LITTER SIZE, BIRTH WEIGHT AND WEANING

WEIGHT IN DORSET, FINNISH LANDRACE OR

BOOROOLA MERINO SIRED LAMBS

By

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CHAPTER I

INTRODUCTION

Increasing the number or weight of lambs weaned or
marketed per ewe is the most economically important factor
in sheep production. With an increase in litter size, it is
possible to have an increase in revenue without an
enlargement in ewe numbers. Even in extensive sheep systems
the relative economic values of triplets and twins are 170%
and 180%, respectively (with singles at 100%) (Nitter,
1982). The increase in lamb numbers is particularly
advantageous in management situations where the expanding
labor requirements of multiple births can be met. In this
type of intensive system triplets have a slightly higher
value than twins (210% vs 180%).

There are several different methods which could be used
to arrive at this goal. One of the most obvious methods of
increasing lambing percentage is through a selection
program. However, due to the low heritability of lambing
percentage the progress which can be made through selection
is slow (Nitter, 1985; Terrill, 1984).

Another avenue which has been explored to a larger
degree in recent years is the utilization of highly fecund
breeds in a crossbreeding program. In the United States,

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interest in the Finnish Landrace breed (Finn) has generally been centered on its potential contribution to increasing fecundity in crosses with domestic breeds (Boylan, 1985; Dickerson, 1981; Young et. al., 1985). The high fecundity rate of the breeds, including Finns, which are used in this type of crossbreeding program is thought to be the result of selection pressure for fecundity. The basic problem encountered in the utilization of these breeds in a crossbreeding system is that a moderate to high proportion of the fecund breed must be retained in order for a increase in litter size to be observed.

Until recently fecundity in sheep, like most production characteristics of domestic livestock, was assumed to be an exclusively polygenic trait. Although this appears to be the case for most fecund breeds, there is now evidence that the exceptional fecundity of some breeds of sheep is due to a gene with a major effect on litter size. The Booroola strain of the Merino breed is one of the more extensively studied of these breeds. The high fecundity level of the Booroola Merino can be traced to the action of a single gene (F) with a major effect on the endocrine mediated control of ovulation rate (Bindon and Piper, 1986; Bradford et. al., 1986; Davis et. al.,1982; Jonmundsson and Adalsteinsson, 1985; McNatty et. al., 1984; Meyer and Davis, 1983; Piper and Bindon, 1982; Piper et. al., 1985).

The focus of this thesis is the examination of the F_1 offspring of Booroola Merino, Finnish Landrace and Dorset

rams from Rambouillet ewes. This will allow the evaluation of performance of offspring from the Booroola Merino and the Finnish Landrace, a breed whose large litter size is polygenic in nature, against the traditional F_1 animal (Dorset-Rambouillet) for use in Oklahoma.

CHAPTER II

REVIEW OF LITERATURE

Introduction

In the sheep industry, litter size is the trait in which improvement would result in the greatest economic return to the producer. Due to the high incidence of multiple births, selection for increased litter size would seem a reasonable goal. However, due the low heritability of litter size (Shelton and Menzies, 1968), the speed with which selection progress could be made will be slow.

Therefore there has been considerable interest in recent decades in use of highly fecund breeds. The inherent problem is, if the inheritance is polygenic, a high percentage of the parentage of the crossbred animal must be the high fertility breed in order for the crossbred animal to have a significant change in litter size over the non-fecund parent. This may be considered a disadvantage because a seemingly large percentage of the high fecundity breeds were developed under highly specialized conditions. Therefore the genetic merit for many of the traits of economic importance in sheep production schemes in this country are below the average of the more common breeds.

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It is generally accepted that reproductive efficiency in sheep is highly related with weight of lamb marketed per ewe. This ratio is largely a function of lambs weaned per ewe per year, so research to increase lambs per lambing and number of lambings per year is essential to immediate economic return for the sheep industry (Gerrits et. al., 1979).

In recent years breeds have been found in which this increase is due to the effect of genes at a single locus. This discovery has caused concentration of research in this area. The most extensively researched of these breeds and the focus of this graduate study is the Booroola strain of the Australian Merino.

History of the Booroola Merino

The Booroola Merino was developed initially by two commercial sheep breeders, the Seears brothers of "Booroola", Cooma, New South Wales, Australia, and later by the Commonwealth Scientific and Industrial Research Organization (CSIRO) Divisions of Animal Genetics and Animal Production (Turner, 1978). The Booroola flock maintained by CSIRO was formed in 1958 with triplet- and quadruplet-born ewes, and with a quintuplet-born ram obtained from the Seears brothers (Bindon and Piper, 1986). The duration and exact nature of the selection process used by these commercial sheep breeders in developing this multiple birth flock are not known. However, it has been established that

these breeders practiced selection only on the ewe portion of the flock and purchased sires annually from stud flocks with no history of multiple births (Turner, 1978).

With this type of breeding program, the magnitude of the increase in fecundity obtained by the Seears brothers could not have resulted from increases in the frequency of favorable alleles at loci with small effects on litter size (Bindon and Piper, 1986). The only reasonable genetic model to account for the observed increase is that its occurrence was due to a gradual increase in the frequency of individuals carrying a single gene with a major effect on litter size (Piper and Bindon, 1982b).

Turner (1982) has examined the major gene theory in relation to the origins of the Booroola Merino. The gene could have arisen as a mutation in the Seears' flock. Alternatively, since all males used in their breeding program were obtained from a single source, it may have survived in that flock as a gene that existed in either the (non-Merino) "Cape" or "Bengal" breeds that arrived in Australia in 1788 and 1792, respectively. Historical evidence favors the "Bengal" sheep as the origin of the F gene, since this sheep was known to be highly fecund and to breed twice a year (Gerran et. al., 1985). Both breeds were incorporated into the early flock of Sir Samuel Marsden, to which were added some Spanish Merinos after their arrival in Australia in 1797. There is further historical evidence from the Australian Merino flock register to show that

animals from the Marsden flock were used in formation of the Merino studs from which the Seears brothers made their annual ram purchases (Bindon and Piper, 1986).

Phenotypic Evidence for Fecundity

The Booroola Merino is one of a small number of sheep breeds with high genetic merit for fecundity. These breeds are a valuable genetic resource for improvement of sheep reproductive efficiency, since they can be used to bring rapid increases (40-60%) in fecundity by genetic substitution (Allison et. al., 1982; Bindon and Piper, 1986a; Bindon and Piper, 1986b; Piper and Bindon, 1984; Robertson, 1982; Walkley et. al., 1984;).

It has been shown that one copy of the Fecundity (F) 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 (Davis and Armstrong, 1984/85).

Extensive research has demonstrated the high ovulation and lambing rates of the Booroola Merino (Allison et. al., 1980; Bindon and Piper, 1986; Davis et.al., 1982; Owens, 1984/85; Owens, 1985a; Owens, 1985b;). These results indicate an average increase in lambing rate for the homozygous and heterozygous carriers of the fecundity gene as compared to the normal Merino. In a comparison between control (++) and Booroola (F+) Merino ewes, it was found that Booroola ewes in the study had an average litter size

of 2.29 (range 1-7) with 40% of the litters greater than 3, while control Merinos had a mean litter size of 1.22 (range 1-2) (Bindon and Piper, 1986).

High ovulation rates have been recorded in both Booroola and Booroola-cross flocks but the observation that some progeny of Booroola sires showed no increase in fecundity (Allison et. al., 1980) indicated that this trait in the Booroola Merino wasinherited differently from that in other commonly known high fecundity breeds which are accepted as being polygenic.

Until this time, most breeds of high fecundity have been shown to have early attainment of puberty, an extended breeding season, high ovulation rates and substantial prenatal embryonic wastage. The Booroola does not share the characteristic of a prolonged estrus period and its pattern of ovulation, relative to estrus, seem to differ from the other high fecundity breeds (Bindon and Piper, 1982a). The Booroola Merino has been found to have a greatly shortened period of anestrus as compared to other sheep breeds. The long sexual season of the Booroola may be related to enhanced sensitivity of its pituitary to gonadotrophin releasing hormone (Bindon and Piper, 1982a)

Genetic Makeup of the Booroola Merino

The high lambing rate in the Booroola Merino is thought to be caused by a single gene pair which has the gene action of partial dominance (Smith, 1985; Bindon

et.al., 1985; Piper et.al., 1985; Davis et.al., 1982).
Evaluation of the Booroola strain began by identifying
carriers of the F gene. The criterion which was used to
identify possible carriers of the F gene was ovulation rate.
Homozygous ewes (FF) were those which had ovulations of 5 or
more. Heterozygous individuals (F+) were identified as
having ovulation rates of 3 to 5. When researchers compared
frequencies resulting from these ovulation rates and Hardy-
Weinberg expectation they were found to be in close
agreement (Piper et. al., 1985, Smith et. al., 1985e).

A problem arises when this criterion is used to
distinguish F gene carriers in breeds which normally have
higher lambing rates than the Merino. For example, in a
study in New Zealand involving Booroola x Border Leicester
ewes the mean ovulation rate of the ewes was 3.82 ± 0.20,
and of these, 20% had ovulation rates of five or more.
While in a similar study with F_1 Booroola x conventional
Merino there were very few (7.8%) ovulation records of five
or more (Piper et.al., 1985).

Effects of the F gene

The first studies of the Booroola Merino were in
comparisons with other non-carrier Merinos. This was
accomplished either in a straight comparison or by utilizing
the Booroola Merino in a crossbreeding program. Piper and
Bindon (1982a) found the following results:

1) There was a significant difference in ovulation rate between the Booroola Merino and the control Merino.

2) There was an increase in litter size of 56% in the Booroola Merino crosses as compared to the controls.

3) There was a reduction in lamb survival rate in the Booroola Merino crosses.

4) The combined effects of fertility, fecundity and lamb survival resulted in a 16% increase in lambs weaned for the Booroola Merino crosses.

Ponzoni et. al. (1985), in a study involving crosses of different Merino strains, found that the Booroola strain showed a significant increase in number of corpora lutea per ewe ovulating and in number of lambs weaned per ewe bred. There was no significant difference between crosses for number of ewes ovulating per ewe bred, number of ewes lambing per ewe bred, ewe rearing ability, number of lambs dead per lamb born or number of lambs weaned per ewe bred.

Beetson and Lewer (1985) compared of the reproductive performance of Booroola Merino ewe and control Merino ewes. In the study, control ewes had a higher proportion of barrenness and fewer multiple births than Booroola cross ewes. At first lambing, Booroola cross ewes lambed 0.57 and weaned 0.27 more lambs per ewe present at breeding than did Merino ewes. Differences between the control and the Booroola cross Merinos at second lambing were similar to the results for first lambing. The total weight of the lambs weaned per ewe by Booroola cross ewes was greater than the

control Merinos. Other researchers have reported similar results in comparison of reproductive performance between Booroola and control Merinos (Ponzoni et. al., 1982; Robertson, 1982).

Research which compared the differences in performance traits other than reproduction (i.e. fleece quality and quantity, lamb growth rate, mature body weight, etc.) found little or no difference between control and Booroola Merino (Montgomery et. al., 1983/84; Ponzoni et. al., 1985). In addition, Booroola Merino ewes had a higher incidence of breeding out of season and more overt estrus cycles than control Merinos (Piper and Bindon, 1982b). This trait could be a vital importance to utilization of the breed under Oklahoma production methods where fall lambing is desirable in order to utilize wheat pasture.

The Booroola Merino ewe is also a later maturing animal than other fecund breeds. Young and Dickerson (1986) reported that 1/2 Booroola Merino ewe lambs had a later age at 1st estrus (188.7 vs 177.1) and a lower percentage of cycling ewes at 7 months of age (56.8 vs 90.2) than did their Finn cross contemporaries.

Effects of the Fecundity Gene
on the Endocrine System

The presence of the fecundity gene either in homozygous or heterozygous condition has a vast impact on the endocrine system of the animal. The most striking example of this is

the greatly reduced level of inhibin in Booroola Merino ewes, which results in correspondingly high follicle stimulating hormone (FSH) levels (Bindon and Piper, 1982; Bindon and Piper, 1984; Bindon et. al., 1985a; Bindon et. al., 1985b; Bindon and Piper, 1986; McNatty et. al., 1985; McNatty et. al., 1986; Robertson et. al., 1984; Piper and Bindon, 1982a).

Effect of Inhibin Levels on Ovulation Rate

The action of the F gene is seen primarily in its effect on the secretions of inhibin. Inhibin is one of the negative feedback mechanisms on FSH secretion. At the current time there is a renewed interest in inhibin, a non-steroid compound found in the ovarian follicular fluid, and its effect on ovulation rates in various species. In addition it appears to have no effect on luteinizing hormone (LH) (Hoffman et. al.. , 1979; Lumpkin et. al., 1981; Marder et. al., 1977).

O'Shea et. al. (1984) found that injections of a partially purified preparation from bovine follicular fluid increased ovulation rate in Merino ewes. This increase in ovulation rate resulted in an increased litter size in early pregnancy.

Cummins et. al.. (1983) found Booroolas had lower (P < .001) inhibin levels than did control Merinos. The inhibin reference standard was an ovine testicular lymph protein preparation with an arbitrary potency of 1 U/mg. The

inhibin level found in control Merinos was 1230 ± 130
U/ovary, while Booroola Merinos showed levels of 400 ± 60
U/ovary.

Location of Inhibin Production and
Mode of Action in the Female

Granulosa cells are the source of inhibin in the
ovarian follicle of the female of several species. Inhibin
production in many species increases with an increase in
follicle size up to the LH surge and luteinization. In
sheep, this increase has not been observed and may be
attributed to an increase in antral fluid volume (Tsonis et.
al., 1983).

Female Response to Inhibin Levels. The most plausible
theory for the increased litter size in the Booroola Merino
is that the F gene causes a deficiency of ovarian peptide
hormone, inhibin, resulting in reduced feed back inhibition
of FSH secretion (Bindon and Piper, 1984).

Many researchers have found that the increased lambing
rate found in the Booroola Merino is due primarily to
increased levels of FSH and a greater sensitivity to
existing FSH levels. As stated earlier this increased level
of FSH is primarily caused by a decrease in the levels of
inhibin (Bindon and Piper, 1984a; McNatty et. al., 1985;
Piper and Bindon, 1982b; Robertson et. al., 1984).

McNatty et. al..(1986) found that follicles from FF and F+ ewes produced estradiol and reached maturity at a smaller diameter than ++ ewes. Based on this finding they reported that the maturation of more than five follicles in FF ewes and 3-4 follicles in F+ ewes may be necessary to provide a follicular cell mass capable of producing the same quantity of estradiol as from 1-2 preovulatory follicles in ++ ewes.

Subsequent investigation found the ovaries of the Booroola Merino had 2 to 4 times more primordial follicles (P<.01) and 1.5 to 2 times more preantral follicles (P<.05) than did control Merinos (Driancourt et. al.., 1985).

Due to the rapid advances which could be made through the control of inhibin levels, there is a great deal of interest in developing methods whereby these levels could be controlled. At this time, two different approaches to the problem are under study, these are either through biochemical methods or through the process of genetic engineering involving the insertion of genes from strains of animals demonstrating regulatory effects on inhibin production. One of breeds of prime consideration for the process of genetic engineering to decrease inhibin levels would be the Booroola Merino due to its naturally lower levels of this hormone and the control of this reduction appears to be at a single locus.

Male Expression of the Fecundity Gene. At the present time there has been no direct expression of the fecundity gene in the males (Oldham and Gray, 1984; Piper et.al., 1985). In other breeds of highly fecund sheep the male exhibits a corresponding response in testicular size, sperm volume and sperm motility (Kilgour et.al., 1985; Moore et.al., 1985). In a study by Lee and Land (1985) it was found that lines of sheep which had been selected for increased testicular size had an increased response to LH and females from this line had a tendency to have larger litter sizes than those whose line had been selected for small testicular size.

Walker et.al. (1985) found that the prepubertal adhesion score at five months was lower (P < 0.05) in male progeny of FF sires than of F+ or ++ sired ram lambs. However, no significant differences were found among live weight, testicular volume, semen volume, sperm concentration, proportion of rams mounted and proportion of rams that served estrus ewes. Although these studies found no significant difference between the traits measured there was a tendency for prepubertal Booroola males to have higher levels of FSH than their control Merino contemporaries (Bindon et.al., 1985). It is thought that the presence of testosterone in mature rams has a masking effect on the FSH levels in Booroola rams.

At this time the only method for determining the genotype of the Booroola Merino rams is through a progeny

testing program. It appears that this gene, which has such an effect on the reproductive performance of the ewe, apparently has no significant impact on the male carriers of the F gene (Bindon et. al., 1985).

Booroola Merino used in a Crossbreeding Program to Increase Lambing Rate

The value of the Booroola Merino as a genetic resource lies in its ability to bring about rapid increases in reproductive rate when crossed with less fecund sheep. Because the increase in fecundity reported in the Booroola Merino is due to a single major gene, crossbred females could have a very small percentage Booroola Merino and maintain high ovulation rates and lambing percentages.

Although the performance of a Booroola cross may not be ascribed entirely to the F gene, due to a small increase above the Merino average which is seen in ++ Booroola, it is thought that the effects on reproductive performance are primarily due to the F gene. In any event, the practical exploitation of the F gene to date (and for the immediate future) would seem to depend on outcrossing procedures where the effects of the F gene are partly confounded with the effects of the remainder of the Booroola genome. The results described below are therefore relevant to the agricultural impact of the F gene (Bindon and Piper, 1986).

The Booroola may be used to improve the reproductive potential in crosses with breeds which have traditionally

been the major sheep breeds in the United States. In the future, through the use of recombinant DNA technology it may be possible to develop a breed that is homozygous for the F gene, yet retain the desirable attributes of that breed. However, at this time the gene mapping of the ovine species is not extensive enough to allow this type of gene manipulation. But, the same results can be accomplished by utilization of a backcrossing scheme and selection (Bindon and Piper, 1986).

Meyer and Kirton (1985) found no significant differences in growth traits between the Booroola Merino crossbred, Romney and Perendale ram lambs. The date of birth and weaning rank accounted for a significant variation in the live weight of the lambs. Of the three breeds utilized in this experiment Booroola carcasses were the fattest and longest. In an earlier comparison of Booroola Merino, Perendale and Romney sheep, Meyer and Kirton (1984) found no indication that the F gene influenced growth or carcass characteristics of carriers.

Bindon et. al. (1984a) compared the performance of Border Leicester or Dorset Horn ewes crossed with either a control (++) or a Booroola Merino. The study found that the genotypes having a copy of the F gene had a 55-62% higher ovulation rate, were 46% more fecund and have more (21-36%) lambs weaned per ewe bred despite a lower lamb survival rate. This level of production represented a 24%

improvement in economic return per ewe bred (Bindon et. al., 1984b).

Montgomery et. al. (1985) studied the performance of Booroola X Romney ewes of the ++ and F+ genotypes. The F+ females showed a significantly higher mean ovulation rate as compared to the ++ ewes at three different ages. At 7-9 months of age the mean ovulation rates were 1.61 and 1.06 respectively, at 1.5 year it was 2.71 and 1.41 respectively and at 2.5 year of age the F+ females had a mean ovulation rate of 2.74 as compared to the ++ ewes with a mean ovulation rate of 1.48.

Davis and Hinch (1985a) compared performance of local New Zealand breeds used in a crossbreeding system with Booroola Merino. The breeds which were used in the study were Leicester, Corriedale, Romney, Coopworth and Merino. They observed an overall increase in ovulation rate, litter size and total number of lambs in Booroola cross ewes. There was also a higher lamb mortality rate in most cases in the Booroola cross ewes.

Davis (1985) compared the performance of Booroola Merino X Coopworth ewes with 50, 25 and 12.5% Booroola inheritance and purebred Coopworth ewes. In this study all of the 50% Booroola ewes were F+, and half of the 25 and 12.5% Booroola Merinos were expected to be F+. For the three crossbred groups and the purebred Coopworth ewes the ovulation rate was 2.74, 2.16, 2.31 and 1.76 and litter size was 2.46, 1.77, 1.86 and 1.52 respectively.

The benefits of utilizing the Booroola Merino in a crossbreeding system can be better realized in a situation which has relatively intensive management (Bindon and Piper, 1986). This type of management scheme would be more able to meet the increase labor demands which would result from the increased number of multiple births.

The Finnish Landrace

The Finnish Landrace (Finn) breed is one of the more common high fecundity breeds in the United States. The increase in litter size which is attributed to this breed is thought to be polygenic in nature and was developed over a considerable period of time through selection.

Young et. al. (1985) found that of the breeds they studied the Finn exhibited greatest potential for increased lamb production among a number of breeds available in the United States. Finn-sired lambs had a higher survival rate from birth to 10 weeks than Rambouillet cross (RX) or other purebred lambs. Finn-cross (FX) lambs were 0.33 to 0.76 kg lighter at birth than RX or purebred lambs, but breed group weights did not differ significantly at 10 or 22 weeks.

A small difference was found in survival to weaning between lambs from FX cross ewes and those from RX ewes (61 vs 65%) even though more FX lambs were born as twins or triplets. With no adjustment for type of birth, lambs from FX ewes were lighter at 31 weeks of age, but rate of gain from 10-31 weeks of age was only slightly lower. At 31

weeks FX lambs had a higher dressing percentage, higher kidney fat percentage, slightly lower quality score and leg conformation score. In addition FX lambs showed less backfat than RX lambs.

Combining the differences in fertility, litter size, lamb survival, growth rate and carcass composition, the net advantage of FX over RX ewes in expected weight of boneless cuts per ewe exposed was approximately 28%. If flock management was such that the number of lambs weaned approached number born alive, the FX advantage would approach 36%. If differences in fleece value, size of ewe, and increased cost associated with costs incurred due to high litter size were included the FX advantage over RX ewes would be somewhat less (20-25%).

Expression of High Fecundity in Finns

In a study at the RLH Meat Animal Research Center (MARC) in Clay Center, NE it was found that, when compared to Dorset, Rambouillet and Targhee ewes, Finn and Finn cross ewes were among the youngest to reach puberty and they were the lightest at puberty. In addition, the ovulation rate for both the Finn and Finn cross ewes was significantly higher than the Rambouillet or Dorset ewes which were used in the comparison (Young et. al., 1985).

Dickerson (1977) in a review of literature on the Finnish Landrace reported the following observations: The use of 1/2 Finn 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 with use of 1/2 Rambouillet x domestic breed crossbred ewes. The 1/2 Finn crossbred ewe lambs begin lambing at 1 year and had a 50% increase in lamb crop. A higher percentage of the lambs from 1/2 Finn ewes were twins or triplets and they averaged 2.5 to 3.0 kg lighter at 10 weeks. But livability, postweaning gain and carcass yield and grade at the same slaughter weight closely approached that for lambs produced from 1/2 Rambouillet ewes. The 1/2 Rambouillet crossbred ewes were superior to purebred ewes of the same breeds in fertility and in livability of crossbred lambs.

Use of 1/4 Finn crossbred ewes lead to an approximate 20% increase in lamb crop above domestic crossbred ewes. Under poor range conditions and/or severe climatic conditions at lambing, the lambing percentages from 1/4 Finn ewes may be very comparable to 1/2 Finn ewes and the 1/4 Finn ewes tended to have a greater productive life. However, 1/2 Finn ewes had a clear advantage when ewe nutrition and lambing care are adequate.

Gains from use of breed differences and hybrid vigor were greatest when first cross 1/2 Finn ewes from breeds of superior maternal merit are mated with sires of breeds which exhibited superior livability, growth and carcass characters in their market lambs.

Rhind et. al. (1980) utilized Finn x Dorset Horn ewes to examine the effect of level of nutrition, season and location on lambing rate and cyclicity. Results showed that even in well nourished Finn x Dorset Horn ewes spontaneous estrus tends to be inhibited by lactation. Also, the level of suppression is dependent on the season. In spite of the natural inhibition, estrus could be easily induced by hormonal therapy. However it was noted that artifical induction of estrus caused fertility level, particularly in ewes mated in March. This effect on fertility was not associated with differences in ovulation rates between lactating and non-lactating ewes or between mating season (December or March).

Clarke and Hohenboken (1983) found that FX ewes produced larger litters at birth and weaning. In addition, total litter weights were greater than Romney or Cheviot cross ewes at weaning.

In a separate study which compared lambing date and lamb production of spring lambing Rambouillet, Dorset, Finn and their F_1 crosses, Finn and FX ewes were lighter at maturity than any of the other groups (Iniquez et. al., 1986). Finn and Finn cross ewes generally lambed later when compared to other groups. Considering all groups, about one-half of the Rambouillet and Dorset ewes lambed by January 10 to 14, whereas Finn ewes did not lamb on average until 16 to 20 days later. A difference of approximately 11 to 14 days was still evident when 95% of the flock had

lambed. As expected, Finn and FX ewes had the largest litter sizes whereas Rambouillet ewes had the smallest litters. Among the purebreds, Rambouillet ewes weaned a higher percentage of single-born lambs than did Finns. This ranking was reversed when lambs were born as multiples. Lambs from Rambouillet/Finn cross ewes had the best survival considering both birth types. Differences in survival between singles and twins agree closely with a general estimate based on differences in birth weight between the two birth types.

Vesely and Swierstra (1986) used eight genetic types (Dorset x 3/4 Dorset, Dorset x 3/4 Finn, Finn x 3/4 Dorset, Finn x 3/4 Finn, Romanov x 3/4 Dorset, Romanov x 3/4 Finn, Romanov x Western, Western x Western) to study breed differences for age and weight at conception, conception rate, ovulation rate, litter size, and prenatal mortality. Lambs sired by Romanov conceived at an earlier age than those sired by Dorset or Finn rams. Ovulation rate and litter size were similar for Romanov and Finn sired lambs and smaller for Dorset sired lambs. Finnish Landrace additive effects for ovulation rate and litter size were positive and significant. Finn maternal effects on weight and age at conception and ovulation rate were significantly lower than the Dorset Horn. They found no significant difference in prenatal mortality among the crosses.

Finn ewes are seasonal breeders. This trait is carried through to cross of Finn with non-seasonal breeds (Thomas

and Whiteman, 1979; Aboul-Naga et. al., 1985). However, Notter and Copenhaver (1980) found, in their accelerated lambing system, a significant increase in conception rate in the April breeding among the 1/2 Finn ewe as compared to the 1/4 Finn x 3/4 Rambouillet and the 1/2 Rambouillet x 1/2 Suffolk ewes. One possible reason for this apparent contradiction may be explained by changes in environment and day length. Wheeler and Land (1977) and Goot and Maijala (1977) indicated that the frequency of estrus among Finn ewes was near maximum in April but declined sharply in May and June.

Chiquette et. al. (1984) observed no differences in prepubertal LH levels among Finn, Suffolk or Finn-Suffolk ewe lambs. They did find that the most fecund ewe within each genetic grouping had a significantly higher LH level than did her peers.

Quirke et. al. (1985) found no significant differences in age at onset of puberty among Suffolk, Dorset, Finn, Finn-Dorset and Rambouillet ewe lambs. There was a significant increase in days from first to last cycle in the Finn and Finn-Dorset ewes. Young et. al. (1985) reported a significantly greater scrotal circumference, mean testis length and mean testis diameter of Finn and Finn cross rams than Rambouillet, Dorset and Targhee. Demonstrating the effect of higher fecundity which could be measured in the male.

Comparisons between the Finn and

Booroola Breeds

Davis et. al. (1983) found, when comparing the ratio of single, twin, or greater births in Booroola and FX ewes that, with FX ewes, the relative proportion of ewes giving birth to twins did not change, rather the increase in total lambs came from a decrease in number of singles and a corresponding increase in number of triplets. However, in the Booroola Merino a decrease in the proportion of twins was observed with an increase in the number of single, triples and quadruplets. This change in proportion seen in the Booroola line is due to the sharp changes in litter size among the various carrier levels in the Booroola

Problems Encountered with High

Fertility Breeds.

The single gene basis of the Booroola's increased fecundity may limit its commercial utilization under management circumstances in which the size of the fecundity increase which is conferred by a single copy of the F gene (approximately 1 extra lamb) is considered to be too extreme.

Lamb Survival

Hinch et. al. (1983) found that the survival rate of multiple birth litters is influenced by year, ewe age,

litter size and birth weight. When the variation due to birth weight was accounted for there was a marked reduction in the effect of year and litter size. The apparent ewe age effect was closely associated with the effect of lamb birth weight. However, it was also found that lambs born to litters of three or greater had a significantly lower probability of survival than either lambs born as single or twins, regardless of birth weight.

Owens et. al. (1985) found a significant decrease in birth weight as litter size increased. Again they found that heavier lambs had a greater chance for survival. Survival of lambs was significantly affected by their behavior after adjustment for birth weight. With an increase of 1 minute in the interval from delivery to when the lamb first attempts to stand, stands or attempts to find the udder its chances of survival are decreased by about 1%.

Additional Consideration of Difficulties for High Fecundity Breeds.

Another problem which is increased in a highly fecund breed is the incidence of freemartins. It is established that the freemartin condition, although rare, does exist in sheep and that, as in cattle, its occurrence depends on a pregnancy of mixed sexes and early placental anastomosis between different sexes (Bindon and Piper, 1986). Sheep freemartins do occur more often in litter sizes of 3 or more (Slee, 1963). The frequency of freemartins may be as high

as 5% of all females born in Booroola populations, and these
are observed in ewes with high ovulation rates (4-9) and
litter sizes greater than 2 (Bindon and Piper, 1986).

Bindon and Piper (1986) also reported a low incidence (
< 10%) of the ewe lambs which reached puberty within the
first year of life.

Summary

The Booroola Merino or at least the F gene, has a place
in the commercial sheep industry in this country. Through
various crossbreeding programs and possible future use of
recombinant DNA technology, it can be used to increase the
lambing rate of the principle sheep breeds in the United
States. Since a single gene pair is apparently responsible
for the high lambing rate of the Booroola Merino this gene
can be implanted in another breed of sheep through a series
of backcrosses (Smith, 1985; Owens, 1985b). This will
produce a synthetic breed of sheep which has most the
characteristics of the breed used in the backcross and also
contains the fecundity gene (Elsen et.al., 1985).

Location of animals which are carriers of the fecundity
gene could be greatly enhanced by advancement in bioassay
technique. Tsonis et. al. (1986) found an extremely
sensitive and reliable bioassay for inhibin based on
inhibition of ovine pituitary FSH secretion in vitro was
developed and used to measure exogenous and endogenous
inhibin activity in the ewe. The sheep inhibin bioassay is

30-40 times more sensitive than conventional rat inhibin bioassays.

One type of producer who could benefit greatly is the farm flock owner who is able to provide the care necessary for multiple birth lambs. This person could use the Booroola Merino gene in either a heterozygous or a homozygous condition. The increase in number of lambs born to the different genotypes of the F gene (FF or F+) would be the primary concern for the producer in deciding which genotype to use in his breeding program, but either genotype would cause an increase in the number of lambs born and a corresponding increase in the labor required at lambing. The intensive management which is possible in the farm flock situation would make this increased labor requirement feasible. The utilization of this gene would allow the farm flock owner to increase his total weight of lambs per year without increasing the number of ewes.

Robertson (1985) reported that the F gene expression can be useful even in extensive husbandry. Although with the decreased availability of labor and therefore a corresponding decrease in assistance to the lambs at birth, there is a higher lamb mortality rate. However, even with this increase in lamb mortality there was still an increase in the overall lambs weaned.

CHAPTER III

LITTER SIZE, BIRTH WEIGHT AND WEANING
WEIGHT IN DORSET, FINNISH LANDRACE OR
BOOROOLA MERINO SIRED LAMBS

Summary

A total of 242 six or eight year old Rambouillet ewes
were exposed to sires of one of three breeds, Dorset,
Finnish Landrace(Finn) and Booroola Merino(Booroola). These
matings resulted in 343 F_1 progeny, of which 51 were from
Dorset sires, 169 from Finn and 136 from Booroola. Litter
size and survival to 70 days were unaffected by breed of
sire, however, the 70 day weights of the Finn sired lambs
were 1.71 kg heavier than the Dorset sired lambs and 3.59 kg
heavier than the Booroola sired lambs ($P < 0.0001$). In
addition Dorset sired lambs were 0.25 kg heavier at birth
than either the Finn or Booroola sired lambs ($P < 0.05$).
Mean performance for litter size, birth weight, survival to
weaning and 70 day weight for Dorset, Finn and Booroola
sired lambs respectively were: 1.68, 1.76, 1.68; 4.92, 4.67,
4.67; .74, .79, .71; 18.90, 20.61, 17.02. Individual sire
also had a significant ($P < 0.005$) effect on the 70 day
weight of the lambs and birth weight ($P < 0.05$). However,
similar effects were seen between sires for litter size and

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survival to weaning. Body condition of the ewe at breeding had a significant effect on lamb survival to weaning ($P < 0.005$). There was also a tendency for lambs from ewes with a condition score of 2 and 3 to be heavier at birth ($P < 0.07$) and for higher condition score ewes to have larger litters ($P < 0.12$). Single lambs were 1.16 kg heavier at birth than twin born lambs and 2.099 kg heavier than triplets ($P < 0.0001$). The 70 day weights reflect these same effects on litter size, with 70 day weights being 22.297 kg for singles, 17.22 kg for twins and 17.0 kg for triplets. In addition the survival rate among triplet born lamb was significantly lower (58% vs 83.3% and 83.4%) than either twin or single births ($P < 0.05$). Month of birth showed a significant effect on litter size ($P > 0.07$) and birth wt ($P > 0.001$). The presence of mastitis in the ewe prior to breeding decreased birth weight 0.4097 kg ($P < 0.005$). In addition to the aforementioned effect on 70 day weight, ewe lambs were 2.51 kg lighter than wethers ($P < 0.02$) and lambs reared by their dam were 5.25 kg heavier than lambs reared in the nursery ($P < 0.0001$). These results indicated that the Booroola Merino, while contributing a gene for prolificacy, produced lambs that have relatively slow growth rate and a lowered survival rate.

(Key Words: Sheep, Booroola Merino, Finnish Landrace, Litter Size, Growth Performance)

Introduction

Litter size is an important component of production efficiency in the sheep industry. In recent years the discovery of the Booroola strain of Merino in Australia has provided a potential opportunity for altering litter size in commercial flocks. The increase in litter size of the Booroola Merino over control Merino ewes is remarkable (2.9 vs .7 lambs) with ovulation rates in the Booroola Merino as high as nine (Bindon and Piper, 1986; Bindon et. al., 1985; Davis et. al., 1982; Montgomery et. al., 1983/84; Owens, 1985a; Piper et. al., 1985; Piper and Bindon, 1982). This increase is apparently caused by a single gene called the fecundity gene (F gene) with an action much like the classic red, roan and white in Shorthorn cattle (Davis and Hinch, 1985; Meyer and Davis, 1983; Turner, 1978).

Proper evaluation of this breed requires comparison to a highly fecund breed which derives its fecundity by more normal quantitative gene action. The Finnish Landrace is a highly fecund breed (Dickerson, 1977) for which there is a large amount of research information and ample availability of the breed for evaluation. Comparison to a breed, such as the Dorset, which is a frequent contributor to a crossbred ewe flock is also useful.

With these thoughts in mind, a project was initiated to compare the productivity and reproductive biology of the Booroola Merino, Finnish Landrace and Dorset Breeds. The

focus of this thesis is the initial performance to weaning of two-breed cross lambs.

Materials and Methods

The study, of which the result of the first year constitute this thesis, was planned as two phases and three divisions within each phase. The following is a detailed description of Phase I of the project. The ewes at initiation of the project were 6 and 8 year old Rambouillet ewes which had been lambed for several seasons at the USDA ARS Forage and Livestock Research Laboratory near El Reno, Oklahoma. Approximately 300 of these ewes were used in the fall of 1986 matings. A portion of these ewes (n=42) were bred to Dorset rams. The remaining ewes were broken into equal portions (n=129) and bred to Finn and Booroola Merino rams, which had been previously determined by progeny test to be homozygous carriers of the Fecundity (F) gene. Based on this beginning information and using estimated performance levels found in the literature, the estimates of performance listed in Table II were calculated. Projections were used to determine the number of ewes necessary to produce the crossbred ewes division I of phase I (Fall 1986 & 87).

The crossbred ewe lambs will be used in the second division of Phase I. A proportion of each group (i.e. Dorset x Rambouillet, Booroola Merino x Rambouillet and Finn x Rambouillet) will be mated to Rambouillet rams. In

addition, Booroola Merino x Rambouillet ewes will be mated to Booroola Merino rams and Booroola Merino x Rambouillet rams selected from the same matings as the ewes. The remaining Finn x Rambouillet ewes will be mated to Finn and Finn-Rambouillet rams. The purpose of these matings is to produce 1/4, 1/2 and 3/4 Booroola Merino and Finn ewes. These matings were scheduled to be made in 1987-1989, however, initial results show that due to late puberty in the Booroola Merino cross ewes they are to be moved to an 18 month breeding program and the first matings will be made in the Fall of 1988.

Crossbred ewes resulting from the matings in division II will all be mated to Suffolk rams to evaluate the eight breed combinations as commercial ewes. These matings will be made beginning in Fall of 1989 on the Finn and Dorset cross ewes and in fall of 1990 on the Booroola Merino and both will continue until the conclusion of the project in 1993. The breakdown of animal numbers for each year of the study is shown in Tables III and IV.

The following is the detailed description of the first year of the project outlined above. Rambouillet ewes (n=242), located at the USDA ARS Forage and Livestock Research Laboratory, El Reno, Oklahoma were randomly assigned to one of three sire breed groups (i.e. Dorset, Finnish Landrace or Booroola Merino). Beginning September 15, and continuing for 60 days, ewes were placed with fertility tested rams which were either Finnish Landrace

(Finn), Dorset or Booroola Merino. Booroola Merino rams were progeny tested homozygous carriers of the Fecundity gene (FF) (L.D. Young, personal communication). They were obtained from the RLH Meat Animal Research Center in Clay Center, Nebraska. US MARC also furnished the Finn rams which were used in the study. Dorset rams were obtained from a purebred breeder in the El Reno area. Rams' fertility had been evaluated by semen volume, sperm motility and sperm concentration. All ewes were scored for body condition 6 weeks prior to breeding using the New Zealand scoring system (Table I) (Pryor, 1980) and were checked for evidence of mastitis.

In addition, an evaluation of Fecundin was superimposed on these ewes. Ewes were injected with 2 CC's of vehicle or Fecundin compound (Anti-androstenedione) twice at a 3 week interval prior to the onset of breeding season.

Ewes were handled as one large flock during the gestation period in order to reduce any variation which might be due to the location of the ewes during the winter. At lambing, ewes were placed in smaller lambing pastures. Ewes lambed primarily unassisted and the lamb numbers reflected by this study were based on the number of full term fetuses for each ewe.

All traits were analyzed using least-squares procedures. The model included the fixed effect of sire breed, sex of the lamb, rearing status (nursery vs dam), litter size, presence of mastitis, month of birth, ewe

condition score and all two-way interactions. Three-way interactions were not included. Sire breed was included as a random effect and was used as the test term for sire breed. Ewes given half condition scores, such as 2.5, were combined with ewes that had the first whole condition score lower. Total number of term fetuses born was used as the litter size criterion. Weaning weight of lambs were adjusted to 70 days. Nonsignificant sources of variation were omitted from the model and least-squares means were obtained from the reduced model.

Results and Discussion

A total of 356 lambs (154 ewes and 173 wether) resulted from first year matings. Sire breed least-squares means for birth traits are shown in Table V. Total numbers of lambs and lambs born alive were not significantly affected by breed of sire. Breed did not have a significant effect (P > 0.10) on birth weight however lambs sired by Dorset rams tended to be heavier than either the Finn or Booroola Merino sired lambs (Table V). Similarly, breed of sire did not have a significant effect on survival of lambs to weaning (70 days), but Finn sired lambs tended to have a greater survival rate (78.8%) followed by the Dorset (74.0%) with the lowest survival in the Booroola Merino sired lambs (70.7%). Weaning weight was affected by breed of sire (P < .001). Finn sired lambs were the heaviest (20.61 kg)

followed by Dorset (18.90 kg) and Booroola Merino (17.02 kg) (Table VI).

Individual sire had a significant effect on birth weight ($p < .05$) and weaning weight ($p < .005$). A sire x treatment (Fecundin compound) interaction ($p < 0.06$) was found for litter size with a proportion of the rams showing a significantly greater increase in litter size among Fecundin treated ewe than among the non-treated ewes. Lambs from litters of three were significantly smaller (3.74 kg) than twin born lambs (4.68 kg) and both were smaller than single born lambs (5.85 kg) ($p < 0.0001$) (Table VII). Owens et al (1985b) reported similar decreases in birth weight as litter size increased, with their single lambs averaging 2.184 kg heavier at birth than quadruplet lambs. Triplet lambs also exhibited a greatly reduced survival rate over twins ($p < .05$) and singles (58% vs 83.4 and 83.3). Hinch et. al. (1983) also found a significant effect of litter size on survival, with lower survival rates in litters greater than two. In addition, single born lambs were 5.07 kg heavier at 70 days than twins and 5.30 kg heavier than triplets ($p < 0.0001$).

The survival rate for lambs from ewes with condition scores of 2 or 3 prior to breeding was significantly higher ($p < 0.001$) than those from condition score 1 or 4 (there were no condition score 5 ewes in this study) (Table VIII). A litter size x ewe condition score interaction ($p < 0.005$) was observed for lamb survival to 70 days. Birth weights

from condition score 1 ewes were significantly lower (P < 0.06) than condition score 2, 3 or 4 ewes (4.43 kg vs. 4.83, 4.95, 4.83 respectively). In addition, a litter size x condition score interaction (P < 0.005) was seen for birth weight. Twin or triplet lambs born to ewes which had either a low or high condition score showed a significantly lower survival rate than lambs born or ewes having a condition score of 2 or 3. However, ewes giving birth to single lambs showed an increase in survival rate which corresponded to an increased condition score in the ewe. Lamb birth weight from ewes showing the presence of mastitis was reduced (P < 0.005) by 0.41 kg. Wether lambs were 2.01 kg heavier than the ewe lambs at 70 days of age (P < 0.02). Lambs which were reared by their dams had an average weight of 20.94 kg while lambs reared in the nursery averaged 16.74 kg (P < 0.0001). Significant interactions were observed between sex of lamb x manner reared (dam vs nursery) (P < 0.005), sex of lamb x presence of mastitis in the ewe (P < 0.06) and ewe condition score x month of birth (P < 0.0001) for the 70 day weights of the lambs.

These results suggests that, among these three breeds, differences were minimal for birth and early post-natal characteristics (i.e. litter size, birth weight and survival to weaning). However, at weaning the Finn sired lambs were the heaviest followed by the Dorset sired lambs. Meyer and Kirton (1984) found in comparisons between Romney and Perendale and Booroola Merino that the 1/2 Booroola lambs

were significantly lighter at weaning. Lambs sired by
Booroola Merino rams were significantly lower in body weight
at 70 days than either the Finn or Dorset sired lambs.
Other research indicates that the lighter body weight
results from typical Merino performance and was not caused
directly by the presence of the F gene. Ponzoni et al
(1985) found no significant differences between ++, F+ and
FF genotypes for fleece quality or quantity, birth weight,
gain from birth to weaning, from 3 months to 9 months and
from 9 months to 15 months. Similar results have been
reported by other researchers (Beetson, 1985; Piper and
Bindon, 1982).

From these results the growth and performance of the
crossbred lambs by rams of these three breeds would rank
them Finn, Dorset and Booroola Merino for survival and
growth to weaning. Of course consideration of the Booroola
Merino will not be complete until reproductive performance
is included. Based on these data it would seem that, due to
their poor performance, the Booroola Merino would be best
utilized in a backcrossing system to implant the gene into
another breed. The Booroola could also be utilized as the
source of this genetic material to be implanted in another
breed through genetic engineering.

Table I

New Zealand Condition Scoring System

Grade 1	The spinous and transverse processes are sharp, the fingers pass under the transverse processes and it is possible to feel between the processes.
Grade 2	The processes are smooth and rounded. The fingers can be passed under the transverse processes with pressure.
Grade 3	The spinous processes are smooth and rounded and have only a small elevation. Individual bones can be felt only by applying pressure. Firm pressure is needed to feel over the ends of the transverse processes.
Grade 4	Spinous processes can be detected only by firm pressure. the ends of the transverse processes cannot be felt.
Grade 5	The spinous processes cannot be detected, nor can the transverse processes. The eye muscles (iliopsoas and psoas minor) are very full and fat.

Table II

Estimates of Performance Parameters used in Developing Phase
I of the Booroola Merino Breeding Project

Trait	Value
Birth to Breeding Survival(%)	80
Yearly Death Loss(%)	10
Ewes/Ram	20
Rambouillet(R) Lambing %	110
Dorset(D) x R Lambing %	110
Booroola Merino(B) x R Lambing %	160
Finnish Landrace(F) x R Lambing %	160
R x R-D Lambing %	110
R x B-R Lambing %	160
B-R x B-R Lambing %	160
B x B-R Lambing %	160
R x F-R Lambing %	160
F-R x F-R Lambing %	160
F x F-R Lambing %	160

Table III

Break Down of Ewe Numbers from Phase I of the Animal
Breeding Project Evaluating the Booroola Merino

Yr	R[a]	DxR	BmxR	FxR	RxRD	Rx BmR	BRxBR	Bm xBmR	RxFR	FRxFR	FxFR
1	300										
2	180	18	0	57							
3		34	57	82	8	0	0	0	12	12	12
4		31	82	74	22	12	12	12	23	28	28
5					34	28	28	28	36	41	41
6					30	19	19	19	33	37	37
7					27	17	17	17	30	33	33
8					25	15	15	15	27	30	30

[a]R - Rambouillet; D - Dorset; Bm - Booroola Merino; F -
Finnish Landrace; S - Suffolk

Table IV

Break Down of Ram and Lamb Numbers from Phase I of the
Animal Breeding Project Evaluating the Booroola Merino

Yr	D[a]	Bm	F	R	BmR	FR	S	Total Lambs
1	3	6	6	0	0	0	0	330
2	3	4	4	3	0	3	0	309
3	0	3	3	4	3	3	3	327
4	0	3	3	4	3	3	7	493
5	0	0	0	0	0	0	12	364
6	0	0	0	0	0	0	10	294
7	0	0	0	0	0	0	9	266
8	0	0	0	0	0	0	8	240

[a]R - Rambouillet; D - Dorset; Bm - Booroola Merino; F -
Finnish Landrace; S - Suffolk

Table V

Least Squares Means for Birth Characteristics in
Dorset, Finn and Booroola Merino Sired Lambs

Breed of Sire	Total Born	Born alive	Birth weight
Dorset	1.65(35)	1.42(35) [a]	4.92(51)
Finn	1.59(115)	1.40(115)	4.49(169)
Booroola Merino	1.65(92)	1.38(92)	4.48(136)
Standard[b] Error	0.217	0.086	0.221

[a]Numbers of animals is shown following each mean.
[b]Standard errors shown are averages.

Table VI

Least Squares Means for Weaning Characteristics in Dorset,
Finn and Booroola Merino Sired Lambs.

Breed of sire	Survival to Weaning	Adjusted weaning Weight
Dorset	0.740(51)[a]	18.90(47)
Finn	0.788(169)	20.61(156)
Booroola Merino	0.707(136)	17.02(124)
Standard[b] Error	0.073	0.841

[a]Numbers of animals is shown following each mean.
[b]Standard errors shown are averages.

Table VII

Least Squares Means for Birth Characteristics

	Total Born	Born alive	Birth weight
Month of birth			
February	1.65(184)	–	4.15(274)
March	1.41(57)	–	4.59(80)
April	2.06(1)	–	5.52(2)
Std Error[b]	0.254	–	0.266
Litter Size			
Single	–	–	5.84(114)
Twin	–	–	4.68(216)
Triplet	–	–	3.74(26)
Std Error			0.237
Ewe Condition Score			
1	1.53(37)	1.36(37)	4.42(51)
2	1.63(121)	1.46(121)	4.83(175)
3	1.72(72)	1.50(72)	4.95(110)
4	1.95(12)	1.66(12)	4.83(20)
Std Error	0.226	0.104	0.247

[a]Numbers of animals is shown following each mean.
[b]Standard errors shown are averages.

Table VIII

Least Squares Means for Weaning Characteristics

	Survival to Weaning	Adjusted weaning Weight
Sex		
Female	–	17.83(154)
Male	–	19.84(173) [a]
Std Error [b]	–	0.844
Month of Birth		
February	0.779(274)	–
March	0.688(80)	–
April	–	–
Std Error	0.049	–
Type of Rearing		
Dam	–	20.94(265)
Nursery	–	16.74(62)
Std Error	–	0.817
Litter size		
Single	0.833(114)	22.30(102)
Twin	0.834(216)	17.23(203)
Triplet	0.581(26)	17.00(22)
Std Error	0.082	0.886
Mastitis		
Presence	–	18.96(35)
Absence	–	18.72(292)
Std Error	–	0.845
Ewe Cond Score		
1	0.628(51)	–
2	0.861(175)	–
3	0.924(110)	–
4	0.582(20)	–
Std Error	0.088	–

[a] Numbers of animals is shown following each mean.
[b] Standard errors shown are averages.

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APPENDIX

Table IX

Mean Squares from Reducde Model Analysis of Variance

Source	Adjusted 70 day Wt (kg)^2	Lamb Survival to 70 day	Litter Size	Litter Size Alive	Lamb Birth Weight
Breed of sire(B)	387.16***	0.219	0.117	0.011	1.223
Sire(Breed)(Sb)	54.57***	0.143	0.198	0.166	1.018
Sex of lamb(S)	111.41**	–	–	–	–
Type of Rearing(R)	661.72***	–	–	–	–
Litter size(L)	775.66***	0.457**	–	–	27.384***
Birth Month(M)	–	0.160	0.754	–	4.425***
Treatment(T)	–	0.634**	1.573**	1.370	4.700***
Ewe Cond Score(C)	–	0.683***	0.657	0.333	1.328
Presence of Mastitis(Pm)	1.38	–	–	–	4.574***
SxR	146.90***	–	–	–	–
SxPm	65.45	–	–	–	–
Ewe Cond score and Presence of Mastitis combined classes	98.05***	–	–	–	–
MxT	–	1.003***	–	–	–
LxC	–	0.444***	–	–	1.993***
Sb(B)xT	–	–	0.570	0.527	–
TxC	–	–	–	1.154**	–
TxPm	–	–	–	–	2.311**
Remainder	17.64	0.117	0.315	0.353	0.534

**P<.05,   ***P<.01

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