Animal (2011), **5:3**, pp 347–355 © The Animal Consortium 2010
doi:10.1017/S1751731110002107

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Comparison of the longevity and lifetime performance of Scottish Blackface ewes and their crosses within hill sheep flocks

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(Received 31 March 2010; Accepted 20 September 2010; First published online 29 October 2010)

A study was undertaken to compare the longevity and lifetime lamb output of purebred Scottish Blackface (BF) ewes with a range of crossbred genotypes from Scottish BF dams. For up to five successive breeding seasons, 1143 Scottish BF, Swaledale × BF (SW × BF), North Country Cheviot × BF (CH × BF), Lleyn × BF (LL × BF) and Texel × BF (T × BF) ewes were mated to a range of sire breeds on six hill farms across Northern Ireland. Dentition and lamb output were recorded annually until completion of the study or until the ewe was removed due to death or culling. Timing of mortality and the main reason for culling were also recorded. When survival analysis was undertaken, SW × BF and CH × BF ewes had better longevity ($P < 0.05$) than BF ewes due to their lower culling rate ($P < 0.01$) and lower mortality rate ($P = 0.06$), respectively. The relative proportion of LL × BF and T × BF culled due to infertility was lower ($P < 0.05$) than SW × BF and CH × BF, while a higher ($P < 0.05$) proportion of LL × BF and T × BF ewes were culled for prolapses compared with the other breed crosses. SW × BF ewes had consistently higher bite scores ($P < 0.001$) compared with BF, LL × BF and T × BF, indicating a greater prevalence and degree of overshoot. In ewes aged 5.5 years old, SW × BF also had a higher incidence of tooth loss ($P < 0.01$) compared with the other breeds. However, the proportion of SW × BF culled due to poor teeth condition was lower ($P < 0.05$) than BF. Across all breeds, the chances of surviving to their next mating were influenced by ewe breed ($P < 0.05$), age at mating ($P < 0.001$), body condition score at weaning ($P < 0.001$), number of missing teeth ($P < 0.001$) and average daily live weight gain per litter ($P < 0.05$). The cumulative number and weight of lambs weaned per ewe over five successive matings was higher ($P < 0.05$) for crossbred compared with pure BF ewes; however there were no differences in lifetime output between the different crossbred ewes studied. This study demonstrates that the higher lamb output of crossbred hill ewes does not compromise their longevity compared with pure Blackface, resulting in greater total lifetime production. When the crossbred ewes are sired by a second hill breed, longevity may be improved.

Keywords: crossbreeding, lamb output, culling, mortality

Implications

The results of this study demonstrate that adopting a crossbreeding policy on hill flocks using Swaledale (SW), Cheviot (CH), Lleyn or Texel sires to produce high output replacement ewes has no detrimental effects for ewe longevity compared with keeping purebred Blackface ewes. When a second hill breed sire such as SW or CH is used to produce the crossbred ewes, longevity can be improved. The net result is that lamb output over 5 years can be up to 22% higher from the crossbred ewes. Therefore, crossbreeding offers significant potential to improve the profitability of hill sheep farming and should be considered more widely than at present.

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Introduction

The hill sheep sector is a major contributor to lamb production in Europe, with more than 90% of the 65.8 million breeding ewes in the European Union – 25 kept within less favoured areas (European Commission, 2006). However, the physical performance of hill flocks, in terms of conception rate, average litter size, lamb growth rate and lamb carcass conformation, are often inferior to those of other sectors of the industry (Dawson and Carson, 2002; Carson *et al.*, 2004). Improvements in both production efficiency and market returns are essential, if the hill sheep sector is to remain viable.

Ewe breed has been shown to influence lamb output of both hill (Carson *et al.*, 2001) and lowland (Carson *et al.*, 2004) flocks through its effects on litter size, lamb birth weight, milk production and lamb mortality. The hill sheep sector of United Kingdom is dominated by purebred genotypes, with the Scottish Blackface (BF) being the most common (Pollott and Stone, 2006). Use of crossbred ewes in hill flocks is uncommon; however reports comparing purebred and crossbred ewes under hill conditions have consistently demonstrated higher lamb output from crossbred ewes (Donald *et al*., 1963; Al-Nakib *et al*., 1997). In a concurrent study, replicated across six commercial hill flocks, Annett *et al*. (2010) demonstrated that retaining crossbred replacements from Scottish BF dams sired by Swaledale (SW), Lleyn (LL) or Texel (T) sires increased weaned lamb output/ewe mated by more than 21% compared with purebred Scottish BF due to their greater prolificacy and heavier lamb weights at weaning.

To date, there have been no reports on the lifetime performance of crossbred ewes under hill conditions. Longevity is a major issue in hill flocks, where the annual replacement rate can exceed 20% (Department of Agriculture and Rural Development, 2009), so it is inappropriate to evaluate crossbred ewes based on their annual performance alone. Retaining crossbred ewes sired by lowland-type breeds, which have been selected under less harsh conditions, may result in reduced hardiness and longevity when compared with the traditional hill breed types (Hohenboken and Clarke, 1981). On the other hand, heterosis for survival and 'fitness' traits may be expressed in crossbred ewes (Fogarty *et al*., 1984; Simm *et al*., 1994) which could benefit their longevity and lifetime performance.

Consequently, the aims of this study were to investigate longevity and lifetime lamb output of purebred Scottish BF ewes compared with a range of crossbred genotypes in a hill environment.

Material and methods

Animals

This study was carried out on six hill farms in Northern Ireland over a 5-year period between October 2003 and September 2008. Details of the animals used are outlined in a concurrent study (Annett *et al*., 2010). In brief, on each of the six farms, 200 purebred Lanark-type Scottish BF ewes were mated with BF, SW, North Country Cheviot (CH), LL and T rams over a 3-year period (October 2001 to 2003). The female progeny from each of these matings – Scottish BF, SW × BF (SW × BF), North Country CH × BF (CH × BF), LL × BF (LL × BF) and T × BF (T × BF) – were retained for further breeding, which commenced when the ewes were approximately 1.5 years old. Details of the numbers of ewes per farm of each breed are shown in Table 1. Over a 5-year period, the crossbred ewes were allocated each year to single sire mating groups, balanced for ewe breed, live weight, body condition score (BCS) and age. In years 1 and 2 (2003 to 2004) ewes were joined with T, Dorset and LL rams while in years 3 to 5 (2005 to 2007) T, Dorset, LL and Suffolk rams were used. All of the rams were from UK sire reference schemes and represented the top 25% of recorded sires for each breed. The rams were all unrelated and were purchased at local pedigree sales by each of the six producers.

Table 1 *Numbers of ewes per farm at the beginning of the study*

	Ewe breed					
Farm	BF	SW × BF	CH × BF	LL × BF	T × BF	Total
1	42	24	23	32	47	168
2	47	45	41	55	35	223
3	45	42	39	35	42	203
4	29	27	29	33	35	153
5	44	37	47	43	51	222
6	30	33	30	37	44	174
Total	237	208	209	235	254	1143

BF = Scottish Blackface; SW × BF = Swaledale × Blackface; CH × BF = Cheviot × Blackface; LL × BF = Lleyn × Blackface; T × BF = Texel × Blackface.

Measurements

Ewe live weight (to the nearest 0.5 kg) and BCS (Russel *et al*., 1969) were recorded 1 week before mating, 6 weeks pre-lambing, 6 weeks post-lambing and at weaning. The permanent incisors of all ewes were assessed pre-mating for bite position, looseness, wear and general condition. Bite position was scored in relation to the anterior edge of the dental pad on a scale of 1 to 5, with 3.5 being the edge of the dental pad and lower scores being behind it (Duckworth *et al*., 1962). Looseness and wear were each scored on a 4-point scale with 1 indicating firm and unworn, respectively. Pregnancy status was determined by ultrasound scanning between day 70 and 100 of pregnancy and ewes determined to be carrying at least one foetus were considered productive. Ewes that were barren as hoggets (i.e. following their first mating at 1.5 years old) were retained on-farm for breeding the following year; however barren ewes >2 years old were culled from the flock. Lambs were tagged at birth and the tag number was recorded alongside the dam tag number, date of birth, sex and birth weight (to the nearest 0.1 kg) of the lamb. Lambs were weighed again (to the nearest 0.5 kg) at approximately 6 weeks of age and at weaning. When ewes were culled, the date and reason for culling were recorded as follows: barren (non-productive), teeth condition (excessive tooth loss, looseness or wear), udder problems (mastitis in one or both quarters, pendulous udders, large teats, etc.), vaginal prolapse, abortion, poor body condition (BCS at mating <1.5), feet problems (persistent foot rot and/or lameness resulting in poor locomotion), severe parturition difficulties and maternal instinct (poor mothering ability, leaves lambs).

Statistical analysis

All data were analysed using GenStat (2009). Binary data (proportion of ewes alive and productive at each mating, ewe dentition, mortality and culling rates, reasons for culling) were analysed using generalised linear models, assuming a binomial distribution with a logit-link function, with fitted fixed effects for farm + year of birth + ewe breed. Where ewe breed effects were significant, the *t*-probabilities of all pairwise comparisons were used to test for significant differences between breeds.

Lifetime lamb output was determined in two stages. First, within each age group, lamb output of ewes was determined as the product of the proportion of ewes alive and productive, and the mean productivity per ewe lambed within that age group. The latter was determined in a concurrent study (Annett *et al*., 2010) using linear mixed models with fixed effects for farm + year of birth + days to weaning + lamb sire breed + age + ewe breed + farm × ewe breed + age × ewe breed, and random effects for ewe id × age + ewe breed × sire of ewe. Second, lamb output was then cumulated across all preceding age groups. Where overall effects were significant ($P < 0.05$), pairs of means were compared using the least significant difference (LSD).

Breed effects on ewe longevity were first investigated using Log-rank, Wilcoxon, Tarone–Ware and Peto–Peto tests to compare survivability across breeds. Having established a significant relationship, the hazard ratio (with 95% CI) was estimated for each ewe breed and compared with the pure BF using a Cox proportional hazards model. To determine the production factors that influence ewe survival, stepwise logistic-binomial regression analyses were carried out. Fixed effects that showed a close association ($P < 0.05$) with survival were included in a generalised linear mixed model with a binomial distribution and the fixed effects were re-examined using a Wald statistic. Factors with an associated probability less than 0.05 were included in the final models. For each model, odds ratios were computed with their associated 95% CI.

To display the effects of production factors on longevity, generalised linear mixed models were carried out using the same fitted fixed effects as described before. From the resultant fitted models, predictions of survival probability were formed from the estimated parameters in the model and these were presented graphically.

Table 2 *Total number of ewes alive at mating (subdivided by age and breed)*

Age at mating (years)	Ewe breed BF	SW × BF	CH × BF	LL × BF	T × BF	Total
1.5	237	208	209	235	254	1143
2.5	214	199	195	222	231	1061
3.5	178	178	168	185	189	898
4.5	106	107	104	105	113	535
5.5	32	26	32	37	48	175
Total	767	718	708	784	835	3812

BF = Scottish Blackface; SW × BF = Swaledale × Blackface; CH × BF = Cheviot × Blackface; LL × BF = Lleyn × Blackface; T × BF = Texel × Blackface.

Results

In total, 3812 breeding records from 1143 ewes were investigated across the six farms. A breakdown of these records by age and breed is presented in Table 2.

Longevity

A higher proportion of SW × BF ewes survived to their second mating compared with BF and T × BF ($P < 0.05$; Table 3). Survival to the third mating was higher for SW × BF than BF, LL × BF and T × BF ($P < 0.05$), and the proportion of SW × BF surviving to their 4th mating was higher than all other ewe breeds ($P < 0.01$). While a greater proportion of SW × BF survived to their 5th mating compared with BF ($P < 0.05$), breed effects on the proportions of ewes surviving were no longer evident at the sixth mating. Similar trends were observed for the proportions of ewes that were both alive and productive at scanning. Survival analysis revealed that, in comparison with the pure BF, the probability of a hazard event (i.e. the disappearance of a ewe from the study) at any time was significantly lower with SW × BF (−0.31, $P = 0.004$) and CH × BF (−0.22, $P = 0.038$) ewes only (Table 4).

Table 3 *Effects of age and breed on the proportions of live and productive ewes relative to those joined with a ram at 1.5 years old*

Age at mating (years)	Ewe breed[1] BF	SW × BF	CH × BF	LL × BF	T × BF	s.e.d	Significance[1]
Alive at mating							
1.5	1.000	1.000	1.000	1.000	1.000	–	–
2.5	0.895^{a}	0.952^{b}	0.923^{ab}	0.928^{ab}	0.898^{a}	0.0252	*
3.5	0.743^{a}	0.851^{b}	0.794^{ab}	0.775^{a}	0.740^{a}	0.0384	*
4.5	0.587^{a}	0.726^{b}	0.603^{a}	0.575^{a}	0.595^{a}	0.0451	**
5.5	0.355^{a}	0.471^{b}	0.448^{ab}	0.414^{ab}	0.425^{ab}	0.0524	*
6.5	0.157	0.231	0.284	0.159	0.272	0.0644	ns
Alive and productive at scanning							
1.5	0.870	0.919	0.910	0.916	0.911	0.0271	ns
2.5	0.799^{a}	0.866^{b}	0.844^{ab}	0.870^{b}	0.872^{b}	0.0329	*
3.5	0.674^{a}	0.804^{b}	0.693^{a}	0.686^{a}	0.697^{a}	0.0418	*
4.5	0.524^{ab}	0.622^{b}	0.554^{ab}	0.546^{ab}	0.515^{a}	0.0522	*
5.5	0.322	0.364	0.427	0.385	0.391	0.0746	ns

BF = Scottish Blackface; SW × BF = Swaledale × Blackface; CH × BF = Cheviot × Blackface; LL × BF = Lleyn × Blackface; T × BF = Texel × Blackface.
Means within rows sharing a common character in their superscript are not significantly different ($P > 0.05$).
[1]Probability level denoted by asterisk: * ($P < 0.05$), ** ($P < 0.01$), *** ($P < 0.001$) or ns (non-significant).

Table 4 *Survival analysis for pure BF ewes and their crosses*

Ewe breed	HR	95% confidence interval for HR	Probability
BF	1.00	–	
SW × BF	0.69	0.54–0.89	0.004
CH × BF	0.78	0.61–0.99	0.038
LL × BF	0.90	0.72–1.13	0.368
T × BF	0.85	0.68–1.07	0.163

BF = Scottish Blackface; SW × BF = Swaledale × Blackface; CH × BF = Cheviot × Blackface; LL × BF = Lleyn × Blackface; T × BF = Texel × Blackface; HR = hazard ratio.

Mortality and culling

As a result of their improved survivability, the proportion of SW × BF ewes remaining at the end of the study was higher ($P < 0.01$) than BF and LL × BF (Table 5). Of those that were removed, the proportion of ewes culled was lower with SW × BF than any other ewe breed ($P < 0.001$). There were no breed effects on ewe mortality rate or the timing of mortality, although there was a tendency for lower mortality rates with CH × BF compared with BF ($P = 0.06$).

The primary reasons for culling ewes are listed in Table 6. Proportionately, 0.090 ewes culled had no reason for culling recorded and were excluded from this analysis. The majority of ewes were culled due to barrenness (0.408); although the proportions of LL × BF and T × BF culled as barren were lower than either SW × BF or CH × BF ($P < 0.05$). Udder problems were the second most common reason for culling (0.227) but no breed effects were observed. A higher ($P < 0.05$) proportion of BF ewes were culled for poor teeth condition compared with SW × BF, although fewer ($P < 0.05$) BF, SW × BF and CH × BF ewes were culled due to vaginal prolapse compared with LL × BF and T × BF. Ewes were also culled due to poor body condition, feet problems, abortions, severe lambing difficulties and poor maternal instinct; however the incidence of culling for these reasons was low (<0.040) and did not vary significantly between breeds.

Dentition

For ewes aged up to 3.5 years old, the mean bite position score of SW × BF ewes was consistently higher ($P < 0.001$) than BF and T × BF, indicating a higher incidence and severity of overshoot in the SW × BF (Table 7). With ewes aged 4.5 and 5.5 years old, mean bite score of T × BF was lower ($P < 0.001$) than BF, SW × BF and CH × BF. The incidence of missing (0.026), loose (0.024) and worn (0.018) teeth were low in ewes aged 3.5 years or less. In 4.5-year-old ewes, the incidence of tooth loss was higher ($P < 0.01$) in BF and SW × BF compared with T × BF, and in 5.5-year-old ewes was higher ($P < 0.01$) in SW × BF than any other breed. Breed effects on looseness and wear were not evident at any stage, although the incidence of both tended ($P < 0.06$) to be higher for SW × BF than CH × BF within 5.5-year-old ewes.

Factors affecting survival

In the multiple-regression models (Table 8), factors affecting the chances of survival to the next mating were found to be ewe

Table 5 *Effects of ewe breed on mortality and culling rates*[1]

			Mortality			Time of death				
Ewe breed	Remaining in flock	Culled	Confirmed dead	Missing presumed dead	Total mortality	Early pregnancy	Pre-lambing	Early lactation	Late lactation	Post-weaning
BF	0.363^{a}	0.278^{b}	0.097	0.270	0.365	0.126	0.238	0.179	0.149	0.314
SW × BF	0.482^{b}	0.159^{a}	0.107	0.251	0.357	0.060	0.224	0.183	0.266	0.262
CH × BF	0.431^{ab}	0.282^{b}	0.057	0.231	0.287	0.153	0.164	0.195	0.168	0.314
LL × BF	0.369^{a}	0.309^{b}	0.102	0.222	0.322	0.154	0.148	0.181	0.155	0.354
T × BF	0.403^{ab}	0.253^{b}	0.090	0.256	0.346	0.077	0.227	0.198	0.159	0.334
s.e.d	0.0417	0.0391	0.0266	0.0387	0.0418	0.0487	0.0629	0.0629	0.0617	0.0731
Significance	**	***	$P = 0.06$	ns	$P = 0.06$	ns	ns	ns	ns	ns

BF = Scottish Blackface; SW × BF = Swaledale × Blackface; CH × BF = Cheviot × Blackface; LL × BF = Lleyn × Blackface; T × BF = Texel × Blackface.
Means within columns sharing a common character in their superscript are not significantly different ($P > 0.05$).
[1]See Table 3 for overall effects on survivability and details of statistical abbreviations.

Table 6 *Comparison of the main reasons for culling ewes*[1]

	Barren	Udder problems	Teeth condition	Prolapsed	Poor body condition	Feet problems	Aborted	Lambing difficulty	Maternal instinct
All breeds	0.408	0.227	0.188	0.069	0.040	0.033	0.029	0.004	0.004
Ewe breed									
BF	0.454^{ab}	0.188	0.252^{b}	0.015^{a}	0.043^{a}	0.039	0.025	0.000	0.014
SW × BF	0.531^{b}	0.224	0.100^{a}	0.000^{a}	0.131^{b}	0.030	0.000	0.000	0.003
CH × BF	0.482^{b}	0.192	0.190^{ab}	0.052^{a}	0.050^{ab}	0.000	0.032	0.000	0.000
LL × BF	0.327^{a}	0.267	0.169^{ab}	0.140^{b}	0.017^{a}	0.053	0.032	0.000	0.000
T × BF	0.321^{a}	0.276	0.176^{ab}	0.129^{b}	0.000^{a}	0.037	0.058	0.020	0.000
s.e.d	0.0766	0.0794	0.0680	0.0373	0.0373	0.0311	0.0294	0.0581	0.0422
Significance of ewe breed	*	ns	*	*	*	ns	ns	ns	ns

BF = Scottish Blackface; SW × BF = Swaledale × Blackface; CH × BF = Cheviot × Blackface; LL × BF = Lleyn × Blackface; T × BF = Texel × Blackface.
Means within columns sharing a common character in their superscript are not significantly different ($P > 0.05$).
[1]See Table 3 for overall effects on survivability and details of statistical abbreviations.

Table 7 *Teeth condition in pure BF ewes and their crosses*[1]

	Ewe breed						
Age at mating (years)	BF	SW × BF	CH × BF	LL × BF	T × BF	s.e.d	Significance
Bite position score							
1.5	2.33^{a}	2.52^{b}	2.29^{a}	2.36^{a}	2.38^{a}	0.067	***
2.5	2.76^{a}	2.93^{c}	2.82^{bc}	2.75^{ab}	2.65^{a}	0.067	***
3.5	3.01^{a}	3.15^{b}	3.06^{ab}	3.01^{a}	2.94^{a}	0.067	***
4.5	3.36^{c}	3.36^{c}	3.26^{bc}	3.21^{ab}	3.11^{a}	0.067	***
5.5	3.44^{b}	3.68^{c}	3.34^{ab}	3.32^{ab}	3.22^{a}	0.067	***
Proportion with missing teeth							
1.5	0.000	0.000	0.000	0.000	0.000	0.0001	ns
2.5	0.000	0.000	0.000	0.000	0.003	0.0019	ns
3.5	0.033	0.020	0.039	0.020	0.019	0.0167	ns
4.5	0.172^{b}	0.147^{b}	0.097^{ab}	0.093^{ab}	0.054^{a}	0.0431	**
5.5	0.257^{a}	0.421^{b}	0.074^{a}	0.178^{a}	0.119^{a}	0.0962	**
Proportion with loose teeth							
1.5	0.021	0.007	0.014	0.006	0.012	0.0127	ns
2.5	0.000	0.000	0.000	0.000	0.000	0.0001	ns
3.5	0.037	0.029	0.017	0.032	0.006	0.0163	ns
4.5	0.099	0.064	0.039	0.051	0.040	0.0320	ns
5.5	0.167	0.281	0.100	0.124	0.114	0.0880	$P = 0.06$
Proportion with worn teeth							
1.5	0.000	0.000	0.000	0.006	0.000	0.0036	ns
2.5	0.000	0.000	0.007	0.000	0.000	0.0045	ns
3.5	0.018	0.025	0.018	0.025	0.006	0.0144	ns
4.5	0.083	0.046	0.035	0.049	0.000	0.0271	ns
5.5	0.167	0.281	0.100	0.124	0.114	0.0880	$P = 0.06$

BF = Scottish Blackface; SW × BF = Swaledale × Blackface; CH × BF = Cheviot × Blackface; LL × BF = Lleyn × Blackface; T × BF = Texel × Blackface.
Means within rows sharing a common character in their superscript are not significantly different ($P > 0.05$).
[1]See Table 3 for overall effects on survivability and details of statistical abbreviations.

breed ($P < 0.05$), age at mating ($P < 0.001$), BCS at weaning ($P < 0.001$), number of missing teeth ($P < 0.001$) and average daily live weight gain per litter ($P < 0.05$). Probability of surviving to the next mating was highest for SW × BF (0.881) and lowest for LL × BF (0.738; Figure 1). Age had little effect on survival probability in ewes aged 3.5 years or less (>0.900) but was 0.521 in 5.5-year-old ewes (Figure 2). The probability that ewes in good body condition at weaning (2.5 or above) would survive to the next mating was high (>0.750), but declined rapidly when BCS fell below 2.0 (Figure 3). Increasing incidence of tooth loss resulted in a linear decrease in survival probability, from 0.823 in ewes having a full compliment of teeth, to 0.312 in ewes with five missing teeth (Figure 4). A linear increase in survival probability was observed as average daily live weight gain per litter increased from 180 to 235 g/day although these effects were small (0.788 *v.* 0.837; Figure 5).

Table 8 *Factors attributing to ewes surviving until the next mating*

	OR	95% CI for OR	Probability
Ewe breed			0.026
BF (reference)	1.00	–	
SW × BF	2.04	1.12 to 3.69	
CH × BF	1.15	0.67 to 1.97	
LL × BF	0.77	0.46 to 1.28	
T × BF	1.22	0.71 to 2.07	
Age at mating			<0.001
2.5 (reference)	1.00	–	
3.5	0.89	0.51 to 1.54	
4.5	0.38	0.21 to 0.70	
5.5	0.11	0.05 to 0.24	
Ewe BCS at weaning[1]	16.77	3.43 to 81.96	<0.001
Number of teeth missing[1]	0.63	0.49 to 0.81	<0.001
Average daily live weight gain per litter[2]	1.03	1.01 to 1.05	0.016

BF = Scottish Blackface; SW × BF = Swaledale × Blackface; CH × BF = Cheviot × Blackface; LL × BF = Lleyn × Blackface; T × BF = Texel × Blackface; BCS = body condition score.
[1]OR assumes a one unit increase in the level of factor.
[2]OR assumes a five unit increase in the level of factor.

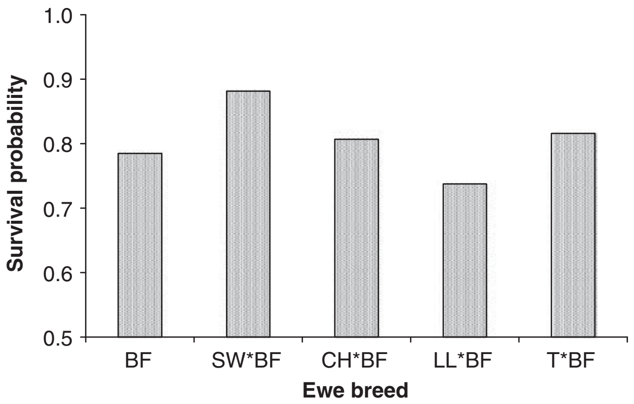

Figure 1 Fitted effects of breed on ewe survival.

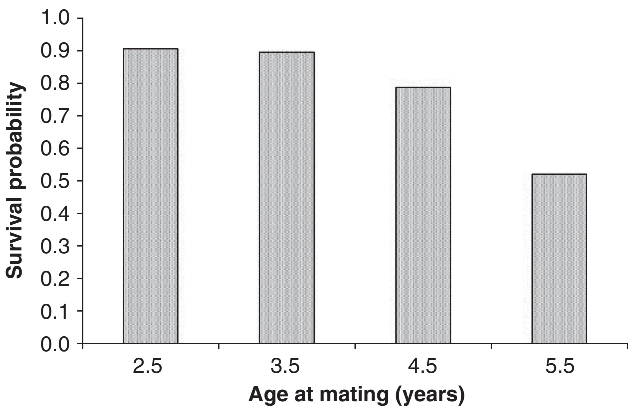

Figure 2 Fitted effects of age at mating on ewe survival.

Lifetime lamb output

When cumulated across preceding parities, the total number of lambs weaned by LL × BF and SW × BF and the total weight of lambs weaned by LL × BF, T × BF and SW × BF ewes were consistently higher ($P < 0.05$) than BF throughout the study (Table 9). With the exception of 1.5-year-old ewes, the cumulative number of lambs weaned by T × BF was also higher than BF. BF and CH × BF reared a similar number of lambs up to 4.5 years old but total lambs reared by 5.5-year-old ewes were significantly higher ($P < 0.05$) for CH × BF. The total weight of lambs reared by CH × BF was consistently higher ($P < 0.05$) than BF from 3.5 years old and above. Over five mating seasons, the total number and the total weight of lambs weaned was similar for all the crossbred ewe types studied.

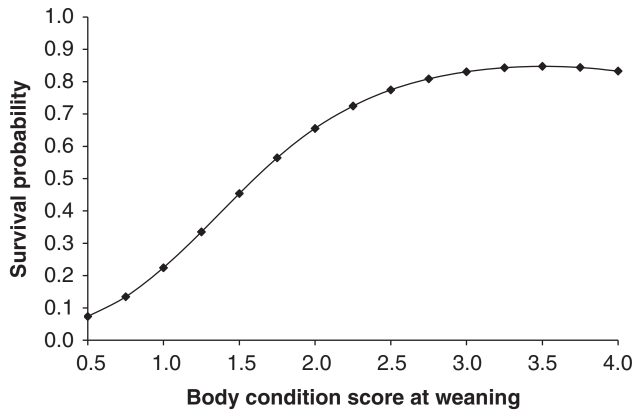

Figure 3 Fitted effects of body condition score at weaning on ewe survival.

Discussion

To date, few studies comparing the performance of hill sheep breeds and their crosses have been undertaken under hill conditions (Donald *et al.*, 1963; Al-Nakib *et al.*, 1986 and 1997; Carson *et al.*, 2001). We believe this is the first study to examine the longevity and lifetime lamb output of crossbred hill ewes, which is surprising considering that replacement costs typically make up around 27% total variable costs of hill sheep flocks (DARD, 2009).

Breed effects on ewe longevity have been reported previously for lowland breed ewes (Vesely and Peters, 1974; Hohenboken and Clarke, 1981; Hanrahan, 2007) and became evident from as early as the second mating (3.5 years old). Overall, crossbred ewes sired by SW and CH rams had better longevity than purebred BF due to their lower culling rate and lower mortality rate, respectively. In practice, these breed differences in longevity translate into average replacement rates of approximately 24%, 25% and 27% for SW × BF, CH × BF and BF ewes, respectively. While it has been claimed that the SW breed is more adaptable to surviving in wet environments than other hill breeds (Steane, 1983), we believe this is the first published evidence to support a claim for greater longevity with this breed. Hohenboken and Clarke (1981) compared four crossbred genotypes on hill pastures and noted that ewes sired by North Country CH sires had better longevity than those sired by lowland breed (Romney, Finnsheep) sires. These observations suggest that hill breeds in general may carry ‘fitness’ genes for improved hardiness and survivability under harsh environments, making them more suitable than lowland breed types as crossing sires to improve longevity.

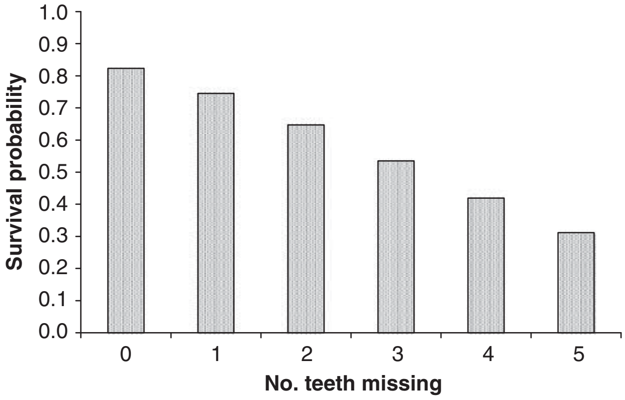

Figure 4 Fitted effects of the number of missing teeth on ewe survival.

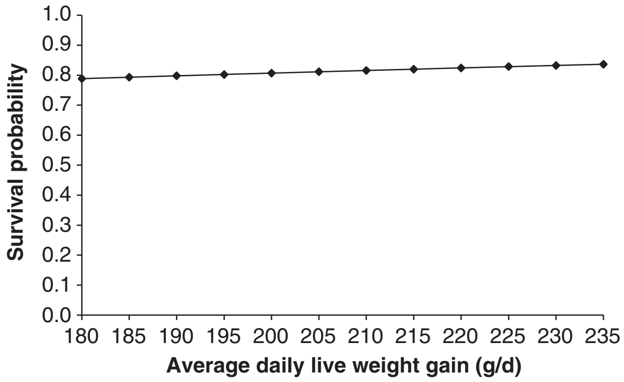

Figure 5 Fitted effects of average daily live weight gain per litter on ewe survival.

Studies in high output sheep systems have demonstrated that increasing prolificacy can impact negatively on the longevity of ewes. Over an 18-year period, Hanrahan (2007) found that the replacement rate of prolific Belclare × ewes were on average 2% higher than Suffolk × ewes. In a further comparison of four crossbred genotypes, Hohenboken and Clarke (1981) noted that prolific Finnsheep × ewes had difficulties adapting to hill conditions. However, within the current study, longevity of the most prolific LL × BF ewes was similar to BF, while SW × BF ewes had superior longevity to the BF due to their lower culling rate. Overall, the potential for reduced biological fitness in the more prolific breed types was generally offset by fewer ewes being culled due to infertility. No direct relationship between litter size and longevity was observed, possibly because the increase in lamb output of the crossbred ewes was achieved mainly through an increased twinning rate. The incidence of triplet births was below 3%, which compares with 10% to 20% of ewes in high output lowland flocks (Hanrahan, 1994

Table 9 *Effects of ewe breed and age at mating on cumulative lamb output at weaning*[1]

	Ewe breed						
Age at mating (years)	BF	SW × BF	CH × BF	LL × BF	T × BF	s.e.d	Significance
Lambs weaned/ewe							
1.5	1.04^{a}	1.19^{b}	1.04^{a}	1.23^{b}	1.14^{ab}	0.068	*
2.5	2.12^{a}	2.41^{c}	2.20^{ab}	2.53^{c}	2.38^{bc}	0.101	*
3.5	3.04^{a}	3.53^{c}	3.20^{ab}	3.60^{c}	3.39^{bc}	0.129	*
4.5	3.77^{a}	4.46^{c}	4.01^{ab}	4.43^{c}	4.19^{bc}	0.152	*
5.5	4.17^{a}	4.96^{b}	4.64^{b}	4.97^{b}	4.73^{b}	0.197	*
Lamb output at weaning (kg/ewe)							
1.5	31.9^{a}	36.5^{bc}	32.8^{ab}	37.9^{c}	36.2^{bc}	2.26	*
2.5	64.8^{a}	74.3^{bc}	69.6^{ab}	78.2^{c}	75.6^{bc}	3.31	*
3.5	93.3^{a}	109.2^{bc}	102.0^{b}	111.6^{c}	107.5^{bc}	4.20	*
4.5	114.6^{a}	136.7^{b}	127.6^{b}	137.4^{b}	132.3^{b}	5.10	*
5.5	125.4^{a}	152.0^{b}	147.2^{b}	154.4^{b}	148.9^{b}	6.28	*

BF = Scottish Blackface; SW × BF = Swaledale × Blackface; CH × BF = Cheviot × Blackface; LL × BF = Lleyn × Blackface; T × BF = Texel × Blackface.
Means within rows sharing a common character in their superscript are not significantly different ($P > 0.05$).
[1]See Table 3 for overall effects on survivability and details of statistical abbreviations.

and 2004), so the small number of triplet-bearing ewes could easily be preferentially managed. A positive relationship between ewe longevity and the average daily live weight gain of her lambs was observed (Figure 5) which could be an indirect effect of litter size, although the overall impact on longevity was small. Selection of crossing sire breed to produce prolific females for hill flocks may be important. SW × BF ewes tended to remain in the flock longer than LL × BF even though both breeds had similar levels of prolificacy (Annett *et al*., 2010). Therefore, ewes sired by prolific hill breed types such as SW may be more appropriate for hill flocks than those sired by prolific lowland breeds.

Ewe mortality (0.335) rather than culling (0.256) was the main reason for ewes being removed from the flock, which contrasts with reports from lowland flocks (McGloughlin and Curran, 1969; Hanrahan, 2007). The peak in ewe mortality between weaning and mating is unexpected considering that ewes are under the least metabolic stress during this time. This mortality rate may, however, be inflated by ewes straying while grazing the more extensive and less favourable hill areas after weaning, although it is impossible to quantify this loss. Breeds effects on culling rates and the reasons for culling have been reported in lowland-breed ewes (Norman and Hohenboken, 1979; Hanrahan, 2007). In agreement with McGloughlin and Curran (1969), the primary reason for culling was due to infertility (0.408) and was followed by udder abnormalities (0.227), poor teeth condition (0.188), vaginal prolapse (0.069) and poor body condition (0.040). The relative rate of culling due to infertility was lower in LL × BF and T × BF compared with CH × BF and mirrors their higher prolificacy (Annett *et al*., 2010). Waterhouse *et al*. (1992) reported increased survival in BF ewes treated with Fecundin® (Glaxo Animal Health, UK) to boost prolificacy. While these authors suggested that increased longevity could be due to more intense management of multiple bearing ewes, it is inevitable that fewer treated ewes were culled for failing to conceive.

Teeth condition was an important culling criterion in this study, in agreement with Sykes *et al*. (1974), although the incidence of tooth loss and wear were uncommon (<5%) in ewes under 4.5 years old. Irrespective of age, there was a linear decline in longevity as the number of missing teeth increased (Figure 4) although no attempt has been made to establish, if this was due primarily to culling policy or a higher mortality risk from a decreased ability to forage. It is worth noting however that the higher proportion of 'broken-mouthed' 4.5 and 5.5 ewes had no effect on the average growth rates of their lambs, reported in a concurrent study (Annett *et al*., 2010), which contrasts with a 50 g/day reduction in lamb growth rate of broken mouthed ewes reported by Sykes *et al*. (1974). However, the older ewes had lower BCSs and experienced greater loss of live weight and body condition during late pregnancy and early lactation (Annett *et al*., 2010), which suggests that milk production was maintained at the expense of body fat and protein mobilisation. Teeth looseness and wear were not influenced by ewe breed, in contrast to Carson *et al*. (2001) who reported greater teeth wear in CH than BF ewes. SW × BF ewes had consistently higher bite scores, indicating a greater incidence of overshoot. While we believe this is the first study to report a breed effect on bite score, there was no evidence that this had a negative effect on ewe or lamb performance. Despite their higher incidence of overshoot and tooth loss, if would appear that SW × BF had sufficient sound teeth remaining to be deemed suitable for further breeding, in the absence of other physical disorders. These observations raise many questions about the relevance of following a strict culling policy for teeth condition.

A policy of culling ewes that were in poor body condition and unlikely to sustain a further pregnancy was common across all the farms involved in this study. Consequently, a significant decline in the probability of survival for ewes in poor body condition (<2.0) at weaning is not surprising (Figure 3). A significant relationship between longevity and age of the ewe was observed, independent of age effects on teeth condition and BCS (Figure 2). This relationship is likely to reflect the increased risk of udder problems, metabolic disorders and other health issues in older ewes. There was no evidence of a breed effect on culling due to udder problems, despite significant variation in prolificacy and lamb output of the breeds studied. This contrasts with Hanrahan (2007) who reported a higher rate of culling for udder problems with prolific Belclare × ewes. Vaginal prolapsing is commonly reported in sheep flocks during the peri-parturient period but typically affects <1% ewes (Low and Sutherland, 1987). Culling ewes following prolapse has been recommended as they are more likely to prolapse again in the future (Litherland *et al*., 2000). In this study, 7% of all ewes were culled due to prolapse, but the relative rate of culling was higher in LL × BF and T × BF compared to the hill breed crosses. Factors predisposing ewes to prolapse are poorly understood, although anecdotal evidence points to increased abdominal pressure in ewes carrying multiple foetuses, consuming poor quality forages and in excessive body condition. Although the majority of prolapse cases were in ewes carrying multiples, in agreement with Hanrahan (2007), breed effects on litter size do not fully explain the higher incidence of prolapse in LL × BF and T × BF. It should be noted that 12/19 ewes culled due to prolapse were from a single farm, which may indicate either a higher prevalence on this farm or a higher priority in culling affected ewes.

Cumulative lamb output over 5 years was higher for all the crossbred ewe types compared with the Blackface, both in terms of the number and the weight of lambs reared. To our knowledge this is the first study to report on the lifetime output of crossbred hill ewes, although several studies have reported increased lamb output from crossbred ewes on an annual basis (Donald *et al*., 1963; Al-Nakib *et al*., 1986 and 1997; Gunn, 1986). The higher lifetime output of the crossbreds relative to BF mirrors their higher annual weaning rate (1.42 *v* 1.31 lambs weaned per ewe lambed; Annett *et al*., 2010) with the exception of CH × BF, which had similar weaning rates to BF but superior longevity. Across all breeds, variation in lifetime output of individual ewes was attributable mainly to differences in their annual weaning rate (0.606), in agreement with Hohenboken and Clarke (1981) and Casas *et al*. (2005), followed by differences in longevity (0.273) and lamb growth rate (0.121). Overall, there were no significant differences in 5-year lamb output between any of the crossbred genotypes studied, although the total number and total weight of lambs reared were numerically highest for LL $\times$ BF.

Acknowledgements

The authors wish to express their sincere thanks to the following hill sheep producers for their help and hard work in undertaking this study: Mr Ian Buchanan, Mr Richard Duffin, Mr Maurice McHenry, Mr Seamus Maginn, Mr Stephen Montgomery and Mr Samuel Wharry. The authors are also grateful to the Department of Agriculture and Rural Development for Northern Ireland (DARDNI) and Agrisearch who provided funding for this project.

References

Al-Nakib FMS, Findlay RH and Smith C 1986. Performance of different Scottish Blackface stocks and their crosses. Journal of Agricultural Science Cambridge 107, 119–123.

Al-Nakib FMS, Bateman N, Findlay RH, Smith C and Thompson R 1997. Comparative performance of British hill sheep breeds and their crosses. Journal of Agricultural Science Cambridge 128, 199–206.

Annett RW, Carson AF, Dawson LER, Irwin D and Kilpatrick D 2010. Effects of breed and age on the performance of crossbred hill ewes sourced from Scottish Blackface dams. Animal; doi:10.1017/S1751731110002090.

Carson AF, Irwin D and Kilpatrick DJ 2001. A comparison of Scottish Blackface and Cheviot ewes and five sire breeds in terms of lamb output at weaning in hill sheep systems. Journal of Agricultural Science Cambridge 137, 221–233.

Carson AF, Dawson LER, Irwin D and Kilpatrick DJ 2004. The effect of management system at lambing and flock genetics on lamb output and labour requirements on lowland sheep farms. Animal Science 78, 439–450.

Casas E, Freking BA and Leymaster KA 2005. Evaluation of Dorset, Finnsheep, Romanov, Texel and Montadale breeds of sheep: V. Reproduction of F1 ewes in spring mating seasons. Journal of Animal Science 83, 2743–2751.

Dawson LER and Carson AF 2002. Effects of crossbred ewe genotype and ram genotype on ewe prolificacy, lamb viability and lamb output in the lowland sector. Journal of Agricultural Science Cambridge 139, 169–181.

Department of Agriculture and Rural Development for Northern Ireland (DARD) 2009. Greenmount Suckler Cows, Beef and Sheep Benchmarking Report 2007/2008.

Donald HP, Read JL and Russell WS 1963. Heterosis in crossbred hill sheep. Animal Production 5, 289–299.

Duckworth D, Hill R, Benzie D, Dalgarno AC and Robinson JF 1962. Studies of the dentition of sheep. 1. Clinical observations from investigations into the shedding of permanent incisor teeth by hill sheep. Research in Veterinary Science 3, 1–17.

European Commission 2006. Study on environmental consequences of sheep and goat farming and of the sheep and goat premium system. Final Report Prepared for the European Commission Directorate-General for Agriculture and Rural Development, Retrieved July 2006, from http://ec.europa.eu/agriculture/eval/reports/sheep2007/full_text_en.pdf

Fogarty NM, Dickerson GE and Young LD 1984. Lamb production and its components in pure breeds and composite lines. 2. Breed effects and heterosis. Journal of Animal Science 58, 301–311.

Genstat 2009. Release 12.1. Lawes Agricultural Trust, Rothamsted Experimental Station, Harpenden, Hertfordshire, UK.

Gunn RG 1986. A note on the comparative reproductive performance of Friesland x North Country Cheviot and North Country Cheviot ewes on two levels of pasture prior to mating. Animal Production 42, 287–289.

Hanrahan JP 1994. Evaluation of crossbred ewe types: ovulation rate and prolificacy. Proceedings of the Irish Grassland and Animal Production Association Annual Meeting, Co. Offaly, Ireland, 21–22pp.

Hanrahan JP 2004. Performance characteristics of Belclare sheep in pedigree flocks. Teagasc Beef and Sheep Production Research Report, 157pp. from http://www.teagasc.ie/publications/2005/grange_04_res_report_for_web_sept_05.pdf

Hanrahan JP 2007. Association between ewe breed type and longevity in a lowland production system. Proceedings of the Agricultural Research Forum, Tullamore, Co. Offaly, Ireland, 72pp. from http://www.agresearchforum.com/publicationsarf/2007/Page%20072.pdf

Hohenboken WD and Clarke SE 1981. Genetic, environmental and interaction effects on lamb survival, cumulative lamb production and longevity of crossbred ewes. Journal of Animal Science 53, 966–976.

Litherland AJ, Lambert MG, Knight TW, Cook T and McDougal DB 2000. Incidence of bearing in ewes that had a bearing at the preceding lambing. Proceedings of the New Zealand Society of Animal Production 60, 44–46.

Low JC and Sutherland HK 1987. A census of the prevalence of vaginal prolapse in sheep flocks in the Borders region of Scotland. Veterinary Record 120, 571–575.

McGloughlin P and Curran S 1969. A comparison of four breeds of sheep as dams for fat lamb production. Irish Journal of Agricultural Research 8, 67–79.

Norman LM and Hohenboken W 1979. Genetic and environmental effects on internal parasites, foot soundness and attrition in crossbred ewes. Journal of Animal Science 48, 1329–1337.

Pollott GE and Stone DG 2006. The breeding structure of the British sheep industry 2003. Report Prepared for the Department of Environment, Food and Rural Affairs (DEFRA) for the Review of the National Scrapie Plan, Retrieved 2004, from http://www.defra.gov.uk/evidence/economics/foodfarm/reports/documents/pollott2003.pdf

Russel AJF, Doney JM and Gunn RG 1969. Subjective assessment of body fat in live sheep. Journal of Agricultural Science Cambridge 72, 451–454.

Simm G, Conington J and Bishop SC 1994. Opportunities for genetic improvement of sheep and cattle in the hills and uplands. In Livestock production and land use in hills and uplands (ed. TlJ Lawrence, DS Parker and P Rowlinson), pp. 51–66. Occasional Publication no. 18, British Society of Animal Production, Edinburgh, UK.

Steane DE 1983. The significance of interactions in practical sheep breeding in northern Europe. Livestock Production Science 10, 39–48.

Sykes AR, Field AC and Gunn RG 1974. Effects of age and state of incisor dentition on body composition and lamb production of sheep grazing hill pastures. Journal of Agricultural Science Cambridge 83, 135–143.

Vesely JA and Peters HF 1974. Lamb production from ewes of four breeds and their two-breed and three-breed crosses. Canadian Journal of Animal Science 54, 543–549.

Waterhouse A, Logue DN and Roger LC 1992. The effects of increased prolificacy on lamb and ewe mortality in an intensive hill sheep system. In Neonatal survival and growth (ed. MA Varley, PEV Williams and TLJ Lawrence), pp. 176–178. Occasional Publication no. 15, British Society of Animal Production, Edinburgh, UK.