PERFORMANCE OF RAMBOUILLET AND CROSSBRED EWES UNDER PRODUCTION CONDITIONS OF THE SOUTHERN GREAT PLAINS

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CHAPTER I

INTRODUCTION

The major products of a sheep production enterprise are meat and wool. The relative importance of each product will depend on the production environment and the genetic resources available to the sheep producer. In Oklahoma, meat production is primary to wool production because of the availability of quality forage throughout the year. Wool production is more important under extensive range conditions that exist in Texas and the western United States.

Efficiency of production in sheep is of prime importance. The sheep industry needs to improve its efficiency of production in order to remain viable and compete with other enterprises for scarce resources and expensive land. Sheep offer a great potential for increasing productivity and efficiency because of their capacity to twin, largely through exploitation of breed diversity and genetic variation (Fogarty, 1984). In order to improve the efficiency of the flock, reproductive rate, lamb growth and survival must be increased. Most reproductive traits are lowly heritable, therefore genetic progress made through selection is slow but permanent. Crossbreeding could be a useful method to complement any selection efforts to improve reproductive traits (Sidwell et al., 1962). Crossbred sheep are known to have higher fertility, prolificacy and lamb livability than purebreds. Of practical significance, however, is the question of the higher mortality rates that are usually associated with the lower lamb birth weights of highly prolific breed types (Donald et al., 1968). Increased milk production, body weights and wool production have also resulted from crossbreeding (Terrill, 1958). Reproductive rate not only affects the number of lambs born and the frequency of birth, but also the time when lambs are born. This also has some important economic significance. One month difference in lambing date can often mean several cents per kilogram difference in sale price (Hulet, 1968). For any sheep production enterprise to be profitable, genetic improvement should be matched by improved nutrition, disease prevention and control as well as sound management of the whole flock. The Booroola Merino and Finnish Landrace are breeds noted for extraordinary prolificacy. The different genetic mechanisms controlling prolificacy in the Booroola Merino and Finnish Landrace offer different opportunities for the development of breeding programs to increase reproductive rate in sheep (Young and Dickerson, 1991).

The present study utilized sire breeds noted for prolificacy in crossbreeding with the Rambouillet (a standard maternal breed) in order to increase reproductive rate. Other sire breeds are used for terminal crossing to increase growth rate and meat production. The first objective of this study was to compare productivity in Rambouillet ewes joined to either Booroola Merino (BM), Dorset (DS) or Finnish Landrace (FN) rams. The second objective was to compare ewe performance of Rambouillet crossing with Booroola Merino, Dorset and Finnish Landrace rams.

CHAPTER II

LITERATURE REVIEW

Prolific Breeds and Strains of Sheep

Prolificacy is defined as the number of offspring per pregnancy. It is a major determinant of reproductive rate in sheep. Bindon and Piper (1986) reiterated that the subject of prolificacy is of interest to animal geneticists since this characteristic is known to respond to selection within breeds and is seen to vary markedly between breeds. Sheep breeds differ greatly in levels of performance for economically important traits as well as in prolificacy. The differences among breeds are genetic in nature and can be exploited rapidly and effectively to increase profits in the sheep industry. The efficiency of meat production by sheep could also be increased in the number of lambs marketed per ewe (Notter and Copenhaver, 1980a). Such a change could be realized by an increase in the number of live lambs born and weaned per ewe lambing, by an increase in the number of lambing per ewe per year or by a combination of the two methods. The number of lambs born per ewe lambing can be increased through the use of prolific sheep breeds and strains such as the Finnsheep (Donald and Reid, 1967) and the Booroola Merino (Turner, 1978; Piper and Bindon, 1982a) in crosses. The different genetic mechanisms controlling prolificacy in Finnsheep and Booroola Merino offer different opportunities for the development of breeding programs to increase reproduction rate in sheep flocks (Young and Dickerson, 1991).

The value of the prolific breeds as a genetic resource lies in the ability to bring about rapid increases in reproductive rate when crossed with other breeds. The prolific breeds of sheep are being used in many countries to improve productivity in both intensive and extensive agricultural systems (Bindon and Piper, 1986). Table I shows the best estimates of ovulation rate and litter size of the major prolific breeds of sheep. This part of the literature review will focus on the two most important prolific sheep breeds or strains in Oklahoma, namely: the Finnsheep and Booroola Merino. These breed and strain of sheep, respectively, are also part of the study in this thesis.

TABLE I

ESTIMATES OF OVULATION RATE AND LITTER SIZE OF THE MAJOR PROLIFIC BREEDS OF SHEEP

	Estimation of:			
	Ovulation rate		Litter size	
Breed	Mean	Range	Mean	Range
Finnsheep	3.5	1-9	2.6	1-7
Romanov	3.4	1-7	2.6	1-5
D'Man	2.8	1-8	2.1	1-6
Booroola Merino	4.2	1-11	2.5	1-7

Source: Bindon, B. M. and L. R. Piper, 1986. Oxford Reviews of Reproductive Biol. 8:414-451.

Finnsheep

This breed is also known as the Finnish Landrace or Finn. It originated in Finland in a region of rugged hill pastures and severe winters. Finnsheep are polled, with no wool on the face and legs. The conformation of the Finn is generally lacking in muscling. Pure

Finns may produce as many as five to six lambs per litter, with an average litter size of 2.5 lambs per litter (Maijala, 1977). It has a reputation not only for extraordinary prolificacy, but also for hardiness of lambs and mothering ability of ewes. These are the reasons why Finnsheep have since been imported into many countries (Maijala, 1969). Finnsheep were first brought to the United States in 1968 as a possible source of germ plasm for improving reproduction rate of commercial sheep flocks. Subsequent research in the United States has shown that for every 1% increase in Finnsheep breeding in the ewe there was approximately a 1% increase in the number of lambs born per ewe lambing (Dickerson, 1977).

Several workers world wide have compared productivity and performance of purebred and crossbred ewes of Finnsheep with other breeds and strains of sheep. Young and Dickerson (1991) have investigated productivity of Finnsheep and crossbred ewes mated to Booroola Merino and Finnsheep rams. Their findings were that Booroola Merino x Finnsheep ewe lambs had larger litters than Finnsheep ewes (due to a substantially higher ovulation rate and litter size) and Finnsheep rams produced lambs with more desirable level of performance than did Booroola Merino rams.

Land et al. (1974) reported data on reproductive performance of 20 Finnsheep and 20 Merino ewes for a four-year period. Each year, both breeds of ewes were mated to both Finn and Merino rams. Ewes of both breeds averaged four years of age at the beginning of the study. Average litter size was greater for the Finnsheep ewes (2.9) than for the Merinos (1.0). Also, a greater number of the Finnsheep ewes lambed (100% vs 85% for the Merinos).

In a different study, Notter and Copenhaver (1980a) reported the performance of 71 1/2-Finnish Landrace, 1/2-Rambouillet (1/2-Finn) ewes; 92 1/4-Finnish Landrace, 3/4-Rambouillet (1/4 Finn) ewes and 20 1/2-Suffolk, 1/2-Rambouillet ewes, which were compared over a five-year period while lambing three times in August, November and April. Conception rates in August (90%), November (79%) and April (53%) differed. In

April, conception rates for 1/2-Finns (60%) were higher than those for 1/4-Finn (45%) or 1/2-Suffolk, 1/2-Rambouillet ewes (38%). Litter size in January (2.21), April (2.46) and September (1.84) differed. Among ewes that entered the study, 1/2 Finns gave birth to 42% more lambs and weaned 24% more kilograms of lamb than did 1/4-Finn. Similarly, the 1/2-Finns gave birth to 52% more lambs and weaned 38% more kilograms of lamb than did 1/2-Suffolk, 1/2-Rambouillet ewes.

Female reproductive traits were studied by Oltenacu and Boylan (1981a) in four pure breeds (the Finnsheep, Suffolk, Targhee and Minnesota 100), the F_1 crosses between Finnsheep rams and females of other three breeds and F_2 and backcross ewes. Lambing and weaning rates were measured in a total of 1,030 parturitions of one to three-year old ewes over three years. Purebred Finnsheep ranked highest of all pure breeds and crosses for precocity of sexual development (percentage of ewe lambs lambing at 12 mo of age), lambing rate and weaning rate. Finnsheep lambs had moderate perinatal mortality, but lambs that were born alive had an excellent survival rate to weaning (97,5%), superior to that of Targhee (85.2%), Minnesota 100 (78.9%) or Suffolk (76.8%). In the same experiment, Oltenacu and Boylan (1981b) investigated birth and weaning weights for purebred Finnsheep, Suffolk, Targhee, Minnesota 100 and their crosses. Finnsheep lambs were the smallest of all lambs at birth, but ranked second among purebreds in 70-d weaning weight (Suffolk, 21.0 kg vs Finnsheep, 17.6 kg). Ewe body weight, grease fleece weight and total adjusted weight of weaned lamb were compared among purebreds and crossbreds. The Finnsheep was the smallest pure breed, yielded the lightest fleeces, but produced the heaviest total weight of weaned lamb. Ewe index was calculated as the total adjusted (male, 70-d equivalent) weight of weaned lamb plus three times the grease fleece weight. The ranking of purebreds was Finnsheep, Targhee, Suffolk and Minnesota 100.

Several US sheep breeds along with Finnsheep were evaluated in a crossbreeding program at the US Meat Animal Research Center (USMARC), Clay Center, Nebraska and several other experiment stations in the US. In his review, Dickerson (1977) noted that the use of 1/2-Finnsheep crosses with such breeds as Dorset, Suffolk, Targhee or Rambouillet as commercial ewes mated with meat breed sires, can reduce ewe costs per pound of market lamb by 20 to 25% compared to the use of 1/2-Rambouillet x domestic US breed crossbred ewes. The 1/2-Finnsheep crossbred ewe lambs were reported to begin lambing at one year and produce at least 50 more live lambs/100 ewes per year. More of the lambs from 1/2-Finnsheep ewes were twins or triplets and averaged 2.2 to 2.7 kg lighter at 10 wk, but livability, post weaning gain and carcass yield and grade at the same slaughter weight, closely approached that for lambs from 1/2-Rambouillet ewes. Furthermore, the crossbreeding studies indicated that under poor range conditions and with severe climatic exposure at lambing, 1/4-Finnsheep ewes may raise nearly as many lambs as 1/2-Finnsheep ewes. However, 1/2-Finnsheep ewes performed better under adequate nutrition and good management.

Bunge et al. (1993a) compared the effects of breed of service sire on lamb production of Suffolk and Targhee ewes. The sires were Finnsheep, Combo-6, Booroola Merino, St. Croix and Barbados. The effects of year, age, age of ewe, sex of lamb, breed of ewe and breed of service ram on fertility, prolificacy, lamb survival and lamb weaning weight were estimated. Ewes mated to St. Croix and Barbados rams had higher fertility rates than ewes mated to Finnsheep rams. Lambs sired by Barbados, Finnsheep and St. Croix rams had higher survival rates to weaning than lambs sired by Booroola Merino rams. The heaviest lambs at weaning were those sired by Finnsheep and Combo-6 rams.

Nitter (1975) has presented results from a comprehensive crossing experiment in West Germany comparing six meat sire breeds and ewes of five 1/2-German Merino crosses, including Finn x Merino. Comparisons were made over three years under both accelerated lambing without hormones and artificial lamb rearing from birth, and conventional spring lambing systems. The 1/2-Finnsheep ewes outperformed other crosses by .2 to .3 in frequency of lambings/year, by 25 to 45 lambs reared artificially from birth but not significantly in lambs reared to normal weaning at five to eight weeks.

Production data of yearling Targhee or Finn-Dorset-Targhee ewes managed as a farm or range flock were evaluated by Iman and Slyter (1993) in South Dakota. A total of 681 animals comprising of 207 purebred Targhee and 474 1/4Finn-1/4Dorset-1/2Targhee crossbred ewes were included in the study. The 1/4Finn-1/4Dorset-1/2Targhee ewes had higher prolificacy (1.93 vs 1.45 lambs) than the Targhee ewes. No differences in lamb survival were detected. However, Targhee ewes had heavier lambs at birth (5.2 vs 4.0 kg) and weaning (26.1 vs 23.4 kg) and produced more wool (3.8 vs 3.2 kg). Although Finn-Dorset-Targhee ewes had lighter lambs at weaning, these ewes weaned 5.8 kg more total lamb weight per ewes weaned more lambs per ewe exposed (1.46 vs 1.09 lambs). Finn cross ewes performed equally well under the two management systems.

Season of lambing and other environmental effects on ewe performance were studied by Fogarty et al. (1984a) and analyzed for purebred Finnsheep (F), Rambouillet (R), Dorset (D), Targhee (T) and Suffolk (S) and the generations of crosses in development of two maternal composite lines (1/2F-1/4R-1/4D) and (1/2F-1/4T-1/4S) in accelerated or annual April lambing. The data involved 10,959 ewe breeding season records for 4,219 ewes of 412 sire families over four years. Fertility of Finn and Finn-cross ewes was significantly higher for May and lower for January lambings relative to Rambouillet and Dorset ewes. Litter size also was higher in annual April (1.9) than in January (1.8) or May (1.7) and September (1.4). Neonatal and preweaning survival was higher in September when litter size was smaller. In the same study, Fogarty et al. (1984b) compared ewe performance of the sheep breeds described above. Ewe production and the components (fertility, litter size, neonatal and preweaning lamb survival and mean lamb weaning weight) were adjusted for age and standardized across season of lambing and years. The Dorset and Finnsheep ewes produced more weight of lamb/ewe exposed than Rambouillet, Suffolk and Targhee ewes because of higher Dorset and Finnsheep fertility, higher Dorset lamb survival and larger Finnsheep litters. Preweaning survival of suckled and nursery lambs was low for Finnsheep and Suffolk and positive heterosis ranged from 9 to 19% in crosses. Mean lamb weaning weights were highest for Suffolk, lowest for Finnsheep, with little heterosis in crosses.

Evaluation of Finnsheep and their crosses was conducted by Olthoff and Boylan (1991) to determine their potential in commercial sheep production. Traits recorded included birth weight, 70-d adjusted weaning weight, age at a constant market weight, pre- and post-weaning daily gain in 468 lambs. Breeds included purebred Finn, Suffolk, Targhee and Dorset, F_1 Finn crossbreds, and multiple crosses from crossbred Finn ewes mated to Suffolk, Targhee, Dorset and Lincoln rams. Purebred Suffolk lambs consistently ranked first for all traits, followed by Targhee, Dorset and Finn lambs. Performance of F_1 crossbreds was similar among sire breeds. The authors did not recommend any specific sire breed based on their study results, however, they speculated that in terminal sire production system, using 1/2 or 1/4 Finn crossbred ewes would take advantage of increased reproductive capacity in the ewe.

Booroola Merino

The Booroola Merino is one of the most prolific sheep breeds in the world. It has excellent fleece characteristics and it is also known for hardiness, longevity and flocking instinct. The Booroola strain of Merino sheep was developed by the Seears brothers near Cooma in New South Wales, Australia, and later by the Common Wealth Scientific and Industrial Organization (CSIRO) Divisions of Animal Genetics and Animal Production (Turner, 1982). The high prolificacy of the Australian Booroola Merino is due to a major gene (Fec^B) that increases the ovulation rate in sheep (Piper et al., 1985). The mode of action of the postulated gene appears to be additive for ovulation rate but may be almost completely dominant for litter size (Piper and Bindon, 1982b). This single gene theory is now commonly accepted as the mechanism for increased reproduction in the Booroolas. Individual sheep can have 0, 1, or 2 copies of the Booroola gene. Introduction of this gene into other sheep breeds can bring about a relatively rapid improvement in their prolificacy. Due to the unique characteristics of the Booroola Merino it is most suitable in the production of first-cross commercial ewes (Allison et al., 1982; Leymaster, 1989; Walkley et al. 1984). Such ewes would have one copy of the gene and an increased ovulation rate relative to the other breed(s) used in the formation of the cross.

Utilization of the Booroola Merino as a genetic resource was in the past confined to Australia and New Zealand now it is of potential for the improvement of sheep reproduction in many other countries including the United States. As such the reproduction and performance of the Booroola Merino and its crosses have been studied extensively in comparison with other breeds of sheep. This part of the literature review will focus on some of the world wide studies which were conducted to evaluate reproduction and productivity of the Booroola Merino and its crosses in comparisons with other breeds and strains of sheep.

Gootwine et al. (1993) compared Booroola Merino with Assaf sheep in Israel. Inheritance of birthweight and growth traits were evaluated. Assaf lambs had the highest and 3/4 Booroola had the lowest birthweights. A negative relationship was found between the birthweight and proportion of Booroola blood in the lamb and its mother. Assaf, 3/4 Assaf, F_1 and 7/8 Assaf ram lambs did not differ in their postweaning growth rate and in their 150 d weight. A similar situation was found among ewe lambs except for F1 ewe lambs which were smaller than Assaf ewe lambs at 150 d. The authors attributed this to sex-linked effects on growth in the Booroola-Assaf crosses.

Ovulation rate and lambing results were investigated by Robertson (1979) in Booroola and Booroola-cross ewes in Western Australia. Rams from Merino Booroola strain, which had been selected for high fertility and fecundity, were mated to unselected Merino ewes in commercial flocks to produce Booroola-cross ewes for comparisons with ordinary Merino ewes. The Booroola and Booroola-cross ewes had similar numbers of lambs born per ewe mated (1.19 and 1.36). Laparascopic examination of ovulation rates were 1.95 and 1.81 in maiden Booroola and Booroola-cross ewes, respectively, and 1.06

in contemporary control ewes. These results suggested that the use of Booroola rams could be the simplest and most effective means yet available of rapidly achieving high lambing rates in Australian Merino and indeed in any other breed used in crosses.

Castonguay et al. (1990) investigated reproductive performance of Booroola x Finnish Landrace and Booroola x Suffolk ewe lambs which were heterozygous for the F gene. Growth rate for their three-way cross lambs were also studied. Finnish Landrace lambs reached puberty earlier (211.3 d) than the other genetic groups (237.8, 233.0 and 232.9 d for Suffolk, Booroola x Suffolk and Booroola x Finnish Landrace x Suffolk, respectively) whereas weight at puberty was lower for Booroola x Finnish Landrace and Booroola x Suffolk (36.8, 36.7 and 47.0 kg, respectively) than for Suffolk (61.1 kg). The corresponding litter size at birth reflected a higher embryonic loss in the Booroola crosses. This scenario confirms reports by Walkley et al. (1984). Overall productivity in terms of kilograms of lamb produced showed a slight, non-significant advantage for Booroola-cross ewe lambs (55.8 and 54.5 kg for Booroola x Suffolk and Booroola x Finnish Landrace) over purebred Suffolk (51.6) and Finnish Landrace (44.9). From this study it is evident that ovulation rate and litter size can be increased by incorporating the F gene in both prolific Finnish Landrace and non-prolific Suffolk genotypes.

Walkley et al. (1984) also studied female reproduction characteristics in high fecundity Merino crosses with South Australia Merino. There were differences between the strains in ovulation rate and litter size but no significant differences in number of lambs weaned. An assessment of the effect of the F gene on aspects of reproductive traits indicated that reproductive wastage between ovulation and birth may negate the superiority in ovulation rate due to the F gene.

Davis and Armstrong (1984/1985) reported that one copy of the Booroola gene increased ovulation rate by 1.51 and litter size by 1.15. Two copies of the gene increased ovulation rate and litter size by 2.88 and 1.69, respectively. Owens (1984/1985) reported similar results on prolific Booroola Merino sheep in Tara Hills, New Zealand. Mean litter size was 2.7 (range 1 to 6) with 60% of ewes lambing producing three or more lambs while the industry based control ewes had a mean litter size of 1.2 lambs.

McNatty et al. (1984/1985) conducted a study to determine the underlying mechanisms which allow Booroola ewes to ovulate three or more ova at estrus. The study demonstrated that in Booroola ewes (five to eight years of age) the basal levels of adenosine cyclic 3', 5-monophosphate or cyclic AMP (a key intracellular messenger promoting steroid synthesis in ovarian cells) were higher in small ovarian follicles (0.1 to 1.0 mm diameter) from ewes with the F gene compared to those levels in follicles from ewes without the F gene. Moreover, the proportions of small follicles from F-bearing ewes which responded to pituitary hormones in culture were greater than from ewes without the F gene. Also the number of potential ovulatory follicles from homozygous (FF), heterozygous (F+) or non-F-gene carriers ranged from 5 to 13, 2 to 4 or 1 to 2, respectively.

Davis (1985) investigated the transfer of Booroola gene to a commercial sheep breed in a New Zealand study. Booroola Merino x Coopworth sheep were produced with 50, 25 and 12.5% Booroola Merino inheritance. Eleven of the 505 Booroola Merinos were F+, and half of the 25 and 12.5% Booroola Merino were expected to be F+. For the three crossbred groups and purebred Coopworth ewes, liveweight at joining averaged 44.0, 48.9, 49.5 and 52.6 kg, respectively. Ovulation rate averaged 2.46, 1.77, 1.86 and 1.52. The proportion of crossbreds with 50, 25 and 12.5% Booroola Merino that had three or more ovulations at one observation was 41, 34 and 39%, respectively.

Mortality in lambs was investigated by Kleemann et al. (1988). The effects of litter size, premating /early pregnancy nutrition and sex of lamb on the causes of mortality in progeny of F+ Booroola x South Australian Merino ewes were examined. Litter size was 2.13 with lamb losses of 29, 47, 66 and 83% for singles, twins, triplets and quadruplets, respectively. Autopsy was conducted on 197 lambs and cause of death was categorized into six major groups (prenatal, dystocia, prolonged birth, starvation, starvation/CNS damage, other). Corresponding mortality percentages were 7.1, 9.1, 27.4, 8.6, 21.8 and 25.9. Mortality was influenced by litter size and nutritional treatment. The 'prolonged birth' category was of increasing importance as litter size increased. This result concurs with those of Hinch et al. (1986) and Beetson and Lewer (1985). The authors concluded from this study that causes of lamb mortality in progeny of F+ Booroola x South Australian Merino ewes are linked with nutritional events 4 to 8 mo prior to term and to variation in litter size.

Davis et al. (1983) studied the distribution of litter sizes within flocks at different levels of fecundity in Boorolas, Finnish Landrace, Finn crosses and two local breeds of sheep. Proportions of ewes having 1 to 4 lambs in 72 local breed flocks with mean litter sizes per ewe ranging from 1.07 to 2.30 were examined and compared with the proportions recorded in 12 groups of Booroola and eight groups of Finn type ewes. Below a mean litter size of 1.70, differences in litter size resulted from differences in the proportion of ewes having singles and twins. Mean litter sizes ranging from 1.70 to 2.30 were accompanied by changes in the proportion of ewes having singles and triplets while the proportion of ewes having twins or quadruplets showed no significant change. The proportions recorded in local breed flocks and groups of Finn-type sheep were similar over litter sizes of 1.70 to 2.30. Groups of ewes carrying one copy of the Booroola gene had more ewes with one, three and four lambs, but fewer ewes with twins, than the local flocks.

The effect of the F gene on ovulation rate and litter size is well documented by Piper et al. (1982b). However, Ponzoni et al. (1985) reported on the possible pleiotropic effects of the F gene on other economically important traits in high fecundity Booroola Merino sheep. Wool production and liveweight of Booroola x South Australian Merino rams classified as being offspring of FF, F+ or ++ Booroola sires were investigated. The final results showed no significant differences among sire genotypes in the various wool and liveweight characters. The results suggested that the F gene had no undesirable pleiotropic effects on the characters under investigation. Other workers have also found no effect of the F gene on any other traits (Bindon et al., 1982; Piper and Bindon, 1982c).

Factors Affecting Growth, Reproduction and Survival Rates in Sheep

Growth Traits

Growth traits are of economic importance to the sheep producer. The producer would prefer that lambs reach market weight as early as possible so that he could make some savings on feed costs. Traits associated with growth are, in general, considered to be of moderate heritability. Therefore any selection programs that emphasize growth rate can usually result in rapid genetic gains. Alternatively, genetic gains could be achieved through crossbreeding programs that utilizes sheep breeds that are noted for transmitting genes for high growth rate and efficiency. In Oklahoma the use of Suffolk and Hampshire breeds as terminal sires has been a common practice. However growth traits are also influenced by many non-genetic factors (environmental factors) and their interactions. This part of the literature review will focus on the effects of dam and sire genotypes as well as the non-genetic factors (sex of lamb, age of dam, year, season, type of birth-rearing) that influence growth traits in a sheep production environment

Effects of Ewe Genotype: The genotype of an individual is determined by inheritance of 50% of genes from the dam and the other 50% from the sire. Lamb growth rate prior to weaning is mainly influenced by milk production of the ewe as well as its genetic potential to efficiently utilize available nutrients for its growth and development. Sheep studies in the United States as well as in other countries, have been compared productivity of different sheep breeds under a wide range of production environments. Breed or genotype of the ewe has been noted to have a significant effect on growth traits of the lamb.

The most comprehensive sheep study is the one reported by Dickerson et al. (1972) in which seven breeds of sheep were compared in straightbred ram lamb growth and carcass characteristics. The breeds were Suffolk, Hampshire, Polled Dorset, Rambouillet, Targhee and Coarse Wool sheep. The study found that relative differences among breeds were quite significant and were consistent from birth to 26 wk. In relation to the general mean, Suffolks were 108% in weight at birth, 111% at 10 wk and 115% thereafter. Dorsets were 85% at all ages. Coarse Wool sheep, Targhee, Rambouillet and Hampshire lambs grouped between 100 and 102%. At weaning, the first three breeds were 106 to 102% and Hampshires were 96%; Corriedales were 104% at birth but only 95% at weaning and subsequently. Farid et al. (1977) compared native fat-tailed sheep in a crossbreeding program in Iran. Breed of dam had a significant effect on all growth traits. In this study, Karakul ewes produced heavier lambs at birth followed by Mehraban and Naeini sheep. Mehraban ewes weaned the heaviest lambs which were also the fastest growing both before and after weaning. In the same study, estimates of maternal effects showed that Naeini consistently had the poorest mothering ability, while Mehraban ewes showed the best mothering ability for weaning weight, final weight and daily gain. Castonguay et al. (1990) in a Canadian study, reported that growth performance of Hampshire-sired lambs from four genetic groups of ewes, showed that Hampshire x Suffolk lambs had the highest average daily gain in both preweaning and postweaning periods.

Effects of Ram Genotype: Breed differences are an important source of genetic diversity for the improvement of livestock production including sheep (Dickerson, 1969). In livestock species, the male animal is the most important source of genes for improvement in economic traits because of its greater reproductive capacity compared to the female animal. Likewise, selection differential for quantitative traits of economic importance is greater in the male than in the female. Several sheep studies conducted on a world-wide basis have demonstrated that the genotype of the sire has a significant influence on the performance of lambs in growth traits. The review of literature clearly demonstrates that the use of Suffolk and Hampshire as terminal sires in crossbreeding programs is desirable to increase growth rates and meat production per lamb marketed. Singh et al. (1967) compared rams from Suffolk, Hampshire and five strains of Minnesota sheep, for effects of breed of ram on lamb weights. Their findings showed that the Suffolk and Minnesota 106 rams produced significantly heavier lambs at birth than the Minnesota 100 rams. On the other hand, the Suffolk and Hampshire rams produced heavier lambs at weaning and the Minnesota 102, Minnesota 103 and Minnesota 107 rams produced significantly lighter lambs at weaning than the Minnesota 100. Trivedi et al. (1978) compared pre-weaning growth rates in Muzaffarnageri and its crosses with Dorset and Suffolk breeds. Their findings were that breed of sire had a significant on lamb growth. The Dorset and Suffolk crossbred lamb were .66 kg heavier than Muzaffarnageri lambs at birth , and 4.02 and 3.35 kg heavier at weaning respectively. Further, the Dorset cross-breds were better than Suffolk cross-breds at all ages studied. In other studies, Coop and Clark (1952), De Baca et al. (1956), Pattie and Donnelly (1962) and Seebeck (1965) reported improved lamb production by using Dorset and Suffolk breeds.

Burditt et al. (1988) did not find any significant effect of sire breed on lamb birth weight, but lambs sired by Dorset rams tended to be heavier than either Finn or Booroola Merino sired lambs. In the same study, however, breed of sire significantly influenced lamb weaning weight. Finn sired lambs were heaviest (20.6 kg) followed by Dorset (18.9 kg) and Booroola Merino (17.0 kg). Olthoff and Boylan (1991) compared the performance of lambs from purebred and crossbred Finnsheep ewes. Their findings showed that Suffolk-sired lambs gained faster pre- and postweaning followed by Targhee, Dorset and Finn sired lambs. Bunge et al. (1993a) reported that lambs sired by Finnsheep and Combo-6 rams were heavier at weaning than lambs sired by Booroola Merino and Barbados rams. When they compared hair vs wool breeds, lambs from hair-breeds were 1.5 kg lighter at weaning than lambs from wool-breeds. In similar sheep studies involving comparisons between hair and wool breeds, Booroola Merino , St. Croix and Barbados breeds have had slower growth than breeds to which they were compared (Foote, 1991; Young and Dickerson, 1991). In a lamb feedlot trial, Sakul et al. (1993) evaluated wether lambs born to Targhee ewes and sired by Australian Merino, Rambouillet and Targhee rams. Lambs sired by Australian Merino gained more slowly than those sired by Rambouillet and Targhee rams.

Year and Season Effects: The components of year/season are temperature, wind and precipitation. These components and their interactions influence the availability of natural and cultivated forage intended for grazing by sheep. The performance of sheep in growth traits is dependent upon the availability (quantity) and quality of feed resources. Several workers have estimated the effects of year/season on sheep performance. Hinch et al. (1985) found year to have a significant effect on variation of birthweight in lambs from Booroola Merino ewe flocks. Flock 1 had a between- year range in mean birthweight of 0.33 kg compared with 0.73 kg for Flock 2 and 0.25 for Flock 3. Stritzke and Whiteman (1982) reported differences in birthweight and 70-d weight between fall, winter and summer-born lambs. Winter and summer-born lambs were 1.28 and .95 kg heavier at birth than were fall-born lambs, respectively. Winter-born lambs were 2.93 and 3.79 kg heavier at 70-d of age than fall-and summer-born lambs, respectively. Blackwell and Henderson (1955) and Gould and Whiteman (1971) reported that spring-born lambs were heavier at birth and at weaning than were fall-born lambs, however, the fall-born lambs gained faster after weaning and reached market weight at a younger age. Trivedi et al. (1978) studied factors affecting preweaning growth rate in Mazaffarnageri and its crosses with Dorset and Suffolk breeds of sheep. The effect of season was significant at all the ages of study. The lambs born from the 15th of December to the 15th of June were heavier than lambs born from the 15th of June to the 15th of December. Cochran et al. (1984) compared Dorset and Finnish Landrace crossbred ewes for reproductive and growth traits. The results showed that lamb birthweight and growth rate were affected by year of lambing. Ewe weight was also influenced by ewe birth year. Fogarty et al. (1984a) found weight of lams weaned/ewe to be higher for annual April than for May and January lambing and was very low for September lambing. Similar results on the effect of year/season on sheep performance were reported by Kaushik and Singh (1968), Trail and Sacker (1969), Rastogi et al. (1975), Dickerson et al. (1975), Oltenacu and Boylan (1981b), Nawaz and Meyer (1992) and Singh and Dhillon (1992). However, Hohenboken et al. (1976a), Rajab et al. (1992) and Bunge et al. (1993a) found no year effects on lamb weaning weight, and Notter and Copenhaver (1980a) found no effect of year on birthweight.

In a New Zealand study by Morris et al. (1993), August-lambing ewes produced heavier lambs at birth than June-lambing ewes. Weaning weights of June-born lambs were lower than those of August-born lambs (0.2 to 2.2 kg) in every year of the study. These results were consistent with those from studies by Trivedi et al. (1978), Reid et al. (1988) and Peterson et al. (1990). However, McQueen (1986) had recorded no difference in birthweight between autumn- and spring-born lambs.

Age of Dam Effects: The effects of age of dam on lamb performance have been studied by many workers. Many results from the literature indicate that there is a consistent pattern in different breeds and flocks of sheep for the effect of age of dam on birth weight. The effect of age of dam on other lamb growth traits is however not consistent. Hazel and Terrill (1946) studied the effects of some environmental factors on weaning traits of range Columbia, Corriedale, and Targhee lambs. Age of dam had a significant effect on lamb weaning weight. Eltawil et al. (1970) evaluated environmental factors affecting birth weight, weaning and yearling traits in Navajo sheep. The results in the study showed that age of dam exerts most of its influence on preweaning traits. Birth and weaning weights were influenced by age of dam much more than was yearling body weight. Dams eight or more years of age had lambs that were heavier at birth than all other groups. However, their lambs were lighter at weaning than those from 4 to 7 yr of age. The authors attributed this to better uterine environment, while not providing as much milk. Wright et al. (1975) reported on the influence of ewe age on productive characters of Southdown sheep. Age of dam was a significant source of variation influencing birthweight. Mean birthweights by age of dam revealed that lambs from two-year-old ewes were lighter than from all other age of ewe classes. Similar results were reported by Vesely and Peters (1964) in Rambouillet, Romnelet, Canadian Corriedale and Romeldale breeds and Smith and Lidvall (1964) in Hampshire lambs. An increase in birth weight was observed up to an age of five years in Bikaneri ewes (Chopra and Acharya, 1971), up to seven years of age in Döhne Merino ewes (Fourie and Heydenrynch, 1982). van Wyk (1993) reported that in Dormer sheep, the average weaning weight of lambs increased with age of dam up to four years and then decreased. The heaviest lambs were from three-to seven -year-old dams and the lightest from two-, eight- and nine-year-old dams. These age of dam effects on weaning weight are in agreement with the findings of Shelton and Campbell (1962), Bichard and Cooper (1966), Dickerson and Laster (1975), Ranson and Mullaney (1976), Mavrogenis (1988), Kleemann et al. (1990) and Rajab et al.(1992). The significance of the effects of age of dam on lamb growth traits is that failure to adjust for age of dam will result in selection bias favoring progeny of older dams with a resulting increase in generation interval and reduced selection differential and slow genetic gains. However, Juma and Faraj (1966), Mavrogenis (1982) and Olthoff and Boylan (1991) found no significant effect of age of dam on birth weight of lambs.

Sex of Lamb Effects: The effects of sex of lamb on growth traits such as birthweight and weaning weight are well known. In general, in most livestock species including sheep, the male neonate is heavier at birth and grows faster than the female. Mature body weight in males is also greater than in females. Gupta et al. (1971) suggested that longer gestation length and hormone profile may be some of the factors contributing towards higher birth weights of male lambs. Studies by Hazel and Terrill (1946), Blackwell and Henderson (1955), deBaca et al. (1956), Sidwell (1956), Harrington et al. (1956), Ruttle (1971), Sidwell and Miller (1971), Dickerson et al. (1972) and Rastogi et al. (1975) all showed that sex has a major influence on birth and weaning weights of lambs. In addition, Trivedi et al. (1978) in studying Muzaffarnageri crosses with Dorset and Suffolk rams, reported that sex of lamb was a significant source of variation at birth and four weeks of age. Male lambs were, on average, 0.23 kg heavier than female lambs at birth. Rajab et al. (1992) also reported similar findings in studies involving three tropical hair sheep in Brazil. Sex of lamb contributed significantly to the variability of lamb growth. Males outweighed females for all eight traits and the trend for the difference increased with age. Bunge et al. (1993) investigated the performance of hair sheep and prolific wool breeds of sheep. Ram lambs were again reported to be heavier by 1.3 kg at weaning than ewe lambs. This result and others previously mentioned agree with the well-known fact that male lambs are heavier at weaning because of greater birth weights and growth rates (Harrington and Whiteman, 1967; Smith, 1977; Langlands et al., 1984; Bunge et al., 1990). In contrast, Juma et al. (1969), Trail and Sacker (1969), Sharma et al. (1978) and Singh et al. (1982) reported no sex of lamb effects on birth and weaning weights of lambs. However, a study by Olthoff and Boylan (1991) on Finn, Dorset, Suffolk, Targhee and crossbred lambs, showed that sex of lamb affected birth and weaning weights but not postweaning growth.

Type of Birth-Rearing Effects: It has been reported from a wide range of sheep studies that type of birth-rearing of lamb has a significant effect on lamb growth traits. Single-born lambs are, in general, heavier than twin-born lambs at birth and weaning. The lower birth and weaning weights of the twin than those of the single may be due limited uterine capacity, inadequate nutrition during pregnancy and competition among twins for milk from the dam during the preweaning period (Singh and Dhillon, 1992). Burditt et al. (1988) in a study involving Dorset, Finnish Landrace and Booroola Merino sired lambs, reported that single-born lambs were heavier at birth than twins (1.16 kg) and triplets (2.10 kg). Weaning weight results showed a similar trend, being 22.3, 17.22 and 17.0 kg for singles, twins and triplets, respectively. Boujenane et al. (1991) studied the effects of genetic and environmental factors on growth to one year and viability of lambs from crossbreeding D'man and Sardi sheep and reported that type of birth and rearing was the most important source of variation on birth weight. Twin and triplet lambs birth weights were 79 and 63%, respectively, of the birth weight of single lambs. Olthoff and Boylan (1991), studying the growth performance of lambs from purebred and crossbred Finnsheep ewes, reported that type of birth had a significant effect on birth weight. The higher birth type categories included nearly all Finn lambs which had the lowest breed average for birth weight. Twins averaged 0.8 kg less than singles, but triplets and quadruplets were intermediate. Further, lambs nursed as singles gained 55 and 64 g faster preweaning and weighed 3.9 and 4.9 kg more at weaning than twin and nursery-reared lambs. Rajab et al. (1992) also reported that type of birth had an effect on lamb growth traits. Single born lambs were heavier at birth than those born as twins. Singh and Dhillon (1992) reported that type of birth accounted for 9.65, 3.50, 1.81 and 0.71% of the variation in weights at birth, weaning, six and 12 mo of age, respectively. Further, the body weights of single-born lambs continued to be significantly higher up to 12 mo of age. Pitchford (1993) studied growth and lambing performance of ewes from crosses between Dorsethorn, Merino and Corriedale sheep. Type of birth effects were also a significant source of variation in birth weight of lambs. Singles had 21% heavier birth weights than multiples. Ramdas et al. (1993), in a study of lamb production of Targhee and prolific breed crossbred ewes, noted that birth and 90 d weaning weight were significantly influenced by birth-rearing type. At 90 d of age, lambs born and reared as singles, were 8% heavier than those born as multiples, and 25% heavier than lambs born as multiples and raised as twins. Similar findings on the effect of type of birth-rearing on growth traits were reported in studies involving a wide range of sheep breeds and production environments by Blackwell and Henderson (1955), Brown et al. (1961), Holtman and Bernard (1969), Magid et al. (1981), Carter et al. (1971), Gould and Whiteman (1971), Hohenboken et al. (1976b), Stritzke and Whiteman (1982), Ercanbrack and Knight (1985), Hinch et al. (1985), Iniguez et al. (1986), Bennett et al. (1991) and Kleemann et al. (1991).

Reproductive Traits

Reproductive efficiency is one of the most important factors which affects profitability of sheep production in the United States (Wilson and Morrical, 1991). Yet it is one of the most difficult to improve (Sidwell and Miller, 1971). Glimp (1971) noted that reproductive efficiency is reflected in the number of lambs weaned and kilograms of lamb weaned per ewe bred. The number of lambs weaned is dependent upon ewe fertility, prolificacy and lamb livability (Sidwell et al., 1972). Increasing the rate of reproduction therefore offers one of the best opportunities for increasing the efficiency of meat production in the sheep enterprise (Bunge et al., 1993a). Many factors influence reproductive efficiency and its components. Alteration of these factors through crossbreeding and selection can assure the sheep producer the desired level of reproductive efficiency in the flock. Because of the complexity of factors affecting reproductive efficiency, this part of the literature review will focus on the those factors deemed to be pertinent in this study: breed of ewe, ram genotype, year, season, age of dam and lamb type of birth.

Effects of Ewe Genotype: There is agreement in most sheep studies that the sheep breeds differ considerably in their reproductive capacity under different production environments. Sidwell and Miller (1971) compared the reproductive efficiency of five different breeds of sheep. The breeds were Hampshire, Targhee, Suffolk, Dorset and Columbia-Southdown-Corriedale cross sheep. Targhee ewes were the most fertile and the Columbia-Southdale the most prolific. In a study involving similar breeds to those previously mentioned, Glimp (1971) also compared reproductive performance of Suffolk, Hampshire, Rambouillet, Targhee, Corriredale , Navajo and Coarse Wool breeds. Their findings showed that Rambouillet and Navajo ewes tended to exhibit estrus and conceive earlier than other breeds. Gestation length was longest in Rambouillet (150.7 d) and shortest in the Suffolk (145.4 d) and Hampshire (144.9) breed. Lambing percents were higher in the Suffolk, Hampshire, Targhee and Coarse Wool breeds than in the Rambouillet and Navajo breeds. In a similar study by Laster et al. (1972), reproductive performance in the crossbreds was superior to that in the purebreds. Dickerson and Glimp (1975) compared nine breeds of sheep for fertility and lamb production. The breeds were Suffolk, Hampshire, Dorset, Rambouillet, Targhee, Corriedale , Coarse Wool and Fine Wool. The most prolific breeds were Suffolk, Dorset, and Targhee. Hohenboken et al. (1976a) compared Hampshire, Suffolk and Willamette ewes for reproduction and lamb production per ewe. Suffolk ewes tended to be lower in fertility and higher in lamb production.

In a study in Oklahoma, Dzakuma et al. (1982) investigated fertility and prolificacy of crossbred ewes under two cycles of accelerated lambing. The ewes in the study were five combinations of Finnsheep (F), Dorset (D) and Rambouillet (R) breeding. The ewes were mated to Hampshire, Suffolk and Hampshire x Suffolk rams. The 1/2D1/2R ewes were more fertile than the 1/4D3/4R and 1/4F ewes. However, the 1/4Finn ewes had the highest prolificacy, 1.66 lambs, compared to that of 1/2D1/2R (1.56 lambs) and 1/4D3/4R (1.50 lambs) ewes. Reproductive performance of Booroola x Finnish Landrace and Booroola x Suffolk ewe lambs heterozygous for the F gene were compared to Finnish Landrace and Suffolk purebreds by Castonguay et al. (1990). Finnish Landrace lambs reached puberty earlier than other genetic groups. Mean ovulation rates were higher in Booroola x Finnish Landrace (3.5) and Booroola x Suffolk (3.1) than for pure Finnish Landrace and Suffolk. respectively. This, in a way, confirms that the Booroola Merino F gene was expressed in Finnish Landrace and Suffolk genotypes.

Nawaz and Meyer (1991) compared six genotypes of sheep produced by mating Coopworth, Polypay and Suffolk rams to Coopworth-type and Polypay ewes. Ovulation rate, litter size and uterine efficiency (defined by Meyer, 1985 as marginal litter size increase resulting from ovulation of an extra egg) were evaluated in the ewes. Daughters of Polypay dams had higher ovulation rate and litter size than daughters of Coopworth-type ewes. Similarly, Polypay-derived ewes exhibited higher uterine efficiency than other genotypes. Bunge et al. (1993b) studied the performance of hair breeds and prolific breeds for lamb production of F_1 ewe lambs. Suffolk F_1 lambs reached puberty earlier and had higher ovulation and greater prolificacy than Targhee dams. Similar findings were reported by Laster et al. (1972). In this study, however, there was no significant breed of dam effect on fertility, a finding which was also reported by Notter and Copenhaver (1980). From the literature, it is quite evident that breeds of sheep exhibit different reproductive capacities. Sheep producers can take advantage of the genetic diversity to improve on ewe reproductive traits. The use of prolific Finnsheep and Booroola Merino breeds is the best starting point to increase reproductive rate in sheep flocks.

Effects of Sire Genotype: Male reproductive performance is an important component of any sheep breeding program through its direct effects on reproductive efficiency (Purvis et al., 1984). Genetic differences exist in the production and characteristics, of ram semen, in the response of semen production to environmental factors and in the expression of mating behavior (Doney et al., 1982). The easiest and fastest way to increase reproductive performance in sheep flocks, is by crossbreeding domestic sheep with the highly prolific breeds such as Finnsheep and Booroola Merino sheep.

There is a clear advantage in using Booroola Merino for crossbreeding as a means to increase lambing percentages. Robertson (1979) conducted a study where rams of Booroola Merino strain were mated to unselected Merino ewes to produce Booroola-cross ewes for comparison with ordinary Merino ewes. Booroola and Booroola-cross ewes had higher ovulation rates than ordinary Merino ewes, suggesting that crossing with the Booroola strain can indeed be an easier and fastest way of increasing lambing percentages. Lamberson and Thomas (1982) investigated the effects of breed of sire on estrous incidence and ovulation rate in ewes sired to Cheviot, Dorset, Finnsheep, Romney and Suffolk rams. Results from this study showed that Finnsheep-sired ewes tended to become anestrous later than all other breeds and the Cheviot had the longest anestrous period. Finnsheep-and Suffolk-sired ewes tended too have higher ovulation rates than Cheviot-and Romney-sired ewes. However, the Finnsheep-sired ewes had a slightly lower ovulation rate/ewe available than Suffolk-sired ewes. The authors attributed this scenario to the lower incidence of estrous in 5 to 8 mo from May through December in 1980 of the study. Other studies have also reported higher ovulation rates in Suffolk ewes when they were compared to other breeds which did not include the Finnsheep (Bradley et al., 1972; Dickerson and Glimp, 1975).

Effects of breed of service ram on ewe fertility, prolificacy and productivity were evaluated by Bunge et al. (1993a). Ewes were of Suffolk and Targhee breeds mated to Finnsheep, Combo-6, Booroola Merino, St. Croix and Barbados rams. Fertility rate of Suffolk and Targhee ewes mated to Finnsheep rams was lower than fertility of ewes mated to rams of all other breeds except the Booroola Merino. Fertility rate of ewes mated to hair-breed rams (St. Croix and Barbados) was higher (9.0%) than rate of ewes mated to wool-breed rams (Suffolk, Targhee Finnsheep, Combo-6 and Booroola Merino). The wool-breed rams were more adapted to the hot summer environment prevailing during the breeding season. There was no breed of sire effect on prolificacy. In a related study, Bunge et al. (1993b) compared production traits of F_1 ewe lambs sired by hair-breed rams and prolific, wool-breed rams (Finnsheep, Combo-6 and Booroola Merino). The F_1 ewe lambs sired by Finnsheep rams reached puberty earlier, F_1 ewe lambs sired by Booroola Merino and Barbados rams were lighter at breeding and ewe lambs from Booroola Merino sires had higher ovulation rates and greater prolificacy than other breeds. When hair-breed rams were compared to wool-breed rams, there were significant differences among the two sire groups in prolificacy and fertility of their F_1 ewe lambs.

The F_1 ewe lambs sired by hair-breed rams had lower prolificacy (-.12 lambs) but greater fertility (+13.6%) than F_1 ewe lambs sired by wool-breed rams.

The greater ovulation rate of Booroola Merino-sired ewe lambs than Finnsheep-sired ewe lambs reported in the study by Bunge et al. (1993b), agrees with the findings of Young and Dickerson (1991) in which Booroola Merino ewe lambs had a 0.2 higher ovulation rate than Finnsheep-sired ewe lambs and by Castonguay et al. (1990) in which Booroola Merino x Finnsheep ewe lambs ovulated 1.6 more ova than straightbred Finnsheep ewe lambs.

To the contrary, however, Burditt et al. (1988) did not find a significant breed of sire effect on total numbers of lambs and lambs born alive. The sire breeds were Dorset, Finnsheep and Booroola. This study did not specifically look at prolificacy and fertility in the ewes, but traits such as total numbers and lambs born alive, are a reflection of fertility and prolificacy in the ewe. Hohenboken et al. (1976a) also reported no breed of sire effect on fertility and prolificacy in diallel crosses among Hampshire, Suffolk and Willamette breeds of sheep. It is not surprising to find conflicting results in the literature because experiments are usually conducted under different environmental conditions and are subjected to management protocols that are also different.

Year Effects: The main components of year are temperature and rainfall. Together these factors interact to influence the quality and quantity of forage, which in turn affects the overall performance of grazing sheep throughout the year. Several sheep studies have reported a significant effect of year on reproductive traits especially those measuring some aspects of fertility and prolificacy. In a study by Sidwell and Miller (1971a) in which ewe reproductive efficiency was measured in several purebred sheep and their crosses, year had a significant effect on fertility, percent lambs born alive of total lambs born and overall reproduction. Hohenboken et al. (1976a) also reported significant influence of year on prolificacy in four breeds of sheep. However, the effect of year was not significant in influencing ewe fertility in the same study. Other researchers working with sheep have also reported significant year effects on reproductive traits (Vakil et al., 1968; Basuthakur et al., 1973; Dickerson and Glimp, 1975; Cedillo et al., 1977; Levine and Hohenboken, 1978; Cochran et al., 1984; Mavrogenis, 1988; Fernandez, 1992; Yusuff et al., 1992; Bunge et al., 1993a 1993b; Morris et al., 1993). In contrast, however, in some studies, the effect of year on reproductive traits was reported to be not significant (Thomas, 1977; Mavrogenis, 1982; Iniguez, 1991; Nawaz and Meyer, 1992; Rajab et al., 1992).

The effects of year on reproductive traits in sheep can be modified by prudent management practices such as supplementary feeding during the winter months, provision of shelter against adverse weather conditions, foster care of orphaned lambs and adequate disease and parasite control in the flock. However, all these measures require extra inputs in the form of labor and finance.

Season Effects: The major components of season that affect ewe reproductive performance are light and temperature. Together these factors and their interactions influence reproductive performance in the ewe and ram. Under natural conditions sheep give birth to their young at specific times of the year when conditions are well suited for the survival of their young. As a result, natural selection pressures have favored the propagation of those genes which couple the time of birth to the most appropriate phase of the annual cycle and food availability (Karsch et al., 1984). In general, female sheep exhibit seasonally-limited periods of polyestrous and anestrous activity. The range of activity in the ewe is associated with the genetic evolution of breed types and with the latitude of their origin (Doney et al., 1982). The initiation of a cyclic estrus is influenced by the light-dark ratio and the period of greatest fertility occurs during the time of decreasing light (late summer and early autumn).

Hafez (1952) noted that in the United States, domestic sheep have an active breeding period in the fall and anestrous period in the spring and early summer. Melatonin has been implicated in the regulation of the reproductive cycle in the ewe as the time keeping hormone. Melatonin levels increase during the dark-phase of the 24-hr day.

Karsch et al. (1984) suggested that daily length of time of elevated melatonin secretion appears to be the trigger that signals the normal fall breeding season in the ewe. O'Callaghan et al. (1992) have noted that there is a strong evidence that seasonal reproductive transitions in certain breeds of sheep notably Suffolk, Dorset Horn and Welsh Mountain are not initiated by changes in photoperiod experienced at about the time of reproductive transitions but instead the breeding season begins in the late summer to autumn as a result of an endogenous rhythm that is synchronized by photoperiodic cues experienced before the summer solstice. The same principle appears to apply in regulating the end of the breeding activity in the winter, but in this case, it is by photoperiodic cues experienced before the previous autumnal equinox (Woodfill et al., 1990).

The subject of the light-dark ratio has been studied extensively in sheep reproduction. In the past, Hafez (1952), Yeates (1949) and Frazer and Lang (1966) have shown that by modifying the light pattern the breeding season can be altered in the ewe. A continuous exposure of ewes to dark treatment has also resulted in initiation of breeding or induced breeding whereas a continuous exposure to light has resulted in cessation of the estrous cycle in the ewe (Dutt, 1953). Low temperature has been shown to shorten the anestrous period in the ewe (Wilson et al., 1959).

Several studies have shown that ovulation rate and lamb production change with changing seasons (Dun et al., 1960; Shelton and Morrow, 1965; Glimp, 1971; Notter and Copenhaver, 1980a; Dzakuma et al., 1982; Lamberson and Thomas, 1982; Montgomery et al., 1985; Obst et al., 1991; O'Callaghan et al., 1992; Morris et al., 1993). From the literature, it is apparent that a high lambing rate is obtainable by breeding during the fall (October to December). However, Boyd (1968) noted that the corresponding lambing dates associated with fall breeding, are often too early in the colder regions and much too late in the warmer regions of the United States and he suggested a number of management regimes that could be put into practice to increase lambing rates irregardless of when the breeding season is initiated. The following management practices were suggested by

Boyd (1968): (a) shearing and drenching of rams and keeping them cool 4 wk before the breeding season starts, (b) shearing and drenching of ewes 2 wk before breeding, placing ewes with sterile rams, increasing feed supply which does not contain high levels of protein 2 wk before breeding, (c) restricting amount of ewe exercise at breeding and placing ewes with fertile rams at night, and (d) providing cool shelter to ewes during gestation and shearing them during the last 4 to 6 wk of gestation. The above measures are an attempt to minimize adverse seasonal effects and, as a result, increase ovulation, conception as well as lambing rates.

Age of Dam Effects: A number of researchers have investigated the influence of age of ewe on her reproductive performance. There is general agreement in the literature that ewe reproductive performance increases with her advancing age up to a point and then declines as the ewe advances in age. Hulet (1968) suggested that age is more of a physiological state than a chronological event, because we usually can observe productive and sound ewes at 8 to 10 yr of age and at the same time younger ewes of 4 to 6 yr of age that are unproductive and unsound. In general, therefore, culling decisions should be based on such things as condition of teeth and physical fitness rather than on age.

According to Dyrmundsson (1973) the age at which a ewe can be mated for the first time is important from the view point of increasing lifetime performance and from the probable correlation between early sexual maturity in the ewe lamb and a generally higher level of reproductive performance in the adult ewe. Hafez (1952) and Dyrmundsson (1973) have both reviewed the occurrence of first estrus in the ewe, while a number of authors have reported considerable variability in the incidence of first estrus within a particular breed of sheep (e. g. Hafez, 1953; Wiggins et al., 1970).

In their report on the influence of age on reproductive performance of Merino sheep, Turner and Dolling (1965) noted that in general, reproductive rate in the ewe rises with increasing age to a peak, with a subsequent decline. The number of lambs born per ewe mated were reported to have increased from a minimum of 0.84 for 2-yr-old ewes to a maximum of 1.11 for 7-yr-old. Further, the proportion of ewes mated which had more than one lamb, rose from a minimum of 0.02 for 2-yr-old ewes to a maximum of 0.20 for 7- to 8-yr-old, with a slight decline thereafter. Similar findings were reported by Sidwell et al. (1962), Inskeep et al. (1967), Glimp (1971), and Laster et al. (1972).

The relationship between ovulation rate and age were investigated by in Booroola Merino and Booroola Merino x Romney (BM x R) ewes by Montgomery et al. (1985) in New Zealand. Their findings revealed that ovulation rates increased significantly between 1.25 and 3.5 yr of age, from 1.25 to 1.54 in BM x R ewes without the Booroola fecundity gene F+. However, between 3.5 and 5.5 yr of age, there were no significant differences in ovulation rates. A report by Meyer (1985) on ovulation rates in nine ewe genotypes of three age groups (1.5, 2.5 and 3.5) showed that ewe age had a significant effect on ovulation rate with 3.5 - and 2.5-yr-old ewes having ovulation rates 20% and 14% higher, respectively than 1.5-yr-old ewes.

Dickerson and Glimp (1975) studied the effects of ewe breed and age on lamb production. Lambings were observed in seven domestic breeds and two strains of crossbred origin in a 4-yr period. Ewe fertility modified curvilinearly with age at lambing from 45 to 75% at 1 yr to 85 to 95 % at 4 to 6 yr of age and 60 to 80% at 9 yr. Further, prolificacy was reported to have increased curvilinearly with age to 160% at 6 yr and decreased to 135% at 9 yr of age. Similar findings were reported by Vakil et al. (1968), Sidwell and Miller (1971a), Rajab et al. (1992) and Bunge et al. (1993).

Type of Birth: A number of researchers have studied different aspects of reproductive performance of singe- vs twin or multiple-born ewes of various breeds. Most of the reports suggest a slight advantage for the twin- or multiple-born ewes in terms of number of lambs born (Dun and Grewal, 1963 in Merino; Vakil et al., 1963 in Rambouillet, Hampshire, Suffolk Columbia and Corriedale; Turner, 1969 in Merino; Combs and Sumption, 1970 in Finnish Landrace). Young et al. (1963) in their review on selection for fertility in Australian Merino sheep, noted that ewes selected for twinning at

5 to 6 yr of age produced 42 multiple births per 100 ewes mated, compared with 15 for ewes selected for bearing singles at 5 to 6 yr of age. Gould and Whiteman (1974) compared lifetime reproductive performance of single vs twin born Dorset x Western crossbred ewes in Oklahoma. Twin-born ewes which lambed at 15 mo had higher lifetime productivity than single-born ewes lambing at the same age (11.8 vs 9.7 lambs). Russell et al. (1988) studied the effects of ewe birth type on her subsequent lamb production in Rambouillet, Columbia and Targhee breeds. Single born ewes had less lambs at birth (1.39) and weaning (1.16) than twins (1.57 and 1.33) or triplets (1.62 and 1.24).

To the contrary, however, Thrift and Dutt (1976) reported that in Southdown sheep, single-born ewes had a slight advantage over twin-born ewes in prolificacy and weaning percentage. Single-born ewes gave birth to 0.5 more lambs, reared 0.4 more lambs and weaned 0.18 kg more lambs per ewe exposed. Similar findings were reported by Basuthakur et al. (1973) in Targhee sheep. However in the same study, the Columbia ewes recorded a significant difference in number of lambs born between single- and twin-born ewes.

Survivability in Lambs

One of the major concerns to sheep producers is preweaning lamb mortality. The factors that influence lamb survivability are both genetic and non-genetic in nature. From a survey of the literature, the most common factors that contribute to variation in lamb mortality are breed, sex of lamb, litter size, birthweight, year and season.

Breed of Ewe: A number of studies have showed that breed of ewe has a significant influence on preweaning lamb mortality. Differences exist among breeds in milk production and mothering ability; together these two factors may act to influence the survival rates in lambs after they are born. Venkatachalam et al. (1949) studied factors affecting lamb mortality in Shropshire, Hampshire, Oxford, Rambouillet, Southdown and Cotswold breeds in Michigan. In this study, Cotswold, Oxford and Hampshire breeds were reported to have higher mortality rates than the other breeds in the same experiment. Purser and Young (1959) compared mortality rates in Blackface and Welsh sheep in Scotland. Preweaning lamb mortality was higher in the Blackface (19.1%) than in the Welsh (12.1%) lambs. Smith (1977) compared lamb mortality in seven domestic U. S. breeds of sheep in Nebraska. Lambs from Hampshire and Corriedale ewes had the highest mortality rates, whereas Course Wool and Targhee had the lowest.

Other sheep studies have showed that breed of ewe has a significant effect on lamb survivability (Dalton et al., 1980 in Romney, Coopworth, Perendale, Cheviot, Drysdale, Corriedale and Merino; Notter and Copenhaver, 1980b in Finnsheep x Rambouillet crosses; Oltenacu and Boylan, 1981 in Finnsheep, Minnesota 100, Suffolk, Targhee and crosses; Macleod et al., 1983 in Blackface, Cheviot, Welsh and crosses; Donnely, 1984 in Merino and Merino crossbreds; Gama et al., 1991 in Suffolk, Composite 1, 2 and 3, Finnsheep, Targhee, Dorset, and Rambouillet; Leymaster and Jenkins, 1993 in Finnsheep crosses). To the contrary, however, breed of ewe was not a significant factor affecting lamb mortality rates in studies by Dickerson et al. (1975) in Finnsheep crosses, Malik and Acharya (1972) in purebred and crossbred Nali and Lohi sheep, Thomas and Whiteman (1979a,b) in 1/2Dorset1/2Rambouillet, 1/4Dorset3/4Rambouillet, 1/4Finnsheep1/2Dorset1/4Rambouillet and 1/4Finnsheep1/4Dorset1/2Rambouillet, Gabina and Ortiz (1985) in Romanov and Finnsheep, Razungles et al. (1985) in Berrichon du Cher and Romanov, Bunge et al. (1992b) in Finnsheep, Booroola Merino, Barbados, St. Croix and crosses and Iman and Slyter (1993) in Targhee and Finn-Dorset-Targhee ewes.

Breed of Sire: Several studies have shown breed of ram to be a significant factor in influencing lamb survival rates. Bunge et al. (1993a) compared survival rate among lambs sired by Finnsheep, Combo-6, Booroola Merino, St. Croix and Barbados rams. Lambs sired by Barbados and Finnsheep rams had higher survival rates than did lambs sired by Booroola Merino and Combo-6 rams. When lambs sired by hair-breed rams (Barbados and St. Croix) were compared to those sired by wool-breed rams, survival rate was 5.9% higher for hair-breed sired lambs. Other studies have also recorded significant differences in mortality rates among lambs sired by different breeds or strains of rams (Carter and Kirton, 1975 in several sire breeds including Southdown, South Suffolk, Dorset Down, Merino, English Leicester, South Dorset Down, Poll/Horn Dorset, Border Leicester, Cheviot, Lincoln, Ryeland, Suffolk, Hampshire and Romney; Dickerson et al., 1975 in Finnsheep, Coarse Wool, Hampshire, Dorset, Rambouillet and Finn crosses; Smith, 1977 in Suffolk, Hampshire, and Oxford; Castonguay et al., 1990 in Booroola Merino, Hampshire, Finnish Landrace and Suffolk; Nuggent and Jenkins, 1991 in Suffolk and Columbia; Young and Dickerson, 1991 in Booroola Merino and Finnish Landrace; Leymaster and Jenkins, 1993 in Texel and Suffolk rams).

However, to the contrary, Burditt et al. (1988) reported no significant effect of breed of sire on lamb survival to weaning. The sire breeds were Dorset, Finnsheep and Booroola Merino. Also, Thomas (1977) reported similar findings in Hampshire, Suffolk, Hampshire x Suffolk and Suffolk x Hampshire sired lambs.

Lamb Birthweight: The weight of a lamb at birth has a significant effect on its chances of survival. McMillan (1983) and Kleemann et al. (1990) have reported a curvilinear relationship between lamb birthweight and survival rate in Waihora and Booroola Merino x South Australian sheep, respectively. The mean optimum birthweights for survival of single-born lambs were 3.2 and 5.1 kg for Waihora and Booroola Merino x Australian, respectively. More multiple than single born lambs die prior to weaning because they are lighter at birth. Other studies have also demonstrated the significant effect of birthweight on lamb mortality (Venkatachalam et al., 1949 in Oxford, Shropshire, Hampshire, Rambouillet, Southdown and Cotswold; Purser and Young, 1959 in Blackface and Welsh Mountain; Smith, 1977 in purebred and crosses of Suffolk, Hampshire, Rambouillet, Dorset, Targhee, Corriedale, Course Wool with Rambouillet and Finnsheep ewes; Dalton et al., 1980 in Romney, Coopworth, Perendale, Cheviot, Dorset-Romney, Drysdale, Corriedale, Merino and Merino-Romney; Notter and Copenhaver, 1980b in

Finnish Landrace crossbreds; Hinch et al., 1983 in Booroola; Weiner et al., 1983 in Scottish Blackface, Cheviot, and Welsh Mountain; Beetson and Lewer, 1985 in Booroola cross Merinos; Scales et al., 1986 in Romney x Suffolk; Castonguay et al., 1990 in Booroola x Finnish Landrace and Booroola x Suffolk; Gama et al., 1991 in Finnsheep, Dorset, Rambouillet, Suffolk, Targhee and three Composite sheep).

Sex of Lamb: Sex has been reported to have a significant influence on lamb survivability. In some reports, however, the alternative has been reported. In a report by Venkatachalam et al. (1949), mortality rate in ram lambs was higher than for ewe lambs. Similar findings were reported by Dickerson et al. (1975), Smith (1977), Dalton et al. (1980), Oltenacu and Boylan (1981a) Wiener et al. (1983), Huffman et al. 1985; Scales et al. (1986), Gama et al. (1991), and Bunge et al. (1993b). On the other hand, Nawaz and Meyer (1992) reported that twin males and females had the same survival rate when born in the same-sex litters; however the results of a separate analysis, carried out with mixed-sex twins only, showed that males had a higher survival rate their co-twin females. Other studies have shown that sex had no significant influence on lamb mortality (Malik and Acharya, 1972; Notter and Copenhaver, 1980b; Macleod et al., 1983; McMillan, 1983; Woollies et al., 1983; Bunge et al., 1993a).

Age of Ewe: The age of dam has been shown to have a curvilinear association with lamb survivability. In general, lamb mortality rate, decreases with age of dam (Purser and Young, 1959, 1964; Hight and Jury, 1970; Dickerson et al., 1975; Smith, 1977; Dalton and Rae, 1978; Dalton et al., 1980; Notter and Copenhaver, 1980b; Oltenacu and Boylan, 1981a; Boujenane et al., 1991). To the contrary, however, Hohenboken et al. (1976a), Atkins (1980), Walker et al. (1979), Hinch et al (1983), Kleemann et al. (1990) and Gama et al. (1991) reported no significant effect of ewe age on lamb mortality.

Litter Size: One of the major non-genetic factors which affects lamb mortality from birth to weaning is litter size at birth. The number of lambs weaned is determined largely by the litter size of lambs born alive and their mortality rate (Jakubec, 1977). More death losses are reported in multiple births lambs than in lambs born as singles because of the low birth weights associated with lambs born as multiples.

Venkatachalam, et al. (1949), in a study of six breeds of sheep, reported that mortality rate was significantly higher in lambs born as multiples (35%) than in single births (20%). Kleemann et al. (1988) reported that in Booroola Merino x South Australian Merino, average litter size was 2.13, with lamb mortalities of 29, 47, 66 and 83% in singles, twins, triplets and quadruplets, respectively. Similar findings were reported by Maijala and Österberg (1977), Smith (1977), Dalton et al. (1979), Oltenacu and Boylan (1981a), Hinch et al. (1983), McMillan (1983), Burditt et al. (1988), Castonguay et al. (1990), Gama et al. (1991), Hall et al. (1992), and Kelly (1992).

Year of Birth: The major components of year are temperature and precipitation. These two factors interact to influence availability of forage which in turn has an indirect effect on lamb survival through the milk production of the ewe. Adverse weather conditions throughout the year have a direct effect on lamb survivability. Because weather conditions will vary yearly, we expect the influence of year on lamb mortality to vary also.

Several investigators have reported have reported a significant influence of year on lamb survivability (Malik and Acharya, 1972; Dickerson et al., 1975; Walker et al., 1979; Dalton et al., 1980; Oltenacu and Boylan, 1981a; Donnely, 1983; Hinch et al., 1983; Macleod et al., 1983; Wiener et al., 1983; Fogarty et al., 1984; Owens et al., 1985; Kleemann et al., 1990; Gama et al., 1991; Bunge et al., 1993a). However, to the contrary, Venkatachalam et al., (1949) and Bunge et al., (1993b) reported that year of birth had no significant effect on lamb survivability.

Season: The components of season that affect lamb survivability are temperature wind and rainfall. In general, sheep will lamb at the time of the year when forage is available and temperatures are mild enough for the survival of their neonate. Extreme weather conditions such as cold, rain and heat contribute directly to the mortality of weak or underweight lambs.

In a study of diallel crossings of Sardi, D'man and D'man x Sardi sheep to investigate genetic and environmental effects on growth and viability of lambs, Boujenane et al. (1991) reported that viability from birth to 30 d differed between lambs born in spring and fall. Lambs born in the fall had higher survival rates than those born in the spring. The authors attributed this situation to better forage availability and less extreme temperatures that were prevailing during the fall lambing season in Morocco. Kleemann et al. (1990) studied factors affecting lamb survival in high fecundity Booroola Merino x South Australian Merino in Cape Borda, Australia which has a Mediterranean type climate. Lamb mortality was reported to be highest in ewes lambing during the winter months of June and July. Further, Fogarty et al. (1984) reported that neonatal and preweaning survival was higher in September when litter size was smaller (1.49) and the weather milder than in January when litter size was higher (1.93). This study was conducted using Finnsheep, Rambouillet, Dorset, Targhee, Suffolk, and two composite lines of sheep at MARC , Nebraska. Conversely, Notter and Copenhaver (1980b), Obst et al. (1991) and Kilgour (1992) did not find any significant effect of season on lamb mortality.

It seems that in order to minimize lamb mortality rates, efforts should be directed towards improving rearing performance of young ewes, survival of multiple born lambs, and overall management.

Summary

The Booroola Merino and Finnish Landrace are major prolific breeds of sheep in use in the United States. Prolificacy is defined as the number offspring per pregnancy. It is a major determinant of reproductive rate in sheep. "The different genetic mechanisms controlling prolificacy in Booroola Merino and Finnish Landrace offer some opportunities for the development of breeding programs to increase reproductive rate in sheep" (Young and Dickerson, 1991). The value of the prolific breeds as a genetic resource lies in the ability to bring about rapid increases in reproductive rate when crossed with other breeds.

In general, the Booroola Merino has higher ovulation rates than Finnish Landrace as straight breds and in crosses. However prolificacy is similar among the two breeds, reflecting higher embryonic losses in the Booroola Merino. In all studies in which the two breeds were compared, the Finnish Landrace produced lambs with more desirable level of performance than the Booroola Merino. Lamb survival rates are in general higher in Finnsheep than in Booroola Merino.

Economic traits in sheep are influenced by genetic and non-genetic sources of variation. The effects of genotype of sire and of dam vary from study to study, but in general, lamb growth traits, ewe reproduction and lamb survival were significantly affected by genotype of sire and of dam. Effects of age of dam, year and season are profound in influencing economic traits.

From the studies cited in the literature, there seems to be no advantage in utilizing the Booroola Merino in terms of overall lamb production because of its contribution to lower birth weights, weaning weight and higher lamb mortalities. Further research is necessary to evaluate the contribution of Booroola Merino in composite breed formation.

CHAPTER III

PRODUCTIVITY OF SPRING LAMBING RAMBOUILLET EWES MATED TO EITHER BOOROOLA MERINO, DORSET OR FINNISH LANDRACE RAMS

Abstract

Booroola Merino (BM), Dorset (DS) and Finnish Landrace (FN) rams were joined to Rambouillet ewes to evaluate productivity of these ewes in lamb growth, reproduction and lamb survival to weaning. Effects of genotype of sire (GOS) were significant ($P < .10$) for birth weight (BWT), weaning weight (WWT), litter weight at weaning (LWW) and litter size at birth (LSB) but not for litter weight at birth (LWB), litter size at weaning (LSW) and lamb viability to weaning (LVW). The interaction of GOS by year of birth (YOB) affected ($P < .03$) LSB. Lambs sired by BM and FN had similar BWT but were lighter ($P < .03$) than lambs from DS sires. Weaning weight was similar ($P > .58$) in lambs from either DS or FN rams and heavier ($P < .0004$) than in lambs from BM rams. Litter size at birth (prolificacy) was similar among ewes joined to either BM or DS (1.89 vs 1.88 lambs) rams and lower ($P < .10$) among ewes mated to FN rams (1.67 lambs). Male lambs were heavier than females at birth ($P < .0002$) and weaning ($P < .0001$). Lambs born and raised singly were heavier ($P < .006$) at birth and weaning than lambs born as multiples and raised either singly or as multiples. However, LWB and LWW was greater ($P < .001$) for lambs born as multiples than in singles. Older ewes (6 yr and older) performed better than younger ewes (2 yr of age) in all traits. Rambouillet ewes performed significantly better in all traits when lambing in 1987 vs 1988. The overall results of this study suggest

that Rambouillet ewes joined to BM rams ranked the last in BWT, WWT, LWW and LSW.

Key Words: Sheep, Booroola Merino, Finnish Landrace, Growth, Prolificacy, Reproduction, Viability.

Introduction

Increasing overall ewe productivity is one of the major goals in the sheep industry. Prolificacy is an important component of overall reproductive ability of the ewe. For many years the Finnish Landrace breed has been used for crossbreeding in some commercial flocks to produce market lambs. However, the Finnish Landrace was not widely accepted because of its small size, poorer quality of wool and lack of adaptability under range conditions (Young and Dickerson, 1991). The Booroola Merino is a prolific breed that has the potential for use in increasing prolificacy in commercial flocks through crossbreeding and other technologies. The genetic mechanism for the inheritance of ovulation rate and subsequent litter size in Finnish Landrace is polygenic in nature, whereas in the Booroola Merino, prolificacy is determined by a single gene (Piper and Bindon, 1982a). The different mechanisms controlling prolificacy in Booroola Merino and Finnish Landrace make it possible to have alternatives to increasing prolificacy in commercial sheep (Young and Dickerson, 1991). In order to utilize these breeds most effectively, it is imperative to assess their performance for economic traits under the same environment. The purpose of this study therefore, was to compare the productivity of Rambouillet ewes joined to either Booroola Merino, Dorset or Finnish Landrace rams, and subsequently to compare the performance of crossbred ewes produced from these matings (Chapter IV).

Materials and Methods

Experimental Animals

The data used in this study were obtained from the USDA-ARS Forage and Livestock Research Laboratory near El Reno, Oklahoma from 1987 to 1988. The dams which were used to generate crossbred lambs were grade Rambouillet ewes between two and eight years of age mated to either Booroola Merino, Dorset or Finnish Landrace rams. The Booroola Merino and Finnish Landrace rams were obtained from the USDA-ARS, Clay Center, Nebraska. During the 1986 breeding season five rams of each breed were used and during the 1987 breeding three different rams of each of these breeds were used. Five Dorset rams were used over the two breeding seasons. The Dorset rams were acquired locally from three different herds. All rams were evaluated for fertility prior to use for breeding purposes. The total number of lambing records used in this study was 673. The distribution of lambings by year of birth at lambing and weaning is presented in Table 2.

TABLE 2

DISTRIBUTION OF LAMBS FROM RAMBOUILLET EWES BY YEAR OF BIRTH (YOB) AT LAMBING AND WEANING

	Number of Lambs		
Year	At Lambing	At Weaning	Weaning Rate (%)
1987	370	266	72
1988	303	237	78
Total	673	503	

Flock Management

Beginning September 15, and continuing for 60 d, ewes were joined to a mob of fertile rams which were either Booroola Merino, Dorset or Finnish Landrace.

The Booroola Merino rams were progeny-tested homozygous for the fecundity gene (F). During the gestation period, ewes were run together as a large flock to eliminate any variation due to pasture effects. At lambing time, ewes were put into smaller lambing paddocks. Throughout their production cycle, ewes were fed to meet NRC nutritional requirements (NRC, 1975).

Traits Studied

Data for each lambing record included dam id, genotype of sire, age of dam, lambing date, sex, type of birth/rearing, birth weight, weaning weight, weaning date and year of birth/lambing. Fertility (FET) for each ewe exposed to a ram was also recorded. Ewes that lambed received an FET score of "1", while those not lambing scored "0" for FET.

The major traits of interest included: ewe fertility (FET), birth weight (BWT), adjusted weaning weight (WWT), lamb viability to weaning (LVW), litter size at birth (LSB), litter size at weaning (LSW), litter weight at birth (LWB) and litter weight at weaning (LWW). Weaning weight was adjusted to a common 70-d age. Fostered and (or) nursery-reared lambs were excluded from the analyses.

Traits that determined overall ewe productivity were divided into three categories for the purpose of presentation of results of this study. The following were the major categories for the ewe performance traits and their components: lamb growth (BWT, WWT), ewe reproduction (FET, LSB, LSW, LWB, LWW), and lamb viability to weaning (LVW).

Statistical Analyses

Traits were analyzed by least squares analysis of variance (Harvey, 1975). Each trait was analyzed separately in order to include only those effects with significant influence on that particular trait. However, models that were similar are herein described together.

The general linear statistical model used to analyze lamb growth traits (BWT, WWT) and lamb viability to weaning (LVW) was as follows:

$Y_{ijklmno} = \mu + A_i + B_j + C_{kn} + D_l + F_m + G_n + AC_{i(kn)} + AD_{il} + AG_{in} + CD_{(kn)l} + DG_{ln} + E_{ijklmno}$, where: $Y_{ijklmno}$ = observed value for BWT, WWT and LVW measured on the o^{th} lamb, born in the n^{th} year, of the m^{th} type of birth/rearing class, in the l^{th} type of birth class, of the k^{th} age of dam class within the n^{th} year of birth, of the j^{th} sex class, sired by ram in the i^{th} genotype of sire.

μ = overall mean

A_i = effect of i^{th} genotype of sire

B_j = j^{th} sex of lamb effect

C_{kn} = effect of the k^{th} age of dam class within the n^{th} year of birth

D_l = l^{th} type of birth class effect

F_m = m^{th} type of birth/rearing class effect

G_n = n^{th} year of birth/lambing effect

$AC_{i(kn)}$ = effect of interaction of i^{th} genotype of sire with k^{th} age of dam within the n^{th} year of birth/lambing

AD_{il} = effect of the interaction between the i^{th} genotype of sire with l^{th} type of birth class

AG_{in} = interaction effect of the i^{th} genotype of sire and the n^{th} year of birth

$CD_{(kn)l}$ = effect of the interaction between the k^{th} age of dam class within the n^{th} year of birth with the l^{th} type of birth class effect.

DG_{ln} = the effect of the interaction between the l^{th} type of birth class with the n^{th} year of birth/lambing

$E_{ijklmno}$ = random error effect, E's assumed NID $(0, \sigma^2)$

The main effect D_l was applied specifically to BWT and LVW, in the place of F_m, while F_m was fitted in the place of D_l for the specific model for WWT. The interactions AG_{in} applied to both BWT and WWT, while DG_{ln} and AC_{il} were fitted in the specific models for BWT and WWT, respectively. The following interactions applied specifically to the model explaining the variance in LVW: AD_{il}, $CD_{(kn)l}$ and DG_{ln}.

The general linear model used to obtain least squares mean estimates of FET was as follows: $Y_{kno} = \mu + C_{kn} + G_n + E_{kno}$, where all terms were defined as above.

The model used to analyze LWB and LWW was as follows: $Y_{iklno} = \mu + A_i + C_{kn} + D_l + G_n + AD_{il} + AG_{in} + CD_{(kn)l} + DG_{ln} + E_{iklno}$, where all terms retain their previous definitions. The interactions AD_{il}, CD_{jk} and DG_{ln} each applied to the specific model for LWW.

To analyze LSB and LSW, the following general linear model was used: $Y_{ikno} = \mu + A_i + C_{kn} + G_n + AG_{in} + E_{ikno}$. All terms retain their previous meaning.

In the preliminary analysis of all the above models, contributions of main effects and all two-factor interactions were examined. Non-significant ($P > .30$) two-factor and all three-factor and higher order interactions were pooled with the model error term. Individual sire could not be fit in the model because ewes were in most cases group-mated. All main effects were considered fixed.

Results

Lamb Growth Traits

The mean squares for BWT and WWT in Rambouillet ewes are presented in Table 3. The overall mean for BWT was 4.12 kg based on 673 lambing records, while WWT had an overall mean of 19.74 kg based on 503 records. Both BWT and WWT were significantly affected by GOS, SOL, AOD, TOB or TBR and YOB. The least squares means and standard errors for BWT and WWT are shown in Table 4. Dorset sired lambs

TABLE 3

ANALYSIS OF VARIANCE FOR BODY WEIGHTS OF LAMBS FROM SPRING LAMBING RAMBOUILLET EWES

	Birth Weight (kg)		Weaning Weight (kg)	
Source of Variation	df	Mean Squares	df	Mean Squares
Genotype of Sire (GOS)	2	2.45*	2	192.84***
Sex of Lamb (SOL)	1	6.89***	1	353.35***
Age of Dam in Year (AOD)	1	2.50*	1	154.92**
Type of Birth (TOB)	1	137.14***	-	--
Type of Birth/Rearing (TBR)	-	--	2	941.17***
Year of Birth (YOB)	1	16.46***	1	81.47*
GOS*YOB	2	1.14	2	43.61
TOB*YOB	1	0.90	-	--
GOS*AOD	-	--	2	29.24
Residual	663	0.49	491	17.46

*P < .05
**P < .01
***P < .001

TABLE 4

LEAST SQUARES MEANS AND STANDARD ERRORS FOR LAMB BODY WEIGHTS MAIN EFFECTS

	Birth Weight (kg)			Weaning Weight (kg)		
Source of Variation	n	LSMean	SE	n	LSMean	SE
Overall Mean	673	4.12	.70	503	19.74	4.18
Genotype of Sire (GOS)		*			***	
Booroola Merino	280	4.14^a	.05	201	18.22^a	.37
Dorset	165	4.38^b	.06	135	20.47^b	.43
Finnsheep	228	4.19^a	.06	167	20.14^b	.46
Sex of Lamb (SOL)		***			***	
female	324	4.14^a	.04	245	18.76^a	.32
male	349	4.34^b	.04	258	20.47^b	.34
Age of Dam in Year (AOD)		*			**	
6 yr (1987)	370	4.42^c	.04	266	20.11^b	.33
2 yr (1988)	116	3.93^a	.08	97	18.00^a	.63
6+ yr (1988)	187	4.18^b	.06	140	20.21^b	.42
Type of Birth (TOB)		***				
single	261	4.77^b	.05	--	--	--
multiple	412	3.72^a	.04	--	--	--
Type Birth/Rearing (TBR)					***	
single/single	--	--	--	223	22.04^c	.31
multiple/single	--	--	--	53	19.29^b	.61
multiple/multiple	--	--	--	227	17.50^a	.33
Year of Birth (YOB)		***			*	
1987	370	4.42^b	.04	266	20.12^b	.33
1988	303	4.06^a	.05	237	19.11^a	.39

[a,b,c]Means within a column in a subgroup with different superscripts differ ($P < .05$)
*$P < .05$; **$P < .01$; ***$P < .001$

were significantly heavier at birth than lambs sired by either Booroola Merino or Finnish Landrace rams (4.38 vs 4.14 and 4.19 kg). The BWT for Booroola Merino and Finnish Landrace sired lambs was similar ($P > .53$). The Dorset and Finnish Landrace rams sired lambs of similar WWT ($P > .58$) and heavier than lambs from Booroola Merino rams. The means for WWT were 18.22, 20.47 and 20.14 kg for lambs sired by Booroola Merino, Dorset and Finnish Landrace rams, respectively.

Sex of lamb (SOL) significantly influenced BWT and WWT. Male lambs were 0.20 kg heavier at birth ($P < .001$) and 1.71 kg heavier at weaning ($P < .001$) than the female lambs.

Birth weight and WWT increased with age of ewe. Older ewes (6+-yr-old) had heavier lambs at birth (4.18 vs 3.93 kg) and at weaning (20.21 vs 18.0 kg) in 1988 than were lambs from younger ewes (2-yr-old). Lambs born in 1987 by older ewes (6+-yr-old) were heavier ($P < .05$) at birth than lambs born in 1988 by ewes of similar age (4.42 vs 4.18 kg). However, WWT was similar ($P >.84$) for both years in the 6+-yr-old ewes (20.11 vs 20.21 kg).

Lambs born as singles were significantly heavier at birth than were lambs born as multiples (4.77 vs 3.72 kg). Similarly, lambs born and raised singly (SS) were significantly heavier at weaning than were lambs born as multiples and raised either singly (MS) or as multiples (MM). The means for WWT were 22.04, 19.29 and 17.50 kg for lambs in SS, MS and MM categories, respectively.

Year of birth (YOB) affected both BWT ($P < .001$) and WWT ($P < .05$) . Lambs born in 1987 were significantly heavier at birth (4.42 vs 4.06 kg) and at weaning (20.12 vs 19.11 kg) than were lambs born in 1988.

Ewe Reproductive Traits

Fertility: The mean squares for FET in Rambouillet ewes are presented in Table 5. The overall mean for FET was 98% based on 482 ewes exposed to the ram (Table 6).

TABLE 5

ANALYSIS OF VARIANCE FOR FERTILITY IN SPRING LAMBING RAMBOUILLET EWES

Source of Variation	df	Mean Squares
Age of Dam in Year (AOD)	1	.27***
Year of Lambing (YOL)	1	.14**
Residual	479	.02

**P < .01

***P < .001

TABLE 6

LEAST SQUARES MEANS AND STANDARD ERRORS FOR FERTILITY IN SPRING LAMBING RAMBOUILLET EWES

Source of Variation	n	LS Mean	SE
Overall Mean	482	.98	.13
Age of Dam in Year (AOD)		***	
6 yr (1987)	244	1.00[b]	.01
2 yr (1988)	119	.93[a]	.01
6+ yr (1988)	119	1.00[b]	.01
Year of Lambing (YOL)		**	
1987	244	1.00[b]	.01
1988	238	.97[a]	.01

[a,b]Means within a column in a subgroup with different superscripts differ (P < .05)

**P < .01

***P < .001

Age of dam within year (AOD) and YOL significantly influenced the variation in FET in Rambouillet ewes. Fertility rate was significantly lower (93%) among the younger (2-yr-old) ewes in 1988, while FET for both 1987 and 1988 in older (6+-yr-old) ewes was 100%. The lowest ($P < .01$) fertility rate was recorded in 1988 (97%) while in 1987 the Rambouillet ewes achieved a fertility rate of 100% (Table 6).

Litter Weight at Birth: Analysis of variance mean squares for LWB are shown in Table 7. Genotype of sire did not affect LWB ($P > .40$). Significant sources of variation for LWB were AOD, TOB and YOB (Table 7). The overall mean for LWB based on 461 ewe records was 6.01 kg. The means for LWB were 6.15, 6.30, and 6.13 kg for ewes mated to Booroola Merino, Dorset and Finnish Landrace rams, respectively.

In 1988, older ewes (6+-yr-old) produced heavier litters than the younger (2-yr-old) ewes (6.12 vs 5.77 kg). The overall heaviest ($P < .05$) lambs were produced in 1987 (6.44 kg).

Ewes having multiple-birth produced 2.86 more kg of lamb than ewes lambing singles (Table 8). The heaviest litters were produced in 1987 than were in 1988 (6.44 vs 5.94 kg).

Litter Weight at Weaning: The variation in LWW was significantly influenced by GOS, AOD, TOB, YOB and the interaction TOB*YOB (Table 7). Based on 388 ewe records, the overall mean for LWW was 25.59 kg (Table 8). Litters from ewes mated to Dorset and Finnish Landrace rams were similar ($P > .05$) in LWW (27.26 vs 27.01 kg) and were significantly heavier than litters produced by ewes mated to Booroola Merino rams (23.53 kg).

Older ewes (6+-yr-old) in both 1987 and 1988, produced litters of similar ($P > .05$) weight at weaning (27.68 vs 26.56 kg) both of which were significantly heavier than litters born in 1988 (21.83 kg) from younger ewes (2-yr-old).

TABLE 7

ANALYSIS OF VARIANCE FOR LITTER WEIGHT AT BIRTH (LWB)[a] AND LITTER WEIGHT AT WEANING (LWW)[b] IN SPRING LAMBING RAMBOUILLET EWES

	Litter Weight at Birth (kg)		Litter Weight at Weaning (kg)	
Source of Variation	df	Mean Squares	df	Mean Squares
Genotype of Sire (GOS)	2	0.87	2	526.83***
Age of Dam in Year (AOD)	1	5.06*	1	491.60**
Type of Birth (TOB)	1	800.58***	1	3050.47***
Year of Birth (YOB)	1	23.51***	1	691.03***
GOS*TOB	-	--	2	79.38
TOB*AOD	-	--	1	120.46
TOB*YOB	-	--	1	271.34*
Residual	455	1.05	378	51.59

[a]LWB = total weight (kg) of lamb born/ewe lambing
[b]LWW = total weight (kg) of lamb weaned/ewe lambing
*P < .05
**P < .01
***P < .001

TABLE 8

LEAST SQUARES MEANS AND STANDARD ERRORS FOR LITTER WEIGHT AT BIRTH (LWB)[a] AND LITTER WEIGHT AT WEANING (LWW)[b] IN RAMBOUILLET EWES

	Litter Weight at Birth (kg)			Litter Weight at Weaning (kg)		
Source of Variation	n	LSMean	SE	n	LSMean	SE
Overall Mean	461	6.01	1.02	388	25.59	7.18
Genotype of Sire (GOS)		NS			***	
Booroola Merino	181	6.15^c	.08	153	23.53^c	.67
Dorset	125	6.30^c	.10	111	27.26^d	.78
Finnsheep	155	6.13^c	.09	124	27.01^d	.74
Age of Dam in Year (AOD)		*			**	
6 yr (1987)	240	6.44^e	.07	194	27.68^d	.55
2 yr (1988)	105	5.77^c	.12	93	21.83^c	1.29
6+ yr (1988)	116	6.12^d	.10	101	26.56^d	.76
Type of Birth (TOB)		***			***	
single	261	4.76^c	.07	222	22.22^c	.51
multiple	200	7.62^d	.08	166	29.64^d	.72
Year of Birth (YOB)		***			***	
1987	240	6.44^d	.07	194	27.68^d	.55
1988	221	5.94^c	.07	194	24.19^c	.73

[a]LWB =total weight of lamb born/ewe lambing
[b]LWW = total weight of lamb weaned/ewe lambing
[c,d,e]Means within a column in a subgroup with different superscripts differ ($P < .05$)
*P < .05; **P < .01; ***P , < .001

Ewes having multiple births produced 7.42 more kg of lamb at weaning than ewes lambing singles (Table 8). Rambouillet ewes produced lighter litters (P < .0001) in 1988 than in 1987 (24.19 vs 27.68 kg).

The interaction TOB*YOB significantly influenced LWW (Table 7). Table 9 shows that in 1987 and 1988, LWW was similar (P > .05) for single-born lambs (22.87 vs 21.57 kg), while LWW was greater in litters born as multiples in 1987 than for those born in 1988 (32.48 vs 26.81 kg).

Litter Size at Birth: The significant sources of variation for LSB were GOS, AOD, YOB and the interaction GOS*YOB (Table 10). The overall mean for LSB based on 461 ewe records was 1.88 lambs (Table 11).

Ewes mated to Booroola Merino and Dorset rams had 1.89 and 1.88 lambs at birth on the average, respectively, while ewes mated to Finnish Landrace rams had the lowest (P < .10) litter size at birth (1.67 lambs).

Age of dam within year of birth had an effect (P < .0001) on LSB. The younger (2-yr-old) ewes were less prolific (P < .0001) than were the older (6+-yr-old) in 1988 (1.12 vs 2.11 lambs). However, the older (6+-yr-old) in both 1987 and 1988 had similar (P > .35) prolificacy rate (2.01 vs 2.11 lambs).

Year of birth had a marked effect on LSB (P < .0001). Rambouillet ewes lambing in 1987 were more prolific than those lambing in 1988 (2.01 vs 1.62. lambs). The means for interaction GOS*YOB (Table 12) show that Rambouillet ewes were more prolific in 1987 than in 1988. The advantage in LSB recorded in 1987 vs 1988 was 8.4, 16.5 and 56% for ewes mated to Booroola Merino, Dorset and Finnish Landrace rams, respectively.

Litter Size at Weaning: The analysis of variance men squares for LSW show that AOD and YOB significantly influenced LSW (Table 10). The overall mean for LSW based on 388 ewe records was 1.29 lambs (Table 11).

TABLE 9

LEAST SQUARES MEANS AND STANDARD ERRORS FOR LITTER WEIGHT AT WEANING (LWW)[a] BY THE INTERACTION: TYPE OF BIRTH VS YEAR OF BIRTH (TOB*YOB) IN SPRING LAMBING RAMBOUILLET EWES

		Litter Weight at Weaning (kg)		
			Least Squares	
Source of Variation		n	Means	SE
Interaction: TOB*YOB				
Type of Birth	Year of Birth			
single	1987	99	22.87[b]	.76
single	1988	123	21.57[b]	.70
multiple	1987	95	32.48[d]	.79
multiple	1988	71	26.81[c]	1.29

[a]LWW = total weight of lamb (kg) weaned/ewe lambing

[b,c,d]Means within a column with different superscripts differ ($P < .05$)

Genotype of sire did not influence (P > .34) LSW. The means for LSW were 1.26, 1.35 and 1.27 lambs for Booroola Merino, Dorset and Finnish Landrace mated ewes, respectively.

Age of dam within year influenced (P < .0001) LSW. In 1988, the younger (2-yr-old) ewes weaned 1.03 vs 1.36 lambs for the older (6+-yr-old) ewes. However, in both 1987 and 1988, the 6+-yr-old ewes weaned litters of similar (P > .60) size (1.39 vs 1.36 lambs). Rambouillet ewes weaned more (P < .0001) lambs in 1987 than in 1988 (1.39 vs 1.20 lambs.

Lamb Viability

The analysis of variance mean squares for LVW are presented in Table 10. Least squares means for LVW in relation to main effects and the two-level interactions between those main effects (GOS*TOB, TOB*AOD, TOB*YOB) are presented in Tables 11 and 12.

Type of birth (TOB), year of birth (YOB) and TOB*YOB were important (P < .05) sources of variation of LVW. Genotype of sire (GOS), sex of lamb (SOL), AOD, and the interactions GOS*TOB, SOL*TOB and TOB*AOD did not contribute (P > .10) to explain the variation in LVW (Table 10).

On the average, Rambouillet ewes had LVW of 85% based on 461 ewe records. Lambs sired by Booroola Merino, Dorset or Finnish Landrace rams had similar (P > .84) LVW (83, 84, 82%, respectively). Male and female lambs had similar (P > .70) LVW (82 vs 84%).

Age of dam within year did not influence (P > .54) the variation in LVW. However, LVW was 17 and 5% lower in lambs from younger (2-yr-old) dams than in older (6+-yr-old) dams in 1987 and 1988, respectively.

TABLE 10

ANALYSIS OF VARIANCE FOR LITTER SIZE AT BIRTH (LSB), LITTER SIZE AT WEANING (LSW) AND LAMB VIABILITY TO WEANING (LVW) IN SPRING LAMBING RAMBOUILLET EWES

	Litter Size					
	At Birth		At Weaning		Viability of Lambs to Weaning	
Source of Variation	df	Mean Squares	df	Mean Squares	df	Mean Squares
Genotype of Sire (GOS)	2	1.99+	2	0.20	2	0.02
Sex of Lamb (SOL)	--	--	--	--	1	0.02
Age of Dam in Year (AOD)	1	42.21***	1	4.03***	1	0.04
Type of Birth (TOB)	--	--	--	--	1	0.43*
Year of Birth (YOB)	1	14.29***	1	2.83***	1	0.81**
GOS*YOB	2	3.08**	1	0.44+	--	--
GOS*TOB	--	--	--	--	2	0.19
TOB*AOD	--	--	--	--	1	0.16
TOB*YOB	--	--	--	--	1	0.58*
Residual	454	0.85	387	0.19	450	0.10

+P < .10
*P < .05
**P < .01
***P < .001

TABLE 11

LEAST SQUARES MEANS AND STANDARD ERRORS FOR LITTER SIZE AT BIRTH (LSB), LITTER SIZE AT WEANING (LSW) AND LAMB VIABILITY TO WEANING (LVW) IN SPRING LAMBING RAMBOUILLET EWES

	Litter Size at Birth			Litter Size at Weaning			Lamb Viability to Weaning		
Source of Variation	n	LSMean	SE	n	LSMean	SE	n	LSMean	SE
Overall Mean	461	1.88	.92	388	1.29	.43	461	.85	.31
Genotype of Sire (GOS)		+			NS			NS	
Booroola Merino	181	1.89[b]	.07	153	1.26[a]	.04	181	.83[a]	.03
Dorset	125	1.88[b]	.09	111	1.35[a]	.05	125	.84[a]	.03
Finnsheep	155	1.67[a]	.09	124	1.27[a]	.05	155	.82[a]	.03
Sex of Lamb (SOL)								NS	
female	--	--	--	--	--	--	172	.82[a]	.03
male	--	--	--	--	--	--	289	.84[a]	.02
Age of Dam in Year (AOD)		***			***			NS	
6 yr (1987)	240	2.01[b]	.07	194	1.39[b]	.04	240	.88[a]	.02
2 yr (1988)	105	1.12[a]	.10	93	1.03[a]	.05	105	.76[a]	.05
6+ yr (1988)	116	2.12[b]	.09	101	1.36[b]	.05	116	.79[a]	.03
Type of Birth (TOB)								*	
single	--	--	--	--	--	--	261	.86[b]	.02
multiple	--	--	--	--	--	--	200	.80[a]	.03
Year of Birth (YOB)		***			***			**	
1987	240	2.01[b]	.07	194	1.39[b]	.04	240	.88[b]	.02
1988	221	1.62[a]	.07	194	1.20[a]	.03	221	.77[a]	.03

[a,b]Means within a column in a subgroup with different superscripts differ (P < .10)
[+]P < .10; *P < .05; ***P < .001

TABLE 12

LEAST SQUARES MEANS AND STANDARD ERRORS FOR LITTER SIZE AT BIRTH (LSB) AND AT WEANING (LSW) BY THE INTERACTION: GENOTYPE OF SIRE VS YEAR OF BIRTH (GOS*YOB) AND FOR SURVIVAL TO WEANING BY THE INTERACTION: TYPE OF BIRTH VS YEAR OF BIRTH (TOB*YOB)

		Litter Size at Birth			Litter Size at Weaning		
Source of Variation		n	LS Mean	SE	n	LS Mean	SE
Interaction: GOS*YOB							
Genotype of Sire (GOS)	Year of Birth (YOB)						
Booroola Merino	1987	91	1.97^{bc}	.10	74	1.28^{a}	.05
Booroola Merino	1988	90	1.81^{b}	.10	79	1.23^{a}	.05
Dorset	1987	35	2.03^{bc}	.16	29	1.48^{b}	.08
Dorset	1988	90	1.74^{b}	.10	82	1.21^{a}	.05
Finnsheep	1987	114	2.04^{c}	.09	91	1.40^{b}	.04
Finnsheep	1988	41	1.31^{a}	.15	33	1.15^{a}	.08

Interaction: TOB*YOB		Survival to Weaning		
Type of Birth	Year of Birth	n	LSMean	SE
single	1987	119	$.87^{b}$	.03
single	1988	142	$.85^{b}$	.03
multiple	1987	121	$.90^{b}$	.03
multiple	1988	79	$.69^{a}$	.05

^{a,b,c}Means within a column with different superscripts differ ($P < .10$)

Single-born lambs produced in both 1987 and 1988 had similar ($P > .68$) LVW (87 vs 85%), while multiple-born lambs produced in 1987 and 1988 had different ($P < .01$) LVW (90 vs 69%).

Discussion

Lamb Growth Traits

Genotype of sire had a significant effect on BWT and WWT. The effect of GOS on BWT was largely due to the contribution of Dorset-sired lambs which were heavier at birth than were lambs sired by either BM or FN rams. These results disagree with those reported in the literature (Young and Dickerson, 1991) who found no significant effect of GOS on BWT of lambs sired by either BM, DS or FN rams. However, GOS significantly affected WWT in other studies (Burditt et al., 1988; Young and Dickerson, 1991), in agreement with the results of the present study. The performance in BWT of lambs sired by BM or FN rams were similar. This is in agreement with reports in the literature involving comparisons of similar breeds of sire to those used in the present study (Burditt et al., 1988; Young and Dickerson, 1991).

Lambs sired by DS and FN rams had similar WWT. When compared to the other breeds, BM rams had consistently lighter lambs at weaning in total agreement with reports in the literature (Burditt et al., 1988; Young and Dickerson, 1991).

The effect of sex of lamb on growth traits are well known. Gupta et al. (1971) suggested that longer gestation length and hormone profile may be some of the factors contributing towards higher BWT and WWT of male lambs. In the present study, male lambs were heavier than female lambs at birth and weaning. Similar results have been reported in the literature (Dickerson et al., 1972; Bunge et al., 1990; Olthoff and Boylan, 1991). In contrast, Juma et al. (1969), Trail and Sacker (1969) and Singh et al. (1982) reported no sex of lamb effects on BWT and WWT.

Age of dam effects on lamb growth performance have been studied by many workers. Results reported in the literature indicate that in general, there is a consistent pattern in different breeds and flocks of sheep for the effect of AOD on BWT. The effect of AOD on other lamb growth traits is however not consistent. Results of the present study demonstrate that in general ewes lambing at 2 yr of age gave birth to and weaned lighter lambs than were ewes lambing at 6 yr or older. Similar findings were reported in the literature (Eltawil et al., 1970; Wright et al., 1975; Dickerson and Laster, 1975; Rajab et al., 1992).

Type of birth influences BWT, while type of birth-rearing affects WWT. Numerous reports in the literature indicate that single-born lambs are in general heavier than multiple-born lams at birth and weaning. The lower BWT and WWT of the multiple-born lambs than those of the single may be due to limited uterine capacity , inadequate nutrition during gestation and competition among multiples for milk in the preweaning period (Singh and Dillon, 1992). The results of the present study confirm numerous reports to the effect that lambs born as multiples are lighter at birth and weaning than are single lambs (Boujenane et al., 1991).

Year of birth is a major factor contributing to the variation in BWT and WWT. The components of year are temperature, wind and precipitation. These components and their interactions influence the availability of natural and cultivated forage intended for grazing by sheep. The performance of sheep in growth traits is dependent upon the quantity and quality of feed resources. In the present study, the effects of YOB were profound in influencing lamb growth performance traits. A number of researchers have reported similar findings on the effect of YOB in BWT and WWT (Rastogi et al., 1975; Dickerson et al., 1975; Nawaz and Meyer, 1992). To the contrary, however, Notter and Copenhaver (1980a) found no effect of YOB on BWT, while Hohenboken et al. (1976a) and Rajab et al. (1992) reported no effects of YOB on WWT.

Ewe Reproduction

Reproductive efficiency is one of the most important factors which affects profitability of sheep production in the United States (Wilson and Morrical, 1991). Glimp (1971) noted that reproductive efficiency is reflected in the number of lambs weaned and kilograms of lamb weaned per ewe exposed to the ram. Many factors influence reproductive efficiency. Alteration of these factors through crossbreeding and selection can assure the sheep producer the desired level of reproductive efficiency. In the present study, reproductive traits were investigated under the following categories: FET, LWB, LWW, LSB, and LSW.

Fertility was influenced greatly by AOD and YOL. There is general agreement in the literature to the effect that ewe FET increases with her advancing age to a point and then declines as the ewe ages.

In the present study, FET was highest among the older ewes (6+-yr-old) than in the 2-yr old ewes. Similar results were reported by in the literature (Vakil et al., 1968; Sidwell and Miller, 1971a; Bunge et al., 1993b). Furthermore, Dickerson and Glimp (1975) observed that ewe fertility modified curvilinearly with age at lambing from 45 to 75% at 1 yr to 85 to 95% at 4 to 6 yr of age and 60 to 80% at 9 yr.

Year of lambing/breeding had a dramatic effect on FET. It seems 1987 was a very good year in terms of weather and forage production because most traits under investigation including FET were significantly enhanced in comparison to 1988. Other researchers have reported significant effects of YOL on ewe fertility (Sidwell and Miller, 1971a; Dickerson and Glimp, 1975; Cochran et al., 1984; Morris et al., 1993). In contrast, however, the effects of YOL was reported not significant in influencing FET (Hohenboken et al., 1976a; Thomas, 1977; Mavrogenis, 1982; Nawaz and Meyer, 1992).

The effects of genotype of sire (GOS) were not significant for LWB and LSW. On the other hand, GOS significantly influenced LWW and LSB (prolificacy). In general, Rambouillet ewes mated to either DS or FN rams were more productive in terms of total weight of lamb weaned per ewe lambing. This is a reflection of preweaning growth and weaning weight advantage in lambs sired by either DS or FN rams. Surprisingly, Rambouillet ewes joined to FN rams were the least prolific and below the average LSB of 2.2 lambs. The expectation was that prolificacy would be similar among Rambouillet ewes joined to either BM or FN rams. Other researchers, however found no significant effect of GOS on prolificacy (Burditt et al., 1988; Young and Dickerson, 1991).

Age of dam in year had a significant effect on LWB, LWW, LSB and LSW. In general, the older ewes (6+-yr-old) were consistently more productive than the 2-yr-old ewes in terms of prolificacy, total weight of lamb born and weaned. These results generally concur with reports in the literature (Turner and Dolling, 1965; Dickerson and Glimp, 1975; Oltenacu and Boylan, 1981b).

Type of birth contributed to the variation in LWB and LWW. Multiple-birth clearly has an advantage over single-birth in terms of total weight of lamb born and weaned. Breeding or selection efforts for multiple-birth would definitely increase performance in LWB and LWW. The use of prolific breeds in crossings versus selection within breed to increase prolificacy and overall lamb production seems to be an attractive option because of its effectiveness and simplicity.

The effects of year of birth were very important in contributing to the variation in LWB, LWW, LSB and LSW. Rambouillet ewes consistently performed better in all the above traits when lambing in 1987 as compared to 1988. The interaction TOB*YOB for litter weight at weaning indicates that single as well as multiple-born lambs performed better in 1987. Similarly, the interaction GOS*YOB for litter size at birth shows that prolificacy among Rambouillet ewes joined to either BM, DS or FN rams was consistently higher in ewes lambing in 1987 than in 1988. The scenario described above clearly shows that ewes lambing in 1987 were exposed to good weather and nutrition during the breeding season and preweaning period.

Lamb Viability

The lambs' ability to survive from birth to weaning was affected by TOB and YOB as well as the interaction TOB*YOB. Genotype of sire as did not affect LVW. Type of birth is one of the non-genetic factors which affects lamb mortality from birth to weaning. The number of lambs weaned is determined largely by the litter size of lambs born alive and their mortality rate (Jakubec, 1977). More death losses are expected in multiple births because of the low birth weight associated with lambs born as multiples.

In the present research, single born lambs had higher survival rate than lambs born as multiples. Similar results have been reported in the literature (Hinch et al., 1983; Castonguay et al., 1990; Gama et al., 1991).

Year of birth had a significant effect on LVW. This is in agreement with findings by other workers (Dickerson et al., 1975; Walker et al., 1979; Fogarty et al., 1984a; Kleemann et al., 1990). The interaction TOB*YOB clearly shows that both single as well as multiple born lambs had better LVW in 1987. In this study, there is overwhelming evidence that Rambouillet ewes lambing in 1987 excelled in all traits under investigation.

Implications

Booroola Merino can be used in the place of Finnish Landrace to increase prolificacy in commercial flocks, however, these matings will result in lower birth and weaning weights as well as lighter total lamb weight at weaning when compared to Finnish Landrace or Dorset breeding.

CHAPTER IV

PERFORMANCE OF EWES FROM RAMBOUILLET CROSSES WITH BOOROOLA MERINO, DORSET AND FINNISH LANDRACE RAMS

Abstract

The performance of three ewe genotypes utilizing Booroola Merino x Rambouillet (BxR), Dorset x Rambouillet (DxR) and Finnish Landrace x Rambouillet (FxR) ewes was evaluated using 638 production records collected from 1991 to 1993 at the USDA Forage and Livestock Research Laboratory near El Reno, Oklahoma. The traits studied were ewe fertility, birth weight (BWT), weaning weight (WWT), lamb viability to weaning (LVW), litter size at birth (LSB), litter size at weaning (LSW), litter weight at birth (LWB) and litter weight at weaning (LWW). The basic model for BWT, WWT, LVW included genotype of dam (BOD), sex of lamb (SOL), age of dam within year/season (AOD), type of birth (TOB) or type of birth/rearing (TBR) and year/season of birth (YSB). The model for fertility, LWB, LWW, LSB and LSW included BOD, AOD, TOB, and YSB. Genotype of dam influenced BWT ($P < .001$), WWT ($P < .05$), LWB ($P < .001$) LWW ($P < .01$) and LSB ($P < .0001$). The DxR ewes were superior in BWT, WWT, LWB and LWW. The BxR and FxR ewes had similar and greater prolificay than DxR ewes. However, the three ewe genotypes were similar in LSW and LSW. Sex of lamb affected BWT ($P < .0001$), WWT ($P < .047$) and LVW ($P <.052$). Female lambs were lighter at birth and weaning and had a higher survival rate than male lambs. Age of dam within year/season explained a significant portion of variation in BWT, WWT and LWW. In general, younger dams tended to have lighter (P < .08) lambs at birth and at weaning (P < .052) than older dams. Type of birth influenced BWT (P < .001), LWB (P < .001), LWW (P < .001) and LVW (P < .01). Single-born lambs were heavier at birth and survived better than lambs born as multiples. Multiple-born lambs produced more total kg of lamb at birth and weaning than did single-born lambs. Lambs born and raised singly (SS) were heavier at weaning followed by lambs born as multiples and raised as singles (MS) and by lambs born and raised as multiples (MM). Year/season explained a large proportion of the variation in fertility, BWT, WWT, LWB. LWW, LSB, LSW and LVW. The following interactions were found to be significant: BOD*TOB, BOD*AOD in BWT; BOD*TBR and TBR*YSB in WWT, while BOD*YSB significantly affected LVW. The DxR ewes performed exceptionally well in lamb growth traits followed by FxR and BxR ewes, respectively. The FxR and BxR dams were similar and more prolific than DxR ewes. Genotype of dam did not affect LSW (P > .87) and LSW (P > .68).

Key Words: Sheep, Crossbred Ewes, Booroola Merino, Growth, Reproduction, Traits, Prolificacy

Introduction

The number of lambs born per ewe in a given period (prolificacy) as well as the total lamb weight weaned per ewe lambing are the major factors which affect profitability in sheep production. Crossbreeding with prolific breeds of sheep such as the Booroola Merino and Finnish Landrace has the potential to improve overall productivity through the increase of litter size of crossbred ewes. However, it may have a negative effect on BWT of crossbred lambs (Dickerson, 1977). Finnish Landrace and Dorset breeds have been shown to have higher reproductive performance than Rambouillet, Columbia and Targhee breeds (Laster et al., 1972 and Dickerson and Glimp, 1975). The Booroola Merino has unique qualities in that its prolificacy is controlled by genes at a single major locus (Piper and Bindon, 1982a). Thus it can provide a rapid mechanism of increasing prolificacy in commercial flocks. The primary objective of this study was therefore, to compare F_1 ewes sired by Booroola Merino (homozygous for the F gene), Dorset and Finnish Landrace rams using Rambouillet ewes for lamb growth traits and ewe reproduction in the environment of the southern great plains in Oklahoma.

Materials and Methods

Experimental Animals

The data for this study consisted of 638 lambing records over a period of three years (1991 through 1993) at the USDA, ARS Forage and Livestock Research Laboratory near El Reno, Oklahoma. Lambings were from three ewe genotypes comprised of Booroola Merino x Rambouillet (BxR), Dorset x Rambouillet (DxR) and Finnish Landrace x Rambouillet (FxR). The total numbers of ewes in each dam group across years were: 95, 202, and 161 for BxR, DxR, and FxR genotypes, respectively. Table 13 presents the distribution of lambs from the three ewe genotypes by year/season of birth at lambing and at weaning. Ewes ranged in age from 2 to 5+ yr. However, not all age categories were represented in each year of the study. The F_1 dams in this study were generated from grade Rambouillet ewes. All F_1 dams were mob-mated to a either Suffolk or Hampshire terminal sires to produce market lambs.

It is of interest to note the presence (for comparison) of the BxR and the FxR ewe genotypes which represent some of the most prolific breeds or strains of sheep: the Booroola Merino and the Finnish Landrace.

TABLE 13

DISTRIBUTION OF LAMBS FROM CROSSBRED EWES BY YEAR/SEASON OF BIRTH AT LAMBING AND WEANING

	Number of Lambs		
Year/Season	At Birth	At Weaning	Weaning Rate (%)
1991-Fall	150	93	62
1992-Fall	255	199	78
1993-Spring	88	59	67
1993-Fall	145	128	88
Total	638	479	

Flock Management

Spring Lambing: The following routine management practices were imposed on the ewes and their lambs each year of the study:

(a) at breeding (September), ewes which had been previously flushed, were joined to a mob of fertile rams at the ratio of 1:30 (ram to ewe). Ewes were maintained on native pasture and flushed with corn

(b) from October to December, ewes continued on native pasture, but also received a corn supplement

(c) in January, ewes were put in a drylot and fed silage and corn to meet late gestation nutritional requirements. Lambs were born in the lot and moved to lambing pens after birth with their dams for about two days before they were moved to mixing pens for three to five days

(d) from February to weaning, ewes and their lambs were put on wheat pastures. Lambs had access to a creep ration

(e) beginning May to August, ewes were put on native bermuda range.

Fall Lambing: In a similar fashion, fall-lambing ewes were subjected to a routine management regime as follows:

(a) ewes were flushed with corn prior to joining to a mob of fertile rams in May and were maintained on native range with corn supplementduring breeding

(b) from late June to August, ewes continued to be maintained on native range

(c) ewes were moved to a drylot in September in preparation for lambing and fed silage and corn to meet late gestation nutritional requirements

(d) Lambs were born in the lot and moved to lambing pens after birth with their dams for about two days before they were moved to mixing pens for three to five days

(e) from lambing to weaning, ewes and their lambs were maintained on wheat pasture, while lambs had access to a creep ration

In both lambing regimes, ewes were fed to meet NRC nutritional requirements.

Data Recorded and Traits Studied

Data for each lamb record included dam ID, genotype of dam (BOD), age of dam (AOD), sire genotype (GOS), lambing date (LD), sex (SOL), type of birth (TOB), rearing type (TBR), birth weight (BWT), weaning weight (WWT), weaning date (WD), and year/season of birth (YSB). Fertility (FET) defined as lambed or not was determined for each ewe exposed to the ram.

The following traits either measured directly or derived from the data were considered for analysis:

(a) ewe fertility (FET) - (0 = open, 1= lambed)

(b) birth weight (BWT) - weight of individual lamb taken within 24 hr of birth

(c) adjusted weaning weight (WWT) - weight of individual lamb at weaning adjusted to a standard age of 70-d

(d) litter weight at birth (LWB) - total weight of lambs born per ewe lambing excluding fostered lambs

(e) litter weight at weaning (LWW) - the total weight of lamb per ewe lambing at weaning excluding fostered or nursery-reared lambs

(f) litter size at birth or prolificacy (LSB) - the number of lambs born to a ewe per lambing

(g) litter size at weaning (LSW) - the number of lambs reared by each ewe to weaning. Fostered or nursery-reared lambs were excluded

(h) lamb viability to weaning (LVW) - alive or dead at weaning. Fostered or nursery-reared lambs were not considered.

For the purposes of presentation and discussion of the results, the above traits were divided into three categories: (1) characteristics of lamb growth which included birth weight and weaning weight; (2) characteristics of ewe reproduction which included fertility, litter size at birth (prolificacy), litter size at weaning, litter weight at birth, litter weight at weaning; and (3) lamb viability to weaning.

Statistical Analyses

All traits were analyzed by least squares analysis of variance (Harvey, 1975). The general linear model included the main effects of genotype of dam (BOD) or sex of lamb (SOL), age of dam within year/season of birth (AOD), type of birth (TOB), type of birth/rearing (TBR) and year/season of birth (YSB). All possible two-and three-way factor interactions were fitted in the original model. However, only those interactions that had a significant F-value of $P \leq .30$ were retained in the reduced model. All main effects were left in the model regardless of their significance level.

Traits of interest (described above) were analyzed separately in order to fit in the model those factors which were determined to influence that particular individual trait. The analysis of variance least squares for the reduced models for individual traits are depicted on the following tables: Table 14 (birth weight and weaning weight), Table 19 (fertility), Table 21 (litter weight at birth and at weaning), and Table 23 (litter size at birth and at weaning and lamb viability).

Age of dam was combined with year/season to a single trait because not all age categories were represented in each year of the study. It was necessary to group together the three and four-year old dams. The five-year and older dams were also grouped. The grouping of ewe age groups was possible because preliminary analysis revealed no significant differences between the specified age groups in the major traits (birth weight, weaning weight and prolificacy). There were a 25 sets of triplets recorded in the data which were subsequently classified together with twin-born lambs as 'multiple-born' in order to utilize the maximum number of records available for the analysis of each specific trait.

The least significance difference (LSD) test was used to test for differences in means whenever an effect had a significant F-value ($P < .05$). All main effects were considered fixed.

Results

Lamb Growth Traits

Birth Weight: The analysis of variance for BWT is presented in Table 14. Birth weight was influenced by BOD ($P < .0001$), SOL ($P < .0001$), AOD ($P < .01$), TOB ($P < .001$) and YSB ($P < .0001$). The interactions BOD*TOB and BOD*AOD also had an effect on birth weight at $P < .001$ and $P < .05$, respectively (Table 14).

TABLE 14

ANALYSIS OF VARIANCE FOR BODY WEIGHTS OF LAMBS FROM CROSSBRED EWES

	Birth Weight (kg)		Weaning Weight (kg)	
Source of Variation	df	Mean Squares	df	Mean Squares
Genotype of Dam (BOD)	2	31.36***	2	39.40*
Sex of Lamb (SOL)	1	19.63***	1	52.13*
AOD in Year/Season (AOD)	4	4.36**	4	60.39**
Type of Birth (TOB)	1	27.38***	-	--
Type of Birth/Rearing (TBR)	-	--	2	401.55***
Year/Season of Birth (YSB)	3	7.12***	3	109.46***
BOD*TOB	2	7.21***	-	--
BOD*YSB	6	1.33	6	24.86
TOB*YSB	3	2.27	-	--
BOD*AOD	8	2.93*	8	24.03
TOB*AOD	4	1.57	-	--
BOD*TBR	-	--	4	34.19*
TBR*YSB	-	--	6	40.33*
Residual	603	.98	442	13.34

*P < .05; **P < .01; ***P < .001

Least squares means and standard errors for BWT main effects are presented in Table 15, while least squares means for the interactions BOD*TOB and BOD*AOD are presented in Tables 16 and 17, respectively.

The overall mean for BWT based on 638 lambing records of crossbred ewes was 3.85 kg (Table 15). Lambs from DxR ewes were heavier at birth (4.52 kg), followed by lambs from BxR (3.88 kg) and FxR (3.61 kg) ewes, respectively. However, birth weights of lambs from BxR and FxR ewes were similar ($P > .05$)

Male lambs were heavier ($P < .05$) than female lambs at birth (4.19 vs 3.83 kg). Single-born lambs were heavier ($P < .05$) than multiple-born lambs at birth (4.31 vs 3.70 kg).

Younger ewes (2-yr old) had lighter lambs at birth than 3 to 4-yr old ewes in 1991-fall (3.29 vs 3.78 kg). Similarly, in 1992-fall the younger ewes (3 to 4-yr old) had lighter lambs at birth than the 5+-yr old ewes (3.65 vs 3.98 kg). In 1993-spring, however, the 3 to 4-yr old and the 5+-yr old ewes had lambs with similar birth weights (4.11 vs 4.16 kg). To the contrary, in 1993-fall, the younger (3 to 4-yr old) ewes had substantially the heaviest ($P < .001$) lambs at birth than the 5+-yr old ewes (5.09 vs 3.97 kg).

Year/season of birth significantly influenced BWT. The heaviest lambs at birth were recorded in 1993-fall (4.53 kg), while the lightest lambs were produced in 1991-fall (3.54 kg). Birth weights recorded in the other year/season were 3.82 and 4.14 kg in 1992-fall and 1993-spring, respectively (Table 15).

Birth weight least squares means for the interactions BOD*TOB (Table 16) show that among the BxR dams, BWT was similar ($P > .05$) in both single-born and multiple-born lambs (3.94 vs 3.83 kg), however, the single-born lambs were 0.11 kg heavier than the multiple-born lambs. Among the DxR dams, lambs born as singles were heavier ($P < .05$) at birth than lambs born as multiples (5.05 vs 4.00 kg). Similarly, among the FxR dams, the single-born lambs were heavier ($P < .05$) at birth than multiple-born lambs (3.95

TABLE 15

LEAST SQUARES MEANS AND STANDARD ERRORS FOR BODY WEIGHTS MAIN EFFECTS

	Birth Weight (kg)			Weaning Weight (kg)		
Source of Variation[a]	n	LSMean	SE	n	LSMean	SE
Overall Mean	638	3.85	.99	479	19.79	3.65
Genotype of Dam (BOD)		***			*	
BxR	136	3.88[b]	.18	86	18.91[bc]	.76
DxR	261	4.52[c]	.08	211	20.49[c]	.39
FxR	241	3.61[b]	.09	182	19.33[bd]	.43
Sex of Lamb (SOL)		***			*	
female	298	3.83[b]	.09	232	19.23[b]	.37
male	340	4.19[c]	.08	247	19.92[c]	.36
AOD in Year/Season (AOD)		**			**	
1991-fall (2 yr)	36	3.29[b]	.19	21	19.42[bce]	.88
1991-fall (3 to 4 yr)	114	3.78[cd]	.13	72	20.54[b]	.50
1992-fall (3 to 4 yr)	143	3.65[bc]	.09	109	19.20[ce]	.39
1992-fall (5+ yr)	112	3.98[cd]	.11	90	20.33[bc]	.47
1993-spring (3 to 4 yr)	26	4.11[cd]	.30	18	17.37[de]	1.22
1993-spring (5+yr)	62	4.16[d]	.17	41	15.93[d]	.69
1993-fall (3 to 4 yr)	56	5.09[e]	.35	53	24.48[f]	1.36
1993-fall (5+ yr)	89	3.97[cd]	.21	75	19.33[bce]	.85
Type of Birth (TOB)		***				
single (S)	212	4.31[b]	.11	--	--	--
multiple (M)	426	3.70[c]	.08	--	--	--
Type of Birth/Rearing (TBR)					***	
single/single (SS)	--	--	--	177	21.58[d]	.45
multiple/single (MS)	--	--	--	65	19.50[c]	.61
multiple/multiple (MM)	--	--	--	237	17.65[b]	.35
Year/Season of Birth (YSB)		***			***	
1991 in fall	150	3.54[b]	.12	93	19.98[cd]	.54
1992 in fall	255	3.82[c]	.07	199	19.77[c]	.32
1993 in spring	88	4.14[cd]	.17	59	16.65[b]	.74
1993 in fall	145	4.53[d]	.20	128	21.91[d]	.85

[a]BxR = Booroola Merino x Rambouillet; DxR = Dorset x Rambouillet;
FxR = Finnsheep x Rambouillet.

[b,c,d,e,f]Means within a column in a subgroup with different superscripts differ (P < .05)

*P < .05; **P < .01; ***P < .001

TABLE 16

LEAST SQUARES MEANS AND STANDARD ERRORS FOR BIRTH WEIGHT (BWT) BY THE INTERACTION: GENOTYPE OF DAM VS TYPE OF BIRTH (BOD*TOB)

Source of Variation[a]		Birth Weight (kg) n	Least Squares Mean	SE
Interaction: BOD*TOB				
Genotype of Dam	Type of Birth			
BxR	single	38	3.94[c]	.23
BxR	multiple	98	3.83[c]	.19
DxR	single	116	5.05[d]	.12
DxR	multiple	145	4.00[c]	.09
FxR	single	58	3.95[c]	.16
FxR	multiple	183	3.27[b]	.09

[a]BxR = Booroola Merino x Rambouillet; DxR = Dorset x Rambouillet; FxR = Finnsheep x Rambouillet.

[b,c,d]Means within a column with different superscripts differ ($P < .05$)

vs 3.27 kg). Table 17 presents the birth weight least squares means for the interaction genotype of dam versus age of dam within year/season of birth (BOD*AOD).

Weaning Weight: The mean squares for WWT are presented in Table 14. Weaning weight was significantly influenced by BOD, SOL, AOD, TBR, and YSB. In addition, the following interactions also influenced WWT: genotype of dam vs type of birth/rearing (BOD*TBR) and type of birth/rearing vs year/season of birth (TBR*YSB). The overall mean for WWT based on 479 lambing records was 19.79 kg (Table 15).

Lambs born and weaned by DxR ewes had the heaviest WWT (20.49 kg), while lambs from FxR and BxR ewes weaned at 19.33 and 18.91 kg, respectively. Male lambs were 0.69 kg heavier ($P < .05$) than female lambs at weaning. Lambs born and raised singly (SS) were weaned at 21.58 kg vs 19.50 kg for lambs born as multiples and raised as singles (MS) and 17.65 kg for lambs born and raised as multiples (MM).

Age of dam within year/season significantly influenced WWT. In 1991-fall, the 2-yr old and 3 to 4-yr old ewes weaned lambs of similar ($P >.20$) weights, however, the older(3 to 4-yr old) ewes weaned 1.12 kg more lamb than the 2-yr old ewes. Similarly, in 1992-fall the younger (3 to 4-yr old) ewes weaned lambs of similar weights ($P > .05$) to lambs weaned by 5+-yr old ewes, however, the older (5+-yr) ewes weaned 1.13 kg more lamb than the 3 to 4-yr old ewes. The younger ewes changed rank in both 1993-spring and 1993-fall. In both cases the younger (3 to 4-yr old) weaned heavier lambs than the older (5+-yr old) ewes (17.34 vs 15.93 kg in 1993-spring and 24.48 vs 19.33 kg in 1993-fall). The WWT differences were, however not significant in 1993-spring.

There were year/season differences in WWT ($P < .0001$). The heaviest lambs were weaned in 1993-fall while the lightest were weaned in 1993-spring (21.91 vs 16.65 kg). In 1991-fall and 1992-fall, however, WWT were similar (19.98 vs 19.77 kg).

Table 18 presents the least squares means and standard errors for WWT by the interactions genotype of dam vs type of birth/rearing (BOD*TBR) and type of birth/rearing vs year/season of birth (TBR*YSB). The interaction BOD*TBR shows that

TABLE 17

LEAST SQUARES MEANS AND STANDARD ERRORS FOR BIRTH WEIGHT (BWT) BY THE INTERACTION: GENOTYPE OF DAM VS AGE OF DAM WITHIN YEAR/SEASON (BOD*AOD)

			Birth Weight (kg)	
Source of Variation[a]		n	Least Squares Means	SE
Interaction: BOD*AOD				
Genotype of Dam	Age of Dam in Year/Season			
BxR	2 yr (1991-fall)	14	2.94	.29
BxR	3 yr (1991-fall)	40	3.46	.19
DxR	2 yr (1991-fall)	12	3.89	.30
DxR	3 yr (1991-fall)	44	4.50	.16
FxR	2 yr (1991-fall)	10	3.06	.32
FxR	3 yr (1991-fall)	30	3.38	.22
BxR	3 yr (1992-fall)	45	3.57	.15
BxR	5 yr (1992-fall)	21	3.34	.22
DxR	3 yr (1992-fall)	65	4.09	.12
DxR	5 yr (1992-fall)	30	4.88	.18
FxR	3 yr (1992-fall)	33	3.31	.18
FxR	5 yr (1992-fall)	61	3.73	.14
BxR	3 yr (1993-spring)	3	3.78	.65
BxR	5 yr (1993-spring)	9	3.74	.33
DxR	3 yr (1993-spring)	16	4.97	.29
DxR	5 yr (1993-spring)	21	4.77	.22
FxR	3 yr (1993-spring)	7	3.60	.39
FxR	5 yr (1993-spring)	32	3.97	.24
BxR	3 yr (1993-fall)	1	6.85	1.01
BxR	5 yr (1993-fall)	3	3.38	.57
DxR	3 yr (1993-fall)	41	4.32	.16
DxR	5 yr (1993-fall)	32	4.79	.18
FxR	3 yr (1993-fall)	14	4.08	.27
FxR	5 yr (1993-fall)	54	3.74	.14

[a]BxR = Booroola Merino x Rambouillet; DxR = Dorset x Rambouillet; FxR = Finnsheep x Rambouillet.

within each ewe genotype (BxR, DxR, FxR), the type of birth/rearing categories consistently maintained their ranks. Lambs within the SS category were always heavier at weaning than lambs in either MS or MM categories, while lambs raised as MS were in turn heavier than MM raised lambs. However, the magnitude of the differences among the type of birth/rearing categories varied within each ewe genotype (Table 18).

The interaction TBR*YSB shows that 1993-fall consistently produced the heaviest lambs at weaning in each of the three birth/rearing categories (SS, MS, MM), while 1993-spring had the lightest lambs at weaning in every birth/rearing category (Table 18).

Ewe Reproductive Traits

Fertility: The analysis of variance for FET in crossbred ewes is presented in Table 19. Year/season of lambing was the only factor influencing ($P < .001$) FET. Overall mean for FET was 88% based on 458 ewe records. The lowest fertility rate (56%) was recorded in 1991-fall, while 100% fertility rates were achieved in 1992-fall, 1993-spring and 1993-fall, respectively (Table 20).

Litter Weight at Birth: Least squares analysis of variance for LWB are presented in Table 21. The following factors significantly affected LWB: BOD, TOB and YSB. The overall mean for LWB was 6.07 kg based on 404 ewe records. The main effects least squares means and standard errors are presented in Table 22. Litters from DxR ewes were the heaviest at birth (6.88 kg), while BxR and FxR ewes produced litters of similar weights at birth (5.80 vs 5.81 kg).

Type of birth was a significant factor explaining variation in LWB. Ewes having multiple-births produced 3.3 more kg of lamb at lambing than ewes lambing singles (7.81 vs 4.51 kg) as depicted in Table 22.

Year/season of birth also influenced ($P < .001$) LSB. Ewes lambing in 1993-spring produced the heaviest litters (7.10 vs 6.11, 5.76, and 5.68 kg for 1993-fall, 1991-fall and 1992-fall, respectively).

TABLE 18

LEAST SQUARES MEANS AND STANDARD ERRORS FOR WEANING WEIGHT (WWT) BY THE INTERACTIONS: GENOTYPE OF DAM VS TYPE OF BIRTH/REARING (BOD*TBR) AND TYPE OF BIRTH/REARING VS YEAR/SEASON OF BIRTH (TBR*YSB)

Source of Variation[ab]		Weaning Weight (kg)		
		n	Least Squares Mean	SE
Interaction: BOD*TBR				
Genotype of Dam	Type of birth/rearing			
BxR	SS	30	19.98[de]	.92
BxR	MS	16	18.92[cde]	1.32
BxR	MM	40	17.84[c]	.81
DxR	SS	99	23.15[f]	.48
DxR	MS	19	20.69[de]	.90
DxR	MM	93	17.63[c]	.41
FxR	SS	48	21.61[e]	.66
FxR	MS	30	18.89[cd]	.77
FxR	MM	104	17.48[c]	.52
Interaction: TBR*YSB				
TBR	YSB			
SS	1991-fall	22	22.59[fg]	.85
SS	1992-fall	82	20.80[ef]	.44
SS	1993-spring	12	18.19[cd]	1.21
SS	1993-fall	61	24.73[g]	.81
MS	1991-fall	14	20.91[def]	1.09
MS	1992-fall	30	20.08[de]	.69
MS	1993-spring	12	16.20[cd]	1.36
MS	1993-fall	9	20.79[def]	1.51
MM	1991-fall	57	16.44[c]	.56
MM	1992-fall	87	18.41[d]	.44
MM	1993-spring	35	15.55[c]	.80
MM	1993-fall	58	20.19[def]	.88

[a]BxR = Booroola Merino x Rambouillet; DxR = Dorset x Rambouillet; FxR = Finnsheep x Rambouillet.

[b]SS = born and raised singly; MS = born as multiple and raised as singly; MM = born and raised as multiple

[c,d,e,f,g]Means within a column in a subgroup with different superscripts differ ($P < .05$)

TABLE 19

ANALYSIS OF VARIANCE FOR FERTILITY IN CROSSBRED EWES

Source of Variation	df	Mean Squares
Genotype of Dam (BOD)	2	0.06
AOD in Year/Season (AOD)	4	0.13
Year/Season of Lambing (YSL)	3	4.64***
BOD*YSL	6	0.10
Residual	442	0.07

***P < .001

TABLE 20

LEAST SQUARES MEANS AND STANDARD ERRORS FOR FERTILITY IN CROSSBRED EWES

Source of Variation[a]	n	LS Mean	SE
Overall Mean	458	0.88	.26
Genotype of Dam (BOD)		NS	
BxR	95	0.86[b]	.02
DxR	202	0.90[b]	.02
FxR	161	0.87[b]	.02
AOD in Year/Season (AOD)		NS	
1991-fall (2 yr)	40	0.50[b]	.04
1991-fall (3 to 4 yr)	93	0.63[b]	.03
1992-fall (3 to 4 yr)	100	1.00[b]	.03
1992-fall (5+ yr)	75	1.00[b]	.03
1993-spring (3 to 4 yr)	14	1.00[b]	.08
1993-spring (5+yr)	33	1.00[b]	.05
1993-fall (3 to 4 yr)	38	1.00[b]	.07
1993-fall (5+ yr)	65	1.00[b]	.06
Year/Season of Lambing (YSL)		***	
1991 in fall	133	0.56[b]	.03
1992 in fall	175	1.00[c]	.02
1993 in spring	47	1.00[c]	.05
1993 in fall	103	1.00[c]	.05

[a]BxR = Booroola Merino x Rambouillet; DxR = Dorset x Rambouillet;
FxR = Finnsheep x Rambouillet

[b,c,d]Means within a column in a subgroup with different superscripts differ (P < .05)

***P < .001

TABLE 21

ANALYSIS OF VARIANCE FOR TOTAL WEIGHT OF LAMB AT BIRTH (LWB)[a] AND TOTAL WEIGHT OF LAMB AT WEANING (LWW)[b]

	Total Weight of Lamb at Birth (kg)		Total Weight of Lamb at Weaning (kg)	
Source of Variation	df	Mean Squares	df	Mean Squares
Genotype of Dam (BOD)	2	52.88***	2	382.98**
AOD in Year/Season (AOD)	4	4.93	1	168.92*
Type of Birth (TOB)	1	992.71***	1	6599.42***
Year/Season of Birth (YSB)	3	22.17***	3	622.66***
Residual	393	2.64	346	57.82

[a]LWB = total weight (kg) of lamb born/ewe lambing

[b]LWW = total weight (kg) of lamb weaned/ewe lambing

*P < .05

**P < .01

***P < .001

Litter Weight at Weaning: The following factors significantly influenced variation in LWW: BOD, AOD, TOB and YSB. The overall mean for LWW was 26.55 kg based on 357 ewe records. Least squares means and standard errors for LWW are presented in Table 22. Litters from DxR ewes were the heaviest at weaning (27.49 kg) but similar in weight to litters from FxR ewes (26.28 kg). The lightest litters at weaning were produced by the BxR ewes (23.27 kg).

Age of dam within year/season also influenced ($P < .05$) LWW. Within each year/season , the older dams tended to wean heavier litters than the younger dams. In 1993-fall, the 3 to 4-yr old dams produced 12% more kg of lamb at weaning than the 2-yr old dams (6.09 vs 5.42 kg). Further, in 1992-fall, the 5+-yr old dams produced 9.5 more kg of lamb than the 3 to 4-yr old dams. Similarly, in 1993-spring and 1993-fall, the 5+-yr-old produced 9% and 0.8 % more kg of lamb than the 3 to 4-yr-old ewes.

Ewes having multiple-births produced 43% more kg of lamb at weaning than ewes lambing singles (Table 22).

The heaviest litters at weaning were produced in 1993-fall (29.60 kg), while the lightest litters were born in 1993-spring (21.44 kg). However, in 1991-fall and 1992-fall, ewes weaned litters of similar weights (26.34 vs 25.34 kg).

Litter Size at Birth: The analysis of variance mean squares for litter size at birth (LSB) are presented in Table 23. Genotype of dam ($P < .0001$) and year/season ($P < .003$) influenced the variation in LSB. The least squares means and standard errors for LSB are shown in Table 24. The overall mean for LSB was 1.96 lambs based on 404 ewe records. The FxR and BxR dams were similar ($P > .14$) and more prolific ($P < .05$) than DxR ewes. Litter size at birth was 2.30, 2.08 and 1.82 lambs for FxR, BxR and DxR ewes, respectively.

Ewes were more prolific in 1993-spring and 1991-fall (2.34 vs 2.23 lambs), while prolificacy was lower in 1993-fall and 1992-fall (1.78 vs 1.92 lambs) (Table 24).

TABLE 22

LEAST SQUARES MEANS AND STANDARD ERRORS FOR TOTAL WEIGHT OF LAMB AT BIRTH (LWB)[a] AND TOTAL WEIGHT OF LAMB AT WEANING (LWW)[b]

	Litter Weight at Birth (kg)			Litter Weight at Weaning (kg)		
Source of Variation[c]	n	LSMean	SE	n	LSMean	SE
Overall Mean	404	6.07	2.64	357	26.55	7.60
Genotype of Dam (BOD)		***			**	
BxR	82	5.80[d]	.20	66	23.27[d]	1.01
DxR	182	6.88[e]	.13	163	27.49[e]	.67
FxR	140	5.81[d]	.16	128	26.28[e]	.78
AOD in Year/Season (AOD)		NS			*	
2 yr (1991-fall)	20	5.42[d]	.36	14	26.42[ef]	2.04
3 yr (1991-fall)	59	6.09[d]	.22	50	26.25[ef]	1.09
3 yr (1992-fall)	100	5.44[d]	.17	87	24.49[e]	.83
5 yr (1992- fall)	75	5.93[d]	.19	68	26.19[ef]	.95
3 yr (1993-spring)	14	6.82[d]	.44	12	23.22[def]	2.22
5 yr (1993-spring)	33	7.37[d]	.29	29	19.66[d]	1.44
3 yr (1993-fall)	38	6.09[d]	.27	37	31.86[g]	1.31
5 yr (1993-fall)	65	6.14[d]	.22	60	27.34[f]	1.05
Type of Birth (TOB)		***			***	
single	209	4.51[d]	.14	178	21.12[d]	.71
multiple	195	7.81[e]	.13	179	30.24[e]	.65
Year/Season of Birth (YSB)		***			***	
1991-fall	79	5.76[d]	.21	64	26.34[e]	1.16
1992-fall	175	5.68[d]	.13	155	25.34[e]	.63
1993-spring	47	7.10[e]	.27	41	21.44[d]	1.34
1993-fall	103	6.11[d]	.18	97	29.60[f]	.87

[a]LWB =total weigth of lamb born/ewe lambing
[b]LWW = total wight of lamb weaned/ewe lambing
[c]BxR = Booroola Merino x Rambouillet; DxR = Dorset x Rambouillet;
FxR = Finnsheep x Rambouillet.
[d,e,f,g]Means within a column in a subgroup with different superscripts differ (P < .05)
*P < .05; **P < .01; ***P , < .001

TABLE 23

ANALYSIS OF VARIANCE FOR LITTER SIZE AT BIRTH (LSB), LITTER SIZE AT WEANING (LSW) AND LAMB VIABILITY TO WEANING (LVW)

	Litter Size					
	At Birth		At Weaning		Lamb Viability to Weaning	
Source of Variation	df	Mean Squares	df	Mean Squares	df	Mean Squares
Genotype of Dam (BOD)	2	8.44***	2	0.03	2	0.04
Sex of Lamb (SOL)	--	--	--	--	1	0.41+
AOD in Year/Season (AOD)	4	0.80	4	0.03	4	0.07
Type of Birth (TOB)	--	--	--	--	1	0.73*
Year/Season of Birth (YSB)	3	4.41**	3	0.58*	3	0.34*
BOD*YSB	-	--	6	0.34	6	0.20+
BOD*AOD	-	--	8	0.31	--	--
Residual	394	0.92	334	0.21	386	0.11

+P< .10; * P < .05; ** P < 01; ***P < .001

Litter Size at Weaning: The analysis of variance mean squares for LSW are shown in Table 23. Year/season of birth was the only factor that affected (P < .043) LSW (Table 23).

The overall mean for LSW based on 357 ewe records was 1.32 lambs. The least squares means and standard errors for LSW are presented in Table 24. There was no effect (P > .86) of genotype of dam (BOD) on LSW. The means for LSW were 1.41, 1.37, 1.35 lambs for BxR, DxR and FxR ewes, respectively.

Year/season of birth was a significant source of variation in LSW. The largest litters at weaning were produced in 1991-fall and 1993-spring (1.47 vs 1.48 lambs), while the smallest litters were weaned in 1992-fall and 1993-fall (1.27 vs 1.29 lambs) (Table 24).

Lamb Viability

Table 23 presents the analysis of variance mean squares for LVW. Sex of lamb (P < .052), type of birth (P < .011), year/season (P < .025) and the interaction of genotype of dam vs year/season (P < .09) were important sources of variation influencing LVW. The overall mean for LVW was 79% based on 404 ewe records. Genotype of dam did not influence (P > .68) LVW. Survival rate to weaning was 80, 81 and 77 % for lambs from BxR, DxR and FxR dams, respectively (Table 24). The means and standard errors for the interaction BOD*YSB are presented in Table 25.

TABLE 24

LEAST SQUARES MEANS AND STANDARD ERRORS FOR LITTER SIZE AT BIRTH (LSB), LITTER SIZE AT WEANING (LSW) AND LAMB VIABILITY TO WEANING (LVW) BY MAIN EFFECTS

	Litter Size at Birth			Litter Size at Weaning			Lamb Viability to Weaning		
Source of Variation[a]	n	LSMean	SE	n	LSMean	SE	n	LSMean	SE
Overall Mean	404	1.96	.96	357	1.32	.46	404	.79	.33
Genotype of Dam (BOD)		***			NS			NS	
BxR	82	2.08^{c}	.12	67	1.41^{b}	.10	82	$.80^{b}$	.06
DxR	182	1.82^{b}	.08	163	1.37^{b}	.05	182	$.81^{b}$	.03
FxR	140	2.30^{c}	.09	128	1.35^{b}	.06	140	$.77^{b}$	.03
Sex of Lamb (SOL)								+	
female	--	--	--	--	--	--	132	$.83^{c}$	.04
male	--	--	--	--	--	--	272	$.76^{b}$	.03
AOD in Year/Season (AOD)		NS			NS			NS	
2 yr (1991-fall)	20	2.11^{b}	.15	14	1.50^{b}	..13	20	.66	.07
3-4 yr (1991-fall)	59	2.35^{b}	.09	50	1.44^{b}	.07	59	.73	.05
3-4 yr (1992-fall)	100	1.91^{b}	.08	88	1.27^{b}	.05	100	.78	.03
5+ yr (1992-fall)	75	1.93^{b}	.09	68	1.27^{b}	.06	75	.80	.04
3-4 yr (1993-spring)	14	2.38^{b}	.22	12	1.54^{b}	.19	14	.80	.10
5+ yr (1993-spring)	33	2.31^{b}	.13	29	1.42^{b}	.09	33	.73	.06
3-4 yr (1993-fall)	38	1.94^{b}	.31	37	1.26^{b}	.16	38	.98	.08
5+ yr (1993-fall)	65	1.62^{b}	.19	60	1.31^{b}	.12	65	.89	.07
Type of Birth (TOB)								*	
single	--	--	--	--	--	--	209	$.84^{c}$	.03
multiple	--	--	--	--	--	--	195	$.75^{b}$	.03
Year/Season of Birth (YSB)		***			*			*	
1991-fall	79	2.23^{c}	.13	64	1.47^{c}	.07	79	$.69^{b}$	.04
1992-fall	175	1.92^{b}	.07	156	1.27^{b}	.04	175	$.79^{c}$	.03
1993-spring	47	2.34^{c}	.16	41	1.48^{c}	.10	47	$.77^{bc}$	.06
1993-fall	103	1.78^{b}	.11	97	1.29^{bc}	.10	103	$.94^{d}$	.07

[a]BxR = Booroola Merino x Rambouillet; DxR = Dorset x Rambouillet; FxR = Finnsheep x Rambouillet

[b,c,d]Means within a column in a subgroup with different superscripts differ ($P < .05$)

[+]$P < .10$; *$P < .05$; **$P < .01$; ***$P < .001$

TABLE 25

LEAST SQUARES MEANS AND STANDARD ERRORS FOR LAMB VIABILITY TO WEANING (LVW) BY THE INTERACTION: GENOTYPE OF DAM VS YEAR/SEASON OF BIRTH (BOD*YSB)

Source of Variation[a]		Lamb Viability Weaning		
		n	Least Squares Means	SE
Interaction BOD*YSB				
Genotype of Dam	Year/Season of Birth			
BxR	1991-fall	26	.65	.07
BxR	1992-fall	46	.69	.05
BxR	1993-spring	7	.86	.13
BxR	1993-fall	3	1.00	.19
DxR	1991-fall	34	.67	.06
DxR	1992-fall	72	.85	.04
DxR	1993-spring	22	.83	.07
DxR	1993-fall	54	.91	.05
FxR	1991-fall	19	.76	.08
FxR	1992-fall	57	.85	.05
FxR	1993-spring	18	.61	.08
FxR	1993-fall	46	.88	.05

[a]BxR = Booroola x Rambouillet; DxR = Dorset x Rambouillet;
FxR = Finnsheep x Rambouillet

Female lambs had a higher ($P < .052$) survival rate to weaning than their male littermates (83 vs 76%).

Type of birth was a significant source of variation affecting LVW. Lambs born as singles had higher survival rates than lambs born as multiples (84 vs 75%) (Table 24).

Year/season of birth significantly affected LVW. Lamb survival rate to weaning was the highest in 1993-fall (94%), while 1991-fall had the lowest survival rate (69%). However, similar survival rates were recorded in 1992-fall and 1993-spring (79 vs 77%).

Age of dam within year/season did not influence LVW ($P > .60$). However, lamb survival rate to weaning tended to be slightly higher among older ewes when compared with younger ewes in the same year/season. The reverse was also true only in 1993-fall where LVW was slightly higher among younger (3 to 4-yr old) ewes than in older (5+-yr old) ewes (98 vs 89%). This scenario might have been due to the presence of a higher proportion of older ewes (6 and 7-yr old) in the 1993-fall data set.

Discussion

The results of the present study will be discussed under the three categories describing the major traits which are the subject of this investigation, namely: lamb growth, ewe reproduction and lamb viability to weaning.

Lamb Growth Traits

The effect of BOD was a significant factor influencing lamb growth (BWT and WWT). The DxR lambs ranked first in both BWT and WWT measurements. Several studies cited in the literature have reported a significant effect of BOD on lamb growth traits. Olthoff and Boylan (1991) compared growth performance of lambs from purebred and crossbred Finnsheep ewes and reported lambs from Dorset dams ranked higher than lambs from Finnsheep ewes. Similar findings were reported by Cochran et al. (1984) in comparisons of Dorset and Finnish Landrace crossbred ewes. The birth weight and adjusted 90-d weights were larger (P< .001) for lambs from Dorset dams than lambs from 1/4-Finn or 1/2 Finn dams. Whiteman et al. (1974) reported that lambs produced by 1/4-Finn ewes were lighter at birth and at 70-d of age than were the lambs produced from the DxR ewes. The above citations agree with findings from the present study, where lambs from DxR were ranked first in BWT and WWT followed by lambs from BxR in BWT and FxR lambs in WWT, respectively.

Sex of lamb influenced lamb growth traits. Male lambs were heavier at birth and at weaning than their female littermates. In general, this situation is consistent with observations in most livestock species, where the male neonate is heavier at birth and grows faster than its female counterpart. The present results concur with findings by other researchers. Studies by Hazel and Terrill (1946), Dickerson et al. (1972) and Rajab et al. (1992) all showed that sex of lamb has a major influence on lamb BWT and WWT. In contrast, Juma et al. (1969), Trail and Sacker (1969) and Singh et al. (1982) reported no sex effects on lamb BWT and WWT. Contrasting results in studies involving similar traits are expected in the literature because experimental procedures and environmental conditions vary from study to study.

The effects of age of dam within year/season were profound. Similar findings were reported by Eltawil et al. (1970) who evaluated environmental factors affecting BWT, WWT and yearling weight (YWT) in Navajo sheep. The results in that study showed that AOD exerts most of its influence on pre-weaning traits. In other words, BWT and WWT were influenced by AOD much more than was YWT. The results of the present study also are in agreement with findings reported by Vesely and Peters (1964), Dickerson and Laster (1975), Kleemann et al. (1990) and Rajab et al (1992).

The findings on the effects of type of birth/rearing on BWT and WWT reported in this study are in agreement with results reported by Blackwell and Henderson (1955), Gould and Whiteman (1971), Stritzke and Whiteman (1982), Burditt et al. (1988), Kleemann (1991) and Rajab et al. (1992). As expected, the single-born lambs raised as singles (SS) had heavier BWT and WWT than lambs born as multiples and raised either singly or as multiples.

Year/season effects were pronounced throughout the present study. This situation was expected on account of inherent variation in temperature, wind and rainfall amount as well as its distribution. These factors in combination, determine the quantity and quality of forage within a particular year, which in turn influence ewe performance. Several workers have also reported significant effects of year/season on lamb growth traits (Gould and Whiteman, 1971; Dickerson, 1975; Cochran et al., 1984; Nawaz and Meyer, 1992). However, Hohenboken et al. (1976a), Rajab et al. (1992) and Bunge et al. (1993a) found no year effect on WWT, while Notter and Copenhaver (1980a) found no effect of year on BWT.

Ewe Reproductive Traits

Fertility: Overall fertility was high in all the ewe genotypes, therefore BOD did not significantly affect fertility in the ewe. The results are in agreement with findings reported by Laster et al. (1972), Notter and Copenhaver (1980a) and Ercanbrack and Knight (1985) who found no difference in fertility between 1/4 Finn-crosses and purebred Columbia , Targhee, or Rambouillet ewes. Bunge et al. (1993b) also reported no significant effect of breed of dam on fertility in Suffolk and Targhee ewes mated to Finnsheep, Combo-6, Booroola Merino, St. Croix and Barbados rams.

Year/season of breeding influenced fertility to a large extent. Similar findings were reported by Bunge et al. (1993b). The low fertility rate (56%) recorded in 1991-fall lambing season could be attributed to adverse environmental factors such as excessive ambient temperatures during the joining period (1991-summer). This effect can have consequences in both the ewe and the ram.

Prolificacy: Ewe prolificacy is a function of the genetic potential of the ewe for ovulation rate, ability of the ova to be fertilized and be able to develop into a viable offspring. Number of lambs born per ewe lambing was influenced BOD and YSB. This is in close agreement with results reported in other breeds (Glimp, 1971; Sidwell and Miller 1971b; Dzakuma et al., 1982; Bunge et al., 1993b). In the present study, the FxR and BxR ewes were more prolific than were the DxR ewes, which can be attributed to the higher ovulation in the BxR and FxR dams. The low lambing rates recorded in 1992-fall and in 1993-fall (1.92 vs 1.78 lambs) could be attributed to the presence of a large proportion of older ewes (6+-yr) in the data set.

Litter Size at Weaning: Genotype of dam did not influence LSW. However, this trait was significantly affected by year/season of birth. In a similar way as LSB, litter size at weaning was the low in 1992-fall and in 1993-fall (1.27 vs 1.29 lambs). This situation is a direct reflection of litter size at birth.

Litter Weight at Birth and at Weaning: Genotype of dam, TOB, and YSB significantly influenced LWB and LWW. The DxR dams ranked first in both LWB and LWW, being a reflection of the higher BWT and WWT of their lambs. Other workers also reported significant BOD effects on LWB and LWW (Ercanbrack and Knight, 1985; Rajab et al., 1992; Iman and Slyter, 1993).

Age of dam within season did not influence LWB. This is in agreement with results reported by Oltenacu and Boylan (1981), on the other hand, AOD had a significant influence on LWW, in close agreement with findings reported by Coop and Clark (1952), Dickerson and Glimp (1975) and Atkins (1980).

The effect of TOB was a significant source of variation influencing LWB and LWW. In the present study, multiple-birth (MB) resulted in more kg of lamb at birth and at weaning than was single-birth (SB). The advantage of MB in LWB and in LWW compensates for the high mortality rates (to be discussed later in the chapter) associated with MB. In certain production environments, producers are often faced with the option of selecting for MB or SB. The choice of one criterion over the other usually will depend on the production environment (especially nutrition) and the level of flock management. In the harsh environments coupled with low level of management, the SB selection criterion is advisable, while the MB criterion is recommended under a good nutritional environment coupled with a high level of management that is conducive to raising of lambs by their dams from birth to weaning.

Year/season of birth also significantly affected LWB and LWW. Findings in the present study were in close agreement with reports by Fogarty et al. (1984a) and Kleemann et al. (1991). The results of the present study indicate that lambs born in 1993-spring had the highest LWB and the lowest LWW. These results should be interpreted with caution because there was a small sample size in this particular year for both LWB and LWW (47 vs 41 records) which could have contributed to the large variations in both traits as shown by the standard errors associated with means for LWB (7.10±.27) and LWW (21.44±1.34).

Lamb Viability

Type of birth significantly affected LVW. This is in agreement with findings by Venkatachalam et al. (1949) in a study of six breeds of sheep, they reported that mortality rate was higher in lambs born as multiples (35%) than in single births (20%). Kleemann et al. (1988) reported that in Booroola Merino x South Australian Merino, average litter size was 2.13, with lamb mortalities of 29, 47, 66 and 83% in singles, twins, triplets and quadruplets, respectively. Similar findings were reported by Jakubec (1977), Maijala and Österberg (1977), Hinch et al. (1983) Castonguay et al. (1990), Gama et al. (1991), Hall et al. (1992) and Kelly (1992).

In the present study, the higher mortality among lambs born as multiples is indicative of the inadequacy of dam's milk to sustain the life of MB lambs. It could also be a reflection of the lighter BWT associated with the MB lambs. Lamb survival is critical during the first few weeks of life when the lamb is entirely dependent on the mothering ability of the dams.

Year/season of birth influenced LVW. The highest lamb mortalities (31%) were recorded in 1991-fall. These high mortalities were associated with corresponding larger LSB (2.23 lambs) and LSW (1.47 lambs). On the other hand, the lower mortality rate in 1993-fall (6%) was associated with low LSB (1.78 lambs) and low LSW (1.29 lambs), respectively. Several researchers have reported similar, significant effects of YSB on LVW in other breeds(Dickerson et al., 1975; Walker et al., 1979; Fogarty et al., 1984a; Owens et al., 1985). To the contrary, however, Venkatachalam et al. (1949) and Bunge et al. (1993b) reported that YSB had no significant effect on LVW.

Genotype of dam did not influence LVW, concurring with results reported in other breeds (Malik and Acharya, 1972; Dickerson et al., 1975; Thomas and Whiteman, 1971 a,b; Bunge et al., 1993b; and Iman and Slyter, 1993). This is in disagreement with reports by Venkatachalam et al. (1949), Smith (1977), Dalton et al. (1980) and Leymaster and Jenkins (1993), all of whom reported a significant effect of BOD on LVW.

Sex of lamb also affected LVW significantly. Male lambs had a 9% higher mortality rate than their female litter mates. These findings are in close agreement with reports in other breeds (Dickerson et al., 1975; Smith, 1977; Oltenacu and Boylan, 1981a; Huffman et al., 1985; Scales et al., 1986; Gama et al., 1991; Bunge et al., 1993b).

Implications

The Dorset-cross ewes were superior in birth weight, weaning weight, litter weight at birth and litter weight at weaning as well as having a slight advantage in fertility and lamb viability to weaning. On the other hand, the Finnish Landrace-cross and the Booroola-cross ewes were similar in prolificacy and superior to the Dorset crossbred ewes. Based on the above results, Dorset-cross ewes are recommended for the production of market lambs, while Booroola Merino and Finnish Landrace crosses are more suited for increased. Further evaluation of the different proportions of (1/4, 1/2, 3/4) Booroola Merino crosses is necessary in order to find the optimum level at which this breed can perform under the present production environment. It is desirable to maintain the F-gene from the Booroola Merino in a breed such as the Dorset because of its mothering and milking abilities, as well as the the ability to breed out of season.

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