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An evaluation of two grassland-based systems of mid-season prime lamb production using prolific ewes of two genotypes

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A 4-year study was undertaken to evaluate the effects of two contrasting management systems [year-round grazing (YRG) and normal seasonal grazing followed by indoor feeding during winter (GWF)] on performance of mid-season lambing ewes. On the GWF system, the annual stocking rate was 14.4 ewes/ha, grass silage was conserved for winter feeding indoors, and the ewes were lambed indoors and were then turned out to pasture. The YRG system was stocked at 10.5 ewes/ha, was grazed during the winter, had outdoor lambing and the animals had access to all the farmlet for summer grazing. The ewes were Belclare and Cheviot × Belclare which were balanced across systems. Mean lambing dates and fertiliser N application rates were 20 and 30 March, and 85 and 92 kg/ha, for the GWF and YRG systems, respectively. Concentrate supplementation during late pregnancy was similar on both systems. For the GWF and YRG systems, litter size, lamb mortality, number of lambs reared, birth weight (kg), weaning weight (kg) and lamb carcass output (kg/ha) were 2.17 and 2.24 (s.e. 0.038), 10.1 and 13.8% ($P = 0.05$), 1.77 and 1.78 (s.e. 0.042), 4.0 and 4.7 (s.e. 0.05, $P < 0.001$), 27.9 and 30.8 (s.e. 0.25, $P < 0.001$) and 469 and 348, respectively. Belclare ewes had a higher litter size (2.34 v 2.07; s.e. 0.038, $P < 0.001$) and number of lambs reared per ewe joined (1.86 v 1.69; s.e. 0.048, $P < 0.01$) than the Cheviot × Belclare ewes. There were no significant interactions between system and ewe breed type. It is concluded that the YRG system of prime lamb production was sustainable using prolific ewes but at a reduced stocking rate (−26%) and with greater lamb mortality relative to the GWF system. Ewe genotypes with a mean litter size of up to 2.34 lambs are suitable for both systems. Lamb carcass output of 501 kg/ha was achieved from a primarily grass-based system of mid-season prime lamb production using prolific ewes (Belclare).

Key words: indoor lambing; lamb production; outdoor lambing; year round grazing

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Introduction

Sheep production in the EU is now market led rather than subsidy driven as a consequence of the decoupling of farm subsidies from production. Prime lamb production in Ireland is seasonal and grass-based, with lambing normally targeted to coincide with the start of grass growth in spring. For mid-season prime-lamb production systems, Keady and Hanrahan (2006) concluded that litter size, and consequently lamb carcass output per ewe, together with grassland management are the main factors affecting the efficiency of prime lamb production. Utilisation rate is a major factor affecting the cost per kg of grazed grass consumed (Keady *et al.*, 2002). From a study spanning 4 years, Nolan (1972) reported lamb carcass outputs of 203 and 301 kg/ha for grass-based systems stocked at 10 and 15 ewes/ha, respectively; litter size was 1.4. Nolan (1972) also reported that the optimum stocking rate was around 15 ewes/ha. Ewe prolificacy can be readily altered by exploiting established differences between breeds. For example, Hanrahan (1994) reported litter size differences due to sire breed of up to 0.4 in crossbred ewes from Scottish Blackface dams. The Belclare breed, developed from a range of genetic resources, has a litter size of about 2.2 under average management conditions (Hanrahan, 1997), and Belclare-cross ewes have been shown to have a higher prolificacy than a wide range of other crossbred types (Hanrahan, 1989).

Grennan (1993), reviewed a number of studies undertaken at Athenry Research Centre and concluded, that during the main grazing season, optimum levels of lamb performance pre- and post-weaning are obtained by grazing pastures to set sward heights that vary with grazing system and season of the year. More recently, there has been interest in extending the grazing season into the winter (referred to as extended or deferred grazing) and reducing or eliminating indoor winter feeding. Recent studies have shown that extended grazing of ewes in mid (Flanagan, 2003; Keady, Hanrahan and Flanagan, 2007; Keady and Hanrahan, 2009b), late (Carson *et al.,* 2004; Keady *et al.,* 2007) or throughout (Keady *et al.,* 2007; Keady and Hanrahan, 2009a) pregnancy increased lamb birth and weaning weights relative to lambs from ewes that were housed, unshorn, and offered grass silage for the winter period. Keady and Hanrahan (2009a,b) concluded, based on the weight of weaned lamb, that medium feed-value grass silage offered indoors supported the same level of animal performance as extended grazed herbage offered at allowances of 1.4 and 1.8 kg dry matter (DM) in mid and late pregnancy, respectively.

The primary objective of this study was to evaluate two contrasting grass-based systems of prime lamb production, using prolific ewes capable of yielding high levels of carcass output per hectare. The systems had approximately the same stocking rates and levels of fertiliser N inputs used by Nolan (1972), but employed two ewe breed types with inherently higher prolificacy potential. The two systems involved either housing the ewe flock during the winter period and offering grass silage, which is conventional in Ireland, or grazing all year round with the flock being over wintered outdoors on autumn saved pasture, thus maximising the use of grazed grass in the ewes diet. The two ewe breed types differed in prolificacy and were used to evaluate possible interactions between production system and prolificacy. To account for differences between years in weather conditions which can impact on grass growth and quality and, consequently, on animal performance and system output, the study was conducted over four successive years.

Materials and Methods

The study was undertaken at the Teagasc Knockbeg Sheep Unit, Carlow (52°51'N, 6°57'W). It was initiated when ewes were joined with rams in October, 2000 and continued until autumn, 2004, when the fourth crop of lambs were slaughtered.

The two systems were normal seasonal grazing followed by indoor feeding during winter (GWF) and year-round grazing (YRG). The main characteristics of the systems are presented in Table 1. The GWF system involved 9.6 ha divided into 5 paddocks, differing in area, stocked at 14.4 ewes/ha, whilst the YRG system involved 15 ha divided into 5 paddocks, differing in area, stocked at 10.5 ewes/ha. The mean lambing dates for the ewes on the GWF and YRG systems were 20 March and 30 March, respectively. At the start of the study, 294 ewes [88 and 206 were Belclare × Belclare (Belclare) and Cheviot × Belclare (Cheviot-x), respectively] from the mixed-age (≥1.5 years) flock on the farm were allocated, at random within breed, to the two systems. In early autumn each year routine culling was undertaken mainly for teeth wear, udder disease and age (all ewes over 5 years of age were usually culled from the systems). Ewe replacements were 18 months-old and were assigned at random, within breed type, to the systems so as to maintain flock size. The Belclare and Cheviot-x ewes were born (in March) on different farms but were reared together from about 6 months of age until introduced to the Knockbeg flock.

The swards in both farmlets were predominantly of perennial ryegrass but had somewhat different histories. The GWF swards were seeded in 1985 with 11.2, 18.0 and 2.2 kg/ha of Talbot and Meltra perennial ryegrasses and Huia white clover, respectively. In the YRG system, 28% of the farmlet was seeded in 1984, 37% was seeded in 1986 (11.2, 17.9 and 2.2 kg/ha of Talbot and Meltra perennial ryegrasses and Huia white clover, respectively), 20% was seeded in 1994 (18 and 12 kg/ha of Moy and Amigo perennial ryegrasses, respectively), 15% was seeded in 1998

Table 1. Description of seasonal grazing plus winter feeding (GWF) and year round grazing (YRG) production systems

Season	GWF	YRG
Autumn	Grazed all the farmlet.	Grazed half the farmlet. Other half conserved for winter grazing.
Winter	Ewes housed, unshorn, in straw bedded sheds. Grass silage was offered *ad libitum*.	Grazed the half of the area conserved in Autumn – fresh herbage allocated daily.
Spring	Ewes housed and offered silage supplemented with concentrate prior to lambing. Mean lambing date was 20 March. Ewes and lambs moved to pasture within three days of lambing.	Winter grazing continued until two weeks prior to lambing. Ewes received concentrate supplementation prior to lambing. Mean lambing date was 30 March. Ewes and lambs moved to fresh pasture post lambing.
Summer	Ewes grazed grass/clover sward unsupplemented. Lambs received creep from 8 weeks. Lambs weaned at 14 weeks. Paddocks closed for silage conservation.	Ewes grazed rotationally, unsupplemented. Lambs received creep from 8 weeks. Lambs weaned at 14 weeks. Excess herbage removed.

(3.4, 3.4, 3.4, 9.0, 10.2, 4.5, 1.1 and 1.1 of Napoleon, Spelga, Respect, Montando, Veritas and Tyrone perennial ryegrasses, and Sussi and Aran white clovers, respectively).

Production systems

GWF system: Rams were joined with the flock during the first week of October and removed during the third week of November. The ewes were treated for liver fluke (Fasinex 5%, Novartis Animal Health Inc, Basel, Switzerland) and housed in early December (straw bedded pens) in groups of 25 to 27 at a space allowance of 1.8 m^2 per ewe. Whilst housed, they were offered (daily) grass silage *ad libitum* and had access to water. Single-, twin- and triplet-bearing ewes were supplemented with a proprietary pelleted concentrate which was formulated to contain 180 g/kg crude protein (CP). From days 32 to 18, and 18 to 4, prior to expected start of lambing, and from day 4 to lambing, ewes were offered, respectively, 250, 400 and 700 g concentrates once daily on top of the silage. Two weeks prior to lambing ewes were vaccinated against clostridial diseases and pasteurellosis (Heptavac P Plus, Intervet Ireland Ltd., Dublin). Ewes and their lambs were moved to pasture within 3 days of lambing. Within system, some lambs from triplet and larger litters were fostered onto ewes with singles or ewes whose lambs died at or shortly after birth.

Ewes rearing singles or twins received no concentrate supplementation but their lambs were offered creep concentrate from about 8 weeks of age until drafting for slaughter; the maximum allowance per lamb was 300 g/day. Triplet-rearing ewes received 1 kg concentrate daily until 5 weeks post lambing and their lambs had access to creep concentrate from 2 weeks of age onwards. The lambs were weaned at an average age of 14 weeks and were rotationally grazed. All the farmlet received fertiliser N in February (58 kg/ha) and was available for grazing post lambing. Swards were grazed in a rotational system. One quarter of the farmlet was closed for silage conservation in early to mid April and received 84 kg/ha N. Herbage was harvested as large bales in late May and ensiled after a 24 h wilting period in round bales without additive treatment. The bales were transported to the storage area immediately after baling, wrapped with six layers of plastic film and stacked two high.

Lambs received anthelmintic treatment for internal parasites at 5, 10 and 14 weeks, and subsequently at 4 to 6 week intervals until slaughter. The anthelmintic used was rotated yearly between benzimadozole, levamisole and the macrocyclic lactones. Ewes received no treatment for internal parasites and were shorn in early June each year. Ewes and lambs were treated for foot rot and scald by walking through a footbath, which contained a solution of zinc sulphate diluted in water, as required. Ewes and lambs received a pour-on treatment (Vetrazin pour-on, Novartis Animal Health Inc, Basel, Switzerland) for the control of fly strike.

YRG system: Three paddocks were closed (one 2.5 ha paddock weekly) between mid September and early October and received fertiliser N (33 kg/ha) to enhance herbage production for extended grazing from early December to early March. Rams were joined with the ewes in the third week of October and were removed in the first week of December. During extended grazing, the herbage was allocated in blocks which involved placing electrified mesh fences in front of, and behind, the flock daily. The herbage was allocated at the same time each day. From early December to mid January, the ewes received a herbage allowance of 1 kg DM daily and this was increased to 1.3 kg DM daily from mid January to early March. In early March (2 weeks before the start of lambing) block grazing ceased, ewes were vaccinated against clostridial diseases and pasteurellosis (Heptavac P Plus, Intervet Ireland Ltd., Dublin) and were moved to the lambing paddocks. Ewes were treated for liver fluke (Fasinex 5%, Novartis Animal Health Inc, Basel, Switzerland) at the start and end of block grazing. Ewes were grouped on the lambing paddocks according to predicted litter size, based on earlier ultrasonic scanning.

In early February, the 50% of the farmlet closed in early December for grazing immediately prior to and post lambing received fertiliser N (57 kg/ha). In mid March, the other 50% of the farmlet which had been extended grazed (winter) received similar fertiliser N dressing.

All ewes received a daily allowance of a proprietary pelleted concentrate of 250 and 400 g/day per ewe during weeks 6 and 5, and 4 through 1, respectively, prior to movement to the lambing paddocks. Twin and triplet-bearing ewes received 600 g concentrate per ewe daily from then until lambing while single-bearing ewes received no concentrate supplementation in this period. The concentrate was the same as offered to the GWF ewes and was distributed daily on the sward. Ewes and lambs were removed from the lambing paddocks within 24 h of lambing and were subsequently managed in a rotational grazing system. Some lambs from triplets and larger litters were fostered onto ewes with singles or ewes whose lambs were dead at, or died shortly after, birth. Ewes rearing singles or twins received no concentrate supplementation after lambing. Triplet-rearing ewes received 1 kg concentrate daily for 5 weeks after lambing. Concentrate supplementation was made available to lambs reared as triplets from about 2 weeks of age and to all lambs from about 8 weeks of age until drafting for slaughter; the maximum allowance per lamb was 300 g/day. Ewes were shorn on the same date as the GWF flock. Internal and external parasite treatments of the ewes and lambs were also as described for the GWF flock. The lambs were weaned at an average age of 14 weeks. During the post-weaning period the lambs were rotationally grazed in a leader-follower system, lambs leading and ewes following, until 3 weeks prior to mating. Excess herbage was conserved for silage and these paddocks subsequently received fertiliser N (34 kg/ha). Pastures were topped during the grazing season as required.

Measurements

On swards for winter grazing, the pre-grazing herbage mass was estimated by cutting randomly chosen quadrats (0.25 m^2). Fifteen quadrats were cut in early December on the pasture to be grazed until mid January. On swards to be grazed from mid January to early March, 15 quadrats were cut in mid January. The herbage was cut to ground level using rechargeable hand shears (Gardena, Ulm, Germany).

In 2001, herbage was bulked by groups of three quadrats for determination of DM concentration. Afterwards, the dried herbage was milled and analysed for CP, ash and DM digestibility (DMD) concentrations. In 2001 also, representative samples of silage were obtained from each of five bales and bulked for the determination of pH and concentrations of ammonia N and DM. The dried samples were then milled and analysed for CP, ash and DMD concentrations. Silage DM concentration was determined by oven drying at 40 °C for 48 h. Grass DM concentration was determined by oven drying at 98 °C for 16 h. Other methods of analysis of herbage and silage were as described by Keady and O'Kiely (1996).

From mid March to early December during each grazing season, sward height was recorded at 40 locations within each paddock used for grazing, once every 2 weeks, with a rising plate meter (Ashgrove plate meter, Hamilton, New Zealand).

Ewe live weight and body condition score (Russel *et al.*, 1969) were recorded at the end of the joining period, at mid pregnancy, at 5 weeks post lambing and at weaning. Ewe body condition score was also recorded within 24 h of lambing. Litter size and the number of dead-born lambs were recorded. Lambs alive at 5 weeks of age were classified as reared. Lambs were weighed within 24 h of birth and at about 5, 10 and 14 (weaning) weeks of age, and prior to slaughter. Carcass weight was recorded for each animal at slaughter. Routine records were maintained of mortality and of the principal reason for involuntary culling of ewes.

Statistical analysis

Animal performance data were analysed using the mixed model procedures of SAS (SAS, 2000). All models included fixed effects for year, system, ewe age (2, 3, 4 or 5+) and ewe genotype. Ewe identity within breed was included as a random term. Sex and number of lambs reared per ewe were also included as fixed effects for analysis of lamb live weight, live weight gain, age at slaughter and carcass weight. In the case of birth weight, rearing type was replaced by birth type (1 to 4). Data on the incidence of ewe fertility and culling, and lamb mortality were analysed using Proc GENMOD (SAS, 2000) with a logit link function.

Results

Feeds

The mean pH and concentrations of DM, ammonia N, CP and DMD of the silage offered in 2001 were 4.2, 182 g/kg, 126 g/kg N, 132 g/kg DM and 764 g/kg DM, respectively. The mean DM, CP, ash and DMD of the herbage extended grazed in 2001 were 158 g/kg, 244 g/kg DM, 109 g/kg DM and 753 g/kg DM, respectively.

In two of the four years (2001, 2003) of the study, ewes on the YRG system received on average 12 kg extra concentrate (sugar beet pulp) during late pregnancy to offset an inadequate supply of herbage during winter grazing (1 kg sugar beet pulp DM per kg DM reduction in extended grazed herbage allowance).

Sward height for the grazing paddocks is presented in Figure 1. The mean sward heights of the grazing paddocks in the GWF and YRG systems were 5.4 and 6.3 cm, respectively.

Ewe performance

The effects of production system and ewe genotype on ewe body condition score and live weight are presented in Table 2. Ewes on the YRG system had significantly ($P < 0.001$) higher body condition score at lambing and 5 weeks post lambing, and were heavier ($P < 0.001$) at 5 weeks post lambing than ewes on the GWF system. System did not significantly affect ewe live weight post mating or at weaning, or body condition score post mating, at mid pregnancy or at weaning. Cheviot-x ewes were significantly ($P < 0.001$) heavier and had higher body condition scores at all times except at lambing than Belclare ewes.

The effects of system and ewe genotype on ewe fertility, litter size and lamb mortality are presented in Table 3. The incidence of dead-born lambs was significantly higher ($P < 0.001$) on the YRG system and there was no evidence for any

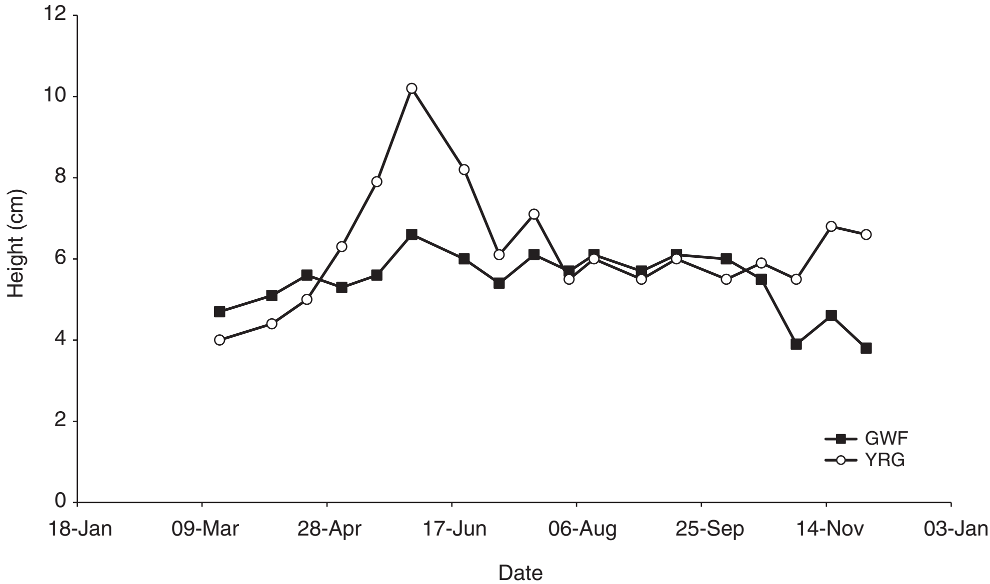

Figure 1. Seasonal variation in sward height on the grazing areas of the GWF and YRG production systems.

Table 2. The effects of production system and ewe breed on ewe live weights and body condition scores

Variable	Production system (S)		s.e.	Ewe breed (G)		s.e.	Significance	
	GWF[1]	YRG[2]		Belclare	Belclare × Cheviot		S	G
Live weight (kg) at:								
Post mating	70.8	70.4	0.43	69.0	72.2	0.44		***
Mid pregnancy	74.3	70.3	0.46	71.1	73.4	0.49	***	***
5 weeks post lambing	67.7	73.1	0.53	68.8	72.0	0.54	***	***
Weaning	69.1	70.4	0.53	67.9	71.6	0.54	(P = 0.051)	***
Body condition score[3] at:								
Post mating	3.58	3.58	0.026	3.50	3.66	0.022		***
Mid pregnancy	3.45	3.49	0.020	3.41	3.54	0.026		***
Lambing	3.19	3.40	0.023	3.27	3.33	0.023	***	(P = 0.06)
5 weeks post lambing	2.95	3.24	0.023	3.02	3.17	0.023	***	***
Weaning	3.22	3.25	0.025	3.14	3.32	0.026		***

[1] GWF = Grazing, winter feeding.
[2] YRG = Year round grazing.
[3] Scale 1 (thin) to 5 (fat).

birth-type by system interaction. Whilst total lamb mortality to 5 weeks of age was not significantly higher (P = 0.06) on the YRG system there was a highly significant interaction (P < 0.001) between birth type and system. For the GWF and YRG systems total lamb mortality estimates were 3.0 and 13.6%, 4.8 and 7.4%, and 16.1 and 14.9%, for single, twin and triplet birth types, respectively. System did not

Table 3. The effects of production system and ewe genotype on ewe fertility, litter size and lamb viability

Variable	Production system (S)		s.e.	Ewe breed (G)		s.e.	Significance	
	GWF	YRG		Belclare	Belclare × Cheviot		S	G
Ewe fertility[1]	0.92	0.93		0.93	0.92			
Litter size	2.17	2.24	0.038	2.34	2.07	0.038		***
Dead-born lambs (%)	3.8	8.0		7.6	7.7		***	
Total lamb mortality to 5 weeks[2] (%)	10.1	13.8		11.8	12.5		P = 0.06	
Number reared per ewe joined	1.77	1.78	0.042	1.86	1.69	0.043		**

GWF = Grazing and winter feeding; YRG = Year round grazing.

[1] Back transformed proportion of joined ewes lambing.

[2] Significant ($P < 0.001$) lamb birth type and production system interaction for total lamb mortality to 5 weeks.

significantly affect ewe fertility, litter size or the number of lambs reared per ewe joined. Belclare ewes had a higher litter size ($P < 0.001$) and reared more lambs ($P < 0.01$) than Cheviot-x ewes. Ewe genotype did not affect ($P > 0.05$) ewe fertility, number of lambs born dead or total lamb mortality to 5 weeks.

Lamb performance

The effects of production system and ewe genotype on lamb birth weight and subsequent performance to weaning are presented in Table 4. Lambs born on the YRG system were heavier ($P < 0.001$) at birth and weaning, and grew faster ($P < 0.001$) from birth to 5 weeks and from 5 to 10 weeks. System did not significantly influence lamb growth rate from 10 weeks to weaning. Lambs from the Cheviot-x ewes were heavier at birth ($P < 0.01$) and grew faster from birth to 5 weeks ($P < 0.05$). However, ewe breed did not significantly influence lamb growth rate from 5 to 10 weeks, 10 weeks to weaning, birth to weaning or weaning weight.

Age at slaughter and slaughter traits are presented in Table 5. Lambs born on the YRG system were slaughtered at similar live weight and carcass weight to lambs from the GWF system but at a younger age ($P < 0.001$). Lambs from the Belclare

Table 4. Least squares means for the main effects of production system and ewe breed on lamb live weights and growth rates

Variable	Production system (S)		s.e.	Ewe breed (G)		s.e.	Significance	
	GWF	YRG		Belclare	Belclare × Cheviot		S	G
Birth weight (kg)	3.97	4.67	0.055	4.24	4.41	0.049	***	**
Weaning weight (kg)	27.9	30.8	0.25	29.2	29.6	0.26	***	
Growth rate (g/d)								
Birth to 5 weeks	253	278	3.1	261	270	3.2	***	*
5 to 10 weeks	246	287	3.2	266	267	3.3	***	
10 to 14 weeks	228	220	4.1	226	223	4.2		
Birth to weaning	245	267	2.3	255	257	2.4	***	

GWF = Grazing and winter feeding; YRG = Year round grazing.

Table 5. The effects of production system and ewe genotype on lamb slaughter age and carcass weight

	Production system (S)		s.e.	Genotype (G)		s.e.	Significance	
	GWF	YRG		Belclare	Belclare × Cheviot		S	G
Age at slaughter (d)	168	156	1.4	162	163	1.5	***	
Slaughter weight (kg)	42.1	42.2	0.16	41.9	42.4	0.17		*
Dressing proportion	0.459	0.457	0.1332	0.459	0.457	0.1361		P = 0.08
Carcass weight (kg)	18.8	18.8	0.07	18.7	18.8	0.07		

GWF = Grazing and winter feeding; YRG = Year round grazing.

ewes were lighter at slaughter ($P < 0.05$) and tended to have a higher ($P = 0.08$) dressing proportion. Ewe genotype did not affect ($P > 0.05$) age of lambs at slaughter or carcass weight.

The overall proportion of ewes culled for unacceptable udder condition was 8%. System had no effect ($P = 0.6$) on this proportion but the incidence was higher for Belclare ewes than for Cheviot-x ewes (14.5 v 4.0%; $P < 0.01$). The proportion of ewes culled for broken mouth (tooth wear/damage) was higher ($P < 0.05$) in the YRG system (2.8% v 6.8% for the GWF and YRG systems, respectively). The analysis of the incidence of ewe mortality (5.1% overall) revealed a breed-by-year interaction ($P = 0.013$) reflecting higher mortality in the Belclare than in Cheviot-x ewes in 2001 and 2002 (10.7 and 13.5 % v 2.5 and 1.7 %), whereas in 2003 and 2004 the corresponding values were 4.7 and 3.5% v 5.9 and 3.1%. Examination of the mortality data revealed that in 2001 and 2002 the majority of deaths were 2-tooth ewes.

Discussion

The majority of prime lambs produced in Ireland and the United Kingdom are born in spring and finished, primarily off grass, during the grazing season. Grassland-based systems can be extremely diverse and are affected by issues such as lambing date, stocking rate, over-wintering management, fertiliser N input and ewe breed. Whilst it is recognised that system studies involve many different components that change simultaneously, the effects of which cannot be individually quantified, they enable an examination of the overall effects of combining a range of contrasting options which exist in practice for prime lamb production. In undertaking systems studies it is recognised that the study needs to continue for a number of years, as the outcome may be affected by the prevailing weather conditions which can vary from year to year. In addition, there are cumulative effects over time which can affect the overall outcome. Consequently, the present study was undertaken over 4 years. It is also recognised that it is often not practical to replicate treatments in system studies, but in the present study there was replication over time (years). Consequently, we consider that the results of the study reflect the effects of the systems and are repeatable.

In the two contrasting production systems used the primary objective was to examine if the proportion of grazed grass in the diet could be increased, thus eliminating the requirement for grass silage feeding and housing of the ewe flock during the winter. A second objective was to examine if lambing outdoors could reduce labour and fixed costs associated with indoor lambing. The major differences between the systems were in stocking rate, over-wintering strategies for the ewes, forage conservation, lambing date and management (indoors or outdoors). The lambs were weaned at similar ages and marketed at similar weights from both systems. A final objective was to evaluate the importance of interactions between ewe prolificacy and production system. The ewe genotypes used differed in prolificacy as the number of lambs weaned per ewe put to the ram is a major factor affecting efficiency and profitability of prime lamb production (Keady and Hanrahan, 2006).

Effects of system

The overall performance of the two contrasting systems is discussed, and where appropriate, the response obtained is compared with what might have been expected from previous component studies at Athenry and elsewhere.

Winter feeding: The swards for extended grazing were closed sequentially between 15 September and 15 October with the intention of providing herbage of constant feed value for the winter grazing period. O'Riordan (1995) showed that for swards closed on 1 September, the proportion of dead material increased and the herbage feed value, as determined by DMD, declined between mid December and mid January. However, more recently, Binnie, Mayne and Laidlaw (2001) showed that swards closed on 30 August and 20 September had the same proportion of dead material on 1 November and 1 February, respectively.

Whilst the ewes in both systems were in similar body condition post-mating and in mid pregnancy, by the time of lambing, the ewes on GWF were in poorer condition. Using similar ewes, Hanrahan (1990) concluded that a one unit change in body condition score was equivalent to a 12 kg change in live weight. Thus, even though the ewes in the current study were not weighed at lambing, those on the GWF system were probably about 2 to 3 kg lighter at this stage based on the relationship between body weight and body condition (Hanrahan, 1990). Similarly, Keady *et al.* (2007) reported that ewes which were grazed in winter and managed similarly to those in the present study, had a higher body condition score than housed ewes which were unshorn. The difference in ewe body condition score at lambing in the present study was probably due to some combination of the following factors. Firstly, the nutritive value of forage is a combination of its metabolisable energy concentration and intake potential. In the current study, the forages offered during the winter feeding period had similar DMD values and by inference similar metabolisable energy concentrations. However, intake may have differed. Whilst intake was not measured, the mean daily herbage allowance was 1.15 kg DM/ewe. In similar circumstances to the current study, Keady and Hanrahan (2007a) reported herbage utilisation rates by ewe lambs of 73% and 68% for daily herbage allowances of 1.25 and 1.75 kg, respectively. Likewise, Keady and Hanrahan (2007b) reported utilisation rates of 78% and 71% for single and twin bearing ewes during the final 8 weeks of pregnancy. Assuming the mean utilisation rate in these studies prevailed for the current study, then daily herbage DM intake would have been approximately 0.8 kg/ewe. Whilst the silage offered indoors had similar digestibility to the grazed herbage, the long particle length, as present in unchopped big bales, has been shown to reduce silage intake (Dulphy and Demarquilly, 1972; Fitzgerald, 1996). Therefore, DM and metabolisable energy intakes may have been lower for the ewes offered silage than for those grazed.

Secondly, in two of the four years of the study, ewes on the YRG system received an average of 12 kg extra concentrate (sugar beet pulp) during mid pregnancy to compensate for an inadequate supply of herbage during winter grazing. The concentrate allowance equalled the reduction in the herbage allowance resulting in increased DM and metabolisable energy intakes. At 2 weeks prior to the commencement of lambing, the ewes on the YRG system were distributed over the lambing paddocks, which had leafy herbage of high intake characteristics and metabolisable energy concentration. This would have resulted in increased metabolisable energy intake. Finally, Keady and Hanrahan (2009a) reported that ewes housed unshorn had lower food intake than ewes shorn at housing indicative of a negative effect of potential heat stress indoors on food consumption.

The higher body condition score and live weight of the ewes on the YRG system at 5 weeks post lambing reflects the higher body condition score at lambing and the greater availability of herbage for grazing. Although sward height was lower in the YRG system up to late April, there was also a lower stocking rate so herbage availability per ewe was higher.

Lambing: The absence of an effect of system on litter size and number of lambs reared was consistent with previous studies which have shown that extended grazing in mid (Flanagan, 2003; Keady *et al.,* 2007; Keady and Hanrahan, 2009b), late (Carson *et al*., 2004; Keady *et al.,* 2007) or throughout (Keady *et al.,* 2007; Keady and Hanrahan, 2009a) pregnancy did not significantly alter litter size or number of lambs reared per ewe. Furthermore, live weight and body condition score at mating, which have been shown to influence litter size (Hanrahan, 1990), did not differ between the two systems. The increased lamb mortality on the YRG system may have been due to increase dystocia, especially in the single born lambs as lambs on the YRG system were heavier at birth. Secondly, lambs on the YRG system were born outdoors and therefore prevailing weather conditions at the time of birth may have been inimical to survival. The fact that total mortality for triplet-born lambs was numerically higher for the GWF system may have been partly due to the fact that triplet litters were usually kept indoors (in individual pens) for longer after birth than either singles or twins. The absence of a significant effect of system on the number of lambs reared in the face of the differences in lamb mortality can be explained by the numerically higher fertility and litter size for ewes on the YRG system.

The increased lamb birth weight on the YRG system agrees with data reported previously for ewes which were grazed during pregnancy relative to those housed unshorn. For example, extended grazing in mid (Flanagan, 2003; Keady *et al.,* 2007; Keady and Hanrahan, 2009b), late (Carson *et al.,* 2004; Keady *et al.,* 2007) or throughout (Keady *et al.,* 2007; Keady and Hanrahan, 2009a) pregnancy increased lamb birth weight relative to progeny from ewes which were housed unshorn during the mid and late pregnancy periods. The lower lamb birth weight on the GWF system was probably due to increased heat stress indoors, which has been shown to reduce lamb birth weight (Shelton and Huston, 1968; Alexander and Williams, 1971). Whilst Keady *et al.* (2007) and Keady and Hanrahan (2009a) showed that ewes which were grazed throughout pregnancy produced heavier lambs at birth than for ewes housed unshorn, birth weight was similar to that from ewes which were shorn at housing. Also, Keady *et al.* (2007)

reported that gestation length of ewes grazed during pregnancy was longer than ewes which were housed unshorn. Winter grazing probably leads to higher intakes of crude protein resulting in a greater supply of true protein. Winter grazed herbage has a higher protein concentration than grass silage (Keady *et al.,* 2007; Keady and Hanrahan, 2009a). A summary of six studies showed that true protein accounted for 790 and 553 g/kg N, respectively, for herbage before ensiling and the resultant silages (Keady, 1991). Using these proportions, Keady and Hanrahan (2009b) estimated true protein intakes for ewes in mid pregnancy which were either grazed on low or high herbage allowances or housed and offered low or medium feed value silages of 92, 125, 60 and 77 g/day, respectively. Keady and Murphy (1988) observed that ensiling increased nitrogen degradation in the rumen, consequentially reducing microbial protein supply, while Bell *et al.* (1989) reported that the efficiency of uptake of amino acid nitrogen by the foetus was greater in mid than in late gestation.

Grazing: The lamb growth rates recorded in this study were lower than those recently published (Keady *et al.,* 2007; Keady and Hanrahan, 2009a,b; Carson *et al.,* 2004). The YRG system produced heavier lambs at weaning mainly due to heavier birth weights. Previous studies (Keady *et al*., 2007; Keady and Hanrahan, 2009a,b) have yielded positive correlations between birth and weaning weights. Keady *et al.* (2007), and Keady and Hanrahan (2009a,b) reported responses of 3.35, 3.16 and 3.17 kg in weaning weight per 1 kg increase in birth weight. More recently, Keady and Hanrahan (2009b) attributed 58% and 42% of the increase in weaning weight to increased birth weight *per se* and to higher growth rate, respectively. The higher response in weaning weight in the current study (4.14 kg per 1 kg) probably reflects the higher growth rate of lambs on the YRG system until 10 weeks due to the lower stocking rate and the higher body condition score of the ewes at lambing. However, grass supply increased greatly prior to weaning, probably associated with an increased proportion of stem which reduces both herbage digestibility (Stakelum and Dillon, 1990) and lamb growth rate (Grennan, 1993). The numerically lower lamb growth rate on the YRG system during the 10 to 14 week period was probably a reflection of lower digestibility herbage at a stage when grass rather than milk had become the major portion of the lambs' diet. The lower overall lamb growth rate on the GWF system was probably due to limited herbage availability together with the poorer body condition of the ewes during lactation restricting milk production. Keady and McCoy (2001) concluded from a review of the literature that increasing body condition score of dairy cows at calving increased milk yield and tended to increase fat concentration, culminating in increased milk energy output during the subsequent lactation.

The higher proportion of ewes culled on the YRG system due to broken mouths was probably associated with increased silica intake while winter grazing. Nolan and Black (1970) concluded that the rate of wear of incisor teeth was closely related to silica intake as reflected by faecal silica concentration. Black (1975) observed that ewes grazing short herbage in winter had higher incisor wear than ewes which relied on conserved forage.

Ewe genotype

The Belclare breed which was bred for prolifacy has been shown to increase litter size in the first cross up to 0.40 lambs/ewe (Hanrahan, 1994). Whilst lamb mortality from birth to 5 weeks was greater in the present study than in other published studies (Carson *et al*., 2004; Keady and Hanrahan, 2007a,b) the litter size and number of lambs reared per ewe were greater. The 9% increase in lamb output at weaning for the Belclare breed was due to its greater prolificacy. Whilst food intake was not measured in the present study, as intake is related to live weight (Hanrahan, 1989), little difference would have been expected in intake of the two genotypes. Consequently, the Belclare breed would have better feed conversion efficiency (weight of weaned lamb/food intake) which is an important attribute particularly where stocking rate is high and feed availability is limited.

As there were no interactions between production system and ewe genotype it can be concluded that Belclare ewes producing large litters are as suited to outdoor lambing as Cheviot-x ewes. Similarly, Carson *et al.* (2004) concluded, using four ewe genotypes, that there was no interaction between ewe genotype and lambing either indoors or outdoors. However, litter size of the ewe genotypes in the study of Carson *et al.* (2004) varied from 1.64 to 1.99 whilst in the current study litter size varied from 2.07 to 2.34.

The effect of ewe genotype on mortality was unexpected but was clearly year specific. The specificity of the differential mortality to 2001 and 2002 is supported by the fact that there was no evidence for any difference between these two genotypes in mortality for the years 1999 and 2000 (P = 0.25) when 159 replacements ewes were introduced to the flock under the same production systems as operated over the period of the present study (unpublished data). Hanrahan (2007) reported that relative to Suffolk-x ewes, Belclare-x ewes, which are more prolific, had a higher replacement rate (23% and 21% for Belclare-x and Suffolk-x ewes, respectively).

Carcass output per hectare

Carcass output per ha is a measure of the efficiency of systems of prime lamb production. Carcass output was influenced by both production system (due to stocking rate) and ewe genotype (due to prolificacy). For the Belclare and Cheviot-x genotypes on the GWF and YRG systems, lamb carcass outputs were 501, 458, 365 and 334 kg, respectively. The carcass output value of 501 kg/ha was an increase of 66% relative to that reported by Nolan (1972) using similar stocking rates and N fertiliser inputs. This was primarily due to an increase in weaning rate arising from improvements in genetic merit and management.

Practical considerations

Year round grazing enables the establishment of a low cost (low fixed costs) system of sheep production and should also reduce labour at lambing by eliminating the need for labour indoors between lambing and turnout and the turnout task itself. However, the YRG system was associated with higher lamb mortality. Furthermore, the YRG system necessitated a reduction in stocking rate of 26%, consequently reducing lamb carcass output per hectare. In the YRG system, herbage supply in autumn is a critical factor affecting success as adequate herbage is required both for the ewe breeding season and for lamb finishing, when 50% of the land area is unavailable because of the need to conserve herbage for winter grazing. Winter grazing is dependent on soil conditions and rainfall, both of which impact on herbage utilisation rate and consequently feed costs (Keady *et al.,* 2002). The relative merits of the systems depend on the size of the farm unit and lamb carcass value.

Conclusions

The YRG system provides an alternative system for prime lamb production but at a significantly lower stocking rate and with higher lamb mortality relative to the GWF system. Year round grazing increased lamb birth and weaning weights and reduced age at slaughter relative to lambs from ewes (unshorn at housing) on the GWF system. Ewe genotypes producing litters up to 2.34 lambs are suitable for both the YRG and GWF systems. There were no interactions between production system and ewe genotype on ewe or subsequent lamb performance. Lamb carcass output of 501 kg/ha can be achieved from a primarily grass-based system of mid-season prime lamb production.

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