The effect of stocking rate on the performance of ewes and lambs on Italian ryegrass

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Received 14 February 1992; revised 28 August 1992; accepted 7 December 1992

Italian ryegrass was evaluated over four seasons at stocking rates (SR) of 20, 24, 28, 32 and 36 ewes with lambs/ha. During each of three seasons, between 19 and 24 ewes per SR were milked for 10 weeks, from three weeks *post partum* until the lambs were weaned at approximately 100 days of age. The ewes and lambs were kept on pasture for 12 weeks. An eight-camp rotational grazing system was applied with a fixed period of grazing of 3.5 days per camp. Ewes with twins lost between 2.2 and 15.7% and ewes with single lambs between 1.6 and 11.0% of live mass at the SR of 20 or 36 ewes with lambs/ha, respectively. SR exerted a significant ($P \leqslant 0.05$) effect on lamb growth. At an SR of 20 ewes with lambs/ha, lambs gained mass 35% (single and twin lambs), 40% (twin lambs) and 29% (single lambs) faster than those at an SR of 36 ewes with lambs/ha. A highly significant ($P \leqslant 0.001$) relationship was found between average daily gain and the post-grazing pasture height. The average weaning mass of lambs declined from 22.9 to 17.2 kg ($P \leqslant 0.05$) at an SR of 20 or 36 ewes with lambs/ha, respectively. The relationship between lamb growth and milk production was strongest during the first 6 weeks on pasture. A multiple regression analysis showed that SR accounted for 22.5% ($P \leqslant 0.001$), ewe mass 13.5% ($P \leqslant 0.001$), mean milk production 12.1% ($P \leqslant 0.001$), birth status 5.8% ($P \leqslant 0.001$), ewe mass change 2.3% ($P \leqslant 0.01$) and initial lamb mass 1.8% ($P \leqslant 0.05$) of the variation in lamb growth.

Italiaanse raaigras is oor vier seisoene teen veebeladings van 20, 24, 28, 32 en 36 ooie met lammers/ha geëvalueer. Gedurende drie seisoene is tussen 19 en 24 ooie per veebelading gemelk vir 10 weke, vanaf drie weke *post partum* tot lammers op ongeveer 100-dae-ouderdom gespeen is. 'n Agt-kamp wisselweistelsel is toegepas met 'n vaste wei-periode van 3.5 dae per kamp. Die ooie en lammers het die weidings vir 12 weke benut. Die massaverlies van ooie met tweelinge het tussen 2.2 en 15.7% en dié van ooie met enkelinglammers tussen 1.6 en 11.0% gevarieer by die veebeladings van 20 en 36 ooie met lammers/ha, onderskeidelik. Veebelading het 'n betekenisvolle ($P \leqslant 0.05$) negatiewe invloed op die lamgroei gehad. Die massatoenames van lammers by die veebelading van 20 ooie met lammers/ha was 35% (enkeling en tweeling), 40% (tweelinge) en 29% (enkelinge) hoër as dié van lammers by 'n veebelading van 36 ooie met lammers/ha. 'n Hoogs betekenisvolle ($P \leqslant 0.001$) verwantskap is tussen lamgroei en die na-beweiding weihoogte gevind. Die gemiddelde speenmassa van lammers het tussen 22.9 en 17.2 kg ($P \leqslant 0.05$) by die veebeladings van 20 en 36 ooie met lammers/ha, onderskeidelik, gevarieer. Die verwantskap tussen lamgroei en melkproduksie was die sterkste gedurende die eerste 6 weke op weidings. 'n Meervoudige regressie-ontleding het getoon dat veebelading 22.5% ($P \leqslant 0.001$), ooimassa 13.5% ($P \leqslant 0.001$), gemiddelde melkproduksie 12.1% ($P \leqslant 0.001$), geboortemassa 5.8% ($P \leqslant 0.001$), ooimassa-verandering 2.3% ($P \leqslant 0.01$) en die aanvangsmassa van die lam 1.8% ($P \leqslant 0.05$) van die variasie in lamgroei verklaar.

Keywords: Average daily gain, ewe mass change, Italian ryegrass, milk production, stocking rate.

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Introduction

Italian ryegrass (*Lolium multiflorum*) is widely utilized in South Africa. The growth pattern during autumn and late winter/spring is synchronized with the traditional autumn lambing season. Thus, there is a supply of succulent, high-quality grazing available during peak periods of nutrient requirement, for lactating ewes and pre- and post-weaned lambs. Recommended stocking rate (SR) in practice varies from 24 to 30 ewes with lambs/ha but there is a dearth of information regarding the effect of SR on ewe and lamb performance under South African conditions.

The nutrient composition of ryegrass is typically 2.5 to 4.8% N (15 to 30% CP), 33 to 55% neutral detergent fibre (NDF), 10 to 20% soluble carbohydrate levels and 67 to 79% *in vivo* digestible organic matter (DOM) (MacRae, 1976; Meissner *et al.*, 1989; De Villiers, 1991), suggesting that it is a good source of nutrients for ruminants. However, the nutritive value of forages is a function not only of the nutrient content but also of voluntary consumption. According to Meissner *et al.* (1989), the production potential of sheep grazing cultivated pastures is more a function of quantitative than of qualitative intake. This is in accordance with the contention of Heany (1970) and Waldo & Jorgensen (1981) that voluntary intake, rather than nutritive content, accounts for most of the variation in performance of ruminants on forages. In the majority of sheep production systems on pasture, lambs obtain their nutrients from only two sources, namely milk and grazed herbage. Jordan & Mayer (1989) stated that the most important variable affecting lamb growth rate is milk yield of the ewe. According to Treacher (1983), lambs will not be able to increase herbage intake in response to a low milk intake that results from low herbage intake of the ewe.

The rate at which a pasture is stocked (animals/ha) is probably the most important factor in grazing management (Edwards, 1981). Although SR is widely recognized as a major determinant of the productivity of grazing systems, little information is available on the performance of ewes and lambs on ryegrass and their response to various management procedures. In this study, the effect of five different levels of SR was determined on the performance of South African Mutton Merino (SAMM) ewes and lambs when grazing irrigated ryegrass.

Experimental procedure

Experimental terrain, pasture management and treatments

Italian ryegrass (cv. Midmar) was established on a 3.5 ha vleiland (Katspruit soil form) at the Cedara Agricultural Research Station (29° 32′S; 30° 17′E) in the Natal Mistbelt during 1983, 1984, 1985 and 1987. The altitude at Cedara is 1 075 m and the average annual rainfall 885 ± 142 mm, most of which falls during the summer months (October to March).

The ryegrass is established annually during February at a seeding rate of 25 kg/ha. It is fertilized at 350 kg N/ha/season. The N is applied in the form of limestone ammonium nitrate (LAN – 28% N) in six dressings of 58 kg N/ha/dressing. The first dressing is applied when the seedlings are about 2.5 cm tall and the subsequent five dressings at approximately four-weekly intervals. The pasture is irrigated with a weekly application of approximately 25 mm.

SR of 20, 24, 28, 32 and 36 ewes with lambs/ha were applied during each of four seasons. The land used in the experiment, 3.5 ha of vleiland, was subdivided into eight areas, each of which was further divided into five randomly selected subareas, corresponding to the treatment camps. The sizes of the treatment camps varied, while animal numbers were kept constant over treatments, to obtain the desired SR. The grazing system applied was an eight-camp rotational system with a fixed period of stay of 3.5 days per camp. This allowed for a 24.5-day regrowth period.

Experimental animals

A total of 55, 57, 56, 57 and 54 ewes (initial mass of approximately 63 kg) and 79, 80, 69, 78 and 72 lambs were used for the SR levels of 20, 24, 28, 32 and 36 ewes with lambs/ha, respectively, over the four seasons. The ewes and lambs were moved from kikuyu to ryegrass pasture at approximately 14 days *post partum* (mid-April).

Each year, the ewes with lambs were allocated to the five treatments using a randomized block design, blocking for live mass, birth status (singles and twins), age and sex. Ewes and lambs were weighed every Monday, without water and feed being withheld prior to the weighings. The sheep had free access to fresh water in portable water troughs and to a mineral lick, consisting of 50% salt, 25% bone meal and 25% feedlime. Sheep were dosed and inoculated according to a local management programme. Worm egg counts were conducted on a weekly basis by Allerton Veterinary Laboratories and were also used as a guide for dosing. Lambs were docked at an age of approximately 4 weeks. Ram lambs were not castrated. The animals were kept on the pasture for 12 weeks (84 days, three grazing cycles of 28 days each) before the lambs were weaned at approximately 100 days of age.

Chemical analysis

Herbage samples (hand-cut) were analysed for crude protein (CP) (Kjeldahl procedure; AOAC, 1980), nitrate-nitrogen (NH_3-N) content (the specific ion electrode method; Barker, 1974; Orion Research Inc., 1979), crude fibre (CF) (Bredon & Juko, 1961), dry matter and ash (AOAC, 1980).

Pasture availability

Pasture availability and the severity of grazing were measured with a pasture disc meter (Bransby & Tainton, 1977) and expressed in cm. During 1984 and 1985, disc meter readings were taken in all the camps in the eight-camp grazing system, with only four in 1983 and three in 1987. The mean disc height before grazing (pre-grazing) and the height after grazing (post-grazing) were calculated from 50 in and out readings per camp. The mean pre- and post-grazing heights of the five treatments over the four seasons were used in a regression analysis to predict average daily gain of lambs. The following equation, derived under local conditions and given by Bartholomew (1985), was used to determine pasture DM mass:

$$y = 1101.0 + 156.06d$$

where y = yield in kg dry matter/ha and
d = mean pasture meter disc height.

Milk production

Between 19 and 24 ewes per SR were used to determine milk yield on the ryegrass. The first milking was performed during the third week *post partum*. Thereafter, milk production was measured at weekly intervals for a total of 10 weeks, using a method similar to that of Coombe *et al.* (1960), except that a period of 4 h between milkings was used instead of 2 h. On milking day, the lambs were separated from the ewes, whereafter the ewes were injected with 0.5 ml oxytocin (5 I.U.) intravenously and completely milked out by hand. The exact time of milking was noted and 4 h later the same procedure was followed. From this second milking, the yield was estimated and milk samples were obtained. The quantity of milk produced was multiplied by six to determine the daily production.

Statistical analyses

Analysis of variance (Statgraphics, 1988) on animal performance data was used to test for significance of the treatments. Regression analysis techniques were used to predict the ADG of lambs, using the readings of the height of the pasture before and after grazing. Linear regressions of lamb growth (g/d; Y) on milk yield (ml/d; X) were calculated for the period 3 to 12 weeks *post partum* and for the grazing periods 3 to 4 weeks (early May), 5 to 8 weeks (May/June) and 9 to 12 weeks

(June/July) for the ewes with twin and with single lambs. Multiple regression analyses were performed for the variables ADG of lambs and mass change of ewes, using the predictor variables SR, disc in, disc out, initial ewe mass, ewe mass change, initial lamb mass, mean milk production, season, birth status and sex.

Results and Discussion

Chemical composition

The chemical composition of the ryegrass was not affected by SR (Table 1). The CP concentrations were high in all treatments, and according to the ARC (1980), greatly in excess of the requirements of the sheep in all stages of production.

Ewe performance and pasture availability

The loss of live mass (Table 2), especially at the relatively high SR levels, show that the intake of the ewes was not sufficient to supply the requirements for maintenance plus milk production. Rattray *et al.* (1982) found similar mass losses where ewes, grazing on ryegrass and white clover pastures and with live masses of 55 to 58 kg, were offered a range of herbage allowances (2, 4, 6, 8 and 10 kg DM/ewe/d) from birth of their lambs until weaning 10 weeks later. At the very high allowance (10 kg DM/ewe/d), ewes gained 1.6 to 6.7 kg and at 2 kg DM/ewe/d the ewes lost 4.3 to 6.4 kg over the 10-week lactation period (Rattray *et al.*, 1982).

The average pre- and post-grazing pasture heights are summarized in Table 3. These measurements of pasture availability indicate a decrease in successive grazing cycles with increasing SR and hence the potential problem of competition for forage between the ewes and their lambs.

A pre-grazing height of 13.5 cm, as measured during the first grazing cycle (mid-April/May) (Table 3), predicts a pasture yield of 3200 kg DM/ha. Rattray & Jagusch (1978)

Table 1 Average (± *SD*) chemical composition of the ryegrass grazed, on a dry-matter basis

	Stocking rate (ewes with lambs/ha)				
	20	24	28	32	36
CP (%)	24.07	24.63	24.23	25.32	26.39
	±3.43	±3.42	±2.62	3.99	4.33
NO_3-N (%)	0.32	0.39	0.38	0.29	0.38
	±0.09	±0.11	±0.08	±0.10	±0.17
Ash (%)	13.01	13.33	14.32	12.99	14.45
	±1.21	±1.72	±2.50	±1.62	±1.95
CF (%)	20.85	20.25	19.79	19.04	18.31
	±2.63	±3.12	±2.41	±2.54	±2.33

Table 2 The performance of ewes on Italian ryegrass grazed at five stocking rates over four seasons

	Stocking rate (ewes with lambs/ha)				
Parameter	20	24	28	32	36
Number of ewes					
All ewes	55	57	56	57	54
% Twin ewes	42	40	36	40	35
All ewes					
Mass loss (g/d)	$-14.7^a \pm 8.87$	$-13.4^a \pm 9.88$	$-73.0^b \pm 9.83$	$-69.6^b \pm 8.71$	$-92.3^b \pm 7.91$
Mass loss (%)	$1.8^a \pm 1.18$	$1.4^a \pm 1.41$	9.9 ± 1.31	9.5 ± 1.19	12.7 ± 1.05
Ewes with twins					
Mass loss (g/d)	$-16.5^a \pm 11.05$	$-23.9^a \pm 9.53$	$-75.4^b \pm 18.06$	$-81.6^b \pm 15.20$	$-111.9^b \pm 13.47$
Mass loss (%)	$2.2^a \pm 1.50$	$3.2^a \pm 1.33$	$10.2^b \pm 2.41$	$11.0^{b,c} \pm 2.03$	$15.7^c \pm 1.68$
Ewes with singles					
Mass loss (g/d)	$-13.4^a \pm 13.16$	$-6.2^a \pm 15.25$	$-71.7^b \pm 11.74$	$-61.5^b \pm 10.33$	$-81.6^b \pm 9.42$
Mass loss (%)	$1.6^a \pm 1.73$	$0.2^a \pm 2.19$	$9.7^b \pm 1.56$	$8.5^b \pm 1.46$	$11.0^b \pm 1.26$

$^{a-c}$ Values in the same row with different superscripts are significantly ($P \leq 0.05$) different.

Table 3 The mean pre- and post-grazing (IN and OUT) heights for grazing cycles 1, 2 and 3 over four seasons

Disc		Stocking rate (ewes with lambs/ha)				
reading	Cycle	20	24	28	32	36
IN	1	13.94 ± 4.26	13.65 ± 3.92	14.31 ± 4.55	14.06 ± 3.86	13.57 ± 4.11
	2	7.87 ± 1.52	7.05 ± 1.45	6.91 ± 1.79	6.24 ± 1.17	6.15 ± 1.38
	3	6.65 ± 1.27	5.17 ± 1.09	5.39 ± 1.74	4.39 ± 0.81	4.09 ± 0.82
OUT	1	4.98 ± 0.97	4.32 ± 0.88	4.14 ± 1.15	3.78 ± 0.89	3.41 ± 0.93
	2	3.35 ± 0.79	2.72 ± 0.69	2.48 ± 0.62	2.16 ± 0.49	1.83 ± 0.52
	3	3.22 ± 0.27	2.21 ± 0.25	1.96 ± 0.38	1.62 ± 0.28	1.54 ± 0.32

found that during early lactation, the optimum pasture allowance for ewes suckling singles or multiples was 4.5 to 6.5 kg DM/ewe/d from pastures yielding 3 000 to 4 000 kg DM/ha. Using the allowances provided by Rattray & Jagusch (1978), sufficient pasture was supplied during the first grazing cycle in all the treatments to meet the daily dry matter requirements of the ewes in the present study. However, during grazing cycles 2 (May/June) and 3 (June/July), the pasture availability declined to 2 329 kg DM/ha (pre-grazing height = 7.87 cm) at the low SR and 2 060 kg DM/ha (pre-grazing height = 6.15 cm) at the highest SR. During cycle 3, which constituted the last 4 weeks before weaning, the availability declined to 2 139 kg DM/ha (pre-grazing height = 6.65 cm) and 1 739 kg DM/ha (pre-grazing height = 4.09 cm) at the lowest and highest SR levels, respectively. In both the second and third grazing cycle, the pasture availability per ewe was lower than that recommended by Rattray & Jagusch (1978).

From the post-grazing heights (Table 3), it was predicted that the pasture residues during the first cycle were 1 878 and 1 633 kg DM/ha for the lowest and highest SR, respectively. During grazing cycle 2, the post-grazing pasture residues were 1 623 and 1 387 kg DM/ha and during cycle 3, 1 603 and 1 341 kg DM/ha for the lowest and highest SR, respectively. The disc data (Table 3) show that the post-grazing height decreased with advancing cycles and with an increase in SR. According to Rattray *et al.* (1982), the post-grazing pasture residues should be 1 400 to 1 600 kg DM/ha for lactating ewes and their lambs to achieve live mass gains exceeding 200 g/d for twin lambs and closer to 300 g/d for single lambs. These authors pointed out that it becomes increasingly difficult for sheep to harvest pasture when availability falls below 2 000 kg DM/ha. Penning *et al.* (1986) found that herbage intake by ewes and growth rate of lambs increased up to a herbage allowance which was over five times the amount of herbage consumed by ewes.

A stepwise multiple regression analysis was used to identify the factors responsible for variation in ewe mass change. Stocking rate accounted for 16.9% ($P \leq 0.001$) and season for 7.3% of the variation in ewe live mass change. In order to obtain a prediction equation for future purposes, in which seasonal effects are unknown, the regression equation which describes the ewe live mass loss until weaning was modified by omitting season as an independent variable. The regression equation describing ewe mass change is:

$$Y = 97.5\ (\pm\ 17.5) - 5.38\ (\pm\ 0.617)\,SR$$
$$(r^2 = 0.17;\ Sy.x = 66.76,\ P \leq 0.001)$$

where Y = ewe mass change and SR = stocking rate.

Lamb growth

From Table 4 it is evident that SR had a significant ($P \leq 0.05$) effect on live mass gain with lambs subjected to the SR of 20 ewes with lambs/ha gaining 35% (all lambs), 40% (twin lambs) and 29% (single lambs) more than those subjected to the SR of 36 ewes with lambs/ha. The average weaning mass of the lambs declined from 22.9 to 17.2 kg at the SR levels of 20 and 36 ewes with lambs/ha, respectively. This could be the result of the drop in pre- and post-grazing pasture heights (Table 3), which indicates a reduced pasture availability and results in poor intakes due to a lower post-grazing pasture mass.

The data summarized in Table 4 show that (during cycle 1) SR initially had little effect on lamb growth rate, but as the lamb grew older the effect of declining herbage availability (for a SR) became progressively greater. At low herbage allowance, intake reduces milk production by ewes (Gibb & Treacher, 1978) and this causes an increase in herbage intake by lambs (Penning & Gibb, 1979). According to Robinson (1990) the rapid decline in the ewe's milk yield after 6 weeks represents a withdrawal of valuable rumen by-pass protein in

Table 4 The performance of suckling lambs on Italian ryegrass grazed for 84 days at five different stocking rates over four seasons

	Stocking rate (ewes with lambs/ha)				
Parameter	20	24	28	32	36
No. of lambs	79	80	69	78	72
% Twin lambs	57	60	49	51	50
All lambs					
Weaning mass (kg)	$22.9^a \pm 0.511$	$21.7^a \pm 0.492$	$19.9^b \pm 0.532$	$19.4^b \pm 0.479$	$17.2^c \pm 0.519$
ADG (g/d)	$193^a \pm 5.73$	$176^b \pm 5.24$	$157^c \pm 5.91$	$151^c \pm 4.95$	$125^d \pm 5.14$
Twin lambs					
Weaning mass (kg)	$20.8^a \pm 0.531$	$20.1^{a,b} \pm 0.571$	$18.6^{b,c} \pm 0.654$	$18.2^c \pm 0.570$	$15.0^d \pm 0.535$
ADG (g/d)	$186^a \pm 6.46$	$167^b \pm 7.21$	$145^c \pm 8.41$	$147^c \pm 6.95$	$112^d \pm 5.92$
Single lambs					
Weaning mass (kg)	$24.4^a \pm 0.862$	$24.3^a \pm 0.678$	$21.2^b \pm 0.784$	$20.8^b \pm 0.728$	$19.2^b \pm 0.746$
ADG (g/d)	$198^a \pm 9.26$	$197^{a,b} \pm 7.46$	$174^{b,c} \pm 8.29$	$161^{c,d} \pm 7.53$	$140^d \pm 8.00$
ADG (g/d)					
All lambs: Cycle 1	$217^a \pm 8.07$	$217^a \pm 6.74$	$208^{a,b} \pm 8.38$	$199^{a,b} \pm 7.69$	$188^b \pm 8.54$
Cycle 2	$210^a \pm 7.28$	$193^{a,b} \pm 6.48$	$178^{b,c} \pm 8.70$	$171^c \pm 6.33$	$135^d \pm 10.32$
Cycle 3	$155^a \pm 11.31$	$121^b \pm 7.08$	$92^c \pm 6.67$	$89^c \pm 5.38$	$57^d \pm 11.31$

$^{a-d}$ Values in the same row with different superscripts are significantly ($P \leq 0.05$) different.

the form of milk by the lamb. However, in this experiment, lambs were probably unable to increase their intake of herbage during cycles 2 and 3 because of low herbage availabilities and competition with the ewes. The performance of the lambs at all five SR levels is relatively unsatisfactory when compared to the growth rates of 287 g/d over 92 days with an average final mass of 30.1 kg obtained at the Kokstad Research Station for Merino lambs on irrigated oats/ryegrass pasture at 20 ewes and lambs/ha (A.D. Lyle, 1991; personal communication). The Kokstad data suggest a need to critically examine reasons for the relative unsatisfactory ewe and especially pre-weaning lamb performance on ryegrass pasture.

In a stepwise multiple regression analysis, stocking rate accounted for 18.3%, initial ewe mass for 7.5%, birth status (twins and singles) 6.8% and the disc-in reading for 8.6% of the variation in lamb mass gains (Table 5).

Sex (ram vs. ewe lambs) and ewe mass change did not contribute significantly to the variation in lamb growth. Season (year), however, accounted for 13.1% ($P \leqslant 0.001$) of the variation. In order to obtain a prediction equation for future purposes, in which seasonal effects are unknown, the regression equation which describes lamb gain until weaning (Table 5) was modified by omitting season as an independent variable.

Relationship between lamb growth and pasture heights

Figures 1 and 2 illustrate the significant ($P \leqslant 0.01$ and $P \leqslant 0.001$) relationship between ADG and pre- and post-grazing pasture heights. The quadratic equation for post-grazing pasture height and ADG explains 83% of the variation in lamb growth. A highly significant ($P \leqslant 0.001$) relationship between ADG and post-grazing heights, as illustrated in Figure 2, shows that ADG reached a maximum at a post-grazing height of approximately 6 cm. This height equates to approximately 2 037 kg of DM/ha. With a post-grazing height of less than 4 cm, ADG in lambs dropped dramatically.

According to Rattray *et al.* (1982) the effect of pasture allowance on the mass of lambs weaned is highly significant and lamb growth tends to level off above 8 kg DM/ewe/d. The following linear regression equation predicts SR (Y) from the post-grazing pasture height (X):

$$Y = 42.84 - 5.09(\pm 1.26)X$$
$$(R^2 = 0.670; Sy.x = 66.76, P \leqslant 0.01).$$

This equation, using a post-grazing height of approximately 5 cm, indicates that a SR of approximately 17 ewes with lambs/ha on ryegrass is optimal for a lamb growth rate of just over 200 g/d (Figure 2).

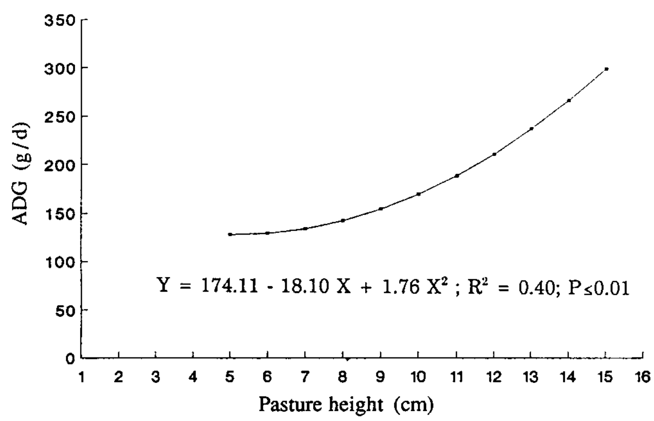

Figure 1 The relationship between average daily gain (Y) and the pre-graizing pasture height (X) in lambs over 12 weeks and four seasons.

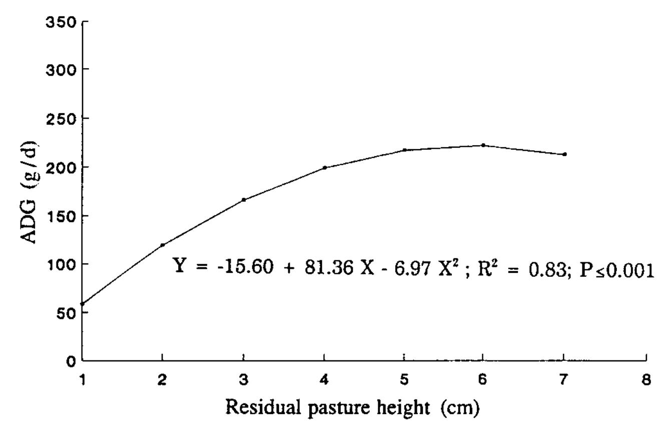

Figure 2 The relationship between average daily gain (Y) and the post-graizing pasture height (X) in lambs over 12 weeks and four seasons.

Table 5 Factors which influenced lamb average daily gain on ryegrass over four seasons, as determined by a multiple regression analysis

Dependent variable	Independent variable(s)[a]	Contribution of independent variables (R^2)	Significance of added independent variable
Y = Lamb average daily gain	Stocking rate (X1)	18.3	$P \leqslant 0.001$
	Stocking rate (X1) + Initial ewe mass (X2)	25.8	$P \leqslant 0.001$
	SR (X1) + IEM (X2) + Birth status (X3)	32.6	$P \leqslant 0.001$
	SR (X1) + IEM (X2) + BS (X3) + Disc In (X4)	40.2	$P \leqslant 0.001$
Regression equation:	$Y = 118.5(\pm 23.8) - 3.281(\pm 0.385)X1 + 1.377(\pm 0.323)X2 - 31.89(\pm 4.26)X3 + 7.30(\pm 1.06)X4$; Sy.x = 40.11		

[a] SR = stocking rate, IEM = initial ewe mass (kg), BS = birth status (single vs. twin) (singles = 0, twins = 1), Disc In = pre-grazing pasture height (cm).

Milk production and ewe and lamb performance

Data relating to mass changes and milk production in ewes with single and twin lambs are summarized in Table 6.

Stocking rate did not exert a significant effect on the average milk production of ewes with single lambs over the total period and over the three grazing cycles (Table 6). Analysis of variance showed no significant difference in milk production between ewes with twins during the first grazing cycle but a significant ($P \leq 0.05$) decrease in milk production during the second and third cycles with increased SR (Table 6). The average milk production over the total period decreased significantly ($P \leq 0.05$) in ewes with twins, with an increase in SR. Gibb & Treacher (1978) obtained similar results, with no significant effect of pasture allowance on milk production during the first 5 weeks of lactation. Thereafter, significant differences were found between treatments, with ewes maintaining higher outputs at the higher pasture allowances. Although greater live mass losses were recorded with increased SR for ewes with single lambs, milk production at higher SR levels was not significantly different to that of ewes grazing at lower SR levels. Williams *et al.* (1976) observed the same trend with ewes grazing short and abundant (long) pastures. In the ewe–lamb unit, the ewe sacrifices her own body tissue towards milk synthesis at low pasture availability in order to sustain the growth of her lamb (Williams *et al.*, 1976). The use of body energy to sustain milk production in the short term is an important compensatory mechanism under conditions of adverse nutrition (Williams *et al.*, 1976). During the first grazing cycle, SR had not yet exerted its full influence on forage availability and forage was not yet limiting at the higher SR levels. Williams *et al.* (1976) showed that low herbage availability on short pastures caused decreases in the intake of lambs before milk production by the ewes was affected. Geenty & Dyson (1986) found increasing lamb growth rate and ewe milk yield as herbage allowance increased from 2 to 8 kg DM/ewe/d.

The simple linear regression equations summarized in Table 7 show highly significant relationships between milk yield and single and twin lamb growth in all the grazing cycles

Table 6 The effect of stocking rate on milk production and mass change in ewes with single and twin lambs on ryegrass

	Stocking rate (ewes and lambs/ha)				
	20	24	28	32	36
Number of ewes with single lambs	12	13	10	14	14
Milk yield (ml/d)					
3 to 4 weeks	$1155^{a,b}$ ± 115.8	$1266^{a,b}$ ± 147.1	1426^{a} ± 116.3	1052^{b} ± 74.6	$1226^{a,b}$ ± 91.1
5 to 8 weeks	1116 ± 129.6	993 ± 130.1	1099 ± 90.4	865 ± 75.5	910 ± 90.1
9 to 12 weeks	674 ± 66.7	569 ± 90.6	663 ± 64.0	530 ± 46.2	498 ± 63.6
Average (3 to 12 weeks)	982 ± 98.5	942 ± 118.8	1063 ± 77.8	816 ± 54.9	878 ± 76.4
Ewe mass change (g/d) (84 days)	$-4.0^{a,b}$ ± 20.37	-11.1^{a} ± 21.61	$-48.4^{b,c}$ ± 13.23	-65.2^{c} ± 11.74	-92.7^{c} ± 14.05
Number of ewes with twins	10	8	9	10	8
Milk yield (ml/d)					
3 to 4 weeks	2062 ± 160.1	1875 ± 156.4	1811 ± 246.1	1911 ± 170.5	1599 ± 269.7
5 to 8 weeks	1609^{a} ± 136.4	$1487^{a,b}$ ± 126.9	$1228^{a,b}$ ± 164.0	$1428^{a,b}$ ± 139.2	1112^{b} ± 177.3
9 to 12 weeks	909^{a} ± 78.4	$887^{a,b}$ ± 62.1	$664^{b,c}$ ± 89.4	$836^{a,b}$ ± 82.8	574^{c} ± 85.1
Average (3 to 12 weeks)	1527^{a} ± 119.4	$1416^{a,b}$ ± 102.2	$1234^{a,b}$ ± 160.8	$1392^{a,b}$ ± 112.9	1095^{b} ± 173.7
Ewe mass change (g/d) (84 days)	-7.1^{a} ± 18.32	$-52.4^{a,b}$ ± 20.80	-75.5^{b} ± 28.47	-96.8^{b} ± 21.38	-108.1^{b} ± 13.72

[a–d] Values in the same row with different superscripts are significantly ($P \leq 0.05$) different.

Table 7 Regression equations predicting lamb growth (g/d; Y) on Italian ryegrass from milk yield (ml/d; X) of ewes

	Equations	n	R^2	Level of significance	Sy.x
Single lambs		63			
Cycle 1	Y = 124.71 + 0.49(± 0.15)X		0.374	$P \leq 0.01$	76.10
Cycle 2	Y = 113.25 + 0.51(± 0.13)X		0.447	$P \leq 0.001$	62.64
Cycle 3	Y = 64.18 + 0.64(± 0.20)X		0.361	$P \leq 0.01$	62.63
Weeks 3 to 12	Y = 94.66 + 0.19(± 0.04)X		0.510	$P \leq 0.001$	47.58
Twin lambs		83			
Cycle 1	Y = 65.80 + 0.42(± 0.05)X		0.686	$P \leq 0.001$	43.88
Cycle 2	Y = 98.71 + 0.38(± 0.07)X		0.480	$P \leq 0.001$	52.28
Cycle 3	Y = 27.66 + 0.58(± 0.16)X		0.361	$P \leq 0.001$	63.48
Weeks 3 to 12	Y = 54.69 + 0.16(± 0.02)X		0.678	$P \leq 0.001$	34.36

and over the total grazing period. The relationship between lamb growth and milk production was strongest, especially for ewes with twins, during the first two milking periods (first 6 weeks on pasture).

The regression coefficients suggest that the lambs became less dependent on milk for growth with advancing age. Geenty & Dyson (1986) found that the regression coefficients tended to be greater during the period from birth to 6 weeks than birth to 12 weeks, indicating a greater dependence of lamb growth rate on milk supply during the initial 6 weeks of lactation. This finding is in agreement with those of Peart *et al.* (1975) and Geenty (1979). However, it is important to note that in the present study, milk supply had a significant effect on ADG in lambs during the last grazing cycle. This agrees with the work of Penning & Gibb (1979), who stressed the importance of high milk yield for maintaining high lamb growth rates in the second and third months of the lamb's life. According to Langlands & Donald (1975), poor growth of lambs weaned onto grass swards confirms the importance of milk production in mid- or late-lactation in maintaining lamb growth rate.

A stepwise multiple regression analysis was used to identify factors responsible for variation in the lamb ADG and the results thereof are summarized in Table 8.

Stocking rate accounted for 22.5%, ewe mass for 13.5%, birth status (singles and twins) 5.8%, mean milk production 12.1%, ewe mass change 2.3% and initial lamb mass for 1.8% of the variation in the lamb mass gain. Season accounted for 10% ($P \leq 0.01$) of the variation in lamb growth. In order to obtain a prediction equation for future purposes, the regression equation was modified by omitting season as an independent variable. It is clear that the major factors which influenced lamb growth rate were SR, ewe mass, birth status and milk production. This is in general agreement with the literature, which indicates that factors influencing the magnitude of lamb growth rates include ewe milk yield (Coombe *et al.*, 1960; Stephenson *et al.*, 1981; Jordan & Mayer, 1989), ewe mass, lamb birth mass and sex (Heath *et al.*, 1984; Jordan & Mayer, 1989). Jordan & Mayer (1989) showed the important role that milk yield exerts in determining growth rate of Merino lambs, with variation in milk yield accounting for 56% of the variation in lamb growth rate. Although ewe mass ($r^2 = 0.37$) and lamb birth mass ($r^2 = 0.24$) had significant effects on lamb growth rate, these effects disappeared when milk yield was included in their regression model. Jordan & Mayer (1989) suggested that the effects of these variables on lamb growth were indirect and were manifested via the milk supply.

Conclusion

Morley (1981) stated that SR affects individual animal performance by an amount which will vary from year to year and from one season of the year to another. The results of the present study showed that at lower SR levels (approximately 20 ewes and lambs/ha), individual ewe and lamb performances were better than at the relatively higher SR levels. The pre- and post-grazing heights indicated that pasture availability for ewes and lambs became a severe problem as the grazing season progressed and the lambs grew older and SR increased, and this negatively influenced intake and therefore animal performance. In the present study SR negatively influenced ($P \leq 0.05$) milk yield of ewes with twins, and exerted a significant ($P \leq 0.05$) effect on the growth rate of single and twin lambs during all three grazing cycles. This illustrates the valuable contribution of milk supply to lamb growth, even on quality pastures. The multiple regression analysis showed that SR accounted for 22.5% ($P \leq 0.001$) of the variation in lamb growth, which illustrates the importance of herbage allowance for lactating ewes and lambs. During early autumn and spring, ryegrass is usually under-stocked, but the same SR during mid-winter may impose severe demands upon animal and pasture. During grazing cycles 2 and 3 the animals were under stress, reflected by the low post-grazing residues. One therefore questions the merit of a fixed 3.5-day rotational grazing system over the season, as used in the present study, where animals were forced to stay in camps for a specific period. A question arises as to whether one should effectively reduce the SR on the pasture by supplementing with silage or any other roughage when pasture availability falls below 6 cm.

The data gathered in this study provided equations to predict average daily gain of lambs and mass changes of ewes on rye-

Table 8 Factors which influenced lamb average daily gain on ryegrass over three seasons, as determined by a multiple regression analysis

Dependent variable	Independent variable(s)[a]	Contribution of independent variable (R2)	Significance of added independent variable
Y = Lamb average daily gain	SR(X1)	22.5	$P \leq 0.001$
	SR(X1) + Ewe mass (X2)	36.0	$P \leq 0.001$
	SR(X1) + EM(X2) + BS(X3)	41.8	$P \leq 0.001$
	SR(X1) + EM(X2) + BS(X3) + MM(X4)	53.9	$P \leq 0.001$
	SR(X1) + EM(X2) + BS(X3) + MM(X4) + EMC(X5)	56.2	$P \leq 0.01$
	SR(X1) + EM(X2) + BS(X3) + MM(X4) + EMC(X5) + ILM(X6)	58.0	$P \leq 0.05$
Regression equation:	$Y = 31.0(\pm 39.0) - 2.191(\pm 0.585)X1 + 2.011(\pm 0.485)X2 - 34.90(\pm 7.34)X3 + 0.05613(\pm 0.0086)X4 + 0.1687(\pm 0.0475)X5 + 6.17(\pm 2.33)X6$ Sy.x = 33.36		

[a] SR = stocking rate, EM = ewe mass, BS = birth status (single vs. twins) (singles = 0; twins = 1), MM = mean milk production, EMC = ewe mass change, ILM = initial lamb mass.

grass. Stocking rate and therefore pasture availability was, according to the multiple regression analysis, primarily responsible for the difference in ewe and lamb performance between SR levels. The optimum SR depends on several different criteria which may have conflicting consequences. Morley (1981) listed these criteria as maximum production per unit area, maximum stability of the pasture, minimum stress on livestock, soil conservation and appearance of livestock. The choice of an optimum SR must be a compromise between these criteria. Most managers would tend to favour profitability of the enterprise, the stability of the system and the appearance of their livestock. A recommendation on the number of ewes and lambs/ha on ryegrass will therefore depend on a specific production system, the weaning mass to be achieved and the future of the lambs post-weaning.

Acknowledgements

Mrs C. Stevens and Mr H. Dicks (University of Natal) are thanked for the biometrical analysis. Dr B.P. Louw, Mr T.J. Dugmore and colleagues are thanked for their constructive criticism and contributions.

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