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Effect of stocking rate on pasture and sheep production in winter and spring lambing systems

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Abstract: A 2-year study was conducted to quantify the effect of stocking rate on pasture and sheep production in winter and spring lambing systems. Pastures were set-stocked with ewes and their winter-born single lambs at low (20 ewes + lamb ha^{-1}), medium (28 ewes + lamb ha^{-1}), and high (36 ewes + lamb ha^{-1}) stocking rates in spring 2012 and by ewes and their spring-born lambs at low (16 ewes + lamb ha^{-1}), medium (24 ewes + lamb ha^{-1}), and high (32 ewes + lamb ha^{-1}) stocking rates in spring 2013. Annual pasture dry matter production ranged from 8.9 to 10.2 t ha^{-1} but was not affected by the spring stocking rates. The average live weight gains of the winter-born lambs were 73 and 10 g $head^{-1}$ day^{-1} for low and medium stocking rates, respectively, while the lambs at the high stocking rate lost 10 g $head^{-1}$ day^{-1} in spring 2012. The spring-born lambs grew at 245, 189, and 133 g $head^{-1}$ day^{-1} for low, medium, and high stocking rates, respectively, in spring 2013. High stocking rates did not have any negative effects on the pasture production or botanical composition but they resulted in poor sheep performance, particularly in the winter lambing system.

Key words: Grazing management, lambing season, pasture production, sheep production, stocking rate

1. Introduction

Arguably, one of the most important management issues for complex pastures is the optimization of animal and herbage production with specific attention to the equilibrium of the composition of the pasture and high animal productivity (1). Designing pasture mixtures of compatible species with various functional and structural attributes that persist under environmental stresses and grazing poses a significant challenge (2). Grazing management adds a layer of complexity to the productivity and persistence of species in mixtures by primarily affecting their competitiveness. In particular, the stocking rate and system of grazing management are the key determinants for the pasture production and the level of animal productivity (3,4). Low stocking rates may allow the animals to be more selective in their grazing and may reduce the competitiveness of the more palatable plants, whereas grazing at high stocking rates may be detrimental to the persistence of plant species that are less tolerant to grazing.

In pasture-based sheep production, achieving high live weight gains is crucial to bring the lambs to slaughter weights before drought or hot temperatures halt pasture growth. Stocking rate is the key management variable and the primary determining factor of the individual and total live weight production in pasture-based feeding systems. In general terms, individual lamb growth rates increase at lower stocking rates due to a greater herbage mass on offer to each animal and improved diet quality facilitated through greater opportunity for selective consumption. Conversely, total animal production per hectare rises to a peak point then reduces as stocking rate increases (5).

Lambing and weaning dates need to be in conformity with the grazing management, pasture growth rates, and production pattern for successfully matching the requirements of animals at varying physiological stages with forage supply and quality. In conventional sheep farming systems of the Central Anatolian region, where 20.1% of the total sheep population of Turkey exists, lambing occurs in winter with a peak period in January and February (6). It is commonly argued that winter-born lambs may be more robust and have greater growth rates than spring-born lambs but may rely heavily on high-input indoor feeding with concentrates until weaning (7,8). However, spring-born lambs may capitalize on high-quality and fast-growing pasture in spring with relatively lower production costs and may provide a higher quality of animal products (9,10). Based on the management

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practices on mating and lambing dates, coupled with the decision on the stocking density, the efficiency of the sheep production in pasture-based feeding systems may vary greatly (11). It is likely that animal performance and pasture composition are sensitive to stocking rate and the physiological stage of the livestock.

However, little information is available regarding the effect of fixed stocking rates on pasture production and sheep performance, in particular in the context of different flock management practices. Hence, an experiment was established to investigate the effect of stocking density on animal and pasture productivity in winter and spring lambing systems in the highland of the Central Anatolian region of Turkey. It was hypothesized that lower stocking rates may lead to greater lamb growth rates with reduced impact on pasture production than higher stocking rates, and that the response of lambs and ewes to the stocking rate may vary depending on their physiological stages. It was also hypothesized that the pastures will differ in productivity and botanical composition because of the physiological and functional attributes of the different species in the pastures and will be influenced by stocking density.

2. Materials and methods

2.1. Site

This study was conducted within a 2.3-ha paddock at the Bahri Dağdaş International Agricultural Research Institute (37°51′N, 32°33′E), Konya, Turkey, from April 2011 to November 2013. The research farm is located in the Central Anatolian highlands at an altitude of 1008 m above sea level and has a dry continental climate with 322 mm long-term average annual precipitation. The site has a highly calcic, clay-loam soil with slightly alkaline characteristics. Soil samples taken in March 2011 were analyzed for background fertility. The main soil properties were: pH (in water) 7.9, soluble salt 0.4 g kg^{-1}, organic matter 24 g kg^{-1}, $CaCO_3$ 186 g kg^{-1}, Olsen P (phosphorous) 79.7 kg ha^{-1}, and K (potassium) 278 kg ha^{-1}.

2.2. Meteorological conditions

Air temperatures and rainfall at the site during the experiment period (2012 to 2013) are presented in Figure 1. The total annual rainfall in 2012 of 329 mm was quite similar to the long-term mean, whereas the total annual rainfall in 2013 was only 184 mm. In most cases, mean monthly air temperatures followed a trend similar to the long-term means. The exceptions were that the mean temperature was 3.2 °C lower than average during February 2013 and 4.8 and 3.9 °C higher than average in February 2012 and December 2013, respectively.

2.3. Pasture establishment and management

A 2.3-ha paddock, which had previously been sown with small grain winter cereals for several cropping seasons, was cultivated and split into 3 blocks before sowing. Each block (64 × 120 m) was divided into 4 subplots (16 × 120 m), which were randomly allocated to a combination of 4 seed mixtures sown on 14 April 2011 (Table 1). These pasture mixtures comprised combinations of white clover, birdsfoot trefoil, perennial ryegrass, cocksfoot, and tall fescue and were sown with 15-cm row spacing in a randomized complete block design with 3 replications with each block as a replicate.

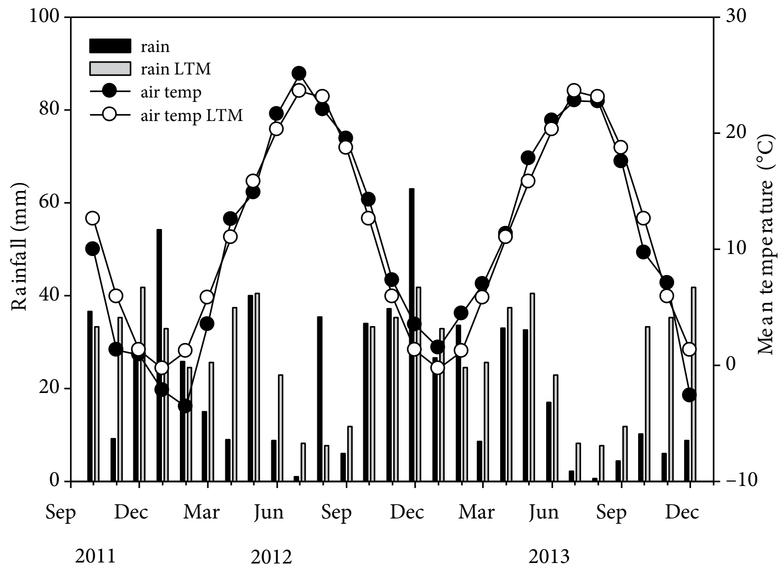

Figure 1. Monthly rainfall and mean daily air temperatures during the experimental period (2011–2013). LTM: Long-term means of air temperature and rainfall are for the period 1975–2010.

Table 1. Sowing rates of 4 pasture mixtures.

Plant species	Cultivars	Sowing rates (kg ha^{-1})			
		(Mix 1)	(Mix 2)	(Mix 3)	(Mix 4)
Cocksfoot	Ambassador	6	0	0	4
Tall fescue	Rendition	0	20	0	10
Perennial ryegrass	Barrage	0	0	20	10
White clover	Ronny	5	5	5	5
Birdsfoot trefoil	Gran san gabriele	3	3	3	3

Based on the soil test results, a total of 200 kg ha^{-1} fertilizer (18% N and 46% P_2O_5) was applied at sowing and repeated in October 2012. Each time the soil water content fell to half of field capacity, all plots received full uniform irrigation to return the soil to field capacity with a line source sprinkler irrigation system. Experimental pastures received a total of 678 and 596 mm of irrigation in 2012 and 2013, respectively.

In both years the pasture mixture subplots were grazed commonly by the flock of lambs and ewes due to land, animal, and financial limitations. The totality of pasture mixture provided a broad base for evaluation of the other factors such as stocking rate, but the effect of stocking rate on the individual pasture mixtures was not evaluated due to the confounding effect of common grazing.

2.4. Stocking rate treatment

All plots were lightly grazed by weaned lambs and dry ewes in the establishment year of 2011. The paddock was fenced to separate the 3 blocks in March 2012. Each block was split into 3 grazing plots (64 × 40 m) vertically running across all the 4 pasture mixtures, thus giving a total of 9 grazing plots in 3 blocks. These grazing plots within each replicate were randomly allocated to the main treatments of low (LSR), medium (MSR), and high (HSR) stocking rates during the spring of 2012 and 2013. In 2012, single lambs born during winter (mid-January) and their dams were set-stocked after weaning at 20 (LSR), 28 (MSR), and 36 (HSR) ewe + lamb ha^{-1} between 24 April and 11 July. All lambs were weaned gradually from 10 to 12 weeks of age. In 2013, single suckling lambs born in spring (early March) and their dams were set stocked at 16 (LSR), 24 (MSR), and 32 (HSR) ewe + lamb ha^{-1} between 19 April and 5 July. After classification according to their live weights (LWs), Anatolian Merino ewes (mean LW = 47.8 ± 5.3 kg in 2012 and 48.1 ± 5.9 kg in 2013) and their single lambs (mean LW = 28.0 ± 2.6 kg in 2012 and 17.1 ± 1.7 kg in 2013) were allocated randomly to the main plots for the spring grazing experiments in both years. The ewes and lambs had free access to water and shade at all times. The age distribution of the dams and sex distribution of the lambs in each stocking rate are given in Table 2. The ewes and lambs were not given any supplemental feeding during the entire grazing period in either year. A flock of dry Anatolian Merino ewes grazed the pasture plots from August to mid-October in 2012 and 2013 with quick rotations to a target post grazing herbage mass of 600 kg dry matter (DM) ha^{-1} for each pasture mixture.

2.5. Measurements

Dry matter production and mean daily growth rates of the pasture plots at 3 stocking rate treatments were

Table 2. The distribution of the dams and lambs based on their age and sex in low (LSR), medium (MSR), and high stocking rate (HSR) treatments in 2012 and 2013.

Year	Stocking rate	Age distribution of dams				Sex of lambs	
		Two	Three	Four	Five	Male	Female
2012	LSR	2	2	1	1	3	2
	MSR	1	2	2	2	4	3
	HSR	1	3	3	2	5	4
2013	LSR	1	1	2	0	2	2
	MSR	1	2	2	1	3	3
	HSR	1	3	3	1	4	4

measured inside 4 (one on each pasture mixture) 1-m^2 grazing exclosure cages during the active growth in spring, summer, and autumn. No samples were collected during the winter period as the pasture growth was halted due to low temperatures. Pasture growth was measured from a 0.25-m^2 quadrat within each exclosure cage by cutting with electric shears to a stubble height of 20 mm. Cages were placed over a new area where the pasture was pretrimmed to 20 mm of stubble height at the start of each new growth period. All herbage from the quadrat cuts was dried in an oven (70 °C) until constant weight. Samples were sorted into different botanical species before they were dried. Mean daily growth rates (kg DM ha^{-1} day^{-1}) were calculated at each harvest by dividing total DM production (kg DM ha^{-1}) by the duration of regrowth since the previous harvest.

Pasture mass (kg DM ha^{-1}) was measured weekly during spring grazing using a calibrated rising plate meter (JenQuip, Feilding, New Zealand) in both years. A total of 100 rising plate meter measurements were recorded across each pasture plot for each stocking rate treatment. Rising plate meter measurements were calibrated by regression against the herbage masses that were obtained from three 0.25-m^2 quadrats.

The nutritive value of the pastures was determined on hand-clipped samples on 28 April and 1 June 2012 but we failed to collect an adequate number of samples for nutritive value analyses in the final period of the grazing on 1 July in 2012. The nutritive value of the pastures was determined on 5 May, 31 May, 21 June, and 12 July in 2013. All herbage from the hand-clipped samples were dried in an oven (70 °C) until constant weight and ground to pass through a 1.0-mm screen in a Retsch mill (SM100) (Retsch GmbH, Haan, Germany). Ground samples were analyzed for ash and crude protein (CP) by AOAC methods (12). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were measured according to method of Van Soest et al. (13). The digestible dry matter (DDM) was calculated based on the ADF values, using the following formula: DDM = (88.9 – (0.779 × % ADF).

Live weight gain (LWG) was determined by weighing the ewes and lambs prior to and following each grazing period. Ewes and lambs were held overnight without access to feed and weighed “empty” the following morning. LWG per head was calculated from the change in weight between each LW measurement date. LWG (kg ha^{-1} day^{-1}) was calculated by multiplying LWG per head by the number of lambs per hectare. In 2012, sheep were weighed on 24 April, 30 May, and 11 July. In 2013, sheep were weighed on 19 April, 10 May, 31 May, 21 June, and 5 July.

2.6. Statistical analyses

Pasture dry matter production (kg DM ha^{-1}) and pasture growth rates (kg DM ha^{-1} day^{-1}) were analyzed by analysis of variance (ANOVA) in randomized complete block design for each measurement period. The effects of stocking rates on LWG per head (g day^{-1}) and per hectare (kg ha^{-1}), nutritive value, botanical composition (g kg^{-1}), and pasture on offer (kg DM ha^{-1}) were analyzed as a repeated measurement using a general linear model (GLM) procedure. The analysis provided an assessment of significance of stocking rate effects and interaction with the time in terms of P-value and their means with standard errors. A linear regression analysis was also performed to articulate the estimated sheep LWG in relation to the relationships between pasture on offer and sheep LWGs. The computations were carried out using GENSTAT statistical software (14). Significant differences among treatment means were compared by Fisher’s protected least significant difference at $P = 0.05$.

3. Results

3.1. Pasture production

Total DM production of the pastures exceeded 10 t ha^{-1} and was nearly equal for all the 3 pasture stocking rates in 2012 (Figure 2 a). DM production of the pastures in 2013 ranged from 8.9 to 10.1 t ha^{-1} but the spring stocking rates had no effect ($P > 0.05$) on the seasonal or total annual DM production (Figure 2b). The mean daily growth rates of the pastures were the highest in spring months with an average of 80 kg DM ha^{-1} day^{-1} and decreased gradually to around 10 kg DM ha^{-1} day^{-1} in summer before increasing again to 20 kg DM ha^{-1} day^{-1} in autumn. Similarly, spring stocking rates had no significant effect ($P > 0.05$) on the mean daily pasture growth rates.

3.2. Botanical composition

Spring stocking rates did not have any impact on any components of the pastures over the course of the study ($P > 0.05$). Regardless of the stocking rates, perennial ryegrass and cocksfoot components of the pastures had a substantial reduction ($P < 0.05$) in their contents (Figure 3a). The trend in reduction of perennial ryegrass component was more dramatic than cocksfoot with a 50% decline in its composition in the pastures over the course of the 2-year study. Despite the significant fluctuations, tall fescue content of the pastures remained more stable when compared to other sown grass components of the pastures. The final tall fescue content of the pastures (178 g kg^{-1}) on 15 October 2013 was similar to that (197 g kg^{-1}) on 1 May 2012.

Average birdsfoot trefoil content of the pastures increased from 120 g kg^{-1} on 1 May 2012 to 360 g kg^{-1} on 15 October 2013 (Figure 3b). The rate of change in the composition of birdsfoot trefoil presented inconsistent variations ($P < 0.05$) among the stocking rate treatments over the study period but the overall effect of stocking rates was insignificant ($P > 0.05$). White clover comprised only 11 to 31 g kg^{-1} of the pastures in 2012 (Figure 3e)

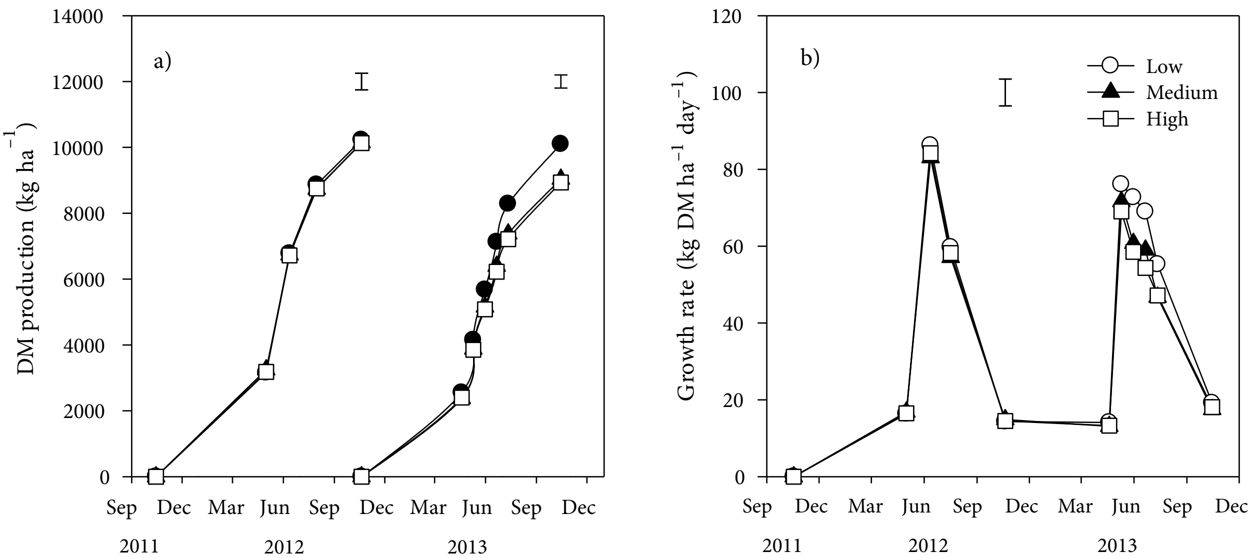

Figure 2. Pasture DM production (kg ha^{-1}) (a) and growth rates (kg DM ha^{-1} day^{-1}) (b) at spring stocking rates of 16–20 (low), 24–28 (medium), and 32–36 (high) ewes with single lambs ha^{-1} from 2011 to 2013. Bars represent the standard error for (a) and maximum standard error for (b).

but as the season progressed the white clover content of pastures increased markedly ($P < 0.05$), exceeding 100 g kg^{-1} of the pasture composition on 15 October 2013.

Averaged across the stocking rate treatments, weed content of the pastures fluctuated ($P < 0.05$) between 10 g kg^{-1} and 190 g kg^{-1}, peaking in summer and plummeting down in winter-early spring seasons (Figure 3d).

3.3. Sheep production

Average daily LWG of lambs and ewes in 2012 and 2013 varied over time (Table 3). In 2012, averaged over the entire spring period, winter-born weaned lambs grew at 73 and 10 g head^{-1} day^{-1} at LSR and MSR respectively, whereas the lambs at HSR lost 10 g head^{-1} day^{-1}. An interaction ($P < 0.01$) was detected between LWG and measurement period for LWG of lambs. Weaned lambs at each stocking rate had increases in their LWs at various levels ranging from 89 to 144 head^{-1} day^{-1} during the first period, whereas the lambs at MSR and HSR had significant LW losses during the second period, except those lambs at LSR, which showed negligible LW gains.

The mean lamb LWGs per head in 2013 were 245, 189, and 133 head^{-1} day^{-1} at LSR, MSR, and HSR, respectively. The LWGs of spring-born suckling lambs showed a steady decrease ($P < 0.01$) as the season progressed for each stocking rate. An interaction occurred ($P < 0.01$) between stocking rate and the measurement period for LWG of the lambs because only the lambs at LSR had increases in their LWs in the final period, whereas lambs at MSR and HSR lost weight during the same period. Significant decreases in ewe LWG per head occurred over the grazing periods at each stocking rate but the magnitude of decline in ewe LWG losses was greater ($P < 0.05$) at MSR and HSR than LSR. This caused a significant interaction between stocking rate and period in both 2012 and 2013.

In both 2012 and 2013, significant interactions occurred between stocking rate and grazing period for lamb and ewe LWG per hectare (Table 4). In 2012, the superior LWGs per hectare for weaned lambs and ewes at HSR during the first period were completely reversed to LW losses during the second period. Averaged over the entire grazing period, lambs at LSR had 1.0–1.5 kg greater LWGs per hectare than those at MSR and HSR.

In 2013, suckling lambs at HSR produced more LWG per hectare during the first and second periods before they provided the lowest LW productions from then until the end of the experiment. However, averaged over the entire grazing period, LWGs per hectare were greatest at MSR, while the LWGs per hectare at LSR were the lowest. The trend in ewe LWG per hectare was similar in 2012 and 2013.

3.4. Pasture availability for sheep during spring grazing

3.4.1. Pasture mass on offer

Over the spring grazing period in 2012, the average herbage mass of the pastures decreased from 1607 to 639 kg DM ha^{-1} at HSR, from 1840 to 735 kg DM ha^{-1} at MSR, and from 1862 to 1229 kg DM ha^{-1} at LSR (Figure 4a). An interaction was detected between stocking rate and period for pasture mass on offer. Pasture mass was similar at all stocking rates until 12 May before it was consistently lower ($P < 0.05$) at HSR and MSR than LSR. In spring 2013, average pasture herbage mass declined gradually from 1577 kg DM ha^{-1} on 29 April to 880 kg DM ha^{-1} on

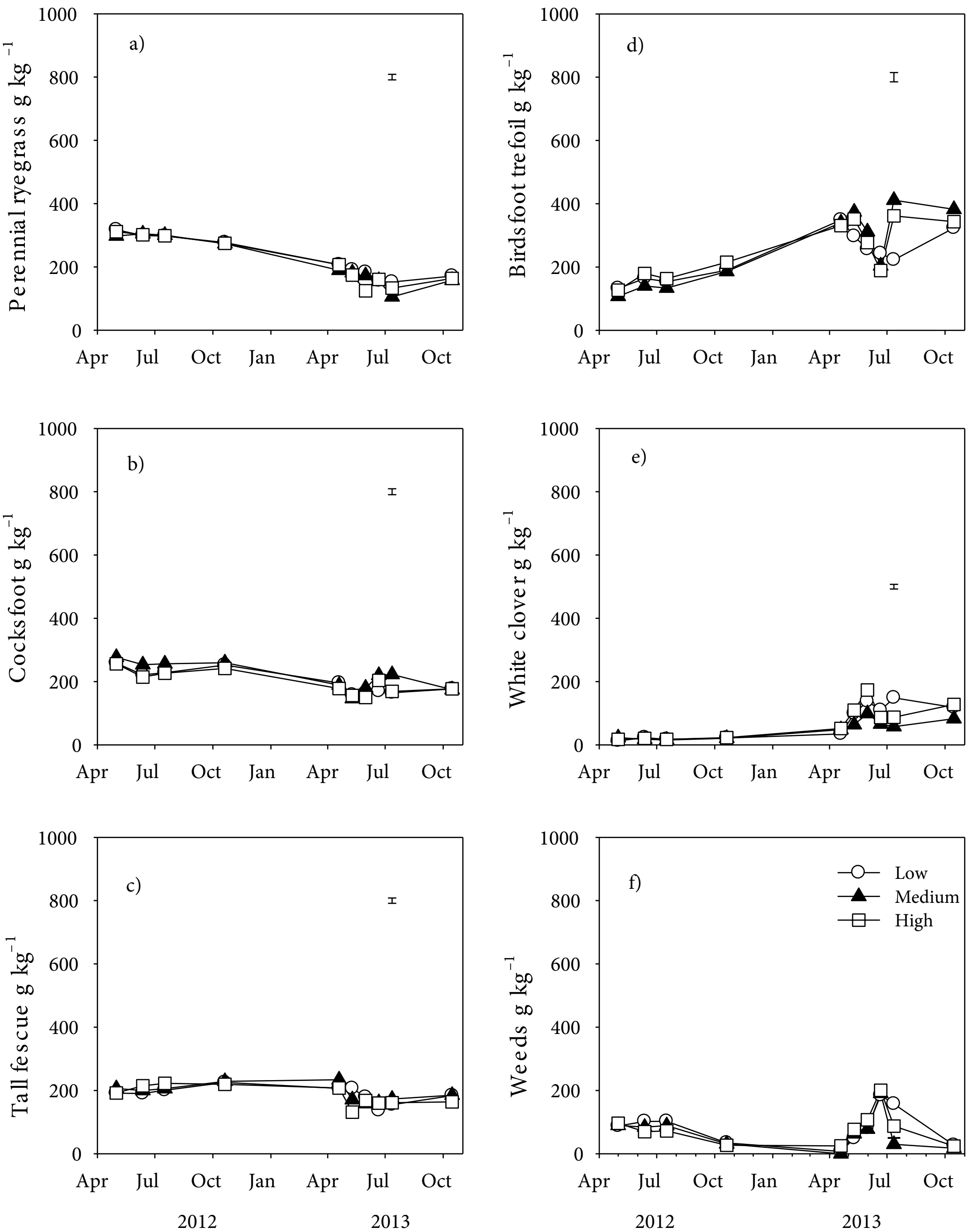

Figure 3. Pasture botanical composition (% DM) of pastures (a–f) at spring stocking rates of 16–20 (low), 24–28 (medium), and 32–36 (high) ewes with single lambs ha^{-1} in 2012 and 2013. Bars represent the standard error (P < 0.05) for stocking rate × period interaction.

1 July with the decrease being sharper in MSR and HSR compared to LSR (Figure 4b). The difference between stocking rates on herbage mass became significant on 29 April when pasture had higher mass at LSR than MSR and HSR. Thereafter the lambs at LSR had higher pasture mass on offer than those on pastures grazed at MSR and HSR.

Strong linear relationships between pasture mass on offer and the LWGs were detected of ewes (R^2 = 0.92 in 2012, P < 0.01 and R^2 = 0.64 in 2013, P < 0.01) and of lambs (R^2 = 0.92 in 2012, P < 0.001 and R^2 = 0.71 in 2013, P < 0.001) (Figure 5). Overall, the lamb and ewe LWGs declined with decreasing forage availability.

Table 3. Least square means for the live weight gain per lamb and ewe (g head^{-1} day^{-1}) over 2 periods in 2012 at 20 (low), 28 (medium), and 36 (high) ewes with single lambs ha^{-1} and 4 periods in 2013 at stocking rates (SRs) of 16 (low), 24 (medium), and 32 (high) ewes with single lambs ha^{-1}.

Year	Period	Lambs			Ewes		
		Low	Medium	High	Low	Medium	High
	24 April to 30 May	144	104	89	187	132	123
	30 May to 11 July	2	–84	–108	–38	–125	–168
	Mean	73	10	–10	75	3	–23
	SE†	7.1	6.0	5.3	12.5	10.5	9.3
2012	P_{SR}‡		0.01			0.01	
	P_P		0.01			0.01	
	$P_{SR \times P}$		0.01			0.05	
	19 April to 10 May	319	294	292	157	98	69
	10 May to 31 May	272	239	180	6	–52	–220
	31 May to 21 June	251	170	58	29	–104	–124
	21 June to 5 July	95	–2	–51	–69	–121	–128
2013	Mean	245	189	133	31	–44	–101
	SE†	16.3	13.3	11.5	25.5	20.8	18.0
	P_{SR}‡		0.01			0.01	
	P_P		0.01			0.01	
	$P_{SR \times P}$		0.01			0.01	

†SE (standard error).
‡P-values are from ANOVA for effects of stocking rate (SR), period (P), and interaction (SR × P).

3.4.2. Nutritive value of pasture on offer
In 2012, the nutritive value of the pastures grazed at LSR, MSR, and HSR did not differ (P > 0.05) between 28 April and 1 June (Table 5). However, significant differences (P < 0.05) occurred in ADF and DDM content of pastures grazed at 3 stocking rates. Pasture grazed at HSR had lower ADF and higher DDM contents than pastures grazed at MSR. The CP, NDF, and ash content of pasture were not affected by stocking rate or period. In 2013 stocking rate × period interactions (P < 0.001) were detected for CP, ADF, NDF, DDM, and ash content of pastures (Table 6). The average ADF content of pastures on offer in 2013 decreased from 346 g kg^{-1} on 10 May to 260 g kg^{-1} on 12 July. The ADF content of pastures at LSR remained relatively stable throughout the grazing experiment, while the ADF content of pastures at MSR and HSR had a steady decrease (P < 0.05) as the grazing season progressed. A similar effect of stocking rate was also observed with DDM and NDF contents of pastures. The DDM content of the herbage on offer ranged from 603 to 708 g kg^{-1} and had an increasing trend over the grazing period at MSR and HSR pastures, while the DDM content of LSR pastures remained relatively similar. HSR and MSR pastures had higher (P < 0.05) DDM contents than LSR pastures on 12 July. The CP content of pastures had an increasing trend from the onset of the spring grazing but the increase at HSR and MSR was sharper in the final period than it was for the pastures grazed at LSR.

4. Discussion
In this study, the effect of stocking rate on sheep and pasture production was investigated in the context of a pasture-based feeding system with specific reference to lambing management.

4.1. Effect of stocking rate on pasture production and botanical composition
At the spring stocking rates tested in this study, there was an inconsequential effect of sheep grazing on the pasture dynamics. The absence of a stocking rate effect on the DM production and, to a lesser extent, on the botanical composition of the pastures that consisted of perennial species was probably due to the relatively short duration

Table 4. Least square means for the live weight gain per ha for lambs and ewes (kg ha^{-1} day^{-1}) over 2 periods in 2012 and 4 periods in 2013 at 16 (low), 24 (medium), and 32 (high) ewes with single lambs ha^{-1} stocking rate (SR).

Year	Period	Lambs			Ewes		
		Low	Medium	High	Low	Medium	High
	24 April to 30 May	2.3	2.5	3.2	3.0	3.2	4.4
	30 May to 11 July	0.04	−2.0	−3.9	−0.6	−3.0	−6.0
	Mean	1.2	0.2	−0.3	1.2	0.1	−0.8
	SE†	0.20	0.17	0.15	0.38	0.32	0.28
2012	P_{SR}‡		0.01			0.01	
	P_P		0.01			0.01	
	$P_{SR \times P}$		0.01			0.05	
	19 April to 10 May	5.1	7.1	9.3	2.5	2.4	2.2
	10 May to 31 May	4.4	5.7	5.8	0.1	−1.2	−7.0
	31 May to 21 June	4.0	4.1	1.8	0.5	−2.5	−4.0
	21 June to 5 July	1.1	0.0	−1.2	−1.1	−2.9	−4.1
2013	Mean	3.6	4.2	3.9	0.5	−1.1	−3.2
	SE†	0.44	0.36	0.31	0.69	0.56	0.48
	P_{SR}‡		0.14			0.01	
	P_P		0.01			0.01	
	$P_{SR \times P}$		0.01			0.01	

†SE (standard error).
‡P-values are from ANOVA for effects of stocking rate (SR), period (P), and interaction (SR × P).

of the different grazing intensities imposed only in the spring seasons. Similarly, Thompson et al. (3) from annual pastures grazed at stocking rates ranging from 8 to 40 sheep ha^{-1} in Australia and Ates et al. (15) from cocksfoot-subterranean clover pastures grazed at 8.3 and 13.9 sheep and their twin lambs ha^{-1} in New Zealand reported that spring stocking rates did not affect total annual pasture production.

Given that the effect of spring stocking rates on the botanical composition was minor, temperature appears to be the principal determining factor for the persistence of and the major driver governing the seasonal pasture growth pattern and production under irrigated conditions. The prevailing effect of climate was clearly reflected in the pasture growth rates, which varied from approximately 20 kg^{-1} ha^{-1} day^{-1} during the mid-October to mid-April period (winter) to 90 kg ha^{-1} day^{-1} in mid-April and May (spring) in the current study. It was of note that the reduction in pasture growth rates towards summer under nonlimiting water conditions was probably associated with the summer dormancy that temperate pasture species typically exhibit even in irrigated pastures (16).

One of the features of the results was that the establishment of cocksfoot, and in particular tall fescue, was slower than that of perennial ryegrass as evidenced by their lower proportion in the pastures in spring 2012. The establishment of perennial ryegrass is usually faster because of its lower thermal time requirement at germination (90 °C days) and emergence (160 °C days), as compared to tall fescue (150 °C days for germination; 190 °C days for emergence) and cocksfoot (210 °C days for germination; 250 °C days for emergence) (17). Although the ease of establishment of perennial ryegrass is a major asset, its poor persistence and low tolerance to high temperatures are major limitations, offsetting its value as a pasture plant in such environments (18). The relatively more persistent tall fescue in pastures compared to perennial ryegrass and cocksfoot probably confer its tolerance to high summer temperatures under nonlimiting water and fertility. This result concurs with the findings of Lowe and Bowdler (19) and Neal et al. (20), who reported that perennial ryegrass had a substantial reduction in biomass production when daily temperatures exceeded 30 °C, and the decline was more profound than tall fescue, white clover, and birdsfoot trefoil in Australia.

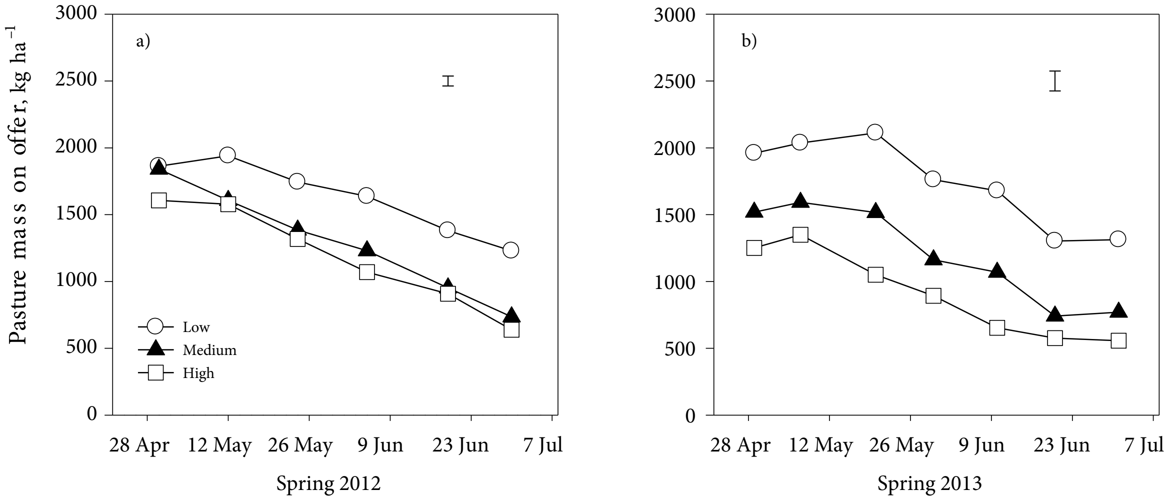

Figure 4. Pasture mass (DM kg^{-1} ha^{-1}) at spring stocking rates of 16–20 (low), 24–28 (medium), and 32–36 (high) ewes with single lambs ha^{-1} in spring 2012 (a) and 2013 (b). Bars represent the standard error ($P < 0.05$) for stocking rate × period interaction.

It was of note that the performance of both white clover and birdsfoot trefoil was exceptional, with steady increases in their proportions during the season. Both pasture legumes did not appear to be negatively affected by excessive competition from the other species or high temperatures under irrigated conditions in summer. This was also highlighted by Davies (21) and Nolan et al. (22), who reported that clovers are generally more favored by higher temperatures than temperate pasture grasses. Given its tolerance to high temperatures, drought, and grazing with its prostrate growth habit, birdsfoot trefoil appears to be a valuable plant for pastures in dry continental climates. Nevertheless, the increase in legume components of the pasture mixtures did not translate into increased dry matter production of the pastures, possibly due to reduced components of sown grass. Similar to our results, Stevens and Hickey (23) reported that the higher sown grass component of binary tall fescue and cocksfoot mixtures, as compared to their pure sowings, did not result in greater biomass production due to the relative decreases in the clover and other grass components of the mixtures.

4.2. Effect of stocking rate on sheep performance and the efficiency of pasture-based sheep production as affected by the lambing season

The LWGs obtained at LSR in 2012 were similar to the mean 78 g head^{-1} day^{-1} at the stocking rate of 107 weaned lambs ha^{-1} reported by Ates et al. (24) in a 3-year study conducted in the Central Anatolia region of Turkey. However, the growth of the weaned lambs obtained in the present study was much lower than the 251 g per head day^{-1} reported by Nicol et al. (25) for weaned lambs grazing on irrigated perennial ryegrass-white clover pastures in an intensive lamb finishing system in New Zealand, probably due to more favorable climatic and pasture conditions as well as superior animal genetics. The LW gains of lambs at MSR and HSR were unsatisfactory, which suggests that the grazing intensity was too high for optimum lamb production, although the stocking rates tested in the current study did not cause any detrimental effect on pasture DM production or botanical composition. Despite the weight losses of dry ewes ranging from 38 to 125 g head^{-1} day^{-1} at LSR and MSR in the second half of the study during summer months, over the entire grazing period ewes gained 3 to 75 g LW day^{-1}. However, dry ewes at HSR lost 23 g head^{-1} day^{-1} during the entire grazing period, indicating that the stocking rate was not optimized for the ewes at HSR.

Therefore, initial stocking rates were reduced for each treatment in spring 2013. Together with the reduced stocking rates and increased legume content of the pastures, the spring-born suckling lambs grew at 245, 189, and 133 g head^{-1} day^{-1} at LSR, MSR, and HSR, respectively, in 2013. Similar effects of stocking rate on ewe and lamb LWGs were reported in many studies around the globe (11,3,4). However, there are no publicly available data relating LWGs of lambs to stocking rate in Anatolia to compare the findings of this study. Overall, these values are similar to or slightly lower than the lamb LWGs of 208, 275, 250, and 263 g day^{-1} at 27, 20, 22, and 19 ewes ha^{-1} stocking rates from perennial ryegrass pastures in the U.K. (11).

Lamb growth rates decreased as the season progressed in both winter and spring lambing systems, and this effect was more prominent at HSR. Of note was that even at LSR in the spring lambing system, a major reduction in LWG of lambs occurred in lamb growth rates from 245 g head^{-1}

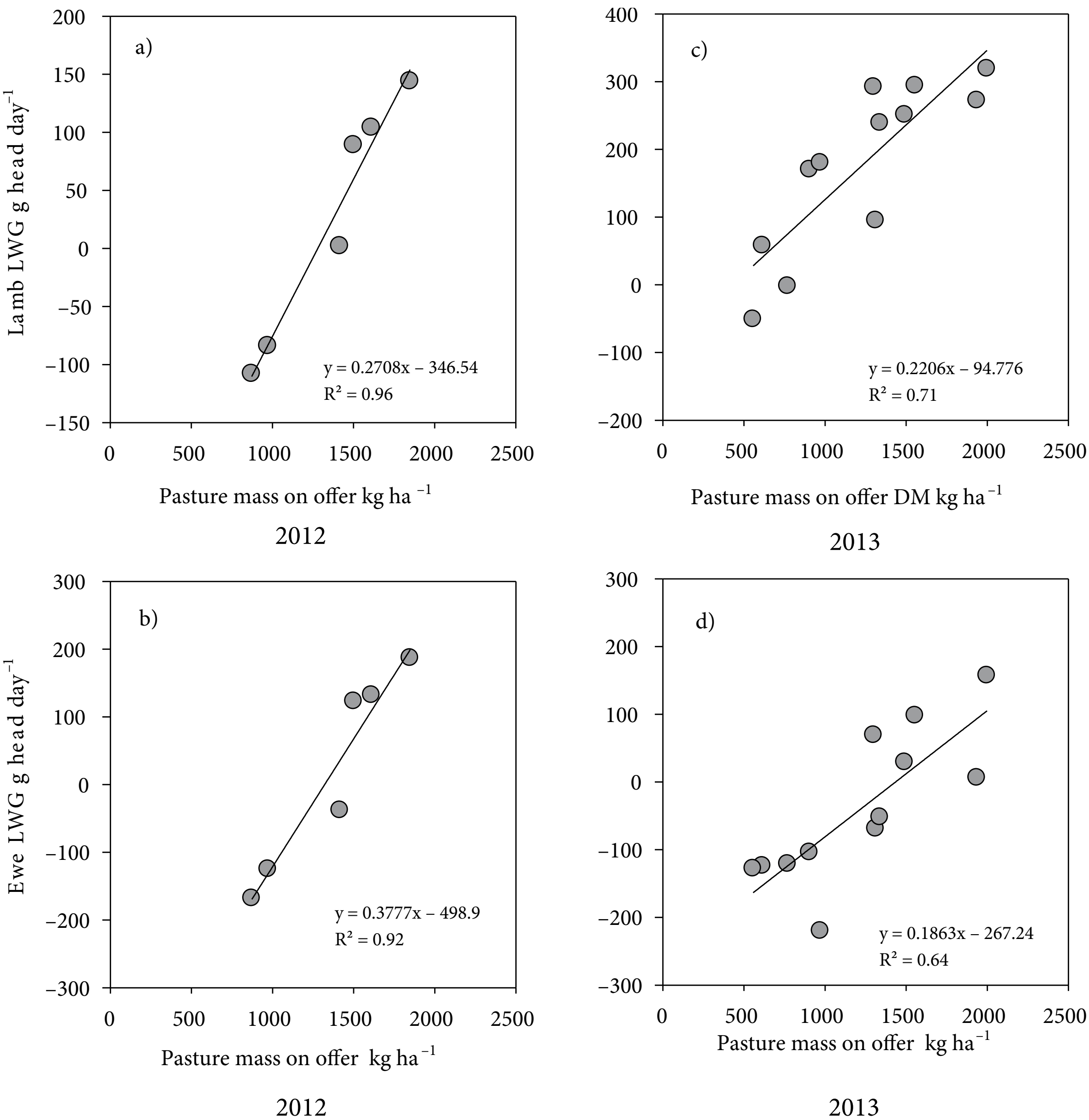

Figure 5. Lamb and ewe liveweight gains relative to pasture mass on offer in spring 2012 and 2013 (a–d). $P < 0.01$ for lambs in 2012 and 2013, and $P < 0.001$ for ewes in 2012 and 2013.

day^{-1} in the third period (31 May to 21 June) to 95 g head^{-1} day^{-1} in the final period (21 June to 5 July) of the grazing study. The accentuated reduction that was observed in LWGs of the sheep after 21 June most probably relates to the reduced pasture growth rates. This was despite the fact that pasture on offer was maintained above 1300 kg ha^{-1} at LSR and the increasing nutritive value of pasture on offer, due to the new growth of plant tissues as suggested by the increasing DDM and declining ADF and NDF contents at MSR and HSR. However, the increasing nutritive value of the pastures did not offset the negative impact of decreasing herbage DM, which possibly led to lower DM intake of ewes and lambs. A further explanation for the reduced LWGs of the lambs may be the high temperature stress that the sheep encountered during summer (26).

It appears from the results that the available pasture mass on offer was the main determinant for the performance of both lambs and ewes as evidenced by the linear regression analysis that indicated the strong relationship between pasture on offer and sheep LWGs. High stocking rates reduced the pasture on offer and animal production dramatically, primarily due to lower pasture allocation per animal and thus less available forage for grazing sheep on these pastures. Litherland and Lambert (27) reported that an increase of 260 kg DM ha^{-1} in herbage mass during lactation increased twin lamb growth rates by 50

Table 5. Least square means for the nutritive value (% DM) of pasture on offer at spring stocking rates of 20 (low), 28 (medium), and 36 (high) ewes with single lambs ha^{-1} in spring 2012.

Date	SR	Ash	CP	ADF	NDF	DDM
	Low	98	172	329	493	633
28 April	Medium	105	170	328	521	633
	High	109	171	309	539	648
	Low	102	175	319	530	640
1 June	Medium	108	156	342	508	623
	High	106	167	307	570	650
SE†		4.3	7.5	10.4	24.5	8.1
P_{SR}‡		0.20	0.39	0.05	0.16	0.05
P_P		0.70	0.43	0.92	0.36	0.92
$P_{SR \times P}$		0.64	0.53	0.55	0.54	0.55

†SE (standard error).
‡P-values are from ANOVA for effects of stocking rate (SR), period (P), and interaction (SR × P).

Table 6. Least square means for the nutritive value (g kg^{-1} DM) of pasture on offer at spring stocking rates of 16 (low), 24 (medium), and 32 (high) ewes with single lambs ha^{-1} in spring 2013.

Date	SR	Ash	CP	ADF	NDF	DDM
	Low	164	145	332	503	630
10 May	Medium	180	160	365	493	605
	High	185	157	340	479	624
	Low	124	172	301	489	654
31 May	Medium	157	184	288	469	664
	High	155	165	302	383	654
	Low	135	187	304	481	652
21 June	Medium	165	173	283	454	668
	High	194	177	283	510	669
	Low	140	177	322	457	638
12 July	Medium	128	256	224	413	714
	High	131	267	235	399	706
SE†		5.6	6.1	7.5	13.6	5.9
P_{SR}‡		0.001	0.001	0.001	0.001	0.001
P_P		0.001	0.001	0.001	0.001	0.001
$P_{SR \times P}$		0.001	0.001	0.001	0.001	0.001

†SE (standard error).
‡P-values are from ANOVA for effects of stocking rate (SR), period (P), and interaction (SR × P).

g per head day^{-1} due to greater ewe intake. It is notable that despite lower stocking rates in 2013 than in 2012, the herbage on offer at LSR followed a similar trend, while herbage on offer at MSR and HSR declined more rapidly. In particular, herbage mass on offer at the high stocking rate was reduced down to 1250 kg DM ha^{-1} only a week after the commencement of the grazing and then declined further to 1050 kg DM ha^{-1} on 20 May. Overall pasture on offer was maintained at 340 kg DM ha^{-1} less in 2013 than in 2012, possibly indicating the higher intake of lactating ewes compared to dry ewes.

4.3. Practical implications

4.3.1. Lamb production

The value of pastures is dependent upon their capacity to produce high-value animal products, which is a function of the combination of the quality and quantity of herbage intake and the cost of maintaining this production. In high-input irrigated pastoral production systems, high efficiency and profitable utilization of pastures with high animal productivity are critical. Lambs grazing at lower stocking rates may result in faster growth rates due to the higher intake of feed with better nutritional value enabled by selective consumption, whereas grazing at higher stocking rates will increase total LWG per ha but may result in producing lambs with lower body weights that are sold cheaply as store lambs (15). In the present study, the final LWs of lambs at approximately 177 days of age in the winter lambing system was 33.7, 28.8, and 27.2 kg for LSR, MSR, and HSR, respectively, whereas the final LWs of lambs at approximately 120 day of age in the spring lambing system was 36.0, 31.7, and 27.3 kg for LSR, MSR, and HSR, respectively. It is plausible that the lambs could not reach the target live weights of 35 kg even at LSR in the winter lambing system, while the average live weight of spring-born lambs was 36 kg in the LSR. These findings indicate that the LWGs of lambs need to be maximized during spring, and lambs need to be weaned and drafted before the end of June when the pastures have a major decline in their daily growth rates due to increasing temperatures and summer dormancy. Grazing with spring-born suckling lambs may present a more efficient utilization of these high input pastures. Furthermore, applying lower grazing rates and/or supplemental feeding may be necessary, particularly in the winter lambing system, to maintain high lamb growth rates and ensure that lambs reach target slaughter weights before the onset of high summer temperatures.

4.3.2. Ewe body conditions

Ewes have the ability to adapt to nutritional constraints through mobilization or accumulation of body reserves in forage-based feeding systems that often consist of underfeeding and refeeding periods depending on the seasonal pasture growth and stocking rate (28). The consequences of the magnitude of the underfeeding may be closely associated with the grazing management, pasture allowance, and physiological status of the animals. Despite the higher stocking rates imposed in the spring grazing in 2012 compared to 2013, the weight losses that were observed in ewes were not as dramatic as in 2013. As lambs with these ewes achieved high growth rates compared to winter-born lambs, the results suggest that the suckling lambs may have benefitted from the buffering effect of the mobilization of adipose reserves to maintain milk production, which commonly occurs at early stages of lactation (28). Apart from the reduced pasture production in 2013, the results of pasture mass on offer also indicated that even at LSR the lactating ewes and lambs may have had a higher intake than nonlactating dry ewes and weaned lambs. Furthermore, due to decreasing milk production, in particular at HSR, lambs had more pasture intake to compensate their declining milk intake, and this may have caused an increasing competition for pasture feed and increased grazing intensity compared to MSR and LSR (27). The implication of weight loss during lactation is that ewes grazing at HSR need to gain more body weight during summer and early autumn to meet premating live weight targets for the improvement of conception rates (29). The heavy weight losses of the lactating ewes in the spring lambing system indicate that sheep would require more energy intake to replenish their body tissues and reach an ideal body condition at mating (Table 7). However, the spring lambing system would present an opportunity of a longer period of refeeding to improve the body conditions of the ewes until mating that takes place in early October, as compared to the winter lambing system that provides a shorter period of refeeding until mating in mid-August.

4.4. Conclusions

The findings of this study indicate that maximizing sheep production from sown pastures should be done during the spring season when plant growth is not restricted by either moisture or high temperatures. Thus, the focus of production should be on lamb fattening in spring while managing pastures for the maintenance of dry ewes during the summer period. It appears that in a set-stocked grazing system, medium stocking rates during the early spring with a reduced stocking rate towards summer would be a good strategy for optimum pasture management in both lambing and grazing systems. Although the high spring stocking rates imposed in this study were not detrimental to pasture productivity, they reduced sheep growth and production when compared to medium and low rates. It appears that high-input irrigated pasture-based feeding may be more suitable for the spring lambing system as the LWGs of weaned lambs, even at low stocking rates, were not high enough to enable lambs to reach target slaughter weights.

Table 7. Approximate energy and extra feed required for ewes to reach their initial body weights before mating.

Lambing system	Stocking rate	Final body weight (kg)	Body weight change (kg)	Total extra feed requirement (kg DM)†	Required energy (ME MJ/day)‡
Winter lambing	LSR	52.0	+6.4	N/A	N/A
	MSR	47.4	−0.9	5.4	1.67
	HSR	45.3	−2.7	16.2	5.0
Spring lambing	LSR	50.4	+2.5	N/A	N/A
	MSR	45.3	−3.7	22.2	2.61
	HSR	39.6	−8.0	48	5.65

†It takes 65 MJ (6 kg DM) to gain 1 kg of live weight (30).
‡Thirty-five days until mating for the winter lambing system (11 July–5 August) and 92 days (5 July–5 October) for the spring lambing system.

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References

1. Deak A, Hall MH, Sanderson MA. Grazing schedule effect on forage production and nutritive value of diverse forage mixtures. Agron J 2009; 101: 408-414.
2. Foster A, Vera CL, Malhi SS, Clarke FR. Forage yield of simple and complex grass–legume mixtures under two management strategies. Can J Plant Sci 2014; 94: 41-50.
3. Thompson AN, Doyle PT, Grimm M. Effects of stocking rate in spring on liveweight and wool production of sheep grazing annual pastures Aust J Agric Res 1994; 45: 367-389.
4. Ates S, Lucas RJ, Edwards GR. Stocking rate effects on liveweight gain of ewes and their twin lambs when grazing subterranean clover-perennial grass pastures. Grass Forage Sci 2015; 70: 418-427.
5. Jones RJ, Sandland RL. The relation between animal gain and stocking rate: derivation of the relation from the results of grazing trials. J Agr Sci 1974; 83: 335-34.
6. Ceyhan A, Serbester U, Çınar M, Ünalan A, Akyol E, Şekeroğlu A. Current condition and directions of livestock breeding in the Central Anatolia Region. Turkish Journal of Agriculture - Food Science and Technology 2013; 1: 62-66 (in Turkish with abstract in English).
7. Yılmaz O, Denk H, Bayram D. Effects of lambing season, sex and birth type on growth performance in Norduz lambs. Small Ruminant Res 2007; 68: 336-339.
8. Norouzian MA. Effects of lambing season, birth type and sex on early performance of lambs. New Zeal J Agr Res 2015; 58: 84-88.
9. Jenkinson CMC, Peterson SW, Mackenzie DDS, McDonald MF, McCutcheon SN. Seasonal effects on birth weight in sheep are associated with changes in placental development. New Zeal J Agr Res 1995; 38: 337-345.
10. French P, Stanton C, Lawless F, O'Riordan EG, Monahan FJ, Caffrey PJ, Moloney AP. Fatty acid composition, including conjugated linoleic acid, of intramuscular fat from steers offered grazed grass, grass silage, or concentrate-based diets. J Anim Sci 2000; 78: 2849-2855.
11. Penning PD, Parsons AJ, Orr RJ, Treacher TT. Intake and behaviour responses by sheep to changes in sward characteristics under continuous stocking. Grass Forage Sci 1991; 46, 15-28.
12. AOAC. Official Methods of Analysis of AOAC International. 17th ed., 2nd rev. Gaithersburg, MD, USA: AOAC; 2003.
13. Van Soest PJ. Robertson JB, Lewis BA. Method for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J Dairy Sci 1991; 74: 3583-3597.
14. Payne RW. The Guide to GenStat Release 12 Part 2: Statistics. Harpenden, UK: Lawes Agricultural Trust, Rothamsted Experimental Station; 2009.
15. Ates S, Lucas RJ, Edwards GR. Effects of stocking rate and closing date on subterranean clover populations and dry matter production in dryland sheep farms. New Zeal J Agr Res 2013; 56: 1-15.
16. Volaire F, Norton M. Summer dormancy in perennial temperate grasses. Ann Bot 2006; 98: 927-933.
17. Moot DJ, Scott WR, Roy AM, Nicholls AC. Base temperature and thermal time requirements for germination and emergence of temperate pasture species. New Zeal J Agr Res 2000; 43: 15-26.
18. Moot DJ, Brown HE, Pollock K, Mills A. Yield and water use of temperate pastures in summer dry conditions. Proceedings of the New Zealand Grassland Association 2008; 70: 51-59.

19. Lowe K, Bowdler TM. Growth, persistence, and rust sensitivity of irrigated, perennial temperate grasses in the Queensland subtropics. Aust J Exp Agric 1995; 35: 571-578.

20. Neal JS, Fulkerson WJ, Lawrie R, Barchia I. Difference in yield and persistence among perennial forages used by the dairy industry under optimum and deficit irrigation. Crop Pasture Sci 2009; 60: 1071-1087.

21. Davies A. White clover. Biologist 1992; 39:129-133.

22. Nolan T, Connolly J, Wachendorf M. Mixed grazing and climatic determinants of white clover (*Trifolium repens* L.) content in a permanent pasture. Ann Bot 2001; 88: 713-724.

23. Stevens DR, Hickey MJ. Effects of binary seed mixtures of ryegrass, cocksfoot and tall fescue on pasture production. Proceedings of the New Zealand Grassland Association 2000; 62: 141-146.

24. Ates S, Isik S, Keles G, Aktas AH, Louhaichi M, Nangia V. Evaluation of deficit irrigation for efficient sheep production from permanent sown pastures in a dry continental climate. Agric Water Manage 2013; 119: 135-143.

25. Nicol AM, Bryant RH, Ridgway MJ, Edwards GR. Liveweight gain per head and per ha throughout the year of lambs grazing conventional pastures and those that switch from grass to clover. Proceedings of the New Zealand Grassland Association 2010; 72: 211-216.

26. Marai IFM, El-Darawany AA, Fadiel A, Abdel-Hafez MAM. Physiological traits as affected by heat stress in sheep — A review. Small Rumin Res 2007; 71: 1-12.

27. Litherland AJ, Lambert MG. Herbage quality and growth rate of single and twin lambs at foot. Proceedings of the New Zealand Society of Animal Production 2000; 60: 55-57.

28. Blanc F, Bocquier F, Agabriel J, D’hour P, Chilliard Y. Adaptive abilities of the females and sustainability of ruminant livestock systems. A review. Anim Res 2006; 55: 489-510.

29. Rattray PV, Thompson KF, Hawker H, Sumner RMW. Pastures for sheep production. In:Nicol AM, editor. Livestock Feeding on Pasture. Occasional Publication No. 10. Christchurch, New Zealand: New Zealand Society of Animal Production; 1987. pp. 89-105.

30. Beef + Lamb New Zealand. Ewe Body Condition Scoring (BCS) Handbook. Auckland, New Zealand: Beef and Lamb; 2013.