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Effects of joining at 7 months, and ewe genotype, on the performance of ewes to 19 months of age and that of their progeny to slaughter

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ABSTRACT

Two ways of reducing the cost of replacements are increasing litter size and number of litters produced; thus, the total weight of lamb carcass output per ewe lifetime. The effects of ewe genotype on the performance of ewes lambing at 1 year and of their progeny to slaughter, and the effect of age at first joining (7 or 19 months) on BW at ~19 months and survival to joining at 19 months were evaluated over two consecutive years, using 460 ewe lambs from three genotypes: Belclare (**Bel**), Suffolk × Belclare (**Suf × Bel**) and ≥ 75% Suffolk ancestry (**Suf75**). Lambs from the three genotypes were at a similar proportion of mature BW and half of the lambs, within genotype, were allocated to be joined for the first time at 7 or 19 months. The ewe lambs were managed in a grass-based rotational-grazing system, except when housed from December to March on a grass silage-based diet. Belclare ewes had larger litters ($P < 0.001$), reared more lambs per ewe joined ($P < 0.01$), were lighter at lambing and at 19 months ($P < 0.01$), were of smaller body size at 19 months ($P < 0.001$) and their progeny were lighter at weaning ($P < 0.05$) relative to Suf75 genotype; the Suf × Bel ewes were intermediate for most traits but had a significantly lower litter size ($P < 0.05$) than Bel ewes. Progeny from Suf × Bel ewes were 17 days younger at slaughter ($P < 0.01$) relative to those from Bel ewes. Ewe genotype had no effect ($P > 0.05$) on lamb mortality (born dead, total mortality to weaning), lambing assistance, number of ewes that failed to lamb, or on ewe survival to 19 months of age. Increasing ewe BW at joining increased the probability ($P < 0.001$) of rearing at least one lamb and this effect was consistent across genotypes. There were significant relationships ($P < 0.001$) between ewe BW at lambing and lamb BW at birth and at weaning of 0.053 (SE 0.0089) kg and 0.29 (SE 0.049) kg, respectively. Ewes that lambed at 1 year were 2 kg lighter ($P < 0.001$) at 19 months of age and had a smaller body size ($P < 0.01$) relative to those not joined. It is concluded that ewe genotype had a significant effect on number of lambs reared, and thus lamb carcass output. Whilst lambing at 1 year reduced BW by 2 kg when joined at 19 months, it did not affect ewe survival to that stage.

Implications

Breeding ewes to lamb at 1 year has minimal impact on body weight or size at 19 months of age whilst body weight and genotype have large impacts on ewe productivity at 1 year. Increasing ewe body weight at joining increases the probability of rearing a lamb; ewe lambs should have reached 66% of mature body weight at joining. There is a positive relationship between ewe body weight at lambing and progeny body weight at birth and weaning. Progeny born to 1-year-old ewes can achieve a carcass weight of 20.5 kg on grass-based systems prior to the end of the grazing season.

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Introduction

The number of lambs reared per ewe joined is a major determinant of profitability in mid-season production systems (Keady and Hanrahan, 2006). The mean number of lambs reared per ewe joined on Irish lowland farms is approximately 1.3 and has remained relatively static for the last 30 (Hanrahan, 2010). The lack of any improvement in ewe productivity likely reflects many factors but these include absence of change towards adoption of more prolific ewe genotypes (Hanrahan, 2001; Hanrahan and Keady, 2014; Keady and Hanrahan, 2018b). Currently, 73% of lowland ewes in Ireland have been sired by one of the three main terminal sire breeds (Suffolk, Texel and Charollais; Keady et al., 2019), and two of these breeds have inherently low productivity (Hanrahan, 2001). In Ireland, Suffolk and Suffolk-cross ewes account for

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54.8% of lowland ewes whilst Belclare-X ewes have increased from 4.4% in 2008 to 9.5% in lowland flocks in 2016 (Keady et al., 2019), hence this study covers the range from present to future ewe genotypes. The Belclare breed was developed from a range of genetic resources (Hanrahan, 1989, 1997) and has a litter size of about 2.2 under typical management conditions. Belclare-cross ewes have a higher prolificacy than a wide selection of other crossbred types (Hanrahan, 2001; Hanrahan and Keady, 2014). Other key factors, in order of importance, that influence efficiency of prime-lamb production from pasture-based systems are grassland management, feed value of forage offered during housing in winter, shearing at housing and condition score at joining (Keady and Hanrahan, 2006). Ewe replacement policy has also been identified as a determinant of efficiency since the cost of rearing a ewe replacement to 19 months (the typical time of first joining) is equivalent to ~25% of the total value of lamb carcass produced during her lifetime (Keady, 2014).

The mean replacement rate on lowland sheep units in Ireland is 22% (Keady, 2014) and has been shown to be affected by ewe genotype (Hanrahan, 2007). Replacement costs can be reduced by increasing litter size and increasing the number of litters produced per ewe lifetime, and therefore lifetime lamb carcass output (Keady and Hanrahan, 2018b). Previous authors have reported that the onset of breeding activity in ewe lambs is controlled by environmental factors, as in mature ewes, but in light-weight ewe lambs, the environmental factors are modified by the influence of BW (Keane, 1974), and that there is an association between age at first oestrus and BW (Keane, 1975; Quirke, 1978), and genotype (Quirke, 1978). Benefits to joining ewe replacements to lamb at 1 year of age include increasing the number of litters per lifetime, thus lifetime performance, a higher number of lambs born on a farm annually and farm net margin, plus potential to achieve a higher rate of genetic improvement. However, the progeny from young ewes are lighter at birth and at weaning (Keady, 2014).

The hypotheses that informed the study design, which is part of an evaluation of the effect of joining to lamb at 1 year on lifetime performance, were that (i) joining at 7 months does not negatively affect ewe survival or BW when joined at 19 months, (ii) progeny from ewes joined at 7 months can be drafted for slaughter prior to the end of the grazing season, (iii) productivity of ewes joined at 7 months is influenced by genotype but there is no interaction between genotype and any effect of joining on ewe survival to, or BW at, 19 months.

Material and methods

Animals and management

A total of 460 March-born ewe lambs (~7 months old), representing three genotypes and chosen to have average initial BW of ~55% of estimated mature BW for the corresponding genotype, were allocated to the study over two consecutive years. The three genotypes were Belclare (**Bel**) (n = 170; initial BW 43.4, s.d. 4.51, kg), F_1 Suffolk × Belclare (**Suf × Bel**) out of Bel ewes (n = 128; initial BW 44.2, s.d. 4.94, kg) and ewe lambs with ≥75% Suffolk ancestry (**Suf75**; Suffolk rams by Suffolk-cross ewes) (n = 162; initial BW 46.7, s.d. 4.08, kg). The Bel and Suf × Bel animals were born and reared at this research station. The Suf75 animals were purchased at approximately 4 months of age from a total of five commercial farms in each year; three farms were represented in both years. The Bel, Suf × Bel and Suf75 ewes were sired by at least 26, 25 and 15 rams, respectively. The mature BW for Suffolk and Belclare ewes is 83 and 77 kg, respectively (Hanrahan, personal communication); the mature BW of the Suffolk × Belclare ewes is expected to be approximately 80 kg.

The animals were assembled at Athenry each year, at approximately 4 months of age, and managed, as one flock, in a rotational-grazing system on predominantly perennial ryegrass (*L. perenne*) swards until the study was initiated in late September. On assembly, all animals were treated for gastrointestinal parasites, using monepantel (Zolvix; Novartis UK Ltd, Frimley/Camberley, Surrey, England) administered orally, and cydectin (1.0% w/v) (Moxidectin; Fort Dodge, South Hampton, UK) administered subcutaneously, and liver fluke using closantel (Flukiver; Janssen Animal Health, Buckinghamshire, UK) administered orally. Anthelmintic treatments for gastrointestinal parasites were also administered immediately prior to the start of the study, prior to housing, and at weaning (ivermectin; Oramec; Merial Animal Health, Harlow, Essex, England). All animals were vaccinated against enzootic abortion (Enzovax; MSD Animal Health, Buckinghamshire, England) and toxoplasma abortion (Toxovax; MSD Animal Health, Buckinghamshire, England). The ewe lambs were vaccinated against pasturella pneumonia and clostridal disease (Heptavac-P; MSD Animal Health, Buckinghamshire, England) at the start of the study and again 4 weeks later. Each year the ewe lambs were stratified, on BW at the end of September, within each genotype and randomly allocated to two groups. These groups were then allocated at random to one of 2 'age at first joining' treatments: at 7 months or 19 months. The study commenced on 10 and 15 October in years 1 and 2, respectively.

The 'age at first joining' treatment groups were managed separately, on similar pasture, in a rotational-grazing system, from the initiation of the study until housing in early December. Ewe lambs assigned to the 'joined at 7-month' treatment were joined with vasectomised rams for 48 h on 10 and 15 October in years 1 and 2, respectively, to ensure, as far as possible, that all animals had commenced ovarian cyclicity when joined with fertile rams. Entire Charollais rams, which were raddled, were introduced for a 36-day-joining period on day 14 after the introduction of the vasectomised rams. Ewe lambs with raddle marks were recorded at intervals during the joining period and the raddle colour was changed on day 13 and day 23 of the joining period to facilitate grouping of the pregnant ewe lambs (postscanning) by expected lambing date.

All ewe lambs were housed (about 1 December) in slatted pens during mid- and late-pregnancy; grass silage was offered once daily in sufficient quantities to allow a refusal of 50–100 g/kg offered. Animals were shorn within 1 week of housing and those that had been joined were scanned for litter size in January. Annual booster vaccine (Heptavac-P, MSD Animal Health, Buckinghamshire, England) for pasturella pneumonia and clostridal disease was administered, to animals that had been joined, 2 weeks prior to start of the lambing period; the animals that were not joined received their annual booster vaccine at the same time.

Ewe lambs that had been joined received 200 g concentrate daily from mid-January to mid-February. From mid-February to 6 weeks prior to expected lambing date, ewe lambs scanned as carrying singles and twins received 250 g concentrate daily whilst those scanned as carrying triplets received 300 g concentrate daily. During the final 6 weeks of pregnancy, those scanned as carrying singles, twins and triplets received totals of 19, 26 and 33 kg concentrate supplement, respectively. The daily concentrate allowance was stepped from 0.25 to 0.6 kg, 0.3 to 0.8 kg, 0.5 to 0.9 kg for ewe lambs scanned as carrying singles, twins and triplets, respectively. Published values (Agricultural and Food Research Council [AFRC], 1993) for CP and metabolizable energy (ME) for individual feed ingredients were used to formulate the concentrate supplement. The concentrate in year 1 consisted of (fresh weight) 180, 190, 100, 165, 300, 40 and 25 g/kg of barley, maize, sugar beet pulp, soya hulls, soya bean meal, molasses and minerals plus vitamins, respectively; in year 2, the composition (fresh weight) was

180, 190, 100, 145, 200, 80, 40, 40 and 25 g/kg of barley, maize, sugar beet pulp, soya hulls, soya bean meal, rapeseed meal, maize distillers, molasses and minerals plus vitamins, respectively. The ingredients were milled through a 3-mm screen, before mixing and pelleting. The concentrate was offered once daily at ~1000. The estimated mean CP and ME concentrations of the concentrates offered in years 1 and 2 were 231 g/kg DM and 12.85 MJ/kg DM; 220 g/kg DM and 12.83 MJ/kg DM, respectively.

Ewes lambed indoors and were put to pasture (predominantly perennial ryegrass), with their lambs, within days of parturition. Those ewes rearing one lamb were managed together in a rotational-grazing system and received no concentrate postlambing; those rearing two lambs were managed as a separate flock and offered a daily concentrate supplement of 0.5 kg for 5 weeks postlambing. If a ewe was nursing triplets at turnout, one lamb was removed to an artificial rearing unit. Concentrate was offered, from birth until weaning, to lambs reared as twins, up to a maximum of 300 g per lamb daily. Between weeks 5 and 14 (weaning), all lambs had access to concentrate (maximum 300 g/day). From weaning until drafted for slaughter, all lambs were managed as a single flock, with no concentrate supplementation. Lambs were treated for internal parasites as described by Keady and Hanrahan (2018b). Ewe and ram lambs were drafted for slaughter when BW exceeded 41 and 42 kg, respectively, during July; these thresholds were increased to 44 and 45 kg subsequently.

Ewes that were not joined were put to pasture (predominantly perennial ryegrass) when 50% of the joined group had lambed. Both joined and not-joined groups of ewes were managed in a rotational-grazing system with similar pre- and postgrazing sward heights. At weaning, the joined and not-joined groups of ewes were treated for internal parasites using an oral ivermectin (Oramec; Merial Animal Health, Harlow, Essex, England) and managed subsequently as one flock in a rotational-grazing system until joining at ~19 months of age.

Forages

Herbage from the primary growth of permanent, predominantly perennial ryegrass, swards was ensiled on 9 and 23 May in the successive years, following wilting (24 h). The herbage was mown and ensiled, and additive applied as described by Keady and Hanrahan (2015).

Measurements

Sward height was monitored throughout the study to provide objective information on the grazing-management system employed. It was recorded, at 50 positions located randomly across the paddocks being grazed, using a rising plate meter (Ashgrove Pastoral Products, Hamilton, New Zealand), pre- and postgrazing during the grazing period from initiation of the study to housing, and from turnout postlambing until lambs were drafted for slaughter.

The silages that were offered each year had four core samples, removed from each silo 1 week prior to the ewes being housed, and analysed for DM, CP, ammonia–nitrogen (N), DM digestibility (**DMD**) and ME concentrations as described by Park et al. (1998).

BW was recorded for all ewe lambs in late September, immediately prior to the initiation of the study, and subsequently at key time points based on the production cycle of the ewe lambs joined at 7 months, namely, postjoining (end November), mid-pregnancy (mid-January), 5 weeks postlambing (mid-May), weaning (mid-July) and at 19 months of age. Ewes that lambed at 1 year were weighed at lambing, and body condition (**BCS**) was assessed (Russel et al., 1969) immediately postlambing; their BCS was also recorded at 5 weeks postlambing. All ewes were assessed for BCS in July, and at 19 months of age (early October). Withers height, body length, chest (heart) girth and the circumference of the cannon bone were recorded for all ewes as described by Keady and Hanrahan (2018a) at 19 months of age. This collection of linear measurements (**LMs**) will be referred to as body size.

Lambing assistance score was recorded as described by Keady and Hanrahan (2018b). Within 24 h of birth, lambs were tagged and weighed, and lambs dead at this time are referred to as born dead. Total lamb mortality refers to lambs born dead plus lambs that died from birth to weaning. Lambs were weighed, and average BW gain calculated for the intervals as described by Keady and Hanrahan (2021). Lambs were slaughtered, within 18 h of drafting, at an EU approved abattoir and information on carcass weight (cold) and classification were recorded as described by Keady and Hanrahan (2021).

Statistical analyses

All data analyses were performed using SAS/STAT software (Version 9.4 for Windows; © 2002–2012); ewe traits were analysed by fitting linear models using either Proc GLM (BW, BCS, litter size, number of lambs reared) or Proc GENMOD with a logit link function (fertility, lambing assistance, and whether at least 1 lamb was reared). Lamb performance traits (growth and carcass traits) were analysed using Proc MIXED to fit a linear mixed model with dam as a random effect whilst lamb mortality was analysed using Proc GENMOD. All models fitted, whether using Proc GLM, Proc MIXED or Proc GENMOD, had fixed effects for ewe genotype and season; where the dataset included animals that were assigned to the 'Not-Joined' treatment a fixed effect for treatment was included. Two-way interactions among the fixed effects were examined in all cases and any interaction with a *P* value less than 0.2 was retained in the final model; otherwise the interaction terms were removed. Fixed effects for sex, and birth type (birth BW) or birth-rearing category were added to models for analysis of lamb performance traits; since only 6 sets of triplets (all to Bel ewes; 4 sets in year 1) were involved, this category was combined with twins in all cases. The small number of artificially reared lambs were excluded from all analyses of lamb traits except for BW at birth and lamb survival. Differences among genotypes were evaluated using the Tukey-Kramer adjustment for multiple comparisons. Analyses were also undertaken to explore the effects of ewe BW and BCS at lambing on selected ewe and lamb performance traits. In these analyses, the values for BW and BCS were expressed as deviations from the appropriate genotype-x-season subclass mean. The effects of year and genotype on the distribution of lambing date were evaluated using Proc LOGISTIC.

Results

The mean pre- and postgrazing heights of the swards grazed by the ewe lambs in September, October and November were 11.3 and 6.3; 9.5 and 6.0; and 7.7 and 4.7 cm, respectively. From April, May, June and to weaning in July, mean pre- and postgrazing sward heights for the lactating ewes and their lambs were 7.2 and 4.2; 8.7 and 5.9; 8.4 and 5.8; and 7.7 and 5.3 cm, respectively; for the dry ewe hoggets, 5.8 and 3.7; 6.0 and 4.7; 6.8 and 5.0 cm, respectively. Pre- and postgrazing heights of the swards grazed by the lambs postweaning in July, August, September and October were 6.4 and 5.1; 8.5 and 6.7; 8.3 and 6.2; and 9.1 and 5.7 cm, respectively. The mean pH, and concentrations of DM, CP, ammonia N, DMD and ME concentrations of the silages offered when housed during pregnancy were 3.9, 213 g/kg, 127 g/kg DM, 60 g/kg N, 765 g/kg DM and 11.7 MJ/kg DM, respectively.

The effects of ewe genotype and joining treatment (where appropriate) on ewe BW, BCS, body size and survival to 19 months are presented in Table 1. Ewe genotype had a significant effect on BW at each weight time point. Relative to Bel, the Suf75 ewes were heavier (P < 0.01) at the end of September, postjoining, mid-January, lambing, 5 weeks postlambing, weaning and at 19 months of age. Whilst Suf × Bel were numerically heavier than Bel at all weight time points, none of these differences was significant (P > 0.05). Differences in BW between Suf75 and Suf × Bel were significant in mid-September, postjoining and in mid-January (P < 0.01) but not at the other time points, although the Suf75 ewes were heavier at all times. Suf75 ewes had a higher BCS than Bel ewes at lambing (P < 0.01), 5 weeks postlambing (P < 0.01) and at weaning (P < 0.05). The differences among genotypes for BCS at 19 months were not significant (P > 0.05). Ewe genotype had a significant effect (P < 0.001) on body size at 19 months of age. Relative to Bel, the Suf × Bel and Suf75 had a lower withers height, greater body girth, and greater cannon bone circumference. Ewe genotype had no effect (P < 0.05) on the proportion of ewes that survived to 19 months.

Ewes that were joined at 7 months of age were significantly heavier (P < 0.001) in mid-January, at lambing and 5 weeks post-lambing than those that were not joined. Joining had no effect on BW or BCS at the time of weaning (early July). Joining had a significant effect (P < 0.01) on body size at 19 months of age. Ewes that were joined were lighter at 19 months (P < 0.01) and had a smaller body size (P < 0.001) reflecting differences in body girth and cannon bone circumference. Joining had no effect (P < 0.05) on the proportion of ewes that survived to 19 months.

There was a significant interaction (P < 0.05) between ewe genotype and age at joining for BCS at 'weaning'. This reflected the absence of any effect of joining on BCS of Suf75 ewes whereas joining was associated with a BCS reduction of 0.2 units in the other genotypes. The interaction between genotype and joining treatment was not significant for any of the other traits in Table 1.

Ninety eight percent of ewes joined were mated (marked) and 87% produced lambs. The distribution of lambing is presented in Fig. 1, where lambing date is expressed relative to date the vasectomised males were introduced. The incidence of lambing displayed clear peaks around days 163 and 170 after the date of vasectomised ram introduction and there was no evidence for any effect of genotype or year on the distribution pattern, based on analysis of day of lambing classified into three groups (namely, peak at day 163 (i.e., < day 166) peak at day 170 (days 166 to 175) and those that lambed after day 175). Of ewes that lambed, 78% did so within the first 21 days of the lambing period (by day 26 over 90% had lambed).

The effects of ewe genotype on litter size, number of lambs reared, assistance at lambing and lamb mortality are presented in Table 2. The Bel ewes had a significantly higher litter size than Suf × Bel (P < 0.05) and Suf75 (P < 0.01), and reared more lambs (per ewe joined, and per ewe lambing) than the Suf75 ewes (P < 0.01). Whilst the Bel ewes reared more lambs than Suf × Bel ewes, the differences (0.14 and 0.16 per ewe lambed and joined, respectively) failed to reach significance (P > 0.2). Ewe genotype had no effect (P > 0.05) on the proportion of ewes assisted at lambing or that failed to lamb, or on the number of lambs born dead or on total lamb mortality.

The effects of ewe BW in late September on the probability of rearing at least one lamb to weaning are presented in Fig. 2 for the 3 ewe genotypes. As ewe BW at joining increased, the probability of rearing at least one live lamb increased (P < 0.001). The slopes did not differ significantly among the genotypes. The difference between the means for Bel and Suf75 approached significance (P = 0.10).

The effects of ewe genotype on lamb performance traits are presented in Table 3. Lambs born to Bel dams were significantly lighter at birth and at weaning than those born to either Suf × Bel or Suf75 dams (P < 0.05), whilst the latter two breeds did not differ. The progeny of Suf × Bel dams had higher BW gain from 5 to 10 weeks (P < 0.05), 10 to 14 weeks (P < 0.01), birth to weaning (P < 0.01) and birth to slaughter (P < 0.05), and were heavier at weaning (P < 0.01) than lambs from Bel dams. Relative to lambs from Suf × Bel dams, the progeny of Bel ewes were older (P < 0.01) at slaughter. The growth performance of the progeny of the Suf × Bel was numerically better than lambs from Suf75 dams but none of the differences were statistically significant. Ewe genotype had no effect (P > 0.05) on lamb BW at slaughter, ADG from birth to 5 weeks, carcass weight, fat score, or dressing proportion.

Table 1
BW and condition score, and body measurements for ewe lambs up to 19 months of age: effects of genotype and joining at 7 months of age.

	Genotype (G)[1]				Joined (J)			Significance		
	Bel	Suf × Bel	Suf75‡	SEM	Yes	No	SEM	G	J	G × J
BW (kg)										
end September	43.2^{a}	44.4^{a}	46.5^{b}	0.36	44.9	44.5	0.29	***	ns	ns
postjoining (end Nov)	49.8^{a}	50.7^{a}	53.9^{b}	0.40	51.9	51.1	0.29	***	0.09	ns
mid-January	45.3^{a}	46.1^{a}	48.4^{b}	0.40	48.7	44.4	0.32	***	***	ns
March/April (lambing)	46.6^{a}	48.1^{ab}	49.1^{b}	0.53	54.7	41.2	0.43	**	***	ns
5 week postlambing	49.2^{a}	50.5^{ab}	51.8^{b}	0.48	51.9	49.1	0.39	***	***	ns
July (weaning)	54.2^{a}	55.5^{ax}	56.6^{b}	0.49	55.2	55.6	0.40	**	ns	ns
19 months	59.2^{a}	61.1^{b}	62.0^{b}	0.51	59.8	61.8	0.42	***	***	ns
Body condition score										
lambing	3.15^{a}	3.22^{a}	3.34^{b}	0.036	–	–		***	–	–
5 week postlambing	2.97^{a}	2.98^{a}	3.13^{b}	0.036	–	–		**	–	–
July (weaning)	3.07^{a}	3.07^{a}	3.17^{b}	0.027	3.04	3.18	0.022	*	***	*
19 months	3.36	3.34	3.37	0.021	3.24	3.48	0.021	ns	***	ns
Survival (%) to 19 months	94.7	94.4	95.1	–	95.2	94.3	–	ns	ns	ns
Body measurements at 19 months										
withers height	66.6	65.0	64.6	0.25	65.3	65.5	0.20			
body girth	93.4	94.8	94.7	0.42	93.4	95.2	0.34	***[2]	**[2]	ns[2]
body length	57.2	57.4	56.4	0.27	57.1	56.9	0.22			
cannon bone circumference	8.47	9.18	9.63	0.045	9.03	9.16	0.037			

ns = not significant, * = P < 0.05, ** = P < 0.01, *** = P < 0.001.
[1] Bel = Belclare, Suf × Bel = Suffolk × Belclare, Suf75 = ≥75% Suffolk.
[2] Results of multivariate tests for body measurements.
[a,b] Means without a common superscript are significantly different at P < 0.05.

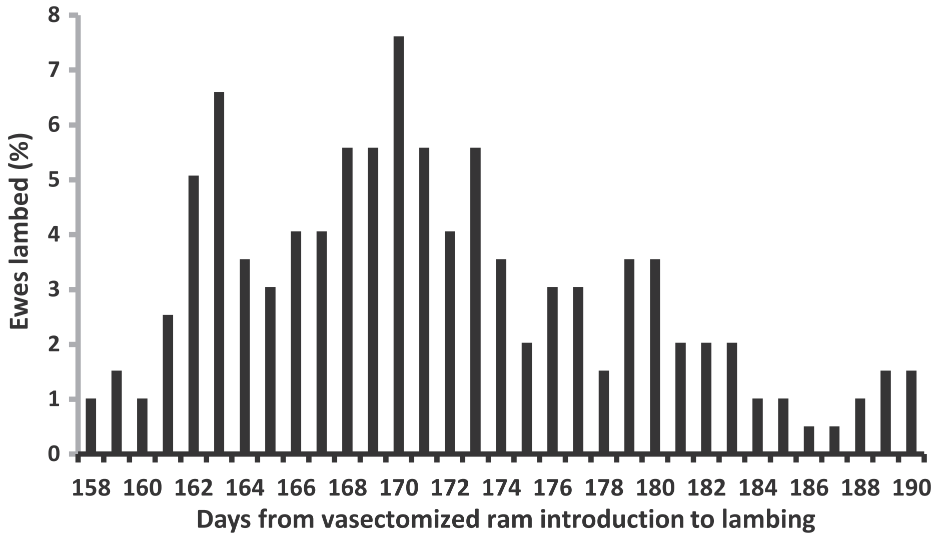

Fig. 1. Distribution of lambing date.

Table 2
Litter size, number reared, assistance at lambing and lamb mortality for ewes joined to lamb at 7 months.

	Genotype[1]				
	Bel	Suf × Bel	Suf75	SEM	Significance
Litter size	1.65[a]	1.41[b]	1.26[b]	0.066	***
Number of lambs reared					
per ewe lambing	1.32[a]	1.19[ab]	1.01[b]	0.076	**
per ewe joined	1.17[a]	1.01[ab]	0.82[b]	0.080	**
Assisted at lambing (%)	45.6	53.3	45.7	–	ns
Failed to lamb (%)	10.7	13.8	18.5	–	ns
Ewes with ≥ 1 lamb reared[2] (%)	83.3	76.2	70.0	–	$P = 0.13$
Lamb mortality (%)					
born dead	12.1	10.6	10.0	–	ns
total[3]	16.3	14.8	17.6	–	ns

ns = not significant, * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$.
[1] Bel = Belclare, Suf × Bel = Suffolk × Belclare, Suf75 = ≥75% Suffolk.
[2] Per ewe joined.
[3] Lambs born dead plus lambs that died from birth to weaning.
[a,b] Means without a common superscript are significantly different at $P < 0.05$.

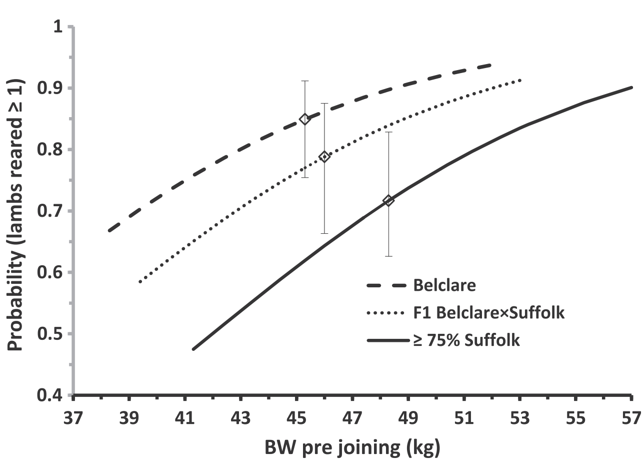

Fig. 2. The effect of ewe genotype and BW on the probability of rearing ≥1 lamb.

Discussion

The objectives of the study were to evaluate the effect of joining to lamb at 1 year of age on the performance of ewe lambs, representing three genotypes, to 19 months, and the effect of genotype on reproductive performance of those joined to lamb at 1 year and the performance of their progeny to drafting for slaughter. The ewe genotypes used in the current study were chosen because they were known to differ in prolificacy, and thus productivity. The ≥75% Suffolk was used as it is the most common genotype in Ireland with 54.8% of the national lowland ewe flock classified as Suffolk-X type (Keady et al., 2019) whilst the Belclare was used because of its proven high productivity (Hanrahan, 1989).

An issue with joining ewe lambs is age at first oestrus and consequently the proportion that are pregnant following the joining period. Hanrahan (2012, unpublished) using data from Keane (1974) and Hanrahan and O'Riordan (1990) and other unpublished observations estimated that 25 d from joining would elapse before 75% of ewe lambs exhibit their first oestrus and, that after a 35-d joining period a significant proportion would not have had the opportunity for a second service, whilst 5% would be unlikely to exhibit first oestrus before the end of the joining period. Ewes that have been isolated from rams and are anoestrus can be stimulated to ovulate by the introduction of a sexually mature ram (Knight, 1983) and this 'ram effect' was utilised in the current study with the objective of initiating cyclicity, and thus synchronise oestrus, such that lambs would have two opportunities of being served during a 35-day joining period. In the current study, the 2 peak times

Table 3
Effect of dam genotype on performance of lambs born to 1-year-old ewes.

	Genotype[1]				
	Bel	Suf × Bel	Suf75	SEM	Significance
BW at birth (kg)	4.39[a]	4.73[b]	4.74[b]	0.098	*
BW at weaning (kg)	29.0[a]	31.9[b]	30.9[b]	0.53	***
BW gain (g/d)					
birth to 5 weeks	266	283	262	7.7	0.13
5–10 weeks	254[a]	285[b]	283[b]	8.2	**
10–14 weeks	229[a]	262[b]	252[b]	8.4	**
birth to weaning	255[a]	279[b]	269[ab]	5.0	**
birth to slaughter	209[a]	228[b]	220[ab]	4.8	*
BW at slaughter (kg)	46.2	46.9	47.4	0.46	ns
Carcass weight[2] (kg)	20.5	20.6	20.6	0.20	ns
Carcass fat score[2]	2.95	2.94	2.93	0.057	ns
Dressing proportion (g/kg)	438	437	431	2.8	ns
Age at slaughter[3] (d)	207[a]	190[b]	201[ab]	4.0	**

ns = not significant, * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$.
[1] Bel = Belclare, Suf × Bel = Suffolk × Belclare, Suf75 = ≥75% Suffolk.
[2] At constant carcass weight.
[3] At fat score = 3.
[a,b] Means without a common superscript are significantly different at $P < 0.05$.

of lambing correspond with mating peaks at days 17 and 24 after the introduction of vasectomised rams (assuming gestation length = 146 days). Previous authors have reported that oestrus activity peaks after approximately 18 and 24 d (Knight, 1983), 17 and 23 d (Hanrahan and O'Riordan, 1990) and 18 and 25 d (Chanvallon et al., 2011) after exposure to rams.

The joined and not-joined groups of ewe lambs were managed similarly from the initiation of the study to postjoining at the end of November, as indicated by similar values for BW gain (118 and 115 g/d). The decline in BW from postjoining to mid-January is partly attributable to the removal of the fleece after animals were housed. During the housing period, ewes that had been joined gained more BW than those not joined but this reflects the fact that diets offered to the two groups of ewe lambs differed due to concentrate supplementation. Whilst the silage offered in the current study had a high feed value, as determined by digestibility and intake characteristics, lambs offered silage as the sole diet lost BW.

During the indoor housing period, lambs that were joined and pregnant were supplemented with concentrate with the objective of not only ensuring a level of nutrition adequate to meet the demands of pregnancy but also to allow a gain in BW such that pregnancy would not impair their progress towards attaining normal mature BW. Supplementation with concentrate increased BW gain as expected. Keady and Hanrahan (2013 and 2015) reported that increasing concentrate supplementation, to lambs offered high feed value grass silages from 0.2 to 0.5 kg/d and from 0.4 to 0.8 kg/d, increased lamb BW gain from 148 to 178 g/d and from 116 to 185 g/d, respectively. An analysis of lamb BW at birth showed significant impact of both ewe BW and BCS: the regression coefficients were 0.053, SE 0.0093, kg/kg for ewe BW ($P < 0.001$) and −0.74, SE 0.206, kg per unit change in BCS ($P < 0.001$); these effects did not depend on litter size or ewe genotype. These relationships suggest that if additional nutrient supply is partitioned to maternal BW gain, lamb BW at birth will be increased whereas if partitioned to fat deposition lamb BW at birth is reduced. Wallace et al. (1996) reported that increasing ewe lamb BW gain during the first 2 trimesters of gestation reduced placental weight and lamb BW at birth. However, Kenyon et al. (2005 and 2008), using singleton- and twin-bearing adolescent ewes, reported that increasing the plane of nutrition throughout pregnancy increased ewe BW but did not affect lamb BW at birth. However, Mulvaney et al. (2012), using twin-bearing adolescent ewes, reported that increasing the plane of nutrition from mid-pregnancy to parturition increased lamb BW at birth. The different effects of plane of nutrition on lamb BW at birth in these studies may be associated with the partitioning of energy between body growth and fat deposition. The fact that such effects on lamb BW at birth are also influenced by the energy to protein ratio in the diet of the dam (Quirke, 1978) supports the concept of a role for nutrient partitioning, although the mechanisms are likely to be complex.

Analysis of effects of ewe BW and BCS on lamb ADG to weaning yielded significant positive regressions for both ewe BW (2.1, SE 0.47, g/kg; $P < 0.001$) and BCS (20.9, SE 9.86, g per unit BCS; $P < 0.05$). The positive influence of BCS on ADG to weaning is probably due to extra reserves for lactation, thus supporting higher lamb BW gain.

Post-turnout to pasture the lactating ewes lost BW up to 5 weeks but gained BW from this time until weaning. The non-lactating ewes gained BW from turnout to mid-July such that both groups of animals were of similar BW at that stage but the ewes that had not been joined had a higher BCS. Whilst the ewes that were joined as ewe lambs were 2 kg lighter at 19 months, the 'joined' and 'not-joined' groups had attained 75 and 77% of mature BW, respectively. However, it has been reported (Keane, 1974; Kenyon et al., 2008) that breeding adolescent ewes to lamb at about 1 year of age has a negative effect on BW when joined at 19 months (reduced by approximately 6 and 7 kg, respectively). This difference between the current and previous studies is probably attributable to the plane of nutrition offered to the animals during the second and third trimesters of pregnancy when the pregnant ewe lambs received a higher plane of nutrition than the non-pregnant animals so as to minimise any negative effect of pregnancy on the subsequent attainment of normal mature BW. The difference of 2 kg in BW at joining at 19 months recorded in the present is unlikely to influence productivity as previous studies have shown that a difference in BW of up to 8.4 kg at joining (at 19 months) had no effect on ovulation rate, litter size or on the number of lambs reared per ewe joined (Keady and Hanrahan, 2018a and 2018b).

Ewe genotype

Initial BW (end of September) differed among genotypes, by up to 8% reflecting the fact that the experimental animals were chosen to represent the same proportion of the mature BW of their genotype. Previously, Annett et al. (2011), Hanrahan (2001), Hanrahan and Keady (2014) and Keady and Hanrahan (2018b) reported genotype differences in BW at joining of 19%, 14%, 15% and 35%, respectively. Differences among the genotypes in BW at 19 months were similar to those at the beginning of the study. Previous authors, using sheep (Cam et al., 2010; Keady and Hanrahan, 2018a), have reported that, of the body measurements undertaken in the current study, chest girth was most highly correlated with BW. In the current study, the Suf × Bel and Suf75 genotypes had similar body girth and BW and both were greater than the Belclare.

Ewe genotypes are often compared using an efficiency index (Hanrahan 2001). When joining ewe lambs, a key objective is ewe productivity, which reflects differences in ewe fertility, litter size, and ewe and lamb mortality. Ewe BW at joining also impacts ewe lamb productivity as it effects age at onset of cyclicity (Keane 1975; Quirke 1978). In the current study, the probability of rearing at least one lamb can be viewed as an efficiency index for ewe genotype and this index was a function of both ewe genotype and BW at joining. Based on the data from the current study, if the objective was to have an 80% probability of rearing at least one lamb, the Bel, Suf × Bel and Suf75 genotypes would need to be 43.3, 46.4 and 53.1 kg at joining, respectively.

Previous authors (Hanrahan, 2001; Annett et al., 2011; Hanrahan and Keady, 2014; Keady and Hanrahan, 2018b) have reported large effects of ewe genotype on litter size. Belclare-cross ewes have a higher prolificacy than a wide selection of other crossbred types (Hanrahan, 2001; Hanrahan and Keady, 2014). Using data on crossbred ewes, over a 6-year period, Hanrahan (2001) reported that litter size and the number of lambs reared per ewe joined were 0.24 and 0.19 greater for Belclare-cross ewes compared with Suffolk-cross ewes whilst Belclare-cross ewe lambs reared 0.19 extra lambs per ewe joined than Suffolk-cross contemporaries. In the current study, the differences, in litter size and number of lambs reared per ewe joined, between the Bel and Suf75 ewes were 0.39 and 0.35, respectively. This compares with estimates of 0.46 and 0.35 for the difference between Belclare and Suffolk type ewes reported by Hanrahan (2001).

The higher BW gain of lambs from the Suf × Bel ewes between birth and weaning, and their higher weaning weight than the Bel genotype, is probably due to a combination of the following factors. Lambs born to the Suf × Bel ewes were 0.34 kg heavier at birth and results from previous studies at this research centre (Keady et al., 2007; Keady and Hanrahan, 2009a and 2009b) using mature ewes have shown consistently that each 1 kg increase in lamb BW at birth increased BW at weaning by about 3 kg. Secondly, Hanrahan (1999) reported that lambs sired by Suffolk sires were 3 to 8% heavier at weaning. Finally, the mature BW of the Bel ewes is lower than that of the Suf × Bel ewes.

A key factor which should impact the choice of ewe genotype is lamb output per ewe, which is a combination of number of lambs reared per ewe joined and lamb BW at weaning. Keady and Hanrahan (2018b) reported that the total weight of lamb reared per ewe joined differed by up to 221% among ewe genotypes. In the current study, relative to the Suf75 genotype, the total weight of lamb reared per ewe joined was higher by 26 and 19%, respectively, for the Bel and Suf × Bel genotypes. The ranking of the Suf × Bel genotype largely reflects the relatively high weaning weight of its lambs.

Lamb performance at pasture

The grazing management used was targeted to achieve the sward heights of Keady (2010), thus postgrazing sward height increased as the season progressed to prevent lower horizons of the sward canopy, which have lower digestibility, being grazed by lambs. The mean lamb growth rate from birth to weaning (268 g/day) in the present study is similar to the performance for lambs born and reared as twins by adult ewes (Keady et al., 2018) from 12 consecutive years of a rotational-grazing system of prime-lamb production. Even though lamb BW varied by 2.9 kg (9%) at weaning due to ewe genotype, all lambs were finished prior to the end of the grazing season without any concentrate supplementation postweaning, demonstrating what is achievable from good grassland management practices as reported previously by Keady and Hanrahan (2009a, 2009b, 2021) and Keady et al. (2007 and 2018b). The positive relationship observed between ewe BW at lambing and the BW of lambs at weaning is consistent with Kenyon et al. (2008) who reported that increasing ewe BW gain, through increased nutrition during pregnancy, resulted in heavier lambs at weaning and concluded that producers should not avoid relatively high BW gain of ewes lambing at one year of age.

Conclusion

Lambing at one year of age reduced BW, by 2 kg, and body size when joined at 19 months it did not affect ewe survival to that stage and there was no evidence that these effects depended on ewe genotype. Ewe genotype had a significant effect on the number of lambs reared per ewe joined and thus lamb carcass output as carcass weight was unaffected by genotype. Belclare ewes produced larger litters and reared more lambs per ewe joined than Suf75 ewes. Progeny from Suf × Bel ewes were younger at slaughter than those from Bel ewes but there was no differences between genotypes for any other slaughter trait. Increasing ewe BW at joining increased the probability of rearing at least one lamb and this effect was consistent across genotypes. There was a positive relationship between ewe BW at lambing and lamb BW at birth whereas ewe BCS had a negative effect, likely reflecting variation in the partition of nutrients during pregnancy.

Ethics approval

All animal procedures used in this study were conducted under experimental licence from the Irish Department of Health and Children (Dublin) in accordance with the Cruelty to Animals Act 1876 and the European Communities (Amendment of Cruelty to Animals Act 1876) Regulations 2002 and 2005.

Data and model availability

None of the data were deposited in an official repository. They are available to reviewers.

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Author contribution

TWJK was responsible for funding acquisition, project administration and supervision. **JPH** was involved in data analysis. Both authors were involved in the conceptualisation and design of the work; interpretation of the data; and drafting and critically revising the manuscript.

Declaration of interest

None.

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