REPRODUCTIVE PERFORMANCE OF BOOROOLA × FINNISH LANDRACE AND BOOROOLA × SUFFOLK EWE LAMBS, HETEROZYGOUS FOR THE *F* GENE, AND GROWTH TRAITS OF THEIR THREE-WAY CROSS LAMBS

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Reproductive performance of Booroola × Finnish Landrace (BFL, $n=19$) and Booroola × Suffolk (BS, $n=18$) ewe lambs heterozygous for the *F* gene were compared to Finnish Landrace (FL, $n=14$) and Suffolk (S, $n=26$) purebred controls. FL lambs reached puberty earlier (211.3 d, $P < 0.001$) than the other genetic groups (237.8, 233.0 and 232.9 d for S, BS and BFL, respectively) whereas weight at puberty was lower ($P < 0.001$) for BFL, FL and BS (36.8, 36.7 and 47.0 kg, respectively) than for S (61.1 kg). About 95% of BFL and BS ewe lambs had at least one record of three ovulations or more over the first three estruses, including puberty. Mean ovulation rates at breeding (second estrus after puberty) to a Hampshire (H) ram were 3.8, 3.3, 2.2 and 1.7 for BFL, BS, FL and S, respectively (BFL and BS vs. FL and S, $P < 0.001$). The corresponding litter sizes at birth were 2.5, 2.1, 1.6 and 1.3 (BFL and BS vs. FL and S, $P < 0.001$) which reflected a higher embryonic loss in the Booroola crosses. Percentage ova loss ranged between 32.8% (BFL) and 12.8% (S) and was related to the level of prolificacy. Lamb mortality at birth was high in BFL (23.7%) compared to BS, FL and S (6.5, 0.0 and 0.0%, respectively, $P < 0.001$). Litter size at weaning (50 d of age) averaged 1.9, 1.8, 1.5 and 1.3 for BS, BFL, FL and S ewe lambs (BS vs. S, $P < 0.02$). Growth performance of H-sired progeny from the four genetic groups of ewes showed that H × S lambs had the highest average daily gain in both preweaning and postweaning periods (preweaning ADG: 349.9 g d^{-1}; postweaning ADG: 332.1 g d^{-1}) while the other genotypes of lambs performed equally (preweaning ADG: 267.4, 249.5 and 246.8 g d^{-1} for H × FL, H × BFL and H × BS, respectively; postweaning ADG: 281.2, 276.8 and 281.8 g d^{-1} for the same genetic groups). Overall productivity of ewe lambs in terms of kilograms of lamb produced showed a slight, nonsignificant, advantage for Booroola-cross ewe lambs (55.8 and 54.5 kg for BS and BFL) over purebred S (51.6 kg) and FL (44.9 kg). These results indicate that ovulation rate and litter size can be increased by incorporating *F* gene in both prolific (FL) and nonprolific (S) background genotypes without resulting in any significant difference in total weight of lamb produced per ewe.

Key words: Sheep, ewe productivity, Booroola, ovulation rate, crossbreeding

[Performances reproductrices d'agnelles Booroola × Suffolk et Booroola × Finnish Landrace, hétérozygotes pour le gène F, et croissance de leurs agneaux issus d'un croisement triple.]
Titre abrégé: Reproduction chez des agnelles croisées Booroola.

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Les performances reproductrices d'agnelles Booroola × Finnish Landrace (BFL, $n=19$) et Booroola × Suffolk (BS, $n=18$), hétérozygotes pour le gène *F*, ont été comparées à celles d'agnelles de race pure Finnish Landrace (FL, $n=14$) et Suffolk (S, $n=26$). Les agnelles FL atteignaient la puberté plus hâtivement (211,3 j, $P < 0{,}001$) que les autres groupes génétiques (237,8, 233,0 et 232,9 j pour les S, BS et BFL) alors que le poids à la puberté était plus faible chez les BFL, FL et BS (36,8, 36,7 and 47,0 kg) que chez les S (61,1 kg, $P < 0{,}001$). Environ 95% des agnelles BFL et BS avaient au moins un taux d'ovulation égal ou supérieur à 3 à l'une de leurs trois premières chaleurs, en incluant la puberté. Au deuxième oestrus suivant la puberté, les agnelles ont été accouplées à un bélier Hampshire (H) et le taux d'ovulation à la saillie était respectivement de 3,8, 3,3, 2,2 et 1,7 pour les BFL, BS, FL et S (BFL et BS vs. FL et S, $P < 0{,}001$). Pour les mêmes groupes génétiques, la taille de portée à la naissance était respectivement de 2,5, 2,1, 1,6 et 1,3 (BFL et BS vs. FL et S, $P < 0{,}001$) reflétant une plus grande mortalité embryonnaire chez les croisées Booroola. Le pourcentage de mortalité embryonnaire variait de 32,8% (BFL) à 12.8% (S) et était corrélé au niveau de prolificité des femelles. La mortalité des agneaux à la naissance était élevée pour les BFL (23,7%, $P < 0{,}001$) comparativement aux BS, FL et S (6,5, 0,0 and 0,0%, respectivement). La portée au sevrage (50 jours d'âge) était en moyenne de 1,9, 1,8, 1,5 et 1,3 chez les agnelles BS, BFL, FL et S (BS vs. S, $P < 0{,}02$). Les résultats de croissance des agneaux issus des femelles des quatre groupes génétiques indiquaient que les agneaux H × S obtenaient les meilleurs gains moyens quotidiens avant et après le sevrage (GMQ avant sevrage: 349,9 g j^{-1}; GMQ après sevrage: 332,1 g j^{-1}) alors que les performances des autres génotypes étaient semblables (GMQ avant sevrage: 267,4, 249,5 et 246,8 g j^{-1} pour les H × FL, H × BFL and H × BS; GMQ après sevrage: 281,2, 276,8 et 281,8 g j^{-1} pour les mêmes groupes). La productivité globale des agnelles, en terme de kilogrammes d'agneaux produits, montrait une légère supériorité, non-significative, des femelles croisées Booroola (55,8 et 54,5 kg pour les BS et les BFL) par rapport aux races pures S (51,6 kg) et FL (44,9 kg). L'ensemble de ces résultats démontre que le gène F augmente le taux d'ovulation et la taille de portée des agnelles hétérozygotes, aussi bien chez les souches prolifique (FL) que non-prolifique (S), sans cependant produire une augmentation dans la productivité globale de ces agnelles.

Mots clés: Mouton, productivité de la brebis, Booroola, taux d'ovulation, croisement.

Increasing ewe productivity is one of the primary goals in the sheep industry, and ovulation rate is an important component of the overall reproductive potential in the ewe (Hanrahan 1986). Due to the polygenic determinism of ovulation rate, crossbreeding with highly prolific breeds such as Romanov or Finnish Landrace has been the classical genetic way for quickly increasing the number of ova shed. The recent discovery that prolificacy in the Booroola Merino is controlled by a single gene (Piper and Bindon 1982) has provided an alternative for rapidly augmenting prolificacy in sheep. The gene symbol adopted was F, and + for the normal allele (Davis et al. 1982). Davis et al. (1982) have defined three genotypes in the Booroola Merino population based on ovulation rate assessed from repeated (at least three) observations: *FF* ewes (homozygous carriers of the *F* gene) had at least one record of five ovulations or more, *F*+ ewes (heterozygous carriers) had one record of three or four ovulations, and ++ ewes (noncarriers) had no records of more than two. Several reports on crossbreeding with Booroola (Davis et al. 1984; Montgomery et al. 1985; Piper et al. 1985) have shown that ewes carrying the *F* gene (*F*+) had about 1.5 more ovulations and one more lamb at birth than control females (++). However, almost all these experiments used nonprolific genotypes (Coopworth, Merino, Romney) as the recipient breeds in evaluating the effect of the *F* gene.

In the present study, we have addressed the question of whether the *F* gene could be expressed in the Finnish Landrace, which is a naturally prolific breed and in the Suffolk which is considered to be a nonprolific breed. The study compares the reproductive performance of ewe lambs of the Finnish Landrace and Suffolk breeds and their Booroola-sired crosses, heterozygous for the *F* gene. In addition, the growth traits of Hampshire-sired progeny of the four genetic groups has been evaluated.

MATERIALS AND METHODS

Animals

In August 1986, four Booroola Merino rams (2 yr old), homozygous for the *F* gene (*FF*), imported from New Zealand by Agriculture Canada in 1985, were trained for semen collection at the experimental farm of Agriculture Canada in La Pocatière, Québec. At the beginning of September 1986, 35 purebred Finnish Landrace (FL) and 45 Suffolk (S) ewes (3–4 yr old), located at the experimental station of Laval University in St-Augustin, were treated with intravaginal sponges impregnated with 60 mg medroxyprogesterone acetate (Veramix, Upjohn) for 14 d to synchronize the estrous cycle. At sponge removal, FL and S ewes received, respectively, 300 IU and 400 IU of Pregnant Mare Serum Gonadotropin (PMSG, Equinex, Ayerst Laboratories) injected intramuscularly. The ewes were inseminated 55 ± 1 h after sponge withdrawal with Booroola semen collected about 3 h earlier to produce crossbred ewe lambs 1/2Booroola1/2Finnish Landrace (BFL) and 1/2Booroola1/2Suffolk (BS), all heterozygous for the *F* gene (*F*+). Pregnancy diagnosis was performed by determining the serum concentration of progesterone 18 d after insemination. Among the ewes that were not pregnant following the first insemination, another group of 10 FL and 10 S ewes were inseminated a second time to obtain the number of pregnant ewes required. The synchronization of estrus and insemination of that second group of ewes were done in October 1986 according to the same procedures used for the first inseminations (September 1986). During the same period (September-October), adult FL and S ewes were mated with rams of the same breed to produce contemporary FL and S purebred lambs. After lambing between February and April 1987, there were 19 BFL, 21 BS, 15 FL and 32 S female progeny available for experimentation. Experimental animals had free access to good-quality hay and commercial concentrate containing 15% crude protein (200 g per ewe).

Experimental Procedure

In September 1987, the ewe lambs were exposed once a day (approximately 45 min) to vasectomized teaser rams to determine the onset of puberty (first standing behavioral estrus). The number of ovulations following the recorded estruses were determined by laparoscopy, 5–9 d after estrus. The ewe lambs were mated at the third recorded estrus with a fertile Hampshire (H) ram. All ewe lambs returning to estrus were rebred and underwent another laparoscopy.

Growth traits of Hampshire-sired lambs born to ewes of the four genetic groups were evaluated up to 100 d of age. All lambs were weighed at birth, at 50 and 100 d of age. Only two lambs (one male and one female when possible) were left with their dam. The remaining lambs were artificially reared with milk replacer containing 23% crude protein and 23.5% crude fat (Lacvor, Nutrinor, Qué.). They had access to hay and concentrate (18% crude protein) at all times during the preweaning period. Lambs were weaned from their dams at 50 d of age. Between the ages of 50 and 100 d, the lambs were fed ad libitum with commercial grower ration (18% crude protein) and good quality hay. Water was available at all times.

During the experiment, one female FL lamb died before puberty, one BS ewe was culled after being identified as a hermaphrodite, another BS ewe died during laparoscopy, and one BFL ewe was eliminated because of chronic mastitis following weaning.

Statistical Analysis

Data were analyzed by analyses of variance using the GLM procedure (Statistical Analysis System Institute, Inc . 1985). Except for the parameters mentioned below, only genetic group was used as fixed effect in the models utilized. In analyses with more than one source of variation, the interaction effects were not tested.

For analysis of ewe lamb weights (at birth, weaning and at 100 d), the model included genetic group and litter size as fixed effects. Weights at weaning and at 100 d were adjusted for age at weighing. Ovulation rate of the four genetic groups were compared separately for each estrus. In the analysis of the overall ovulation records, the mean ovulation rate of the three estruses was calculated for each ewe, and genetic groups were compared (only ewes with three ovulation records were included in this analysis). Because of the wide difference in the variation of ovulation rate between Booroola crosses and purebred FL and S, embryonic mortality was analyzed independently in Booroola crosses. Genetic group and ovulation rate at breeding were both included as fixed effects in the model for analysis of embryonic mortality. This latter parameter (expressed as a percentage) was defined as (no. of lambs born — no. of recorded ovulations) × 100, and therefore included fertilization failure and embryo death. Data from ewes that were inseminated a second time were also included. Mortality at birth included lambs dead at birth and within 3 h after birth. Females that aborted were excluded from lambing and weaning analyses. Only lambs raised with their dam were used to analyze weaning weight. However, all lambs (naturally and artificially reared) were included to evaluate the number of kilograms of lamb produced per ewe weaning lambs.

For analysis of the growth characteristics of the Hampshire-sired lambs born from ewes of the four genetic groups, the statistical model included genetic group, litter size at birth and sex of lamb as fixed effects.

When model was significant, Duncan's multiple range test was used to compare genetic group means unless a covariate was included. In these cases, orthogonal contrasts were more appropriate. Means presented in all tables are non-adjusted and compared with Duncan's test (except for weights at weaning and at 100 d of ewe lambs which were compared with contrasts). Heterogeneity of variance was tested for all traits and transformation of data was not found to be necessary.

RESULTS

Prepuberal Period

Table 1 shows that S ewe lambs were the heaviest at birth (4.6 kg), followed by BS (4.1 kg), BFL and FL being significantly ($P < 0.001$) lighter than the two other genotypes (2.3 and 2.1 kg, respectively). The same statistical differences were also observed at weaning (26.6 kg for S vs. 23.0, 15.9 and 15.6 kg for BS, FL and BFL, respectively) and at 100 d of age (42.9 kg for S vs. 33.0, 27.0 and 25.1 kg for BS, BFL and FL, respectively). Litter size at birth had a significant ($P < 0.05$) effect on weight at birth and at weaning.

Puberty and Ovulation Rate

All purebred and crossbred ewe lambs attained puberty in their first breeding season. However, FL reached puberty (Table 1) at least 21 d earlier (211.3 d; $P < 0.001$) than other genetic groups (237.8, 233.0, and 232.9 d for S, BS and BFL). Liveweight at first estrus was 14 kg higher ($P < 0.001$) in S (61.1 kg) than in BS, while BFL and FL were 10 kg lighter still. Differences in liveweight at puberty persisted at breeding, S being the heaviest group ($P < 0.001$). Estrous cycle

Table 1. Reproductive performance of Booroola × Finnish Landrace (BFL), Booroola × Suffolk (BS), Finnish Landrace (FL) and Suffolk (S) ewes

	Genetic group			
Traits	BFL	BS	FL	S
Birth weight (kg)	2.3 ± 0.1*c*†	4.1 ± 0.1*b*	2.1 ± 0.1*c*	4.6 ± 0.2*a*
Weaning weight (kg)	15.6 ± 0.3*c*	23.0 ± 0.8*b*	15.9 ± 0.3*c*	26.6 ± 0.8*a*
Weight at 100 d (kg)	27.0 ± 0.7*c*	33.0 ± 0.8*b*	25.1 ± 1.0*c*	42.9 ± 1.0*a*
Age at puberty (d)	232.9 ± 5.1*a*	233.0 ± 3.5*a*	211.3 ± 4.7*b*	237.8 ± 3.5*a*
Weight at puberty (kg)	36.8 ± 0.8*c*	47.0 ± 0.9*b*	36.7 ± 1.0*c*	61.1 ± 1.2*a*
Weight at breeding (kg)	38.4 ± 0.8*c*	47.9 ± 1.0*b*	37.0 ± 0.7*c*	61.9 ± 1.1*a*
Estrous cycle length	17.3 ± 0.5*a*	16.6 ± 0.2*ab*	16.1 ± 0.2*b*	16.3 ± 0.1*b*
Conception rate (%)	94.7 ± 5.3	94.4 ± 5.6	85.7 ± 9.7	92.3 ± 5.3
Gestation length (d)	144.2 ± 0.5*a*	143.4 ± 0.2*ab*	142.3 ± 0.4*b*	143.0 ± 0.3*b*
Litter size at birth‡	2.5 ± 0.2*a*	2.1 ± 0.2*a*	1.6 ± 0.2*b*	1.3 ± 0.1*b*
Litter weight at birth (kg)‡	6.0 ± 0.3*a*	6.3 ± 0.4*a*	4.6 ± 0.3*b*	6.3 ± 0.4*a*
Mortality at birth (%)‡	23.7 ± 7.1*a*	6.5 ± 3.6*b*	0.0 ± 0.0*b*	0.0 ± 0.0*b*
Litter size at weaning ‡	1.8 ± 0.2*ab*	1.9 ± 0.2*a*	1.5 ± 0.1*ab*	1.3 ± 0.1*b*
Litter weight at weaning (kg)‡	23.6 ± 1.3*b*	26.7 ± 1.4*a*	23.3 ± 1.2*b*	29.0 ± 1.8*a*
Total kg of lambs produced‡	54.5 ± 4.9	55.8 ± 4.6	44.9 ± 3.3	51.6 ± 3.7

†Means ± standard error.
‡Hampshire-sire lambs.
a–c Means in the same line with different letters differ significantly ($P < 0.05$).

length was longer in BFL (17.3 d) than in S and FL (16.3 and 16.1 d).

Mean ovulation rates for ewe lambs (Table 2) with three recorded estruses were 3.5 and 3.1 in BFL and BS, significantly higher ($P < 0.001$) than in FL (2.3) and in S ewe lambs (1.7). Distribution of ovulation rate was also different (Table 2, $P < 0.001$) between the genetic groups. Over the first three estruses, approximately 72% of BFL and BS ewe lambs had three or four ovulations whereas FL ewe lambs had an ovulation rate, in most cases (98%), of two or three with no ovulation yielding more than three. Suffolk ewe lambs usually had one or two ovulations (95%). About 95% of the Booroola crosses had one record of an ovulation rate of three or more ovulations over the three recorded estruses. Four S (15%) and 9 FL (69%) had more than two ovulations. Ovulations at breeding (third estrus) were significantly higher ($P < 0.001$) in Booroola crosses (3.8 and 3.3 for BFL and BS) than in FL and S (2.2 and 1.7).

Reproductive Performance

Conception rate (Table 1), defined as the percentage of females that lambed or aborted after the first mating, was not different ($P > 0.78$) between genetic groups and was relatively high (over 85%) for all genotypes. Only two females (1 BS and 1 S) aborted and were excluded from subsequent analyses. Gestation was significantly longer ($P < 0.02$) in BFL ewe lambs (144.2 d) than in S and FL (143.0 and 142.3 d, respectively), BS being intermediate (143.4 d). Overall, embryonic mortality (Table 3) was higher ($P < 0.001$) in Booroola crosses (32.8 and 31.0% for BS and BFL) than in S (12.8%), FL being intermediate (23.8%). Embryonic mortality increased significantly at higher ovulation rates ($P < 0.01$) while no effect of genetic groups was found ($P > 0.70$). For the same ovulation rate, no differences in embryonic mortality were observed between BFL and BS (Table 3). With three and four ovulations, embryonic losses were respectively 33.3% and 22.2% in BFL compared to 30.0% and 37.5% in BS. In FL and S with two ovulations, no statistical difference in ovum mortality was found. Not taking genetic group into account, the overall correlation between the number of ovulations at breeding and embryonic loss was +0.50 (n=77, $P < 0.001$).

Litter size at birth (Table 1) was larger ($P < 0.001$) in Booroola crosses (2.5 and 2.1 for BFL and BS) than in purebred (1.6 and 1.3 for FL and S). Litter weight at birth was

Table 2. Distribution of ovulation rate over their first three estruses, including puberty, in Booroola × Finnish Landrace (BFL), Booroola × Suffolk (BS), Finnish Landrace (FL) and Suffolk (S) ewe lambs

Genetic group	Estrus	n	Ovulation number 1	2	3	4	5	6	7	Mean‡
BFL	1	19	—	5 (26.3)†	5 (26.3)	7 (36.8)	2 (10.5)	—	—	3.3 ± 0.2a
	2	19	—	4 (21.1)	6 (31.6)	8 (42.1)	1 (5.3)	—	—	3.3 ± 0.2a
	3	19	—	1 (5.3)	7 (36.8)	8 (42.1)	2 (10.5)	—	1 (5.3)	3.8 ± 0.2a
BS	1	20	1 (5.0)	6 (30.0)	7 (35.0)	6 (30.0)	—	—	—	2.9 ± 0.2a
	2	18	—	3 (16.7)	8 (44.4)	7 (38.9)	—	—	—	3.2 ± 0.2a
	3	18	—	3 (16.7)	9 (50.0)	4 (22.2)	2 (11.1)	—	—	3.3 ± 0.2a
FL	1	14	1 (7.1)	6 (42.9)	7 (50.0)	—	—	—	—	2.4 ± 0.2b
	2	14	—	8 (57.1)	6 (42.9)	—	—	—	—	2.4 ± 0.1b
	3	13	—	11 (84.6)	2 (15.4)	—	—	—	—	2.2 ± 0.1b
S	1	31	11 (35.5)	19 (61.3)	1 (3.2)	—	—	—	—	1.7 ± 0.1c
	2	32	12 (37.5)	18 (56.3)	1 (3.1)	1 (3.1)	—	—	—	1.7 ± 0.1c
	3	28	11 (39.3)	15 (53.6)	2 (7.1)	—	—	—	—	1.7 ± 0.1c

†Number of ewes (percentage within the same genetic group and estrus).
‡Mean ± standard error.
a–c Means with different letters between genetic groups within an estrus differ significantly ($P < 0.05$).

Table 3. Embryonic mortality (%) and its relation to ovulation rate in Booroola × Finnish Landrace (BFL), Booroola × Suffolk (BS), Finnish Landrace (FL) and Suffolk (S) ewe lambs

Genetic group	Ovulation number 1	2	3	4	5	6	7	Overall mean
BFL	—	25.0 ± 25.0 (2)†	33.3 ± 14.9 (5)	22.2 ± 7.7 (9)	50.0 ± 10.0 (2)	—	71.4 (1)	31.0 ± 6.2*a* (19)
BS	—	0.0 ± 0.0 (2)	30.0 ± 7.8 (10)	37.5 ± 7.2 (4)	70.0 ± 10.0 (2)	—	—	32.8 ± 6.1*a* (18)
FL	0.0 (1)	27.3 ± 7.9 (11)	16.7 ± 16.7 (2)	—	—	—	—	23.8 ± 6.7*ab* (14)
S	0.0 ± 0.0 (11)	15.4 ± 6.7 (13)	66.7 ± 0.0 (2)	—	—	—	—	12.8 ± 4.7*b* (26)

† Mean percentage ± standard error (no. of ewe lambs).
a,b Means with different letters differ significantly ($P < 0.05$).

6.3, 6.3, and 6.0 kg for BS, S and BFL ewes, respectively, compared to 4.6 kg for FL ewes ($P < 0.001$). That difference was still significant after adjustment for litter size. Mortality at birth was higher for progeny from BFL (23.7%, $P < 0.001$) than from BS, FL and S (6.5, 0.0 and 0.0%, respectively). For the same number of lambs born, no differences of mortality at birth were observed between BFL and BS, nor between FL and S. At weaning, BS had higher ($P < 0.02$) litter size (1.9) than S purebred (1.3) while BFL and FL (1.8 and 1.5, respectively) did not significantly differ from BS and S.

Litter weight at 50 d (Table 1) was heavier ($P < 0.001$) in S and BS (29.0 and 26.7 kg) than in BFL and FL ewe lambs (23.6 and 23.3 kg). Adjusted for the number of lambs raised per ewe (averaging 1.7, 1.6, 1.5 and 1.3 for BS, BFL, FL and S, respectively), S ewe lambs weaned the heaviest litters. The total weight of halfbred Hampshire lambs (at 100 d of age) produced by each genetic group was not different, although FL had a tendency to produce less (55.8, 54.5 and 51.6 kg for BS, BFL and S, respectively vs. 44.9 kg for FL, $P < 0.09$).

Growth Performance of the Hampshire-sired Crossbred Lambs

Table 4 indicates that H × S lambs were heavier at birth (4.6 kg, $P < 0.001$) than H × BS and H × FL (3.0 and 2.9 kg), H × BFL being the lightest (2.4 kg). Lamb weight at birth was significantly ($P < 0.001$) influenced by litter size but not by sex ($P=0.17$). Weaning weight was highest ($P < 0.001$) in H × S lambs (22.2 kg). Analogous differences in liveweight were observed at 100 d of age (38.8 kg for H × S vs. 30.4, 29.5 and 29.0 kg for H × FL, H × BS and H × BFL, respectively). Female lambs and lambs born in larger litters had reduced ($P < 0.01$) weight at 50 d. The number of lambs left with their dam only tended ($P < 0.08$) to affect the weight at 50 d. Female lambs had a significantly ($P < 0.001$) lower weight at 100 d. Average preweaning daily gain was 349.9 g d^{-1} for H × S compared to 267.4, 249.5 and 246.8 g d^{-1} for H × FL,

Table 4. Growth traits of Hampshire (H) sired lambs from Booroola × Finnish Landrace (BFL), Booroola × Suffolk (BS), Finnish Landrace (FL) and Suffolk (S) ewes

Genetic Group	Weight at birth (kg)	Weight at 50 d (kg)	Weight at 100 d (kg)	ADG† 0–50 d ($g\ d^{-1}$)	ADG 50–100 d ($g\ d^{-1}$)
H × BFL	2.4 ± 0.1*c*(48)‡	15.2 ± 0.6*b*(28)	29.0 ± 0.9*b*(28)	249.5 ± 10.1*b*	276.8 ± 7.3*b*
H × BS	3.0 ± 0.1*b*(38)	15.5 ± 0.5*b*(31)	29.5 ± 0.7*b*(30)	246.8 ± 8.6*b*	281.8 ± 8.1*b*
H × FL	2.9 ± 0.2*b*(22)	16.3 ± 0.9*b*(20)	30.4 ± 1.1*b*(20)	267.4 ± 14.7*b*	281.2 ± 12.4*b*
H × S	4.6 ± 0.1*a*(35)	22.2 ± 0.6*a*(34)	38.8 ± 0.9*a*(34)	349.9 ± 11.0*a*	332.1 ± 13.1*a*

† ADG: average daily gain.
‡ Mean ± standard error (no. of lambs recorded).
a-c Means in the same column with different letters differ significantly ($P < 0.05$).

H × BFL and H × BS lambs, respectively ($P < 0.001$). Significant effects ($P < 0.05$) of litter size and sex of lamb on ADG 0–50 d were detected. Again, H × S lambs obtained the highest ADG ($P < 0.001$) between 50 and 100 d (332.1 g d^{-1}), the other genetic groups being statistically similar at 281.8, 281.2 and 276.8 g d^{-1} for H × BS, H × FL and H × BFL, respectively. Lamb survival rates were very high during all growing periods; one H × FL lamb died before weaning and one H × BS lamb between 50 and 100 d.

DISCUSSION

In the only other report on Booroola × Finnish Landrace crossbreeding, Young et al. (1988) found that first estrus occurred in BFL at 189 d of age, much younger than what was observed here (232.9 d). Correspondingly, purebred FL attained puberty earlier (183 d) than in the present study (211.3 d), indicating possible local environmental factors affecting sexual maturity. For purebred FL and S, age at first estrus was in agreement with values reported by Dyrmundsson (1973) and Chiquette et al. (1984). In the present study, the introduction of Booroola into FL and S could not reduce age at puberty. Only FL purebreds were younger at puberty. Since BS and BFL ewes reached puberty at the same age as S purebred, the *F* gene does not appear to be associated with early puberty, thereby confirming the report of Montgomery et al. (1985).

Ewe lambs with S genotype background (BS and S) were the heaviest at all stages of development from birth to mating while FL genotypes were the lightest. Liveweight seems to depend mostly on genetic background, with the FL genotype leading to a lighter weight.

Mean ovulation rates for the first three estruses recorded for BFL (3.5) and BS (3.1) ewe lambs were +1.2 and +1.4 higher than for purebred FL and S, respectively, confirming that the *F* gene was expressed in FL and S genotypes. Since this experiment is the first to report results on Booroola × Suffolk crossbreeding, it was not possible to compare with other works, but the increase in ovulation rate was similar to that observed in Booroola crossed with other nonprolific breeds (Romney: Montgomery et al. 1985; Merino and Coopworth; Piper et al. 1985). For BFL, our results differ from Young et al. (1988) who reported a difference of only +0.44 ovulation in favor of BFL compared to purebred FL while the ovulation rate of the FL ewe lambs was similar (2.1) to our finding. Differences in number of ovulations between purebreds and crossbreds in our experiment are closer to those reported between F gene carriers and non-carriers in most experiments (Montgomery et al. 1985; Davis et al. 1984). To discriminate between carriers and non-carriers, better control ewe lambs would involve BFL and BS of genotype ++, but such crosses were not available for the present study. However, knowing the low prolificacy of mature Booroola Merino ++ ewes (1.4 reported by Montgomery et al. (1985)), it is fairly safe to presume that BFL and BS non-carriers of the *F* gene (++) would have an ovulation rate distribution in which three ova shed per ovulation would be a rare event. This was demonstrated with a nonprolific recipient breed in the experiment of Montgomery et al. (1985), where the mean ovulation rate of 1.5-yr-old Booroola × Romney *F*+ (2.7) was higher than the value for ++ (1.4), which was similar to the natural Romney purebred ovulation rate (1.5 reported by Davis and Hinch (1985)). The clear distinction between carriers and noncarriers has also been observed in crosses involving a prolific recipient breed by Bodin (1988) who compared *F*+ and ++ Booroola × Romanov ewe lambs. The mean and distribution of ovulation rate of Booroola × Romanov *F*+ (3.5 at the third estrus and 95% of the ewe lambs having at least one ovulation with three ova shed in three recorded cycles) was similar to those observed for Booroola × Finnish Landrace F+ in our experiment. In the study by Bodin (1988), only one female (out of 17) Booroola × Romanov ++ showed more than three ova shed in four recorded estruses. Purebred Romanov ewe lambs have a mean ovulation rate of 2.5 (Ricordeau et al. 1982) which is similar to the value of 2.3 we report for FL. Thus, the criterion of at least one ovulation yielding more than three ova for distinguishing F+ ewe lambs from ++ animals would appear to be appropriate for both FL and S as background genotype.

Embryonic mortality is associated with the number of ova shed (Bindon et al. 1980; Hanrahan 1980, 1986). This pattern of ova wastage was similar in the present experiment since a correlation of +0.50 was found between the number of ovulation at breeding and embryonic mortality. Our results indicate that embryonic losses were related to ovulation rate rather than genetic groups. This finding supports the observation that classification of carriers of the F gene based on litter size is less precise than ovulation rate because of the high embryonic losses in ewes with high ovulation rates (Piper et al. 1985). However, in our study, at equivalent ovulation rates, there was no difference in ovum mortality between genetic groups for ewe lambs having four ovulations for which BFL tended to have lower embryonic losses compared to BS (37.5 vs. 22.2%). However, these percentages were much lower than the value of 68% for ova loss reported by Bindon et al. (1980) for an ovulation of four in mixed-age Booroolas. Overall, embryonic loss observed in BFL (31.0%) and FL (23.8%) corresponds well to the values found for the same genetic groups by Young et al. (1988), although mean ovulation rate for BFL in the present work was much higher than in the latter study. For S shedding two ova, embryonic mortality (15.4%) was similar to the estimate of 18.0% by Hanrahan (1980). It is not known if poor ova survival observed in Booroola-cross ewe lambs is related to early mating as previously pointed out by other studies in different breeds (Quirke and Hanrahan 1977; McMillan and McDonald 1985) or if it is independent of age at breeding as found in Romanov (Ricordeau et al. 1982). The embryonic mortality pattern observed in Booroola crosses does not seem to differ from the one observed in most breeds (Hanrahan 1980) and carriers of the *F* gene were not different for that trait.

Mean litter size at birth was increased by +0.9 and +0.8 lamb in BFL and BS ewe lambs compared to FL and S. Litter size from these control females was similar to those reported for females of the same breeds lambing at 1 yr of age (Oltenacu and Boylan 1981; Chiquette et al. 1984). Difference in litter size observed in the present study between BFL and FL ewe lambs was much higher than the value of +0.16 found by Young et al. (1988). However, in their experiment, the difference was calculated among mixed-age ewes with a mean litter size of 2.49 for FL, which is far higher than the value of 1.6 for our experiment. As mentioned already with ovulation rate, females carrying the *F* gene lambed about one more lamb than purebred females. A similar difference was reported in most experiments comparing F+ and ++ (Piper et al. 1985; Davis et al. 1984).

High mortality at birth (around 24%) for lambs from BFL females caused a marked decrease in litter size at weaning. Those losses appear to be related to the increased proportion (58%) of litters of three and four lambs in BFL compared to BS where 84% of the ewes gave birth to two or three lambs. All FL and S lambs survived (93% and 100% of FL and S litters consisted of only one or two lambs). Dyrmundsson (1973) stated that high perinatal loss is a major problem associated with breeding ewe lamb and that litter size is probably the main factor responsible for losses among progeny of ewe lambs. In BFL mixed-age ewes, Young et al. (1988) reported a mean value of 1.99 lambs at weaning compared to 1.98 for FL purebred. From our study, it is not possible to ascertain if losses at lambing were the consequence of early breeding of ewe lambs or of multiple births *per se*.

It was not surprising to observe that BS and S ewe lambs weaned heavier litters, since the Suffolk breed is known for good growth performance in addition to high weight at birth. Overall productivity expressed as kilograms of lamb produced per ewe showed little advantage of Booroola crosses over S purebreds but much greater superiority over FL purebreds. Higher lamb survival at birth, expected in mature ewes (Dyrmundsson 1973), would probably increase the productivity of Booroola crosses. Moreover, relatively low (FL) and normal (S) ovulation rates as compared to those reported for mature ewes (Dickerson and Glimp 1975; Oltenacu and Boylan 1981; Young et al. 1985; Fahmy and Dufour 1988) lead us to hypothesize that in mature ewes, the difference between Booroola crosses and FL would probably decrease while it would increase between Booroola crosses and Suffolk.

Low birthweight in lambs from BFL dams was associated with high lamb mortality, as observed earlier by Hinch et al. (1985) in mixed Booroola genotypes. Literature comparisons on growth traits such as weaning weight or average daily gain are difficult due to the differences in age at weaning and lamb management. Nevertheless, our results showed that lambs from H × S crossbreeding obtained the best growth performance, as expected since both parental breeds have excellent growth (Sidwell and Miller 1971; Rastogi et al. 1975). The differences in preweaning growth rate between H × S lambs and other crosses (about 90 g d^{-1}) can be explained partly by the higher proportion of S ewe lambs rearing only one lamb (69%). However, the difference in ADG remains to about 50 g d^{-1} for H × S lambs during the postweaning period. The remaining genetic groups showed similar performance. The results for the H × BFL and H × FL lambs contrast with other reports that noted a lower growth performance of Finnish Landrace crossbreds (Dahmen et al. 1979; Notter and Copenhaver 1980).

Overall, data show little advantage in terms of kilograms of lamb produced per ewe between Booroola crosses and purebred ewe lambs. Our results present performance of ewe lambs and only allow us to speculate on what could be expected in mature ewes. Since adult ewes have better lambing performance (Dyrmundsson 1973), mature BS and BFL ewes would probably have decreased losses at lambing and would have raised more lambs, thereby increasing the difference in productivity between females carrying the *F* gene and control purebreds. However, it remains to be demonstrated that this increase in productivity would be enough to offset the increased costs associated with the additional lambs (labor, milk replacer, etc.). This could be achieved by comparing the genotypes in an intensive management system over several years.

To conclude, the incorporation of the *F* gene in prolific (FL) and nonprolific (S) background genotypes increased ovulation rate and litter size. However, with increased multiple births, lamb survival became a major problem in ewe lambs Booroola crosses. Consequently, there was no significant advantage in terms of kilograms of lamb produced per ewe between Booroola crosses and purebred ewe lambs.

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