and maximum temperatures of 7 and 14°C, respectively, and hot, dry summers with mean minimum and maximum temperatures of 19 and 32°C respectively. The long-term (47 years) average seasonal rainfall is 558 mm, falling mostly in winter and with very high variability among years and months (Figure 1a and b). The rainy season begins in October–November and ends in April. As a result, the vegetation is green between November and April, but during May, most plants dry out and remain so until the next rainy season. The vegetation is a rich hemicryptophytic grassland (Zohary, 1973) dominated by *Hordeum bulbosum* L., *Echinops* spp., *Bituminaria bituminosa* L. and many annual species (Sternberg *et al.*, 2000).

The study took place in twelve paddocks. Treatments comprised a high (1·1 cow ha^{-1}) and moderate (0·5 cow ha^{-1}) stocking rates and two grazing management protocols: continuous stocking (C) (four paddocks of 21–31 ha each) and seasonal stocking, which included an early season period (E) and a late season period (L) (eight paddocks of 11–21 ha each), with two replicates for each of the treatments. These treatments have been maintained without change since 1994. The paddocks were stocked with mature, medium-frame-size cows, Simford (Simmental × Hereford) crossbreds, with about 20% blood from local eastern Mediterranean breeds and with an average body weight of 432 ± 15 kg at calf weaning. The average weaning rate during the 6-year study was 75%, and the weaned calf production at the high and moderate stocking rates was 83 and 40 kg ha^{-1} respectively. In a previous study, dry-matter intake was determined for each cow during March, May and June (Aharoni *et al.*, 2004). It was found that during March, while cows were suckling calves, dry-matter intake was 15 kg d^{-1}, but during May and June, it was reduced to 12 and 10 kg d^{-1} respectively.

In the continuous and early season protocol, the cattle were introduced to the range in mid-January, when the standing biomass exceeded 600 kg DM ha^{-1}. Grazing was deferred at the beginning of the growing season to allow the herbage to reach a threshold beyond which the rate of new plant growth is substantially greater than the rate of biomass consumption by the grazing livestock (Noy-Meir, 1975). The early period of high stocking rate protocol continued till mid-March and the early moderate stocking rate treatment till mid-May. The late-season grazing period began (in separate paddocks) when the early-season grazing period ended.

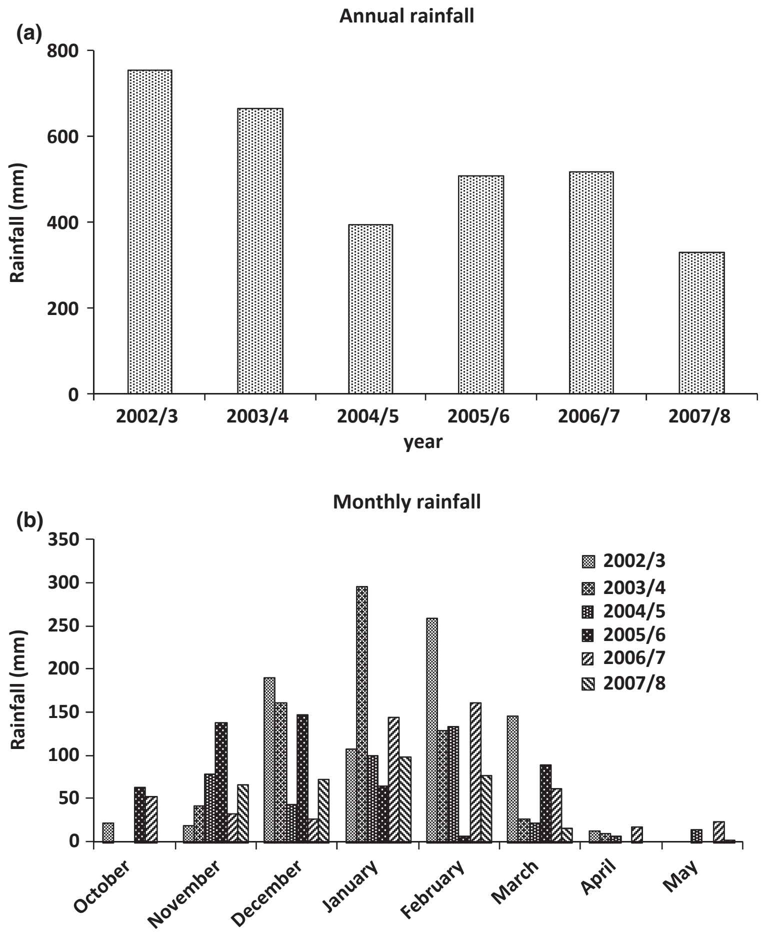

Figure 1 Annual (a) and monthly (b) rainfall during the study period of 2003–2008 in the Karei Deshe experimental farm.

All paddocks were grazed during 2003–2008 until August at the high stocking rate and until November at the moderate stocking rate. The grazing period in the paddocks ended when the standing herbaceous biomass dropped below 600 kg DM ha^{-1}.

Vegetation sampling and analysis

Sampling took place every year between 2003 and 2008 (6 years) at four different periods (seasons): (i) winter – at the beginning of grazing (January–February), (ii) spring – at the peak of vegetation growth (April), (iii) early summer (June) and (iv) end of summer (August–September). Quadrats of 25 cm × 25 cm were randomly placed along permanent transects that crossed all different paddocks, and all above-ground herbaceous standing biomass was harvested. Twenty samples were harvested in each paddock at each of the seasons, totalling 960 samples for each year of the study. The harvested plant material was oven-dried at 65°C and weighed. For each season of each year, samples from each paddock were pooled into three replicates ground to pass a 1-mm sieve and analysed by NIRS for *in vitro* DM digestibility, crude protein (CP; N × 6·25), neutral detergent fibre (NDF) and acid detergent fibre (ADF) contents. The establishment of NIRS procedures used at Agricultural Research Organization has been previously described (see Landau *et al.*, 2004, 2006).

NIRS procedures

As near-infrared spectrometry (NIRS) is an accurate methodology (Landau *et al.*, 2004) and greatly reduces the cost of the chemical analysis of large numbers of pasture samples, we used this methodology.

Reference values

NIRS equations were established with approximately 180 herbage samples from all seasons and relevant ecosystems collected in previous years. To provide reference values for the NIRS calibrations of vegetation chemistry, we used the AOAC (1995) procedure no. 989·03, in which NDF and ADF were assayed according to Goering and Van Soest (1970). Crude protein was assayed by using the automated Kjeldahl method (976·05; AOAC, 1990). The *in vitro* dry-matter digestibility of (IVDMD) was evaluated according to Tilley and Terry (1963). Calibration precision was evaluated according to the multiple coefficient of the determination of calibration (R^2_{cal}), i.e. the proportion of variability in the reference data accounted by the regression equation. The standard error of calibration defined the variability in the differences between predicted and reference values. Calibration accuracy was evaluated by cross-validation and expressed as the standard error of cross-validation (SECV). The statistics of NIRS equations performance is provided in Table 1.

NIRS scanning

Approximately 5 g of samples was packed into infrared transparent quartz cover glass cells and scanned at wavelengths from 1104 to 2492 nm in 2-nm increments with a Foss NIRSystems (Hoganas, Sweden) model 5000 NIR reflectance monochromator spectrometer to collect NIR spectra as log (1/R) where R = reflectance. NIRS equations were applied to all spectra, and Mahalanobis distance (H) between each of the samples and the centroid of the calibration population was calculated for each sample (Shenk and Westerhaus, 1991). As H greater than three, in SD units, means that the sample does not belong spectrally to the calibration population, wet chemistry analyses were carried out for these samples.

Statistical analysis

The data were analysed using PROC MIXED of SAS 9.1 (SAS Institute Inc., Cary, NC, USA). For each parameter, the fixed effects in the model were management system, stocking rate and block. The sampling unit, a random factor, was plot within management system, stocking rate and block. Two repeated measures were used – year and season – and Akaike Information Criterion was used for the selection of covariance structures, UN (unstructured) was used for the season covariance, and AR(1) was used for the year covariance by defining TYPE = UN@AR(1) in the REPEATED statement. Pairwise comparisons of means for specific management systems, stocking rates and seasons were performed by contrast t tests, with multiple test correction by the Holm method ($P = 0{\cdot}05$).

Results

Temporal effects

For all herbage quality parameters, the most significant effect was seasonality ($P < 0{\cdot}0001$). For all management systems and stocking rates, quality tended to decrease from winter through spring to early summer, levelling off in late summer (Figure 2). Levels differed over years ($P = 0{\cdot}002$ for NDF, $P < 0{\cdot}0001$ for all other parameters), possibly following differences in seasonal rainfall among years (Figure 1). Although the year × season effect was significant for all parameters ($P < 0{\cdot}0001$), the ranking of values by season remained the same.

Management effects

Standing biomass

In mid-January, when cattle were introduced to the range, no significant difference in standing biomass was found between treatments. But as a result of early grazing, the standing biomass of herbaceous vegetation was significantly lower during spring, at the peak of the growing season ($P < 0{\cdot}0001$), and in early summer ($P = 0{\cdot}049$) compared with the late grazing. The continuous grazing treatment was found to be in between (Figure 2), while differences between continuous and early and late grazing were significant only during spring ($P < 0{\cdot}0001$). In addition, as expected, a higher biomass of herbaceous vegetation was found in the continuous moderate (CM) stocking rate compared

Table 1 Mean, standard deviation (SD), R^2 values and standard errors of calibration (R^2_{cal} and SE_{cal}) and cross-validation (R^2_{val} and SECV) for NIRS analyses of pasture chemical attributes (*in vitro* dry-matter digestibility (IVDMD), crude protein (CP), neutral detergent fibre (NDF) and acid detergent fibre (ADF), %, on dry-matter basis).

Constituents	*N*	Mean	s.d.	SE_{cal}	R^2_{cal}	SECV	R^2_{val}
IVDMD, %	142	62·7	16·7	3·09	0·97	3·66	0·95
CP,%	178	11·6	6·5	0·62	0·99	0·75	0·99
NDF,%	179	56·7	11·0	2·17	0·96	2·44	0·95
ADF,%	182	33·0	7·6	1·44	0·96	1·57	0·96

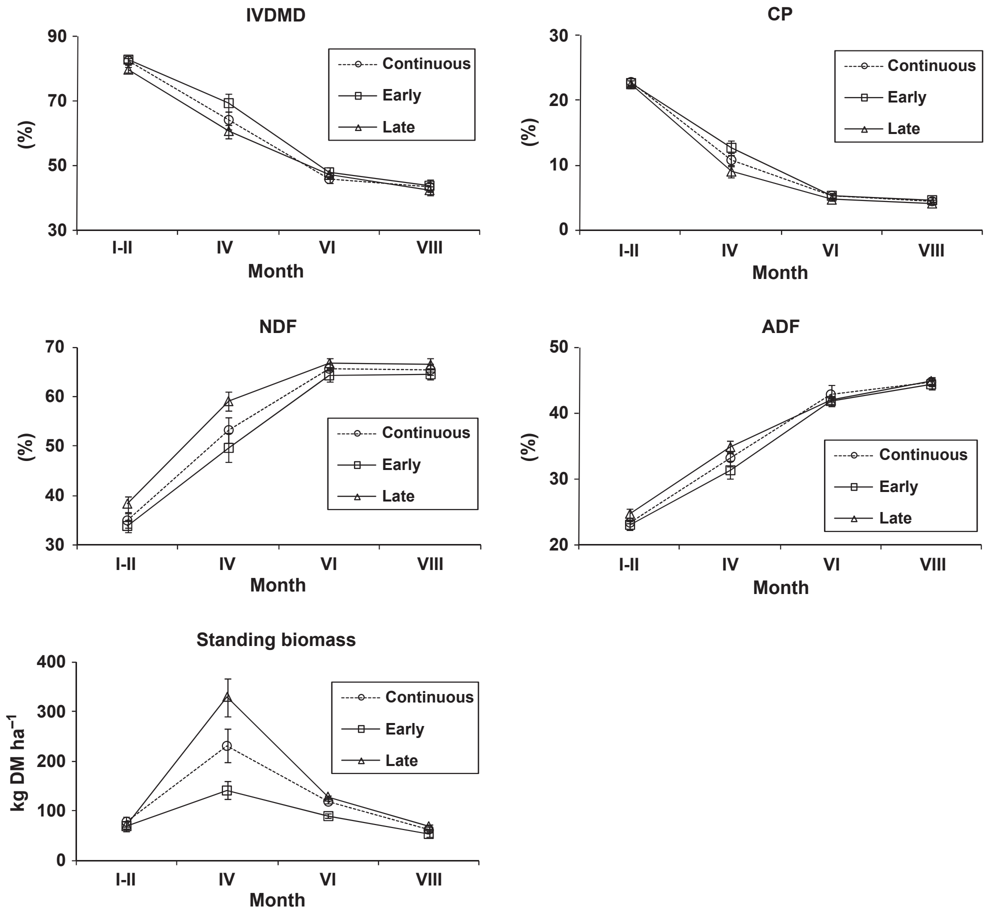

Figure 2 Mean (±s.e. by year) *in vitro* dry-matter digestibility (IVDMD, %), crude protein (CP, % of dry matter), neutral detergent fibre (NDF, % of dry matter) and acid detergent fibre (ADF, % of dry matter) contents and standing biomass of herbaceous vegetation during the grazing season under continuous (C), early (E) and late (L) grazing management systems over the period 2003–2008. (Total 6 year $N = 864$).

with the continuous high (CH) stocking rate (Figure 3). This difference was highly significant during spring and early summer ($P < 0{\cdot}0001$), but also still found in late summer ($P = 0{\cdot}028$).

Digestibility (IVDMD)

Significant interactions were found for management × season ($P = 0{\cdot}0006$), stocking rate × season ($P = 0{\cdot}02$) and management × stocking rate × season ($P = 0{\cdot}02$) (Table 2). During the winter, at the beginning of the grazing season (January–February), digestibility for late grazing was lower than for early or continuous grazing (Figure 2). This finding was significant for the high stocking rate (late vs early, $P = 0{\cdot}006$; late vs continuous, $P = 0{\cdot}004$), but not for the moderate stocking rate. During the spring season, digestibility was again higher for early grazing as compared with late and continuous grazing (early vs late, $P < 0{\cdot}0001$; early vs continuous, $P = 0{\cdot}004$). After the vegetation dried out, its digestibility decreased sharply, and in early and late summer, almost no significant differences were found between the three management systems.

Crude protein

Significant interactions were found for management × season ($P = 0{\cdot}001$) and stocking rate × season ($P = 0{\cdot}0005$, Table 2). During the spring season, CP was higher for early grazing than for late grazing. This finding was significant for the high stocking rate, but not for the moderate stocking rate. Under the continuous grazing regime, values were significantly higher for the high stocking rate as compared with the

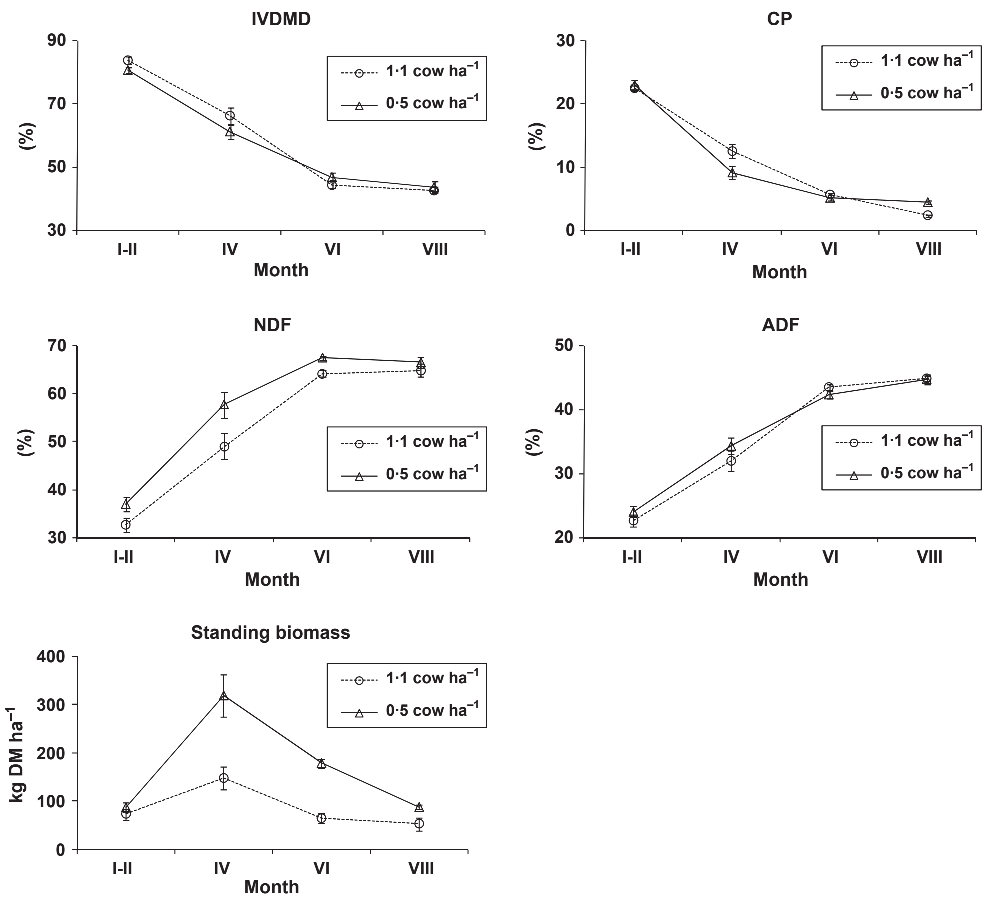

Figure 3 Mean (±s.e. by year) digestibility, crude protein, neutral detergent fibre and acid detergent fibre contents and standing biomass of herbaceous vegetation at four periods during the grazing season under continuous high (1·1 cow ha^{-1}) and moderate (0·5 cow ha^{-1}) stocking rates over the period 2003–2008. (Total 6 year $N = 288$).

moderate one ($P < 0{\cdot}0001$). No differences in CP between the management systems were found during winter, early summer and late summer.

NDF

Overall, NDF was higher for the moderate stocking rate ($P = 0{\cdot}006$) (Figure 2). The management × season interaction was significant ($P < 0{\cdot}0001$, Table 2). During the winter and the spring, NDF was higher for late grazing as compared with early or continuous grazing. In winter, spring and early summer, the finding was significant for the high stocking rate ($P = 0{\cdot}002$, $P < 0{\cdot}0001$ and $P = 0{\cdot}02$ respectively). In early and late summer, NDF was higher for late grazing as compared with early grazing ($P = 0{\cdot}004$ and $P = 0{\cdot}02$ respectively). But no significant difference was found for early and late grazing compared with continuous grazing during both summer periods.

ADF

For this parameter, significant interactions were found for management × season ($P = 0{\cdot}002$) and stocking rate × season ($P = 0{\cdot}05$, Table 2). Similar to NDF, in winter and spring, values were lower for early grazing compared with late grazing. In spring, the difference was significant for the high stocking rate only. No significant differences in ADF between management systems and stocking rates were found in early and late summer.

Discussion

Seasonality and year effect

Typically of all Mediterranean ecosystems, seasonality of rainfall and temperature are the two of the most important factors in determining the variability of vegetation during the year. The length of the growing

Table 2 Differences in herbage quality over the period 2003–2008.

Effect*	Numerator DF	Denominator DF	IVDMD *F* Value	IVDMD *P*	CP *F* Value	CP *P*	NDF *F* Value	NDF *P*	ADF *F* Value	ADF *P*
M	2	5	11·5	0·01	8·8	0·02	25·4	0·002	10·6	0·02
SR	1	5	5·1	0·07	6·0	0·06	21·0	0·006	2·2	0·20
M * SR	2	5	2·5	0·18	0·9	0·45	5·0	0·06	2·8	0·16
Yr	5	138	16·2	<0·0001	11·4	<0·0001	4·1	0·002	12·3	<0·0001
M * Yr	10	138	1·2	0·27	1·7	0·10	2·0	0·04	1·4	0·18
SR * Yr	5	138	0·5	0·77	1·7	0·14	0·5	0·75	0·8	0·56
M * SR * Yr	10	138	0·9	0·50	1·1	0·40	0·9	0·51	0·9	0·54
Season	3	138	1770·4	<0·0001	1272·8	<0·0001	1255·1	<0·0001	1328·4	<0·0001
M * season	6	138	4·2	0·0006	3·9	0·001	5·5	<0·0001	3·7	0·002
SR * season	3	138	3·3	0·02	6·3	0·0005	2·3	0·08	2·6	0·05
M * SR * season	6	138	2·6	0·02	1·4	0·22	1·7	0·13	1·8	0·11
Yr * season	15	138	12·5	<0·0001	7·1	<0·0001	18·3	<0·0001	12·0	<0·0001
M * Yr * season	30	138	1·5	0·07	0·9	0·58	2·7	<0·0001	1·8	0·02
SR * Yr * season	15	138	1·1	0·37	0·6	0·89	1·2	0·29	1·0	0·46
M * SR * Yr * season	30	138	1·2	0·28	0·6	0·94	0·9	0·66	1·3	0·19
Block	1	5	0·7	0·45	0·0	0·95	0·1	0·83	0·5	0·51

*M, Management (continuous, early and late), SR, Stocking rate (High – 1·1 cow ha^{-1} and Moderate – 0·5 cow ha^{-1}), Yr, Year.

season, which differs between years and depends on the timing of the rainfall and the high temperatures followed by dry eastern winds during late spring (Svoray *et al.*, 2008), also contributes to this variability. As a result, the phenological stage of the vegetation which indicates the nutritional values of plant parts differs (Arzani *et al.*, 2004; Aboling *et al.*,2008). Tissue age and type, which are recognized as characteristic of variability of forage quality (Van Soest, 1982; Huston and Pinchak, 1991; Clark *et al.*, 2000), are affected by these irregular conditions and showed significant differences in herbage quality between years. In this study, too, great differences in vegetation quality variables were found between years, but no significant difference was found for the interaction of management × year and stocking rate × year (Table 2). Nevertheless, important changes in species composition and plant functional groups were found between treatments and years, potentially affecting the herbage quality of the range (Aboling *et al.*, 2008).

In the rangelands of the eastern Galilee, Israel, which are dominated by rich hemicryptophytic grassland (Zohary, 1973; Golodets *et al.*, 2010), the length of the green growing season is from 5 to 6 months at the most (Figure 1). The rainy season, which usually begins in November, is followed by germination of annuals and re-growth of perennial herbaceous species (Sternberg *et al.*, 2000). Growth is rather slow during the winter months (December and January), and deferment of the cattle from the main grazing paddocks during this period is common. Mostly, when standing biomass reaches between 700 and 1300 kg DM ha^{-1}, cattle are introduced back into the range (Gutman *et al.*, 1999). At the beginning of the grazing season, when vegetation is young, the quality of the herbage according to all means is very high. But later on, towards the end of the growing season (April), as the vegetation matures, herbage quality deteriorates. This trend in quality continues as well towards the dry season. These significant changes are shown in this study by a decrease in digestibility and protein content, and an increase in NDF and ADF (Figures 2 and 3). But, in addition to the high significant difference between seasons, significant interactions were found also for management × season and stocking rate × season (mainly for the differences in spring).

Management

Between the different management systems, rotational grazing is implemented as a viable grazing strategy, even though the majority of experimental evidence does not support the view that it is superior to continuous grazing (Gutman and Seligman, 1979; Briske *et al.*, 2008). This study, which included treatments of seasonal stocking during the growing season, enabled examining differences in herbage quality between early, late and continuous grazing systems.

As forage plants mature, the nutritive value and quality of herbage decreases (Nelson *et al.*, 1989; De

Santis *et al.*, 2004). In this case, continuous or early grazing maintained younger herbage with relatively higher nutritional values. This seemingly compensates for the lower biomass found in these treatments during the main growing season. However, as shown in Figure 2, this was not true for the dry season and for the beginning of the grazing season, when cattle were first introduced to the range (January). The differences in the nutritional values between early and late turning to pasture were especially prominent at the end of spring (April–May): in percentage points, 6 and 3·6% for IVDMD and CP respectively (Figure 3). The difference in digestibility corresponds to 0·86 MJ d^{-1} of metabolizable energy (ME), associated with a decrease of 0·5 kg in dry-matter intake in replacement heifers (NRC, 1996). A 4-unit difference in CP dietary concentration (expressed as CP % of DM intake) can reduce the average daily gain from 0·9 to 0·3 kg d^{-1}. The minimal CP density for cows weighing 450 kg is 8·7, 9·1, 8·4, 8·0 and 7·5% of DM intake for months 1–5 following parturition (NRC, 1996, Appendix table 21). These values are reached before April in all treatments, but only for cows under early grazing from April to June. Calving dates range from December to April. In other words, early-calving cows may benefit from adequate diets in all treatments, but for late-calving cows, a difference of 4% in CP density has the potential of affecting milk production, and hence calf development, considerably. As forage protein content during the dry summer months is only 4–5%, all cows are offered additional supplementation of poultry litter (CP, 20·3%; NDF, 33·7%; and calculated ME, 6·52 MJ kg^{-1} of DM), *ad libitum*. The onset of this supplementation can be delayed under early, compared with late turning to grazing. This is important, because detrimental effects have been found for poultry litter if supplemented in too large amounts or too long periods (Silanikove and Tiomkin, 1992).

The reason for this highly significant effect found in spring is the highly dynamic response of different annual plant functional groups (mainly grasses, legumes and crucifers) to changes in grazing intensity. This plant community trait constitutes an important factor in determining forage quality in this particular Mediterranean rangeland (Sternberg *et al.*, 2000). Therefore, grazing management decisions may affect beef cattle sustainability under semi-arid Mediterranean conditions.

Stocking rate

In addition to grazing system and timing (management) of grazing, stocking rate also had a significant (though lesser) effect on herbage quality (Table 2, Figure 3). This is shown by comparing P values of the two variables, management and stocking rate, separately or both with season interaction. The non-significant effect of the management × stocking rate interaction only strengthens the statement that both factors separately have a significant effect on vegetation quality.

A stocking rate of 0·5 cow ha^{-1} (CM) for 10 months of grazing, under the conditions of typical Mediterranean grassland of the eastern Galilee, is considered moderate and is the stocking rate that is usually implemented in the study area. However, 1·1 cow ha^{-1} (CH) in this type of range is much higher than any commercial density usually implemented in the region. For the whole statistical model, highly significant differences in digestibility ($P = 0·02$), crude protein ($P < 0·0005$) and ADF ($P = 0·05$) were found for the interaction of stocking rate and season (Table 2), but as shown in Figure 3, it is mostly significant in spring (April), at the peak of the growing season. Mckown *et al.* (1991) showed that the difference caused by diverse livestock densities was higher intake of forage crude protein. These findings are supported by the results obtained by Sternberg *et al.* (2000) and Aboling *et al.* (2008), who showed that an increase in stocking rate leads to a reduction in plant cover by tall grasses and an increase in cover by prostrate annuals legumes. The changes in species composition, combined with new plant tissue re-growth, probably explain the significant increase in crude protein and digestibility. Further studies are needed in order to obtain a generalization of forage quality improvement under grazing at the species level. Under very heavy stocking rates, an increase in the cover of annual thistles and perennial forbs (mainly toxic umbellifers such as *Ferula communis*) was noted in the study area (Sternberg *et al.*, 2000). Caution should be taken when extrapolating the present results to other Mediterranean rangelands, as species trait such as palatability may change between different areas.

Conclusions

Differences in herbage quality were found between the different grazing management systems and stocking rates. These differences, which were most significant during the growing season (spring), were the result of the younger phenological stage of the vegetation that developed as a result of the consumption and changes in plant species composition. Cattle's grazing during the green season was found to be important for improving the quality of the herbage and should be carried out as a controlled defoliation management measure even for relatively short periods in all paddocks. The significant differences in herbage quality found in the present study emphasize the importance of the decision-making process in order to improve cattle grazing management in Mediterranean rangelands and its consequences for the sustainable productivity of the system.

Optimizing the production of cattle on Mediterranean grasslands requires proper management practices. The natural vegetation developed in the studied rangeland is adapted to the ecological and environmental conditions in which they grow and can produce optimal nutrient value and forage availability. There is no single decision that can be used to solve all problems in management practices, but there are some principles such as timing of grazing and determining stocking rates that can be applied to successful Mediterranean rangelands.

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