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Heavy stocking and early-season deferment of grazing on Mediterranean-type grassland

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Abstract

An experiment with beef cows grazing Mediterranean-type grassland was conducted to study the effect of grazing deferment at the beginning of the growing season on pasture productivity and animal performance under intensive herd management conditions. The grazing trial was composed of 4 treatments (deferred grazing at stocking rates of 0.83 and 0.67 cows per ha and continuous grazing at 0.67 and 0.5 cows per ha) replicated in 2 blocks and continued for 5 consecutive years. The herds were given low-energy supplemental feed during deferment and during the dry summer. At the intermediate stocking rate, at which both deferred and continuous grazing were compared, herbage production was significantly reduced by grazing during the 'deferment period' and calf weaning weights without deferment were significantly lower than in the deferred grazing treatments. Weaned live weight per cow was significantly lowest in the continuous intermediate treatment. Weaned weight per hectare was greatest at the highest stocking rate (with deferment). Utilization of supplementary feed per unit weaned live weight was significantly greater in the deferred treatments. Only about a third of the herbage production was grazed, even at the heavy stocking rates. Herbage production varied more between years than between treatments. It is concluded that in the system studied, deferment with supplementary feeding becomes important for both animal and vegetation production as stocking rate approaches and exceeds 0.67 cows ha^{-1}. With deferment, herbage production during the main growing season can be maintained even under heavy grazing pressure. This result can be explained with a simple dynamic growth and grazing model.

Key Words: Beef cattle; herbage consumption; primary production; secondary production; grazing management; trampling

Resumen

Con el objeto de determinar la influencia del pastoreo deferido, al comienzo del periódo de crecimiento de la vegetacion, en la producción de la pastura y en la perfomance del ganado en condiciones intensivas de manejo, fué realizada una experiencia de pastoreo con ganado vacuno de carne en pasturas naturales de tipo Mediterráneo. Esta experiencia de pastoreo estuvo compuesta por cuatro tratamientos: pastoreo deferido a intensidades de 0.83 y 0.67 vacas por ha. pastoreo continuado a intensidades de 0.67 y 0.50 vacas por ha. La experiencia se condujo durante cinco años, realizada en dos bloques.

Durante el período de pastoreo diferido y durante la estación seca fue otorgada alimentación suplementaria compuesta por forrages de bajo contenido energético. En el tratamiento de internsidad intermedia (0.67 vacas por ha.), en el cual pastoreo diferido y continuo fueron comparados, la producción vegetal fue reducida en forma significativa por el pastoreo durante el periodo diferido y el peso al destete de los terneros fue inferior en forma significativa en relacion con el pastoreo diferido.

La producción animal, expresada en peso del ternero destetato por vaca, fue inferior en forma significativa en el tratamiento pastoreo continuado a intensidad intermedia, siendo la produccion por ha. superior bajo intensidad elevada bajo pastoreo rotativo. El consumo de alimento suplementario por unidad de ternero destetado fue superior en pastoreo deferido. Esta respuesta no se reflejó en la producción animal. Solamente un tercio de la producción vegetal fue consumida, incluso bajo intensidad de pastoreo elevada. Las diferencias en produccion vegetal fueron superiores entre los años en relación con las diferencias entre tratamientos. En conclusión: En el sistema particular donde la experiencia fué realizada, el pastoreo diferido y suplemento alimenticio son importantes cuando la intensidad de pastoreo se aproxima o incrementa por encima de 0.67 vacas por ha.

Bajo pastoreo diferido, la producción vegetal puede ser mantenida incluso bajo elevadas presiones de pastoreo.

Estos resultados pueden ser explicados por intermedio de un modelo simple de dinámica de crecimento vegetal y pastoreo.

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Mediterranean grasslands, like many other grasslands, are strongly seasonal (Seligman 1996). The growing season of the herbaceous vegetation in Israel is usually less than 6 months of which 1 to 3 months occur during the late autumn/early winter when the amount of green vegetation is small and inadequate for satisfying the daily feed requirement of livestock. In addition, growth rate is slow and the dry vegetation of the previous season is subject to rapid weathering and decomposition after the first winter rains. During the long dry summer, the above-ground herbage is dead and quality is poor protein content <4% and IVDDM <50% (Holzer et al. 1986). Under these conditions, maintaining animal production under yearlong grazing requires supplementation protein during the long dry summer, and energy during the early growing season. Supplementary feed is given mainly during the summer when most of the herbage is dead and interactions between the vegetation and the grazing animals is minimal. Much stronger interactions occur during the growing season.

Continuous heavy grazing during the early growing phase of a seasonal pasture can delay range readiness, reduce primary production, and restrict intake by the grazing animal (Smith and Williams 1973; Noy-Meir 1975, 1978). Deferment of grazing during the critical early phase, especially at high stocking rates, is a management option that can allow the herbage to grow to a threshold beyond which the rate of new plant growth will be substantially greater than the biomass consumption rate by the grazing livestock (Noy-Meir 1975, 1992; Ungar 1990). From then on, intake of forage by livestock grazing typically sub-humid Mediterranean grasslands should not be limited by herbage availability even at relatively high stocking rates. Nevertheless, interactions with the growing vegetation continue and eventually influence the total seasonal productivity of the sward (Noy-Meir 1978), with possible implications for forage availability during the dry season.

Although these are well substantiated statements, their significance for seasonal and long–term animal production is difficult to establish on rangeland where the vegetation is very heterogeneous in structure, phenology, and response to grazing stress and where feed supplementation plays an important role in the animal production system. Grazing deferment also involves special feeding arrangements for the livestock when they are not allowed free access to the range. This has logistic and economic consequences that tend to offset advantages that deferment may confer on primary production. Such interactions make it necessary to test the effectiveness of grazing deferment for improving animal production in specific vegetation types over a range of grazing pressures and within the context of a viable production system that includes the buffering effects of supplementation as practised in the region (Willoughby 1959).

The present study was conducted to test the hypothesis that early-season deferment of grazing is advantageous to animal production when a Mediterranean type-grassland is subjected to relatively heavy grazing pressure.

Materials and Methods

Overall concept

The trial was conceived as a system experiment that simulated the effects of different grazing treatments on herd and range performance in the context of a commercial beef herd in the region. The implications of this concept were that: ad libitum supplementation with low energy feed, mainly poultry litter, would be given as practised in the region during the summer and early winter when the quality of the range herbage was low; calves kept on the range till weaning in July and August when the range vegetation was dry and of low quality would be given access to better quality feed; and non-pregnant cows after weaning would be replaced with pregnant heifers from the commercial herd on the experimental station. Consequently, the effects of the grazing treatments on replacement rates and on supplementary feed consumption were relevant performance parameters. The buffering effects of these practices on the effects of the grazing treatments are part of the management reality so that the object of the trial was to determine whether, under such conditions, the treatment effects on the grassland carried over to animal performance.

Yearlong grazing trials with herds of beef cows on native Mediterranean grasslands require relatively large areas and large numbers of animals that, together with the complex logistics involved in herd-level system studies, restrict the number of manageable trial paddocks and the number of manageable replications. The possible loss of such a sytem trial, in terms of ambiguity of the results, were seen to be more than balanced by the gain in relevance to range management (Willoughby 1959).

Site

The trial was conducted at the Karei Deshe Experimental Range situated on rocky, basalt slopes near the junction of the Jordan River and the Lake Kinneret (Sea of Galilee), Israel (lat. 32°55'N, long. 35°35'E, alt. 80-150 m a.s.l.). The soil is a black protogrumosol and the vegetation is a hemicryptophytic grassland (Zohary 1973) dominated by many annual species. Perennial herbaceous species, mainly *Hordeum bulbosum* L. and some *Psoralea bituminosa* L. are also important constituents of the vegetation as are the variable amounts of annual and perennial thistles, mainly *Scolymus maculatus* L. and *Echinops* spp. (Gutman et al. 1990 b; Noy-Meir et al. 1989). The climate is typically Mediterranean with cool, wet winters and no rain during the hot summer (June to September). Average annual rainfall during the experiment varied from 404 to 716 mm (C.V. = 0.25) with large differences in distribution between years (Table 1). Monthly C.V. was greatest during autumn and spring.

Herbage growth is normally restricted to the period between November and April when quality of the herbage is high. During summer the herbage is dry and quality is low. After the first rains in autumn, the dry herbage decomposes rapidly and both quality and availability decrease until the new growth herbage becomes available.

Treatments

Limits on treatment number and replication imposed by the size of the paddocks required for system level experiments made it necessary to choose treatments judiciously and with relevance to beef herd management practices in the region. In our case it was possible to implement 4 grazing treatments (Table 2) that were replicated in 2 blocks of paddocks giving a total of 8 paddocks. Paddock size ranged between 26 and 31

Table 1. Rainfall at the Kare Deshe Experimental Range during the experiment

Month[1]	Season 1985/86	1986/87	1987/88	1988/89	1989/90	Mean ± SD
	(mm)					
October	18	59	21	18	23	28±18
November	17	215	9	50	109	80±85
December	76	119	172	152	86	121±41
January	101	146	93	48	141	106±40
February	120	60	138	37	101	91±42
March	14	111	93	98	42	72±42
April	29	6	14	0	35	17±15
May	29	0	0	0	0	6±13
Total	404	716	540	403	537	520±129

[1]There were only negligible amounts of rainfall between May and October.

ha. The stocking rates ranged from moderate (0.50 cows ha^{-1}) to heavy (0.83 cows ha^{-1}) with one intermediate grazing pressure (0.67 cows ha^{-1}). The stocking rate on most commercial ranches with similar rangeland in the region is considerably lower at 0.25–0.33 cows ha^{-1}. The choice of higher stocking rates for the experiment was made because previous trials indicated that the commercial rates were considerably lower than the capacity of the range (Gutman et al. 1990, 1990 b).

The high stocking rate was implemented only with deferment; the moderate only with continuous grazing; and the intermediate with both deferred and continuous grazing This arrangement made possible 3 contrasts of separate effects:

- Heavy vs. intermediate, both with deferment
- Deferment vs. continuous, both at an intermediate stocking rate
- Intermediate vs. moderate, both under continuous grazing as well as 3 contrasts of combined effects:
- Heavy deferred vs. intermediate continuous
- Intermediate deferred vs. moderate continuous
- Heavy deferred vs. moderate continuous.

The paddocks allocated to the continuous treatments were stocked yearlong. In the deferred grazing treatments, deferment began at the beginning of the rainy season in autumn with the regeneration of vegetative growth (usually during November). During the deferment phase, animals in all treatments were allowed ad libitum access to supplementary feed (see below). Deferment continued until the animals in the continuous treatments stopped consuming supplements (late December-mid January). Duration of the deferment phase varied considerably among years (Fig. 1). At the end of deferment, the newly germinated herbaceous vegetation in the deferment treatments was well established and average herbage biomass varied between 95–100 g m^{-2} (DM) between treatments with a S.D. between years of 23 g m^{-2}. The trial was conducted over five full years from 6 December, 1985 until 28 December, 1990. The herds were monitored through the 1991 season to determine calving performance in the season after the end of the experiment.

Livestock

Eight experimental herds numbering 15 to 24 cows per herd were drawn from a herd of beef cows, most of which were Simmental cross breeds maintained on the non-experimental padddocks of the ranch. Young cows were selected (3–5 years old) that weighed an average (±S.D.) of 346±11 kg at weaning in the first year of the experiment and 420 ± 23 kg at the end of the trial. The breeding season to Simmental bulls was in the spring (March–May) and the mean calving date for each year was between 4 and 19 January. Calves were weaned in August, weighed and removed from the experiment. All the cows remained in the paddocks throughout the autumn and until the beginning of the deferment period (Fig. 1). The cows in the deferment treatments were then confined to a small sub-paddock within the treatment paddock near to the water trough and the supplementary feed station in each paddock. This sub-paddock covered ~10% of the treatment paddock area and was fenced with an electrified wire that effectively kept the herd within the restricted area throughout the deferment period. The same area was fenced each year. Even though the vegetation in the deferment area was heavily grazed during deferment, it recovered during the subsequent main green season so that it did not become a true 'sacrifice area'. At the end of the deferment period the electric fence was removed and the herd was given access to the whole paddock. The animals in the continuous grazing treatment had access to the whole paddock throughout the year.

Table 2. Grazing treatments

Treatment	Symbol	Stocking rate (Cows/ ha)	(ha/cow)
Heavy, deferred	Hd	0.83	1.2
Intermediate, deferred	Id	0.67	1.5
Intermediate, continuous	Ic	0.67	1.5
Moderate, continuous	Mc	0.50	2.0

Supplementary feeding

At the beginning of the dry summer season from June onwards, all herds were given poultry litter (metabolizable energy concentration 1.6 Mcal kg^{-1}, DM) *ad libitum* in weighed, mobile feeding troughs (Holzer and Levy 1976). At the beginning of the calving season (late November, early December), barley grain was added (~10%) to the poultry litter so as to increase the metabolizable energy concentration of the feed mix to 1.9 Mcal kg^{-1}, DM. This diet was available to the animals in both the deferred and continuous treatments throughout the deferment period after which the supply of supplementary feed was terminated. During the summer months until weaning (between 1–2 months), calves were given access to a creep with either *Panicum maximum* hay (1987, 1988) or concentrate feed (1989, 1990).

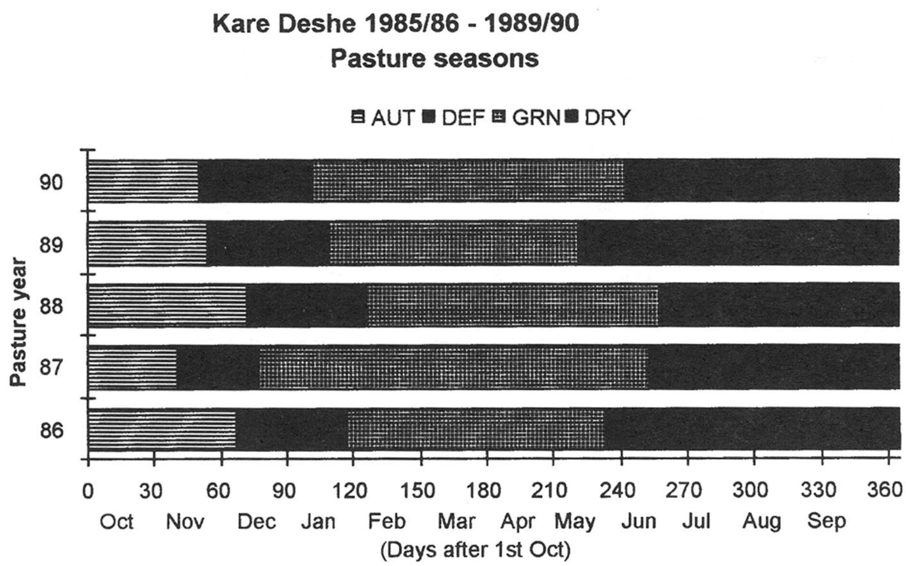

Fig. 1. Duration of pasture seasons in the Karei Deshe Experimental Range during the experimental period, 1985/86–1989/90; AUT-autumn; DEF-early season deferment phase; GRN-main green season; DRY-summer dry pasture period.

Herd management

Every 6 to 8 weeks, cows were weighed in the morning after approximately 18 hours without feed or water. Calving dates were recorded and calves were first weighed when the whole herd was brought to a central corral for periodic weighing or veterinary care. Cows were tested for pregnancy by rectal palpation at weaning and non-pregnant cows were replaced by cows that tested pregnant from the commercial herd. However, culling in fact was less stringent than planned, apparently because either rectal palpation estimates indicated erroneous pregnancies or some cows may have aborted after palpation. Conception rates were determined only after calving confirmed the pregnancy test. Possible abortions or fetal absorption were therefore regarded as non-successful conception. The calves in all treatments were weaned on the same day. Replacement cows, mortality, and conception rates were recorded. Calving rates were calculated as calves born to cows in the treatment herd during the calving season. Weaning rates were calculated as calves weaned per cow in the herd.

Vegetation monitoring

The standing biomass of herbaceous vegetation was estimated at the end of the deferment phase, the end of the green season, and the end of autumn by the calibrated estimate method (Tadmor et al. 1975) along transects that traversed the entire area of each paddock. About 300 quadrats (25 x 25 cm) were estimated in each paddock and 10% were clipped, dried, and weighed for calibration of the estimates.

Estimation of dry matter and net energy (NE) intake from pasture

The normative net energy (NE) requirements for the observed performance (maintenance, gain, pregnancy, and lactation) of cows and calves were calculated according to NRC standards (NRC 1984). The NE content of the supplementary feed was calculated from standard data and the difference between the NE requirement and the NE in the supplementary feed was attributed to forage intake from pasture. Conversion to herbage dry matter was based on local values for NE concentration of herbage in the different seasons of the year (Weitz 1981). During the green season when no supplementary feed was consumed, the calculated average DM intake per cow varied between 12 and 14 kg DM cow^{-1} day^{-1}. Intake measured on a sample of cows by tritium dilution and by chromic oxide marker, also during the green season (Holzer et al. 1990, Na'ali 1996) gave almost identical values. The calculation of intake from normative energy requirements for observed performance is thus sufficiently accurate for the seasonal intake and herbage production estimates in this experiment. For an experiment of this scale it is probably the only practical method available.

Herbage production was estimated as the sum of standing biomass at the end of each phase in the annual cycle plus the amount of herbage consumed by the herd during that phase.

Statistical analysis of results

Analysis of variance was conducted as a repeated measures design with parameter values over 'years' as the repeated measure (compact variable). The analysis was conducted with the SuperANOVA statistical analysis package (Abacus Concepts, Inc., Berkeley, Calif., USA). Treatment and year were analyzed as separate effects and as interacting variables. Block effects either alone or as treatment x block interactions were found to be non-significant (or marginally significant in the case of a few parameters) and so 'blocks' were excluded from the final analysis. Means were separated by Fisher's protected L.S.D. Contrasts between treatment combinations were examined but as they added little to the means separations they were not used in the analysis of the data.

The annual performance of the livestock was calculated from weaning to weaning; the annual herbage consumption was calculated from the beginning of the deferment phase to the beginning of the following deferment phase. As all the cows were with calf in the first year of the experiment, animal performance in the first year of the experiment was not taken into account. The first year for animal performance analysis therefore began with the first weaning at the end of the first green season.

Results

Conception rates were lowest and replacement rates were highest at the heaviest stocking rate but the differences between treatments were not significant (Table 3). Calving rate differences were also not significant, partly because the replacements with pregnant heifers tended to even out differences. Loss of calves after birth resulted in weaning rates being 6–11% lower than

Table 3. Indicators of animal response to grazing treatment (5 year averages)

Treatment	Conception-rate	Replacement rate	Calving rate	Weaning rate	Cow wt	Calf wt	ADG, calves	Weaned LW	Weaned LW
	(%)	(%)	(%)	(%)	(kg)[4]	(kg)[5]	(kg d-1)[6]	(kg cow-1)[7]	(kg ha-1)[8]
Hd-heavy deferred	74	14	86	75	374 ab[9]	192b[9]	0.816b[9]	150ab[9]	121a[9]
Id-intermed. def.	75	13	86	77	385a	202a	0.848a	160a	108ab
Ic-intermed. cont.	76	12	82	72	372 ab	191b	0.795 b	141b	94 b
Mc-moderate cont.	78	10	86	80	370 b	195 ab	0.806 b	161a	79 c
Statistical analysis									
L.S.D[1]	-	-	-	-	13.0	7.6	0.030	17.7	13.8
P<F (treatm.)[2]	N.S.	N.S	N.S.	N.S	0.079	0.035	0.0113	0.1094	0.0001
P<F (years)[3]	N.S	N.S	N.S	N.S	0.0001	0.69	0.0001	NS	NS

[1]Fisher's protected least significant difference, P<0.05
[2]Probability of acceptance of null hypothesis for treatment
[3]Probability of acceptance of null hypothesis for years
[4]Mean weight of nursing cow at weaning
[5]Mean weight of calves at weaning
[6]Average Daily Gain of calves between birth and weaning
[7]Weaned calf liveweight per cow
[8]Weaned calf liveweight per hectare of range
[9]Different small case letters indicate significant differences (P<0.05) between treatments by Fisher's protected L.S.D.

the calving rates; some calves were probably stolen but because of the relatively large size of the paddocks the precise cause of the loss or death of each calf could not be determined. Recalculating the weaning weight per cow on the basis of the calving rates, obviously increased the weaned weight per cow, but made no difference to the treatment effects. Differences in weaning rates between treatments were also not significant (Table 3).

The weights of the nursing cows and calves at weaning, as well as the average daily live weight gain (ADG) of calves were significantly greater in the Intermediate differred (Id) treatment than in the 3 other treatments. The weaned weight per cow was lowest in the Intermediate continuous (Ic) treatment, but the difference was only marginally significant (p=0.036). The only highly significant (p<0.0001) treatment effect on animal performance was in the weaned live weight per hectare of range, where the stocking rate was the main determinant of animal production per unit area (McMeekan 1959, Hart 1972, 1978).

Herbage and supplementary feed utilization differences between treatments during the deferment phase were substantial and highly significant, the use of supplementary feed being much greater in the deferred treatments (Table 4). This indicates that despite the small amounts of available feed in the continuously grazed treatment paddocks, the amount of herbage grazed was large enough to severely suppress the intake of low-energy supplementary feed. There were also significant differences during the autumn phase when, in the Intermediate deferred (Id) treatment, the cows used significantly greater amounts of supplementary feed than in the other treatments and significantly smaller amounts of herbage. In the continuous treatments, Intermediate continuous (Ic) and Moderate continuous (Mc), net energy from supplementary feed consumed during the deferment period constituted 7.4% and 9.5% of the total annual net energy requirement, and in the deferred treatments, Heavily deferred (Hd) and Id, the proportion of supplementary feed consumed during the deferment period, was 25.0% and 23.4% respectively. Over the whole annual cycle, the deferred treatments used ~28% more supplementary feed per cow than in the continuous treatments. During the main green season, when no supplementary feed was given and all animal requirements were met from pasture only, there were no significant differences in animal performance and consequently no significant differences in estimated herbage intake per cow between treatments despite relatively large differences in grazing pressure.

The differences between treatments in the utilization of pasture and supplementary feed per unit of weaned live weight were similar to the treatment differences observed for the utilization of the respective feed sources per cow (Table 5). In both cases, the utilization of supplementary net energy was just over 25% greater in the deferred grazing treatments than in the continuous grazing treatments.

Table 4. Average net energy of herbage and supplementary feed consumed per cow in the herd during the year

	Herbage					Supplementary feed				
Treatment	Defer	Green	Summer	Autumn	Total	Defer	Green	Summer	Autumn	Total
	(Mcal cow-1)									
Hd	53b	2346	522	149a	3071b	355a	-	531ab	537b	1422b
Id	42b	2369	479	78b	2933b	373a	-	600a	625a	1596a
Ic	370a	2317	537	177a	3392a	87b	-	493b	529b	1117c
Mc	371a	2381	529	171a	3437a	118b	-	571ab	551b	1243c
Statistical analysis1										
L.S.D	45.0	-	-	60.0	222.4	46.3	-	88.2	63.9	134.0 s
P<F (treatm)	.0001	.N.S	.N.S	.0089	.0003	.0001	-	.0468	.0201	.0001
P<F (year)	.0001	.0001	.0001	.0001	.0001	.0001	-	.0010	.0001	.0001

[1]See Table 3.

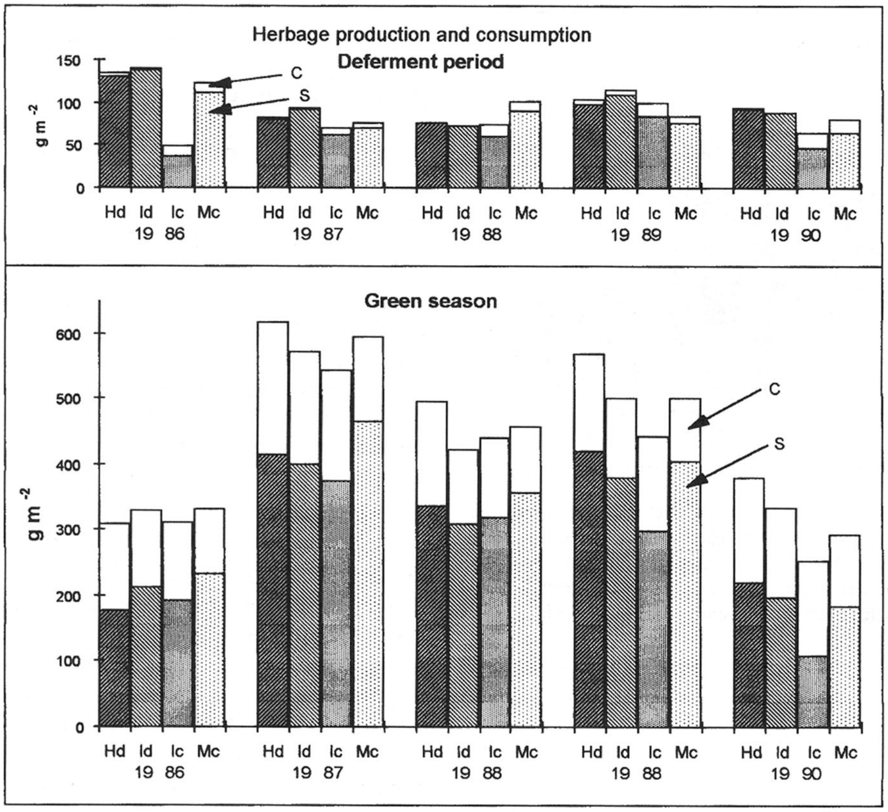

Fig. 2. Standing biomass dry matter (S) and herbage dry matter consumption (C) by beef herds grazing Mediterranean grassland under different stocking rates and management treatments during the deferment period at the beginning of the growing season and at the end of the main green season during the 5 years (1986-90) of the trial. Treatment codes: Hd - Heavy S.R. with deferment; Id - Intermediate S.R. with deferment; Ic - Intermediate S.R., continuous; Mc - Moderate S.R., continuous.

Over the 5-year period, herbage production was much greater than herbage consumption (Table 6). During the main green season, herbage production was considerably greater than herbage consumption in three of the 5 years and in 2 of the years the difference between consumption and production was smaller (Fig. 2). Low seasonal herbage production appeared to be related to small amounts of rainfall in March (Table 1) during the spring flush of growth. Herbage consumption per unit area during the main green season was proportional to stocking rate, with no significant difference between deferment and continuous grazing at equivalent stocking rates (Table 6). Standing biomass at the end of the deferment period was significantly greater in the deferred treatments but the biomass in the grazed (continuous) treatments was substantial, especially at the lower stocking rate (Table 6). At the end of the green season the standing biomass in the deferred treatments was similar to that in the treatment grazed continuously at the low stocking rate. Only in the heavier continuously grazed treatment was the end-of-season standing biomass substantially lower (Table 6). Standing biomass at the end of summer was similar in all treatments except Moderate continuous (Mc), in which it was significantly higher than in the other treatments throughout the experiment (Fig. 3).

Discussion

Herbage growth rates, consumption rates and animal performance

The hypothesis underlying this experiment that early-season grazing deferment on a Mediterranean-type grassland was necessary to maintain system productivity under heavy stocking rates, was derived from quite strong theoretical grounds (Noy-Meir 1978, Ungar 1990) and some experimental evidence (Smith et al. 1972, Benjamin 1977). The experimental evidence from Australia and from the semiarid region of Israel showed that early-season deferment of sheep grazing had a marked effect on annual grassland productivity. In the present study, there was no correlation between standing herbage at the end of the deferment phase and seasonal herbage production even though continuous stocking at the intermediate stocking rate reduced production, especially during the last years of the experiment (Fig. 3). Judging by the effect of the continuous moderate (Mc) and the continuous intermediate (Ic) treatments on herbage production, increasing stocking rate to 1.2 cows^{-1} under continuous grazing would have decreased herbage production even more and in the last year of the experiment could conceivably have seriously affected animal performance. At the intermediate stocking rate, calf growth was marginally (but significantly) greater under deferred than under continuous grazing (Table 3), albeit at a considerably greater cost in supplementary feed. At higher stocking rates, the difference would be expected to increase.

Table 5. Utilisation of net energy from herbage and from supplementary feed for weaned liveweight production

Treatment[1]	Utilisation of NE for production		
	Herbage	Supplementary feed	Total
	------------- (Mcal NE/Kg LW weaned)- ----------		
Hd	20.2b	9.4 ab	29.5
Id	18.4b	10.0a	28.3
Ic	23.7a	7.9bc	31.6
Mc	21.1ab	7.5c	28.7
Statistical analysis[1]			
L.S.D.	2.93	1.57	4.15
D.F.	19	19	19
R^2	0.77	0.69	0.64
P<F (treatment)	0.0076	0.0113	0.39
P<F (years)	0.0001	0.0030	0.0085

[1]See table 3.

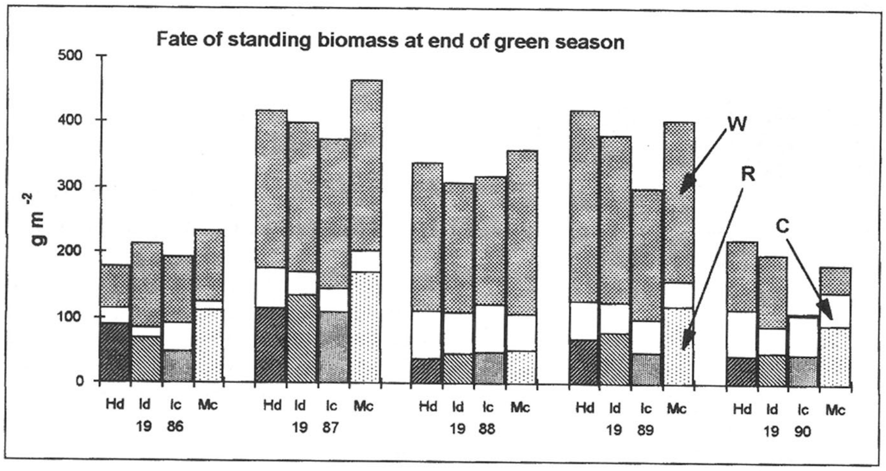

Fig. 3. Allocation of green biomass in the experimental treatments at the end of the green season of each year of the trial (1986-90), to consumption by the livestock (C) during the summer and autumn, to seed dispersal and weathering (W) over the summer and autumn, and to residual standing dry biomass at the end of the autumn (R). Treatment codes: Hd - Heavy S.R. with deferment; Id - Intermediate S.R. with deferment; Ic - Intermediate S.R., continuous; Mc - Moderate S.R., continuous.

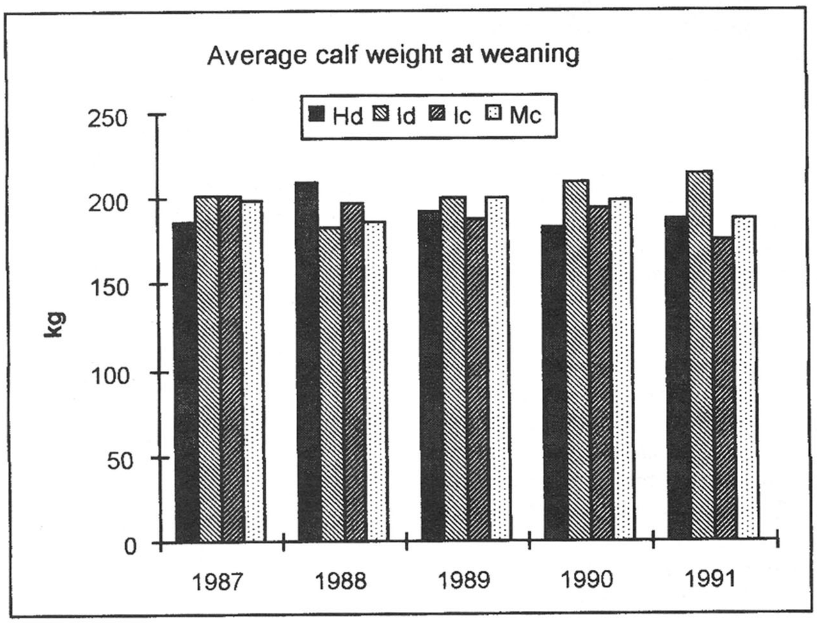

Fig. 4. Average calf weight at weaning in the experimental treatments over the years. Treatment codes: Hd - Heavy S.R. with deferment; Id - Intermediate S.R. with deferment; Ic - Intermediate S.R., continuous; Mc - Moderate S.R., continuous.

Herbage consumption by the cattle even at the intermediate stocking rate was much less than the biomass production during both the deferment and the green season (Fig. 2). With growth rates so much higher than consumption rates during the main growing season, it is not surprising that, despite the considerable differences in stocking rates and early season grazing, differences in herbage availability were barely reflected in animal performance. The abundance of high quality forage during the relatively short green season gave the cows an opportunity to recover lost weight rapidly after calving (compensatory growth?) and during early lactation so that they could provide a reliable source of nutrition for the growing calves. For that reason, the large and significant fluctuations in herbage consumption between years (Table 4) were buffered by the nursing cows so that calf weaning weight was much less variable between years (Fig. 4). Furthermore, the severity of periodic deficiencies in herbage availability or quality during the other phases of the 'pasture year' were buffered by access to low energy supplementary feed.

The effective series of buffers that were built into the management system stabilised animal performance to a large degree, so that the main differences between treatments was the effect of stocking rate on production per unit area and the effect of deferment on the amounts of supplementary feed consumed.

Herbage growth and consumption during the 'deferment' phase

In the treatments that were grazed during the deferment period, herbage production per unit area was much higher than herbage consumption in all years of the experiments (Fig. 2). Nevertheless, estimated mean daily herbage dry matter intake per cow (plus calf) was only 4.2 kg day^{-1}, compared with 14.1 kg day^{-1} during the main green season. This would indicate that herbage intake rate in the treatments that were grazed during the deferment period must have been restricted by the limited amount of herbage available at the beginning of the growing season. At the same time, the grazed pasture continued to grow and the 5-year average amounts of standing biomass (DM) in the treatments at the end of the deferment period were not much lower than in the deferred treatments (Table 6). Consequently, main season above-ground herbage production in the treatments that were grazed during the deferment period was not much less than the herbage that was produced in the deferred treatments (Fig. 2).

The amount of herbage produced by the end of the green season (standing biomass + consumption) was greatest at the heaviest stocking rate (with deferment). This arguably surprising result could be the outcome of a number of factors: the greater initial amount of herbage at the end of deferment at the beginning of the main green season, the heavier utilization of the vegetation and recycling of nutrients at the greater animal density; and possibly more tillering following more intensive herbivory, especially as the sward grows higher (Noy-Meir 1975).

Herbage biomass dynamics during vegetation establishment

The results of this experiment indicate that vegetation growth is not excessively sensitive to grazing during the early establishment phase. The significance of this empirical result would be greater if it could be shown that a fundamental rationale underlies this phenomenon. An attempt to establish such a rationale was made with the aid of a simple model first proposed by Noy-Meir (1975). At the beginning of the growing season, herbage growth can be well described as exponential, with a constant specific growth rate, g, after germination or regeneration of the vegetation (Benjamin et al. 1977). We describe herbage consumption as a ramp function with initial slope representing the grazing efficiency, e, and the horizontal section representing constant satiation intake rate, C_S; below a given amount of biomass, V_r, herbage is unavailable to the grazing animal. The growth and consumption functions are then:

$dV/dt = V(g-sm)-C$

$C = \min(Cs, (V-Vr)e)s, C>=0$

$Ca = \Sigma C$ (over n days of deferment)

where,

V = above ground biomass, DM ($g\ m^{-2}$)

Vr = ungrazable biomass, DM ($g\ m^{-2}$)

g = specific growth rate of the above-ground biomass (d^{-1})

s = stocking rate (cows per m^2)

m = trampling factor (m^2 per cow per day)

C = daily herbage consumption rate ($g\ m^{-2}\ d^{-1}$)

Cs = satiation intake rate, DM (g per cow per day)

e = grazing efficiency (m^2 per cow per day)

Ca = cumulative herbage DM consumption over deferment period ($g\ m^{-2}$)

n = number of days in the deferment phase.

The parameter values were assigned as follows:

The initial biomass at emergence was set to 5 $g\ m^{-2}$ and the specific growth rate to 0.06 day^{-1} after calibration with the biomass data from the ungrazed paddocks during the deferment phase. Mean five-year values were used both for the biomass estimation and the duration of the deferment period (n=51 days). Vr was set to 10 $g\ m^{-2}$ (Cohen 1989) to account for plant parts unavailable to the grazing cows either because of limitations of their mouth parts or because of irregularities in the soil-rock surface (Noy-Meir 1975). The trampling factor was based on the assumption that trampling does not destroy the vegetation but damages it in a way similar to grazing. In fact, when the soil surface is dry, trampling effects are often difficult to detect but when the surface is wet, the damage on a trampled area can be severe. Estimates of area trampled by cattle range between 100 and 250 m^2 per head per day (Rouda et al. 1990; Guthery and Bingham 1996). Taking a mid-value of 160 m^2 and assuming an average 0.25 reduction of photosynthetic tissue in the trampled vegetation, the trampling factor, t, was set to 40 m^2 per cow per day to account for trampling throughout the deferment period, and to 0 without trampling effect. The satiation DM intake rate, Cs, was set to 14 kg per cow (plus calf) per day, based on green season data from this experiment as well as from previous experiments with beef cows on similar pasture (Holzer et al. 1986); the grazing efficiency factor, e, was set to 230 m^2 per cow per day according to Ungar and Noy-Meir (1988).

The model was run over a period of 51 days (the average duration of the deferment phase) with a time step of 1 day. Stocking rate, s, was set for a range of values from 0 to 1 cow ha^{-1}. The results are compared with the observed values in Table 7. The standing biomass at the end of the 'deferment' period in the treatments that were grazed during the 'deferment' phase was closely estimated for the moderate stocking rate treatment without trampling, but at the intermediate stocking rate it took a trampling effect to bring the calculated values closer to the observed. The herbage

Table 6. Average five-year dry matter consumption and end-of-phase standing biomass during different periods in the annual pasture cycle

	Consumption			End of phase biomass		
Period	Deferment	Green season	Year	Deferment	Green season	Autumn
Treatment[1]	($g\ m^{-2}$, DM)					
Id	2.5 c	158 a	218a	95.3 a	314 ab	70.7b
Id	1.6 c	130 b	172c	99.9 a	299 b	75.6b
Ic	13.9 a	126 b	192b	57.7 c	258 c	59.6b
Mc	10.6 b	97 c	146d	82.8 b	329 a	108.9a
Statistical analysis[1]						
L.S.D.	1.78	24.5	17.7	16.5	15.8	16.6
P<F treatment)	0.0001	0.0160	.0001	0.0114	0.0001	.0001
P<F (year)	0.0002	0.0001	.0001	0.0001	0.0001	.0001

[1]See Table 3.

Table 7. Observed and calculated herbage growth and consumption under continuous grazing during the potential deferment period with increasing stocking rate.

		Stocking rate cows per ha (S)				
		S = 0	S = .5	S = .67	S = .83	S= 1
Variable		g (D.M.) m^{-2}				
Observed*	V	98 ± 23	82 ± 18	58 ± 17		
(mean±S.D.)	C_a		11 ± 3.7	14 ± 3.8		
	C'		4.2 ± 1.2	4.2 ± 0.8		
Model	V	101.2	79.5	73.4	68.9	63.4
(without	C_a		11.0	14.0	16.2	18.6
trampling)	C'		4.3	4.1	3.9	3.7
Model	V	101.2	72.8	65.6	60.3	54.1
(with	C_a		10.2	12.5	14.0	15.6
trampling)	C'		4.0	3.6	3.4	3.1

Legend:
S -Stocking rate
V- Standing biomass at the end of the deferment period ($g\ m^{-2}$, DM)
Ca - Cumulative herbage consumption during the deferment phase ($g\ m^{-2}$, DM)
C' - Average daily herbage consumption (kg DM per cow per day)

consumption values were best estimated without the trampling effect. Despite these small discrepancies, the model does show how, in principle, pasture consumption can be severely constrained even though the amount of available herbage is much larger than the amount consumed. The constraint on herbage consumption is also the reason for the relatively small effect of grazing on herbage growth during the deferment period.

Extrapolation to heavier stocking rates led to progressively lower herbage intake rates and total above-ground primary production (Table 7). This, together with the over-estimate of standing biomass at the end of the deferment period as well as the lower total primary production under continuous grazing at the intermediate stocking rate (Ic in Fig. 2), suggests that higher stocking rates without deferment would involve a serious loss in pasture productivity. On the other hand, with deferment it may be possible in most years to maintain higher stocking rates than those implemented in this experiment, with very little loss in pasture productivity. Higher stocking rates (with deferment) would seem to make very little difference to the amount of residual end-of-season biomass (Fig. 3) mainly because of the overwhelming losses due to seed dispersal and weathering. However, the implications of higher stocking rates for animal production as well as for the botanical composition of the sward (Noy-Meir et al. 1989), would have to be determined experimentally, with special emphasis on the poorer years like the first and last years of this experiment.

Conclusions

The results of this experiment lead us to the following conclusions:

a. When grazing is deferred at the beginning of the growing season (during the initial regeneration stage) of a Mediterranean-type grassland on a basaltic substrate, annual animal production at a (high) stocking rate of 0.83 cows per ha can be maintained at a level not significantly different to that attained with continuous grazing at lower stocking rates (0.50 cows per ha). The reason for this low sensitivity of animal production to high stocking rate during the main green season, is the rapid growth rate of the vegetation which exceeds consumption rates and creates an abundance of herbage that does not limit intake even at the high stocking rates applied in this experiment

b. Ad libitum supplementary feed utilization (in terms of net energy) increased from 26% of total net energy requirement per cow in the continuous systems to 34% in the deferred systems. Economic viability of deferment in order to increase stocking rate will therefore be affected by the ratio of prices between weaned live weight and supplementary feed and by fixed pasture costs. These values are specific to the prevailing economic environment.

c. The relatively low degree of utilization of the vegetation during the green season even at the high stocking rate suggests that with deferment and under similar management conditions, the grassland might support even higher stocking rates with minor reduction in animal performance, at least in the average and better than average years.

d. The extent to which stocking rates can be increased above those tested in this experiment without undesirable consequences to the range vegetation and to animal production, requires further study.

Literature Cited

Benjamin, R., Noy-Meir, I., and N. Seligman. 1977. Deferment of grazing a natural pasture in a semiarid region at the beginning of the grazing season. Hassadeh 57: 1868–1973 (Hebrew, with English summary).

Cohen, D. 1989. Herbage production under deferred and continuous grazing on a Mediterranean grassland. Ph.D Thesis, Hebrew University of Jerusalem, Jerusalem, Israel.

Guthery, F.S. and R.L. Bingham. 1996. A theoretical basis for study and management of trampling by cattle. J. Range Manage. 49: 264269.

Gutman, M., N.G. Seligman, and I. Noy-Meir. 1990b. Herbage production of Mediterranean grassland under seasonal and yearlong grazing systems. J. Range Manage. 43:64–68.

Gutman, M., Z. Holzer, N.G. Seligman, and I. Noy-Meir. 1990a. Stocking density and production of a supplemented beef herd grazing yearlong on Mediterranean grassland. J. Range Manage. 43:535–539.

Hart, R.H. 1972. Forage yield, stocking rate and beef gains on pasture. Herb. Abstr. 42: 345–353.

Hart, R.H. 1978. Stocking rate theory and its application to grazing on rangelands. pp. 547–550. *In:* D.N. Hyder ed. Proc. of the 1st Internat. Rangeland Congr. Denver, Colo, USA. pp. 547–550.

Holzer, Z. and D. Levy. 1976. Poultry litter as a protein supplement for beef cattle fed fibrous diets. World Rev. Anim. Prod. 12: 91–96.

Holzer, Z., R.W. Benjamin, M. Gutman, D. Levy, and N.G. Seligman. 1990. The precision and logistics of the tritium dilution technique for measuring intake in free ranging beef cows. World Rev. Anim. Prod. 25:57–60.

Holzer, Z., J.G. Morris, M. Gutman, R.W. Benjamin, N.G. Seligman, and E. Bogin. 1986. Physiological criteria for improvement of production efficiency of beef cows subjected to nutritional and environmental "stress" due to fluctuating seasonal grazing conditions. Final report, BARD Project No. I-132-80, Agricultural Research Organisation, Bet Dagan, Israel.

McMeekan, C.P. 1959. Principles of animal production. Whitecombe and Tombs, Christchurch, N.Z.

Na'ali, A. 1996. The effect of grazing management on the rangeland ecosystem and animal performance in a beef herd in the Upper Galilee. M.S. Thesis, Faculty of Agriculture, Hebrew University of Jerusalem. Rehovot, Israel.

Noy-Meir, I. 1975. Stability of grazing systems: an application of predator-prey graphs. J. Ecol. 63: 459–481.

Noy-Meir, I. 1978. Grazing and production in seasonal pastures: analysis of a simple model. J. Agr. Sci., Cambridge 15: 809–835.

Noy-Meir, I. 1992. Structure and dynamics of grazing systems on seasonal pastures, p. 7–24. *In:* Th. Alberda, H. van Keulen, N.G. Seligman and C.T. de Wit (eds.), Food from dry lands—an integrated approach to planning of agricultural development. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Noy-Meir, I., M. Gutman, and Y. Kaplan. 1989. Responses of Mediterranean grassland plants to grazing and protection. J. Ecol. 77:290–310.

NRC. 1984. Nutrient requirements of beef cattle. 6th edition. National Academy Press, Washington, DC.

Rouda, R.R., D.M. Anderson, L.W. Murray, and J.N. Smith. 1990. Distance traveled by free-ranging supplemented and non-supplemented lactating and non-lactating cows. Appl. Anim. Behav. Sci. 28: 221–232.

SAS 1985. Users guide, statistics. Version 5. SAS Institute Inc., Cary, N.C., USA.

Seligman, N.G. 1995. Management of Mediterranean Grasslands. *In:* J. Hodgson and A. Illius: Ecology and Management of Grasslands. CAB International, Oxford, UK. pp. 359-391.

Smith, R.C.G. and W.A.Williams. 1973. Model development for a deferred grazing system. J. Range Manage. 26: 454–460.

Smith, R.C.G., E.F. Biddiscombe, and W.R. Stein. 1972. Evaluation of five Mediterranean, annual pasture species during early growth. Aust. J. Agr. Res. 23: 703–16.

Tadmor, N.H., A. Brieghet, I. Noy-Meir, R.W. Benjamin, and E. Eyal. 1975. An evaluation of the calibrated weight-estimate method for measuring production in annual vegetation. J. Range Manage. 28: 65–69.

Ungar, E.D. 1990. Management of agropastoral systems in a semiarid region. Pudoc, Wageningen, The Netherlands.

Ungar, E.D. and I. Noy-Meir. 1988. Herbage intake in relation to availability and sward structure: grazing processes and optimal foraging. J. Appl. Ecol. 25:1045–1062.

Weitz, M. 1981. The energetic value of native annual range vegetation. Hassadeh 61:2053–2054 (Hebrew).

Willoughby, W.M. 1959. Limitations to pasture production imposed by seasonal fluctuations in pasture and by management procedures. Aust. J. Agr. Res. 10:248–268.

Zohary, M. 1973. Geobotanical Foundations of the Middle East. Gustav Fischer Verlag, Stuttgart, and Swets and Zeitlinger, Amsterdam.