Kermes oak shrubland resource availability and grazing responses by goats as influenced by stocking rate and grazing system

Tsiouvaras C.N., Nastis A.S., Papachristou T.G., Platis P.D., Yiakoulaki M.

in

Gibon J. (ed.), Lasseur J. (ed.), Manrique E. (ed.), Masson P. (ed.), Pluvinage J. (ed.), Revilla R. (ed.).
Systèmes d'élevage et gestion de l'espace en montagnes et collines méditerranéennes

Zaragoza : CIHEAM
Options Méditerranéennes : Série B. Etudes et Recherches; n. 27

1999
pages 155-164

Kermes oak shrubland resource availability and grazing responses by goats as influenced by stocking rate and grazing system

C.N. Tsiouvaras*, A. Nastis*, T. Papachristou, P. Platis** and M. Yiakoulaki***
*Range Science and Wildlife and Fresh Water Fisheries Department (236),
Aristotle University, 54006 Thessaloniki, Greece
**Rangeland and Wildlife Resources Section, Forest Research Institute,
National Agricultural Research Foundation, 57006 Vasilika, Thessaloniki, Greece

SUMMARY – Seasonal effects of three stocking rates on resource availability and intake of goats were evaluated in a kermes oak (*Quercus coccifera* L.) shrubland in Greece from 1991 to 1994. Stocking rates were: moderate (MSR: 1 goat/ha/y), heavy (HSR: 2 goats/ha/y) and very heavy (VHSR: 4 goats/ha/y). In an adjacent kermes oak shrubland the effects of a continuous and a rotational grazing system on forage conditions and animal performance were studied from 1992 to 1994. The stocking rate was set at 1.3 goats/ha/y. Vegetation cover (62%), forage production (1413 kg/ha) and goat liveweight gain (–2.3 kg/goat) were significantly lower and bare soil + litter higher (38%) in the VHSR compared to MSR (85%, 2905 kg/ha, 1.0 kg/goat and 15%) and HSR (80%, 2067 kg/ha, 0.5 kg/goat and 20%) while there were no significant differences ($P \leq 0.05$) between MSR and HSR in all parameters but the total forage production. The goats' forage intake was lower in HSR and VHSR (32.9 g/kg $BW^{0.75}$ and 33.3 g/kg $BW^{0.75}$ respectively) compared to MSR (46.3 g/kg $BW^{0.75}$) only during the winter. As far as the grazing system is concerned, the bare soil + litter was decreased by 67% and 35% in the rotational and the continuous grazing respectively from 1992 to 1994, while the average forage production, the shoot number from regrowth and the shoot length were higher in the rotational (3018.0 kg/ha, 35.5 n/m^2 and 3.0 cm/shoot respectively) compared to continuous grazing (2413.3 kg/ha, 31.4 n/m^2 and 2.0 cm/shoot respectively). Finally, goats in the rotational grazing gained significantly more weight (1.93 kg/animal) compared to continuous grazing (–0.60 kg/animal).

Key words: Forage production, ground cover, intake, animal performance, Greece.

RESUME – *"Disponibilité de ressources d'une garrigue de chêne Kermès et réponse au pâturage de chèvres compte en fonction du taux de charge et du système de pâturage". Les effets saisonniers de trois taux de charge sur la disponibilité des ressources et l'ingestion de chèvres ont été évalués dans des zones arbustives de chêne Kermès (*Quercus coccifera *L.) en Grèce de 1991 à 1994. Les taux de charge ont été : modéré (TCM: 1 chèvre/ha/an), lourd (TCL: 2 chèvres/ha/an), très lourd (TCTL: 4 chèvres/ha/an). Dans une zone arbustive de chêne Kermès on a étudié les effets d'un système de pâturage continu et rotationnel sur les conditions fourragères et les performances animales de 1992 à 1994. Le taux de charge a été fixé à 1,3 chèvres/ha/an. Le couvert végétal (62%), la production de fourrage (1413 kg/ha) et le gain de poids vif des chèvres (–2,3 kg/chèvre) ont été significativement plus bas et le sol nu + litière ont été plus élevés (38%) dans TCTL comparé à TCM (85%, 2905 kg/ha, 1,0 kg/chèvre et 15%) et TCL (80%, 2067 kg/ha, 0,5 kg/chèvre et 20%) tandis qu'il n'y a pas eu de différences significatives ($P \leq 0,05$) entre TCM et TCL pour tous les paramètres excepté la production totale de fourrage. L'ingestion de fourrage par les chèvres était plus faible pour TCL et TCTL (32,9 g/kg $P^{0,75}$ et 33,3 g/kg $P^{0,75}$ respectivement) comparée à TCM (46,3 g/kg $P^{0,75}$) seulement pendant l'hiver. En ce qui concerne le système de pâturage, le sol nu + litière a diminué de 67% et de 35% pour les pâturages rotationnel et continu respectivement de 1992 à 1994, tandis que la production moyenne de fourrage, le nombre et la longueur des repousses étaient plus élevés en pâturage rotationnel (3018,0 kg/ha, 35,5 n/m^2 et 3,0 cm/repousse respectivement) comparé au pâturage continu (2413,3 kg/ha, 31,4 n/m^2 et 2,0 cm/repousse respectivement). Finalement, les chèvres dans le pâturage rotationnel ont gagné significativement plus de poids (1,93 kg/animal) par rapport au pâturage continu (–0,60 kg/animal).*

Mots-clés : Production de fourrage, couvert du sol, ingestion, performances animales, Grèce.

Introduction

Shrublands cover about 200,000 km^2 in the Mediterranean area (Le Houerou, 1980). Generally, this vegetation type is composed of both evergreen and deciduous shrubs with an understorey of herbs. Kermes oak (*Quercus coccifera* L.), an evergreen sclerophyllous shrub, is the predominant vegetation of a large part of shrublands in Greece, covering approximately 1,500 km^2 or 50% of Greece's total shrubland area (Papanastasis, 1997). This species is easily selected by goats and constitutes a high proportion of their diets (Papachristou and Nastis, 1993a) but its nutritive value is ranged from medium to low (Nastis, 1985). However, when kermes oak shrubland has an open form (shrub cover ≈ 50%) then forage production of herbs is increased and therefore improves grazing conditions and enhances livestock production (Papachristou and Nastis, 1993b). At present, grazing in Greece is applied without any planned management scheme thus neglecting sustainability of the grazing lands. This practice ignores the potential improvement of production by applying improved management schemes. The stocking rate applied has an impact on both the plant community and animal production.

Growth of undisturbed shrubs in the Mediterranean zone regularly terminates by the end of June (Nastis, 1985). A secondary growth appears in late summer or early autumn only when sufficient rain occurs. Repeated clipping, however, can stimulate new growth of evergreen species (Tsiouvaras *et al.*, 1986) through the summer, even without any new rainfall. Since new growth can be stimulated when no regular growth occurs, clipping can be expected to increase the production of forage. This regrowth by clipping is expected to improve forage value since it is highly preferred by goats. However, repeated intensive grazing, especially when the environmental conditions are unfavourable (i.e. limited soil moisture) could result in reduced plant vigour. In order to maintain the desirable vigour under these environmental conditions grazing has to have more than 15 days interval (Tsiouvaras *et al.*, 1986).

There is no information concerning the effect of stocking rate on shrubland composition (i.e. shrub/herb balance), forage production, intake and weight gain of goats grazing on shrublands. Further there is no knowledge of the effects of the application of a grazing system on the above factors. In addition, lightly grazed shrubby species become tall and their production is beyond animal reach. This forage is useless to the animals while it is a fine, potentially combustible material, increasing fire hazard.

Therefore, the objectives of the paper reported here were to evaluate: (i) the effects of three stocking rates on shrubland forage conditions and intake of goats; and (ii) the effects of a continuous and a rotational grazing system on forage conditions and animal performance.

Materials and methods

The study was conducted at the Forest and Range Experimental Centre located at Chrysopigi, near the city of Serres in Macedonia, Greece. The 17-year average precipitation is 540 mm, but its distribution is uneven with a long hot and dry period from May to September. Two different size, 30-ha and 2.8-ha, shrubland areas were used, both dominated by kermes oak. The main herbaceous species were *Festuca valesiaca* Schleich., *Dactylis glomerata* L., *Bromus* spp., *Trifolium* and *Medicago* spp. The stocking rate experiment was contucted in the first area and the grazing systems experiment in the second one.

Stocking rates experiment

The first experimental area was divided into three pastures and each one was stocked at one of the following rates: moderate (MSR: 1 goat/ha/y), heavy (HSR: 2 goats/ha/y) and very heavy (VHSR: 4 goats/ha/y). Goats were introduced into the pastures in December 1990 and thereafter grazed year round for four consecutive years. Their diet was supplemented with 0.5 kg/head/day alfalfa hay, with a crude protein content of 16% on a dry matter basis, from December to April. Twelve two year-old-goats of a local breed were fitted with faecal collection bags and used to collect animal faeces during spring, autumn and winter of 1992. Faeces were collected at 12 h intervals for 5 days during each of the three experimental periods. Morning and evening samples were pooled to obtain a 24 h sample.

In addition, three oesophageally fistulated goats were used for diet sample collection. Extrusa samples were collected once daily for three consecutive days in each test period. The extrusa samples were frozen at –20°C, freeze dried and analysed for *in vitro* organic matter digestibility by a modification (Moore, 1970) of the Tilley and Terry (1963) *in vitro* technique. The animals were weighed every 30 days following a 24 h fast without feed or water. The weight changes of fistulated goats were not considered. Intake was calculated by using the indigestibility factor (Van Dyne, 1968, as reported by Holechek and Vavra, 1982) and was expressed as g DM/kg $BW^{0.75}$.

Shrub and herbage cover of each pasture were estimated with the loop method, applied on four (100 point each) permanent transects (Cook and Stubbendieck, 1986) during June of the years 1991 to 1994. Forage availability was also measured concurrently with cover measurements as follows: each pasture was considered as having four paddocks and within each of them one 1-m^2 quadrat was randomly placed. All potentially grazable forage (i.e. browse –leaves and twigs up to 5 mm diameter– and herbaceous vegetation –all material was clipped at ground level) was harvested in each quadrat, hand separated according to forage class (i.e. browse and herbage), and placed in individual paper bags. It was dried in an oven at 65°C for 48 hours and weighed.

Data from intake and faeces were analysed using ANOVA tests. The experimental design was a two factor factorial over locations. There were three pastures (locations), three stocking rates and three seasons (factors). The protected LSD test (Steel and Torrie, 1980) was used for detecting statistically significant differences ($P \leq 0.05$) between treatments means.

Grazing systems experiment

In the second experimental area a rotation and a continuous grazing system were tested. Vegetation cover of this area was a relatively dense shrub stand (64% shrub cover) composed mainly of kermes oak. The study area was divided into two shrubland sections. Within the first section, four pastures with similar vegetational characteristics were allocated; in those pastures grazing animals could move into a new pasture every week accomplishing a full rotation in three weeks. The other shrubland section remained as one pasture subjected to continuous grazing. The area was fenced with wire netting and water was supplied in each pasture.

The experiment started in spring of 1992 and lasted for three consecutive years. Thirty-two local type meat goats (without definite breed) about two years old and averaging 32 kg were used. The grazing period was initiated at the end of May and lasted for two months each year. The stocking rate was set at 1.3 goats/ha/y. Goats in both treatments were weighed at the beginning and after the termination of the grazing period. During the grazing period goats stayed in the pastures overnight.

Ground cover and plant species composition were determined on permanent transects 25 m long with the loop method (Cook and Stubbendieck, 1986). Three line transects (100 points each) were established in every pasture-replication. Forage availability was determined for each pasture separately before the initiation of grazing. All current growth twigs of shrubs and the herbaceous vegetation were harvested in two 0.25 m^2 quadrats placed on each line-transect. The harvested material from each quadrat was hand separated according to forage class (i.e. browse and herbage), placed in individual paper bags and treated in a similar way as that of the previous experiment. After the end of each grazing trial the number and the length of regrowth twigs were measured in two 0.25 m^2 quadrats randomly taken on the same line transects.

The experimental design was a completely randomised. All results were evaluated using analysis of variance procedures. The protected LSD test (Steel and Torrie, 1980) was used for detecting statistically significant differences ($P \leq 0.05$) between treatments means.

Results and discussion

Stocking rates experiment

Cover of vegetation classes and of dominant plant species (Table 1) was significantly affected by varying stocking rates, while bare soil + litter were significantly increased only under the VHSR. The "other" ligneous vegetation was drastically reduced with both the HSR and the VHSR.

Table 1. Average ground cover (%) of kermes oak shrublands grazed by goats under three stocking rates

Plant species	MSR	HSR	VHSR	LSD
Shrubs	63 a	60 a	50 b	7.20
Quercus coccifera	49 a	51 a	43 b	3.40
Cistus incanus	8 a	7 a	6 a	2.50
Other shrubs	6 a	2 b	1 b	3.35
Herbs	22 a	20 a	12 b	5.15
Grasses	13 a	11 a	6 b	4.05
Forbs	9 a	9 a	6 a	1.85
Vegetation cover	85 a	80 a	62 b	10.60
Bare soil + litter	15 b	20 b	38 a	8.70

[a,b]Means in the same line followed by the same letter are not significantly different ($P \leq 0.05$)

The HSR had no significant effect on the shrubby vegetation canopy (Table 1) which consisted mainly of kermes oak. This indicates that kermes oak has a very high grazing resistance. On the contrary, the other companion woody species were reduced by the HSR probably due to high nutritive value of these species.

Forage production of shrubby species was reduced as grazing pressure increased (Table 2). This was a result of the pruning of all the lower branches by grazing. The herbaceous species were significantly reduced under the HSR and VHSR compared to MSR (Table 2). At the VHSR, a number of bushes were carrying several dead stems. Taking into account animal weight gain (Table 2) sustainable production was secured only under the MSR and HSR for the duration of the experiment. However, under the HSR signs of over-grazing (i.e. live but defoliated branches, bare soil) were observed at the most easily reached sites, for example, close to the watering points. If intensive grazing were to continue over five years without a period of rest (Tsiouvaras, 1988) it is suspected that even the shrubby ecosystem would be destroyed in the long run and that the HSR treatment would therefore not be sustainable.

Table 2. Average forage production (kg/ha) and animal weight gain (kg/animal) of goats grazing in shrublands, under three stocking rates

Pastures	Shrubs	Herbs	Total	Animal weight gain
MSR	1710 a	1195 a	2905 a	1.0 a
HSR	1455 ab	612 b	2067 b	0.5 a
VHSR	1072 b	341 c	1413 c	–2.3 b
LSD	428	204	551	0.8

[a,b,c]Means in the same column followed by the same letter are not significantly different ($P \leq 0.005$)

Livestock production from forage based systems (Hart, 1978) is the integrated product of a complex interaction between the quantity and quality of forage consumed and the efficiency with which consumed nutrients are converted into animal products. The primary factors from the management aspect that can influence these complex relationships (Nastis, 1985) are the stocking rate, grazing frequency, and availability of forage resources within the animals' reach. A stocking rate providing a high availability of forage and the opportunity for selective grazing usually results in a higher output per animal than higher stocking rates. Conversely, over stocking may lead to reduction of valuable species and even to extinction and further to soil degradation and erosion. However, very light grazing or non-grazing may lead to increased shrubland density and height beyond animal reach. In such cases intensive grazing is expected to gradually reduce shrub density and if applied for relatively long periods may even lead to reduced tree canopy cover. In order to secure sustainability of forage production and consequently of animal products, the stocking rate has to be controlled so that a steady but productive state is maintained. A moderate stocking rate that would not drastically reduce the production of the herbaceous layer can be considered as the appropriate stocking rate.

Mean forage intake (Table 3) in the MSR treatment (44.3 g/BW$^{0.75}$) was significantly ($P \leq 0.05$) higher than in the HSR (37.3 g/BW$^{0.75}$) and VHSR (35.4 g/BW$^{0.75}$) treatments. When the stocking rate increased animals had no chance to graze selectively because of the increased removal rate of preferred species and plant parts (Allison, 1985).

Table 3. Intake (g/kg BW$^{0.75}$) of goats grazing in a kermes oak shrubland at three stocking rate treatments (adapted from Yiakoulaki and Nastis, 1996)

Stocking rate	Spring	Autumn	Winter	Mean
MSR	47.5 a	38.5 a	46.3 a	44.3 a
HSR	42.4 a	36.8 a	32.9 b	37.3 b
VHSR	39.7 a	35.5 a	33.3 b	35.4 b
LSD	10.8	6.3	8.4	5.5

[a,b]Means in the same column followed by the same letter are not significantly different ($P \leq 0.05$)

Forage intake in the MSR treatment was not significantly different ($P \leq 0.05$) from that of the other two treatments in spring, but a tendency was observed towards higher mean values (Table 3). Total faecal output in spring and winter was significantly higher ($P \leq 0.05$) in the MSR treatment than that in the HSR and VHSR (Table 4). No significant difference ($P \leq 0.05$) was found in dietary IVOMD between these treatments in spring, but a trend towards greater IVOMD in the VHSR treatment was observed, which may explain why no significant differences ($P \leq 0.05$) were found in intake levels in spring. This is most probably a result of the greater digestibility in the VHSR treatment since the participation of *Trifolium* and *Medicago* species in the goats' diet (Papachristou and Nastis, 1996) was higher.

Table 4. Faeces (g/day) of goats grazing in a kermes oak shrubland at three stocking rate treatments (adapted from Yiakoulaki and Nastis, 1996)

Stocking rate	Spring	Autumn	Winter
MSR	413 a	350 a	464 a
HSR	370 b	359 a	374 b
VHSR	372 b	323 a	330 b
LSD	31.3	48.7	69.4

[a,b]Means in the same column followed by the same letter are not significantly different ($P \leq 0.05$)

Differences in intake were not significant ($P \leq 0.05$) among the three stocking rates in autumn (Table 3). Owing to the heavy forage utilisation most of the preferred species had been consumed and only a small proportion of them was available. Intake was significantly higher ($P \leq 0.05$) in the MSR treatment than in the other two treatments in winter. This may be attributed to the higher forage availability in the MSR, where goats selected the best parts of shrubs while in the other treatments, forage on offer was limited. Additionally, a significant proportion (12%) of the diet's botanical composition (Papachristou and Nastis, 1996) was not identified in the extrusa samples taken from the MSR treatment. The part of the extrusa that cannot be identified is most probably attributed to forbs and shrubby species since grasses are characterised by well pronounced epidermal shapes. As is known, higher amounts of forbs and shrubs in the diet can result in higher intake levels (Ingalls *et al.*, 1966; Short *et al.*, 1974; Yiakoulaki and Nastis, 1995).

The goats' forage intake levels in all treatments were much lower than the values measured by Yiakoulaki and Nastis (1995) in the same area in 1988–1989. This was probably due to the limited forage availability and to the lower nutritive value of the goats' diet in the present study.

The results of this study suggest that goats' intake is lower in the HSR and the VHSR treatments during the winter. These results are in agreement with those of Vavra *et al.* (1973), Pinchak *et al.* (1990) and Mckown *et al.* (1991) who studied the effect of light and heavy stocking rates on cattle intake.

Grazing systems experiment

Average ground cover (Table 5) and species composition (Table 6) in the pastures with the rotational and the continuous grazing presented only small changes through the years. The increase of the broad-leaf plants in the ground cover during 1994 contributed to the decrease of bare soil (Table 5). Grass composition fluctuated during the years, while legumes and forbs increased drastically in 1994 (Table 6), probably due to the favourable combination of precipitation and temperature during the autumn of 1993.

Table 5. Ground cover (%) during three consecutive years, in a kermes oak shrubland grazed under rotational (R) and continuous (C) grazing system

Years	1992		1993		1994	
Grazing system	R	C	R	C	R	C
Woody species	64.7	71.5	64.7	60.5	59.9	60.8
Grasses	6.0	6.3	7.3	9.0	4.5	2.5
Legumes + forbs	10.0	6.0	8.8	11.2	27.5	25.0
Litter	4.0	6.2	7.5	9.5	3.1	5.2
Bare soil	15.3	10.0	11.7	9.8	5.0	6.5

Table 6. Species composition (%) during three consecutive years, of a kermes oak shrubland grazed under a rotational (R) and a continuous (C) grazing system

Years	1992		1993		1994	
Grazing system	R	C	R	C	R	C
Woody species	80.2	85.2	80.1	74.9	65.2	68.9
Grasses	7.4	7.6	9.0	11.2	5.0	2.8
Legumes + forbs	12.4	7.2	10.9	13.9	29.8	28.3

No significant differences in cover and composition existed between the treatments (Table 7). It seems that for vegetation changes related to grazing systems three years is a short period compared to the ten years reported by Gutman and Seligman (1979) and eight years by Fourie *et al.* (1995).

Forage production was higher in the rotational grazing system than in the continuous one (Table 8). This was probably a result of the time for rest given to plants in the rotational grazing which helped them to recover from grazing and to produce new forage (regrowth). Liveweight gain was significantly higher in the rotational grazing than in the continuous (Table 8). Rotational grazing with goats for long term browse utilisation is used by many operators in chaparral vegetation in California; this grazing with a moderate stocking rate maintains the long term productivity of shrubs and secures animal products which produce a return for the operator (Plaister and Dal Porto, 1976, referred by Nichols *et al.*, 1984). However, the results of the present research do not coincide with Heady's review (1961) who reported that animal production was not improved by various systems of rotational and deferred grazing in annual pastures in California. Nor were significant differences in weight gain detected between the rotational and the continuous grazing systems in a grassland in Israel (Gutman and Seligman, 1979). The difference with the results of the present research is probably due to different vegetation type studied (shrubland instead of grassland) and especially to kermes' oak regrowth ability during summer which is favored by the rotational grazing. The liveweight gain in the rotational grazing was probably attributed: (i) to better quality of browse due to more abundant resprouting (new regrowth) of kermes oak when it was grazed periodically; (ii) to higher overall percentage utilisation which was probably facilitated by the higher number and the longer shoots in the rotational compared to continuous grazing (Table 9), that may have led to higher intake levels; and (iii) to confined grazing in the rotational system which was less energy cost to the grazing animals compared to continuous grazing. It seems that the 20-day interval period of rest which was given to kermes oak in the rotational grazing treatment was sufficient for the plants to recover from grazing and to regain their vigour as it is also reported by Tsiouvaras *et al.* (1986).

Table 7. Average ground cover (%) and species composition (%) in a kermes oak shrubland grazed for three consecutive years under a rotational (R) and a continuous (C) grazing system

Grazing system	Ground cover		LSD	Species composition		LSD
	R	C		R	C	
Woody species	63.1 a[†]	64.2 a	11.8	75.2 a[††]	76.3 a	12.3
Grasses	5.9 a	5.9 a	2.1	7.1 a	7.2 a	2.0
Legumes + forbs	15.4 a	14.1 a	4.3	17.7 a	16.5 a	2.8
Litter	4.9 a	7.0 a	2.5			
Bare soil	10.7 a	8.8 a	4.0			

[†]Means of cover in the same line followed by the same letter are not significantly different ($P \leq 0.05$)
[††]Means of composition in the same line followed by the same letter are not significantly different ($P \leq 0.05$)

Table 8. Average forage production (kg/ha) and goat liveweight gain (kg/animal) in a kermes oak shrubland grazed under a rotational and a continuous grazing system

Grazing system	Rotational	Continuous	LSD
Forage production	3018.0 a	2413.3 b	118.74
Liveweight gain	+1.93 a	–0.60 b	0.78

[a,b]Means in the same line followed by the same letter are not significantly different ($P \leq 0.05$)

Conclusions

(i) The MSR and the HSR have caused smaller vegetation changes in a kermes oak shrubland compared to VHSR and are favoured when environmental degradation and sustainability are considered.

(ii) There was no indication that MSR had a nutritional advantage to goats grazing in a kermes oak shrubland when compared to HSR and VHSR.

(iii) The intake of goats grazing in a kermes oak shrubland under a MSR was somewhat greater compared to HSR and VHSR and goats gained more body weight in the moderately stocked pasture.

(iv) A rotational grazing system in a kermes oak shrubland allowed for higher forage production and animal liveweight gain, compared to a continuous grazing system at the same stocking rate.

(v) A three-year period is probably short to detect permanent changes in vegetation cover and composition related to grazing system applied.

Table 9. Average shoot number (n/m^2) and shoot length (cm/shoot) after regrowth in a kermes oak shrubland grazed under a rotational and a continuous grazing system

Grazing system	Rotational	Continuous	LSD
Shoot number	35.5 a	31.4 b	2.57
Shoot length	3.0 a	2.0 b	0.45

[a,b]Means in the same line followed by the same letter are not significantly different ($P \leq 0.05$)

Acknowledgements

This research was part of the project: "Analyse et modélisation du fonctionnement des exploitations. Implications pour la gestion de l'espace en région méditerranéennes en retard de développement", financed by the CAMAR programme of the European Commission.

References

Allison, C.D. (1985). Factors affecting forage intake by range ruminants: A review. *J. Range Manage.*, 38: 305-311.

Cook, C.W. and Stubbendieck, J. (1986). *Range research: Basic problems and techniques*. Society for Range Management, Denver, CO.

Fourie, J.H., Bransby, D.I. and West, N.E. (1995). Effects of stocking rate and continuous and rotational stocking on steers grazing semi-arid rangeland in South Africa. In: *Proc. Fifth International Rangeland Congress "Rangelands in a Sustainable Biosphere"*, Salt Lake City, UT, 23-28 July 1995. Society for Range Management, Denver, CO, pp. 157-158.

Gutman, M. and Seligman, N.G. (1979). Grazing management of herbaceous Mediterranean foothill range in the Upper Jordan Valley. *J. Range Manage.*, 32: 86-92.

Hart, R.H. (1978). Stocking rate theory and its application to grazing on rangelands. In: *Proc. 1st International Rangeland Congress*, Denver, CO, 14-18 August 1978, Hyder, D.N. (ed.). Society for Range Management, Denver, CO, pp. 547-550.

Heady, H.F. (1961). Continuous vs. specialized grazing systems: A review and application to the California annual type. *J. Range Manage.*, 14: 182-193.

Holechek, J.L. and Vavra, M. (1982). Forage intake by cattle on forest and grassland ranges. *J. Range Manage.*, 35: 737-741.

Ingalls, J.R., Thomas, J.W., Tesar, M.G. and Carpenter, D.L. (1966). Relations between *ad libitum* intake of several forages and gut fill. *J. Anim. Sci.*, 25: 283-289.

Le Houerou, H.N. (1980). The role of browse in the management of natural grazing lands. In: *Browse in Africa*, Le Houerou, H.N. (ed.). ILCA, Addis Ababa, pp. 329-338.

Mckown, C.D., Walker, J.W., Stuth, J.W. and Heitschmidt, R.K. (1991). Nutrient intake of cattle on rotational and continuous grazing treatments. *J. Range Manage.*, 44: 596-601.

Moore, J.E. (1970). Procedure for the two-stage *in vitro* digestion of forages. In: *Nutrition research techniques for domestic and wild animals*, Vol. I., Harris, L.E. (ed.). Utah State University, Logan, pp. 5001-5003.

Nastis, A.S. (1985). Nutritive value of oak browse (*Quercus coccifera*) foliage at various phenological stages. Paper presented at the 36th Annual Meeting of the European Association for Animal Production, Kallithea, Greece, 30 Sept.-3 Oct. 1985.

Nichols, R., Adams, T. and Menke, J. (1984). Shrubland management for livestock forage. In: *Shrublands in California: Literature review and research needed for management*, DeVries, J.J. (ed.). California Water Resources Center, University of California, Contribution no. 191, pp.146.

Papachristou, T.G. and Nastis, A.S. (1993a). Diets of goats grazing oak shrublands of varying cover in northern Greece. *J. Range Manage.*, 46: 220-226.

Papachristou, T.G. and Nastis, A.S. (1993b). Nutritive value of diet selected by goats grazing on kermes oak shrublands with different shrubs and herbage cover in Northern Greece. *Small Ruminant Res.*, 12: 35-44.

Papachristou, T.H. and Nastis, A.S. (1996). Diets of goats grazing kermes oak shrubland as influenced by stocking rate. In: *Proceedings of the International Symposium on the Optimal Exploitation of Marginal Mediterranean Areas by Extensive Ruminant Production Systems*, Thessaloniki, 18-20 June 1994, Zervas, N.P. and Hatziminaoglou, J. (eds). EAAP Publication No. 83, Hellenic Society of Animal Production, Athens, pp. 225-226.

Papanastasis, V.P. (1997). Improvement of kermes oak shrublands for sustainable use by livestock (in Greek with English abstract). In: *1st National Rangeland Congress "Sustained Utilisation of Rangelands and Pastures"*, Drama, 6-8 November 1996, Papanastasis, V. (ed.). Hellenic Range and Pasture Society, Publication no 4, pp. 261-270.

Pinchak, W.S., Canon, S.K., Heitschmidt, R.K. and Dowher, S.L. (1990). Effect of long-term, year-long grazing at moderate and heavy rates of stocking on diet selection and forage intake dynamics. *J. Range Manage.*, 43: 304-309.

Plaister, R.E. and Dal Porto, N. (1976). Angora goats for foothill brush area. Unpublished report, University of California, Cooperative Extension, Jackson, CA.

Short, H.L., Blair, R.M. and Sagelquist, C.A. (1974). Fibber composition and forage digestibility by small ruminants. *J. Wildlife Manage.*, 38: 197-209.

Steel, R.G.D. and Torrie, J.H. (1980). *Principles and procedures of statistics*, 2nd edn. McGraw-Hill Book Co. Inc., New York.

Tilley, J.M. and Terry, R.A. (1963). A two stage technique for the in vitro digestion of forage crops. *J. Brit. Grassl. Soc.*, 18: 104-111.

Tsiouvaras, C.N. (1988). Long-term effects of clipping on production and vigor of kermes oak (*Quercus coccifera*). *Forest Ecol. Manage.*, 24: 159-166.

Tsiouvaras, C.N., Noitsakis, B. and Papanastasis, V.P. (1986). Clipping intensity improves growth rate of kermes oak twigs. *Forest Ecol. Manage.*, 15: 229-237.

Vavra, M., Rice, R.W. and Bement, R.E. (1973). Chemical composition of the diet, intake on different grazing intensities. *J. Anim. Sci.*, 36: 411-414.

Yiakoulaki, M.D. and Nastis, A.S. (1995). Intake by goats grazing kermes oak shrublands with varying cover in Northern Greece. *Small Ruminant Res.*, 17: 223-228.

Yiakoulaki, M.D and Nastis, A.S. (1996). Effect of stocking rate on intake and weight gain of goats grazing in kermes oak shrubland. In: *Proceedings of the International Symposium on the Optimal Exploitation of Marginal Mediterranean Areas by Extensive Ruminant Production Systems*, Thessaloniki, 18-20 June 1994, Zervas, N.P. and Hatziminaoglou, J. (eds). EAAP Publication No. 83, Hellenic Society of Animal Production, Athens, pp. 243-247.