# EFFECTS OF SUBSTITUTING DORSET AND FINNSHEEP BREEDING FOR RAMBOUILLET BREEDING ON EWE PRODUCTIVITY OF CROSSBRED EWES

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EFFECTS OF SUBSTITUTING DORSET AND FINNSHEEP

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CHAPTER I

# INTRODUCTION

The American sheep industry is struggling for its very existence. The United States Department of Agriculture estimated the 1976 sheep population at less than 13.5 million head. This figure was approximately 25 percent of the sheep population in 1940 and 40 percent of the 1960 population. The decrease in numbers has resulted in less competitive bidding for available lambs, loss of old markets and prevention of developing new markets due to unavailability of lamb meat and lowered expenditure by federal and state agencies on sheep research.

It is imperative that the sheep industry increase its efficiency of production in order to maximize net income of present flocks and in order to encourage others to pursue sheep-raising and thus expand the industry. Improvement in the reproductive rate of the ewe flock offers one of the greatest single opportunities for increasing the efficiency of lamb meat production. The sheep industry of much of the Southwest and Intermountain West, which have almost 60 percent of total U. S. sheep numbers, is based on the annual production of lambs and wool by Rambouillet or Rambouillet-cross ewes. These ewes are known to be very hardy, to be long lived and to shear heavy, high quality fleeces. They are not, however, known to be highly prolific.

Two whitefaced breeds that are thought to be more prolific than the Rambouillet breed are the Dorset and Finnish Landrace (Finnsheep). The

Dorset breed was developed in England and is one of the few whitefaced mutton breeds in the United States. The Dorset's long breeding season and good mutton conformation made them the ideal producers of light weight lambs desired for the Easter season by certain ethnic groups on the East Coast. In recent years, the Dorset breed has also become popular in the farm flock areas of the Southwest where fall lambs are desired. The Finnsheep breed originated in Finland and did not make its way to the United States until 1968 (Boylan et al., 1976). In their home country they are reputed to reach sexual maturity at very young ages which allows a high proportion of the ewes to lamb at one year of age. They are also known to be very prolific. One Finnsheep ewe is documented as giving birth to nine lambs in a single litter and another ewe has weaned 179 kilograms of five-month-old lambs (Maijala, 1969). Both the Dorset and Finnsheep breeds represent sources of genetic material with which the productivity of Rambouillet flocks may be improved.

The purpose of this study is to estimate the effects of increasing both Dorset and Finnsheep breeding by 1/4 at the expense of Rambouillet breeding in crossbred ewes on ewe productivity traits and the growth traits of the lambs produced under both late winter-early spring and fall lambing conditions.

# CHAPTER II

# REVIEW OF LITERATURE

This literature review will concern itself with published research done in the general areas of a) productivity of straightbred and crossbred ewes of Finnish Landrace, Dorset and Rambouillet breeding, and b) the effect of non-additive genetic phenomena; such as individual heterosis, maternal effects and recombination effects; on ewe productivity and lamb growth.

## Productivity of Straightbred and Crossbred Ewes of Finnish Landrace, Dorset and Rambouillet Breeding

### Finnish Landrace

The Finnish Landrace (Finnsheep or Finn) breed of sheep originated in Finland. It was developed from original home-bred stock from eastern and northeastern Finland. It belongs to the more general class of sheep referred to as "Scandinavian short-tail sheep", for which a short wool-less tail, short ears and a woolless head and legs are typical (Maijala, 1969). The short tail of this class of sheep suggests that they may be more closely related to existing wild types of sheep than the long-tailed breeds found in the United States since a lengthening of the tail is thought to be associated with domestication (Zeuner, 1963).

Ninety-five percent of the 150,000 sheep in Finland are of the Finnsheep breed. They are maintained in very small flocks. In 1959 two-thirds of the total flocks were comprised of only one or two adult sheep, and only 0.4 percent of the flocks contained ten or more adult sheep (Maijala, 1969).

The Finnsheep breed in Finland is very fertile, producing on the average 2.5 lambs per litter. This is the main reason why from 1962 to 1969, Finnsheep animals had been exported to 13 different countries (Maijala, 1969). In Finland, the breed is also reputed to reach sexual maturity at an early age and to have a low percent barren ewes each year (less than two percent) (Maijala, 1969).

In 1962, ten females and five male Finnsheep were imported from Finland by the Animal Breeding Research Organization, Edinburgh, Scotland. The flock was maintained as a closed population with all female progeny (except some black lambs) retained. Ewes have been hand mated each year in October. Donald and Read (1967) have summarized performance of this flock for the four lamb crops from 1963-66. Forty of a possible 43 ewe lambs have lambed at approximately one year of age. All ewes exposed to the ram over one year of age have lambed. Average litter size at birth was 2.0, 3.0 and 3.4 for ewes aged one, two and three or more years, respectively. In spite of indoor lambing and close supervision, mortality was high with 38 percent of the lambs born being lost prior to weaning at 16 weeks of age. Mean fleece weights were 4.5 pounds with a range of 1.7 to 7.1 pounds. The wool fibers had a spinning count of 54-56's.

Donald et al. (1968) reported the productivity of approximately 280 crossbred ewes produced by mating Merino, Finnish Landrace, Border Leicester, Dorset Horn and Clun Forest rams to Scottish Blackface ewes.

The crossbred ewes were evaluated when lambing at approximately one, two and three years of age. Mean body weights taken before breeding each year were lightest for the Finnish Landrace and Merino ewes. Finnish Landrace ewes had the lightest mean fleece weights and the largest number of lambs born per ewe lambing (1.52, 2.02 and 2.30 at one, two and three years of age, respectively). The Clun Forest ewes were the second high group with 1.02, 1.80 and 1.69 at one, two and three years of age, respectively. After adjusting the lamb growth data for year, sex of lamb and type of birth, it was found that lambs produced by Finnish Landrace dams were lighter at birth each year than lambs from the other crossbred dam groups and lighter at weaning each year than lambs from all other groups except the Merino. However, due to their larger litter sizes, Finnish Landrace ewes had higher total litter weights at weaning than all other groups.

A similar trial as the one mentioned previously was done by J. D. Barker (1975) to compare the productivity of crossbred ewes out of Finnish Landrace and non-Finnish Landrace sires under commercial conditions. The data were collected from 34 farms in England, Wales and Scotland from 1964 to 1970. The Finnish Landrace sires used came from the flock maintained at the Animal Breeding Research Organization, Edinburgh, discussed previously (Donald and Read, 1967). The results were very similar to those obtained from the more controlled study done by Donald et al.(1968). Finnish crossbred ewes were 18% lighter ($P<.001$) at mating than the average of non-Finnish crossbreds over the first four years of life. The difference in percent ewes lambing was 16.8 percent in favor ($P<.001$) of the Finnish crossbred ewes at one year of age with no significant differences observed between the two groups at two and three and four years of age ($-2.0 \pm 2.0$ and $2.5 \pm 1.8$ percent, respectively). Over the four year period, Finnish crossbreds had a 27 percent higher lambing percentage ($P<.001$) and 21 percent higher weaning percentage ($P<.01$) than non-Finnish crossbreds.

Lambs born to Finnish crossbreds were 16 percent lighter for singles ($P<.01$) and 20 percent lighter for multiples ($P<.01$) at birth and 11 percent lighter for singles ($P<.05$) and 12 percent lighter for multiples ($P<.05$) at 10 weeks of age than those born to non-Finnish crossbreds. Total litter weight of lamb reared to 10 weeks per 50-kilogram metabolic ewe weight at mating was 16 percent more for Finnish crossbreds. Lamb mortality from birth to weaning was not significantly different between the two groups at one and two years of age but was greatest ($P<.01$) for lambs from Finnish crossbreds at three and four years of age (+7.1 percent).

Land et al. (1974) has reported the reproductive performance of 20 Finnish Landrace and 20 Merino ewes for a four year period (four spring lambings). 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 start of the study. Average litter size was greater ($P<.001$) for the Finn ewes (2.9) than for the Merinos (1.0). Also, a greater ($P<.01$) proportion of the Finn ewes lambed (100% vs 85% for the Merinos).

Female progeny of these 40 ewes (Finn, Finn x Merino, Merino x Finn and Merino) were mated to Welsh rams and their reproductive performance evaluated over a four year period, also. Litter size at one year of age for the Finns, crossbreds and Merinos was 1.8, 1.2 and 0; respectively. Percent ewes lambing at one year of age was 81, 76 and 0 for the Finns, crossbreds and Merinos, respectively. Litter size for ewes two years and older was 2.7, 1.7 and 1.0 and percent ewes lambing was 93, 96 and 62 for Finns, crossbreds and Merinos, respectively.

Nitter (1975a, 1975b) has reported the results of a very interesting study conducted in West Germany. Crossbred ewes produced by mating Bleu du Maine, Finnish Landrace, German Mutton Merino, German Blackhead Mutton, German Bergschaf and Texel rams to Merinoland ewes and straightbred Merinoland ewes were compared for ewe productivity under a very intensive and a less intensive management scheme from 1970 to 1973. The very intensive management scheme included five mating periods from 1970 to 1973 with all lambs removed from their dams between 15 and 40 hours after birth and reared on milk substitutes to four weeks of age. The less intensive management scheme had three mating periods from 1970 to 1973 (spring lambing only) with lambs allowed to suckle their dams until weaning at five to eight weeks of age. Five hundred and seventy-six ewes started the trial.

Under both management systems the Finnish crossbreds had the highest ($P<.05$) litter size at birth. Litter size slaughtered was also highest ($P<.05$) for the Finnish crossbreds under the very intensive management. However, under the less intensive management, Finnish crossbreds did not have significantly higher litter sizes at slaughter than the other ewe groups indicating that the superiority of Finnish crossbreds for litter size at birth disappears at slaughter if artificial rearing of excess lambs is not employed. Under the very intensive system, Finnish crossbreds had the greatest ($P<.05$) number of lambings per year (1.4) indicating that this group was best suited to out-of-season lambing. Fleece weights were lowest for Finnish crossbreds. On both management systems, lambs from Finnish crossbreds were lighter at birth, lighter at weaning and older at a weight constant slaughter.

In 1968, an initial sample of the Finnish Landrace breed was imported into the United States jointly by the University of Minnesota and The United States Department of Agriculture (Boylan et al., 1976). Shortly after this importation a majority of the Agricultural Experiment Stations in the United States with a sheep research program began evaluation of this breed. However, to date, very little of this research has reached the scientific press.

The reproductive traits of 43 Targhee and 42 Finn-Targhee yearling ewes were evaluated by Meyer and Bradford (1973). The study also had a nutritional component, but the nutritional treatment x ewe type interactions were found to be nonsignificant. Ovulation rate was measured by laparotomy twice for each ewe prior to flushing (August) and a third time following flushing. The Finn-Targhees averaged 14 days later ($P<.01$) and were somewhat more variable in onset of seasonal estrus but had shorter ($P<.01$) estrous cycles. Ovulation rate was higher ($P<.01$) for Finn-Targhees, both before and after flushing (2.37 vs. 1.93 and 2.72 vs. 1.94). Finn-Targhees had a higher ($P<.01$) lambing rate than Targhees (2.22 vs. 1.50).

Laster et al. (1972) reported on the reproductive performance of 565 ewe lambs exposed to fertile rams from November 9 to December 14. The ewe lambs were of straightbred Suffolk, Hampshire, Rambouillet, Dorset, Targhee, Corriedale and Coarse Wool breeding, four different $F_1$ Rambouillet crosses and eight different $F_1$ Finn crosses. Finn crosses had an 11 and 33 percent greater proportion ewes lambing, 59 and 79 percent more lambs born per ewe exposed, 58 and 53 percent more lambs born per ewe lambing and 57 and 63 percent more lambs weaned than Rambouillet-cross and straightbred ewes, respectively. Table I summarizes the reproductive performance of the specific breed groups containing Rambouillet, Dorset or Finn breeding.

Dickerson and Laster (1975) reported a study designed to measure the occurrence of puberty in 825 ewe lambs. Ewe lambs were Finn-sired crosses (1/2 and 3/4 Finn), Rambouillet-sired crosses (1/2 Rambouillet) or purebreds of the Suffolk, Hampshire, Rambouillet, Dorset, Targhee, Corriedale or Coarse Wool breeds. The lambs were born from January 26 to May 9, 1971. Percentage reaching puberty by November 10, 1971 was far higher for Finn-sired ($72 \pm 4$) than for Rambouillet-sired ($38 \pm 6$) crosses or purebreds ($34 \pm 5$). Finn crosses reached puberty earlier (219 days) and at a lighter weight (40 kilograms) than Rambouillet crosses (238 days and 44 kilograms) or purebreds (245 days and 45 kilograms).

Preweaning viability and growth was reported on 2,973 purebred (Suffolk, Hampshire, Dorset, Rambouillet, Targhee, Corriedale and Coarse Wool), 2,888 Finn-crosses (1/2, 3/4 Finn) and 1,429 Rambouillet-crosses (1/2 Rambouillet) lambs by Dickerson et al. (1975). Finn-crosses surpassed ($P<.001$) Rambouillet-crosses and purebreds in viability at 10 weeks of age (81 vs. 62 percent). Sex and type of birth-rearing adjusted growth data showed Finn-crosses to be lighter ($P<.001$) at birth than Rambouillet-crosses or Purebreds (3.79 vs. 4.14 kilograms) but similar in weight at 10 weeks (18.7 vs. 18.6 kilograms).

Accelerated lambing programs require ewes than have the potential to lamb out-of-season. Nitter (1975a), referenced previously, indicated that Finnish crossbreds were better suited to an accelerated lambing program than the other ewe groups that he tested due to their higher

TABLE I

REPRODUCTIVE PERFORMANCE OF EWE LAMBS OF RAMBOUILLET, DORSET AND FINN BREEDING[a]

| Breed | No. | Breeding Wt. (kg) | Percent Lambing | Lambs Born/ Ewes Lambing | Lamb Birth Wt. (kg) | Lambs Weaned/ Ewe Lambing |
|---|---|---|---|---|---|---|
| Rambouillet (R) | 43 | 40.4 ± 4.2 | 31 ± 7 | 100 ± 11 | 4.22 ± .23 | 80 ± 16 |
| Dorset (D) | 36 | 33.6 ± 3.5 | 56 ± 7 | 99 ± 8 | 2.92 ± .16 | 58 ± 11 |
| R x D | 15 | 38.9 ± 3.2 | 92 ± 11 | 107 ± 9 | 4.22 ± .19 | 89 + 14 |
| Finn x R | 23 | 40.8 ± 4.5 | 83 ± 9 | 142 ± 8 | 3.19 ± .16 | 118 ± 12 |
| Finn x D | 17 | 39.6 ± 4.6 | 74 ± 11 | 184 ± 10 | 2.86 ± .20 | 149 ± 14 |

[a]From Laster et al. (1972).

number of average lambings per year.

Maijala and Kangasniemi (1972) examined some field data in Finland regarding the occurrence of out-of-season lambing in purebred Finnsheep. The conventional lambing season in Finland is during the first half of the year. Four farms with 38 total ewes had strived for twice-a-year lambing by early weaning and turning the rams in with the ewes shortly after weaning. Three of the 38 ewes were slaughtered during the period due to being barren. The average lambing interval was 231 days with the four farm averages ranging from 220 to 247 days. These lambing intervals are too long for a twice-a-year lambing program but would fit into a three-times-in-two-years program very easily.

The lambing seasons varied from 2 to 70 days. The two day lambing season was accomplished by weaning all lambs the same day and turning the rams in immediately. Maijala states that the abrupt simultaneous weaning may have had a synchronizing effect on the heats of the ewes. The average number of lambs born alive in consecutive litters (2.47, 2.29, 2.16, 2.10) indicated that there may be a constant decline in the livability of lambs as frequent lambings continue.

Land (1971) observed the incidence of estrus in 13 Finnish Landrace, 25 Dorset Horn and 123 Finn-Dorset ewes between 0 and 56 days (before weaning) after lambing in the spring of 1968. The average age of the ewes in each group was 3.5, 4.7 and 2.4 years for the Finnish Landrace, Dorset Horn and Finn-Dorset groups, respectively. A larger proportion ($P<.05$) of the Finnish Landrace (100 percent) displayed estrus within 56 days after lambing than did the Dorset Horn (68 percent) or Finn-Dorset ewes (59 percent). The regression of the percentage of females showing estrus on the age of the ewe was calculated to be .78 percent per month of age in the Finn-Dorset ewes. This figure was used to adjust the incidence of estrus in each of the three breed types to that which would be expected for three-year-old ewes. The adjusted results were 95, 65 and 52 percent for the Finnish Landrace, Finn-Dorset and Dorset Horn females, respectively. This adjustment placed the crossbred ewes within the range of the parental types but did not change the conclusion that the Finnish Landrace ewes exhibited a higher incidence of estrus than the other two ewe types. Of the ewes which mated, 77, 40 and 29 percent of Finnish Landrace, Finn-Dorset and Dorset Horn ewes, respectively, conceived. The above mentioned studies would lead one to believe that the Finnish Landrace has the ability to lamb-out-of-season.

Shelton and Klindt (1976) reported on the occurrence of estrus and ovulation rate of 20 Finn-Rambouillet ewes from September 1, 1972 through October 30, 1974. The ewes were approaching two years of age at the start of the experiment. The ewes were run with one or more vasectomized rams to detect estrus and a random sample of four ewes was laparotomized each month to record ovulation rate. No control group was maintained with the Finn-Rambouillet ewes, but the data collected was compared with similar data collected on Rambouillet ewes maintained under similar conditions and reported by Hulet et al. (1974). The data on the occurrence of estrus indicated that the Finn-Rambouillet ewes had an approximate five month anestrual period from March through August. During the months of April, May and June none of Finn-Rambouillet ewes were detected in estrus. The lowest proportion of Rambouillet ewes detected in estrus during any one month was approximately 32 percent occurring in May. During all months of the year, the proportion of Rambouillet ewes detected in estrus was higher or equal to the proportion of Finnsheep ewes detected. Number of corpora lutea per ewe during the normal breeding season were greatest for Finn-Rambouillet ewes with the greatest percent (40) of the ewes observed recording three corpora lutea. The greatest percent (66) of the Rambouillet ewes observed recorded one corpora lutem. These data, in contrast to that presented previously, suggest that Finn-Rambouillet ewes would not be acceptable for accelerated or out-of-season lambing programs due to their extended anestrual period.

Rambouillet and Dorset

As far as numbers are concerned, the Rambouillet is the most important breed of sheep in the United States. It has been estimated that approximately 50 percent of all sheep in the United States carry some Rambouillet breeding (Briggs, 1969). The main area of Rambouillet production is the Edward's Plateau area of southwestern Texas around San Angelo.

The Rambouillet breed was developed from selection within the Spanish Merino breed with primary emphasis on increased size and improved mutton conformation. An important segment of the breed's development took place at the French government's experimental farm at Rambouillet near Paris. In 1786, 318 ewes and 41 rams were imported from Spain to Rambouillet. A second large importation was made from Spain to France in 1801, and since that time, the flock at Rambouillet has been closed (Dickinson and Lush, 1933).

Spanish Merinos had been introduced into Germany as early as 1765. A number of German breeders, including Von Homeyer, obtained stock from

Rambouillet in the 1860's to improve their own stock. These sheep later became famous for their exceptional size and heavy fleeces (Dickinson and Lush, 1933).

The first and other early importations of Rambouillets into the United States came from Rambouillet and other French breeders from 1840 to 1860. Later the German bred Rambouillets gained great popularity and were imported. So great was this German influence that in 1926, Dickinson and Lush (1933) estimated that 45 percent of the ancestral lines of the Rambouillet breed in the United States ended in animals bred by Von Homeyer in Germany. No other firm bred more than 10 percent of the foundation animals.

The Dorset breed was developed in southern England in the counties of Dorset, Somerset and Wiltshire. The true origin of the breed is very obscure although a small amount of available evidence suggests that Spanish Merino rams introduced into Wales were crossed on the native or wild sheep of that area and later contributed to the Dorset breed (Briggs, 1969). The first importations of the breed were made in 1887. In that same year, an importation was made from Canada to New York and from England to Massachusetts. Dorsets have traditionally been found in the eastern and midwestern United States, but in recent years, their popularity has increased greatly in the farm flock areas of the Southwest (Briggs, 1969). In 1976, Oklahomans registered more Dorsets than breeders from any other state in the United States.

It has been known for some time that both Dorsets and Rambouillets have a shorter anestrous period than the majority of the breeds found in the United States. Hafez (1952) lists both the Dorset and Rambouillet in a table headed "Breeds of Sheep Breeding all the Year Round".

The long breeding season of these breeds is one of the major reasons for their popularity in areas of the country where fall-lambing is preferred over spring-lambing.

Thrift and Whiteman (1969a) have reported the results of a long term study in which the lifetime reproductive performance of 120 purchased Western ewes (predominately Rambouillets) was compared with that of 120 raised Dorset x Western ewes when managed for fall-lambing. On the average, a higher percentage (7.7, $P<.10$) of the Dorset x Western ewes lambed during the fall of each year; they also had a higher lambing rate (.19, $P<.005$), reared more lambs per 100 ewes (22.6, $P<.01$) in the flock and lambed about three days earlier ($P<.01$) than the Western ewes. Wool production of these same ewes (Thrift and Whiteman, 1969b) showed that the Western ewes produced .96 kilograms more ($P<.001$) grease wool per ewe than the Dorset x Western ewes. However, the two breed groups produced clean fleece weights that were quite similar (.05 kilograms in favor of Western, nonsignificant). Birth weights, average daily gain from birth to 70 days of age, 70 day weight, average daily gain from 70 days to market and market age were very similar and not significantly different for lambs produced by the Dorset x Western and Western ewes (Thrift and Whiteman, 1969c).

Lamb production of about 2,000 spring-lambing purebred ewes of the Suffolk, Hampshire, Dorset, Rambouillet, Targhee, Corriedale, Navajo, Coarse Wool and Fine Wool breeds or strains over a four year period has been reported by Dickerson and Glimp (1975). Considering only the Dorset and Rambouillet ewes, Dorset ewes had a higher fertility rate than Rambouillets (83 vs. 77 percent). There was, however, a highly significant breed x year interaction for fertility with breeds changing rank each year. Rambouillet ewes showed more of a curvilinear response for fertility as ewe age increased than did any other breed. At one and eight years of age, Rambouillets had the lowest fertility rates and at four years of age they had the highest fertility rates when compared with the other breeds.

Number of total lambs born and alive at birth, four weeks and ten weeks per 100 ewes lambing were 155 vs. 144, 147 vs 136, 113 vs. 114 and 102 vs. 104 for the Dorset and Rambouillet ewes, respectively. The only difference approaching significance was for total lambs born. This entire study was handicapped greatly by the very high mortality rates in the lambs (32% by 10 weeks of age) which tended to reduce differences among breeds for lamb production after birth.

Growth characteristics of ram lambs of Suffolk, Hampshire, Dorset, Rambouillet, Targhee, Corriedale and Coarse Wool breeds has been reported by Dickerson et al. (1972). At all ages, Rambouillet lambs were heavier than Dorset lambs. Body weights of Rambouillet vs. Dorset lambs at 0, 10 and 22 weeks of age were 4.7 vs. 4.1, 21.6 vs 18.0 and 47.3 vs. 40.5 kilograms, respectively.

## Effect of Non-additive Genetic Phenomena on Ewe Productivity and Lamb Growth

Ewe productivity is a complex trait which has many different interpretations. However, since a ewe produces two products, wool and lamb and the ewe is responsible for the rearing of her lamb(s) to weaning, an obvious overall measure of ewe productivity in a flock would be weight of wool shorn and weight of lamb weaned per ewe exposed to the ram. This overall measure of production is a function of many individual traits, such as: weight of wool shorn, percent ewes lambing of ewes exposed to the ram (fertility), number of lambs born per ewe lambing (prolificacy), percent of lambs born that survive to weaning and weaning weight of the lambs produced.

Traits that describe lamb growth are birth weight, average daily gain from birth to weaning, weaning weight, average daily gain from weaning to market and market age.

The purpose of this portion of the literature review is to present the effects of individual heterosis, maternal heterosis and breed maternal effects on ewe productivity and lamb growth traits as reported in the scientific literature.

## Individual Heterosis

An unconfounded estimate of the magnitude of heterosis for a particular trait can be obtained by the contemporary comparison of two purebreeds with their reciprocal crosses. It is obvious that it is quite easy to measure individual heterosis for wool weight, lamb survival and growth traits by merely comparing the performance of the purebreds with that of the crossbreds. The problem, however, lies in how to estimate individual heterosis for reproductive traits such as fertility and prolificacy. As an example, consider prolificacy. Should individual heterosis for prolificacy be (1) the difference observed between the average prolificacy of purebred dams when mated to rams of the same breed (AxA, BxB) and the average prolificacy of the purebred dams when mated to rams of the other breed (BxA, AxB) or should individual heterosis for prolificacy be (2) the difference observed between the average prolificacy of purebred dams when mated to rams of a third breed (CxA, CxB) and the average prolificacy of $F_1$ reciprocal dams when mated to the same unrelated breed of ram (CxBA, CxAB). This is a difficult question to answer and not made easier by the fact that both types of comparisons are used in papers concerning sheep and both are called estimates of individual heterosis by the various authors.

For the purpose of this literature review, it was decided that for reproductive traits (fertility and prolificacy), comparison (1) above, i.e. 1/2 (BxA + AxB) - 1/2(AxA + BxB), will be considered an estimate of individual heterosis and comparison (2) above, i.e. 1/2(CxBA + CxAB) - 1/2(CxA + CxB), will be considered an estimate of maternal heterosis which will be discussed later. These comparisons have been interpreted in the same manner by Wiltbank et al. (1967) for individual heterosis and by Cundiff et al. (1974) for maternal heterosis in cattle and by Johnson and Omtvedt (1975) for maternal heterosis in swine.

One of the early studies done to estimate heterosis in sheep was reported by Sidwell et al. (1962). Lamb production from 1689 purebred matings of Hampshire, Shropshires, Southdowns, Merinos and Columbia-Southdale were compared with 560 two-way cross matings among these breeds. However, all possible two-way cross matings among the breeds and all reciprocal matings were not included in the study which confounded estimates of heterosis with maternal breed effects. Individual heterosis, expressed as a percent of purebred matings, was .7 percent for fertility, -6.5 percent ($P<.05$) for prolificacy, 4.6 percent for lamb survival to weaning and 2.1 percent for lambs weaned per ewe bred. Growth data for the purebred and crossbred lambs indicated heterosis of 7.2 and 9.8 percent for birth weight and weaning weight, respectively (Sidwell et al., 1964). Heterosis for weight of lamb weaned per ewe bred was 12.9 percent (Sidwell et al., 1964).

Sidwell and Miller (1971a) reported a study in which lamb production from 994 purebred matings of the Hampshire, Columbia-Southdale, Targhee, Suffolk and Dorset breeds was compared with 899 crossbred matings among these breeds. All possible crossbred matings were included. The average level of heterosis shown by each cross was 6.0, 3.3, 8.9 and 20.6 percent for fertility, prolificacy, lamb survival to weaning and lambs weaned per ewe bred, respectively. Growth traits of the crossbred vs. purebred lambs gave heterosis estimates of 2.3, 5.2 and 6.5 percent for birth weight, weaning weight and average daily gain from birth to weaning, respectively (Sidwell and Miller, 1971b). Heterosis for weight of lamb weaned per ewe mated was estimated to be 24.8 percent (Sidwell and Miller 1971c).

Fahmy and Bernard (1973) reported the results of a nine year study comparing percent multiple births from 148 purebred and 103 crossbred matings using the Oxford and Suffolk breeds. Percent heterosis observed was 23.0 percent. $F_1$ ewes (Suffolk x Oxford and Oxford x Suffolk) showed 17.1 percent heterosis for fleece weight over the parental breeds. Although no tabular values were reported for ewe weights, a graph of ewe weights across ewe ages showed that the $F_1$ ewes were always heavier than the heaviest parental breed indicating a large amount of heterosis for this trait.

Heterosis for growth traits of Suffolk x Oxford and Oxford x Suffolk lambs were estimated to be 7.8, 6.6 and 6.9 percent for birth weight, average daily gain from birth to weaning and weaning weight, respectively (Holtmann and Bernard, 1969).

Hohenboken et al. (1976a) reported the results of a crossbreeding study using a diallel cross among three breeds of sheep (Hampshire, Suffolk and Willamette) replicated over three years. A total of 288 straightbred ewes started the trial. Heterosis was 5.7 (P<.01), 1.8, 3.2 and 13.5 (P<.01) percent for fertility, prolificacy, lamb survival to weaning and weight of lamb weaned per ewe mated, respectively. Growth data of 1,209 straightbred and crossbred lambs produced from these matings indicated a 1.2 and 5.6 (P<.01) percent heterosis estimate for birth weight and weaning weight, respectively (Hohenboken et al., 1976b). Crossbred advantage (heterosis) for total gross income per ewe mated was $4.30 or 12.3 percent (Hohenboken, 1976).

Birth and weaning weights of 3358 and 3126 lambs, respectively, produced by straightbred and crossbred matings of six of the Minnesota synthetic lines collected over a five year period were reported by Singh et al. (1967). Crossbred lambs showed a 4.7 percent advantage for birth weight and a 8.1 percent advantage for weaning weight over straightbred lambs. Rastogi et al. (1975) estimated heterosis amounts of 1.6, 2.1, 1.5, 4.3 and 3.0 percent for birth weight, average daily gain from birth to weaning, weaning weight, average daily gain from weaning to market and market age, respectively. The data were collected on 344 crossbred and 616 purebred lambs of Columbia, Suffolk and Targhee breeding. Bradley et al. (1972) reported heterosis for weaning weight to be 2.8 percent when comparing purebred and crossbred lambs of Suffolk, Targhee and Shropshire breeding.

Galal et al. (1972) reported heterosis estimates obtained from 523 lambs born from straightbred and crossbred matings utilizing the Fleisch Merino and two Egyptian breeds (Ossimi and Barki). Heterosis estimates obtained were 2.3, 2.6, 7.2, 6.1 and 31.4 for birth weight, four-month weight, survival to four months, yearling weight and first fleece weight, respectively.

## Maternal Heterosis

The cause of maternal heterosis is thought to be gene interactions (heterozygosity, epistasis, etc.) for maternal traits such as milk production, mothering ability, etc. which allows the crossbred ewe to provide a more favorable environment for her young than the environment provided by the average of the purebred dams. Maternal heterosis can be estimated by comparing the progeny of contemporary ewes of two pure breeds with their reciprocal crosses when all ewes are mated to a ram of a third breed (Dickerson, 1969). The estimate of maternal heterosis obtained in this manner is confounded with one-half the effects of recombination in maternal gametes. Recombination will be covered later, but its effects are generally thought to be negative (Dickerson, 1969). If this is the case, estimates of maternal heterosis obtained using the method above will tend to underestimate the true amount of maternal heterosis present. The magnitude of underestimation will, of course, depend upon the importance of recombination loss.

Sidwell et al. (1962) reported the lamb production from 560 two-way and 507 three-way cross matings. The results obtained are somewhat confounded with maternal effects since all possible $F_1$ ewes were not represented in the three-way cross matings. The pure breeds involved were Hampshire, Shropshire, Southdown, Merino and Columbia-Southdale. Percent increase of three-way over two-way cross matings was 1.6, 15.0 ($P<.05$), 0.0 and 13.2 ($P<.05$) percent for fertility, prolificacy, lamb survival to weaning and lambs weaned per ewe bred, respectively. Growth traits of the two-breed and three-breed cross lambs gave maternal heterosis estimates of 3.8 percent for birth weight and 6.2 percent for weaning weight (Sidwell et al., 1964). Combining the reproduction and growth data gave a 22.6 percent maternal heterosis estimate for weight of lamb weaned per ewe bred.

Fahmy and Bernard (1973) compared the percent multiple births produced by Oxford x Suffolk and Suffolk x Oxford ewes with that produced by Oxford and Suffolk ewes when all ewes were mated to Cheviot rams. Heterosis was estimated to be 23.0 percent for this trait. Maternal heterosis for growth traits estimated from the lambs produced from these matings were 3.7, 7.3 and 6.5 percent for birth weight, average daily gain from birth to weaning and weaning weight, respectively.

Bradley et al. (1972) compared the reproductive performance of straightbred and crossbred ewes of Suffolk, Targhee and Shropshire breeding and found no heterosis for fertility, prolificacy and number of lambs weaned per ewe exposed.

Hohenboken and Cochran (1976) compared the reproductive performance of 180 purebred and crossbred ewe lambs of Hampshire, Suffolk and Willamette breeding when mated to Shropshire rams. Heterosis for fertility and prolificacy were 25.0 and 10.0 percent, respectively. Maternal heterosis for lamb weaning weight and lamb survival to weaning were 8 and -5 percent, respectively. The increased mortality of lambs from crossbred dams was attributed in part to the greater number of lambs born to this group. Maternal heterosis for lamb production per ewe mated was 30 percent.

Aboul-Naga and Galal (1973) estimated maternal heterosis for first fleece weight using performance of back crosses, first crosses and parental breeds (e.g. $H_M = A \cdot AB - 1/2(A+AB)$. Two Egyptain native breeds

(Ossimi and Barki) and one imported breed (Merino) were used. The amount of maternal heterosis calculated in kilograms was .23$\pm$.06 for ewes from Merino x Ossimi and Ossimi x Merino dams and .10$\pm$.07 for ewes from Merino x Barki and Barki x Merino dams.

Grand-Maternal Heterosis for Reproduction

Previously, when considering reproductive traits, the comparison of the performance of purebred ewes when reciprocally mated to rams of a different breed vs. the performance of purebred ewes when mated to rams of the same breed has been called individual heterosis and the comparison of the performance of reciprocal crossbred ewes vs. the performance of purebred paternal ewes when all ewes are mated to a third breed of unrelated rams has been called maternal heterosis. Continuing along these same lines, the comparison of the performance of crossbred ewes produced from crossbred dams vs. the performance of crossbred ewes produced from purebred dams when all ewes are mated to the same breed of unrelated sire can be called grand-maternal heterosis; e.g. $H_{G.M.} = 1/2[D \times (C \times AB) + D \times (C \times BA)] - 1/2[D \times (C \times A) + D \times (C \times B)]$. Therefore, in order to estimate grand-maternal heterosis a comparison among three- and two-breed-cross ewes is needed. Only one study was found in which such a comparison was made.

Sidwell et al. (1962) compared 713 lambing records of two and three-breed-cross ewes for reproductive traits over an eight-year period. Parental breeds represented were Southdown, Shropshire, Hampshire and Merino. All possible two- and three-breed crosses were not included which allows the estimates obtained to be confounded with average direct gene effects, maternal breed effects and maternal heterosis. Average performance of the two- and three-breed crosses was 90.0 vs.

92.3, 147.6 vs. 149.0, 84.0 vs. 89.4 and 105.2 vs. 117.2 for fertility, prolificacy, lamb survival and percent lambs weaned of ewes bred, respectively. Estimated maternal heterosis for these traits would be 2.6, 0.9, 6.4 and 11.4 ($P<.05$) percent, respectively. Sidwell et al. (1964) combined the reproductive data with the weaning weights of the lambs produced and found that three-breed-cross ewes weaned 3.8 kilograms more lamb per ewe exposed than did two-breed-cross ewes. This yielded a heterosis estimate of 13.2 percent.

Of the crosses used by Sidwell et al. (1962), there was only one set represented in the two and three-breed-crosses which upon comparison would yield an unconfounded estimate of grand-maternal heterosis. This comparison involved the comparison of the average of Southdown x Shropshire·Hampshire and Southdown x Hampshire·Shropshire ewes with Southdown x Shropshire and Southdown x Hampshire ewes. Extrapolated data using only these crosses yielded grand-maternal heterosis estimates of 0, -7.1, .5 and -5.3 for fertility, prolificacy, lamb survival and percent lambs weaned of ewes bred, respectively. These results differ greatly from those obtained from comparing all two- and three-breed-crosses. Some bias may still be in these last estimates since all Southdown x Shropshire ewes were mated to Hampshire rams, Southdown x Hampshire ewes were mated to Shropshire rams and both three-breed-cross ewes were mated to Merino rams.

## Maternal Effects

The term maternal effect implies an influence of the mother on her offspring other than through the genes she transmits to it (Bradford, 1972). As used here, maternal effects are those influences on the lamb due to the average effects of the genes possessed by the dam. Maternal breed effects can easily be estimated by comparing the performance of reciprocal crossbred individuals.

In the study reported by Sidwell et al. (1962) a comparison of the reproductive performance from 271 lambings of Hampshire x Shropshire and Shropshire x Hampshire ewes when mated to both Merino and Southdown rams can be extrapolated. The Hampshire x Shropshire ewes had a higher percent ewes lambing (+6.6), a lower percent of lambs born of ewes lambing (-19.8), a higher percent of lambs weaned of live lambs born (1.8) and the same percent of lambs weaned of ewes bred when compared with the Shropshire x Hampshire ewes. Weights of lambs produced by these same ewes and some additional ewes of similar breeding added later showed that lambs produced by Hampshire x Shropshire ewes were similar in birth weight and slightly lighter (-.5 kilograms) in weaning weight (Sidwell et al., 1964). It is hard to determine which of these differences are significant ($P<.05$) since this data was estrapolated from a larger set. However, it appears that the only difference of large magnitude is that observed for percent of lambs born of ewes lambing.

Fahmy and Bernard (1973) reported that percent multiple births produced by Oxford x Suffolk and Suffolk x Oxford ewes when mated to Cheviot rams was similar (64.5 vs. 63.6 percent). Fleece weights were also similar ($P>.05$) among the reciprocals. From a graph of body weights presented over ewe ages of two to nine, the Suffolk x Oxford and Oxford x Suffolk ewes appeared to be quite similar in this trait.

Land et al. (1974) has reported a nonsignificant difference in average litter size ($.04 \pm .12$) between two-, three- and four-year old Finn x Merino and Merino x Finn ewes when mated to Welsh rams. When lambing at one year of age, Merino x Finn ewes recorded a nonsignificant advantage in average litter size over the Finn x Merino ewes (.16 lambs).

Bradley et al. (1972) found no significant difference among reciprocal crossbreds for 120 day weights of the lambs that they produced. Parental breeds used were Suffolk, Shropshire and Targhee.

Maternal effects tend to be more important for growth traits than for reproductive traits. Sidwell et al. (1964) reported that 137 Shropshire x Hampshire lambs were heavier ($P<.05$) at birth, heavier ($P<.05$) at weaning and gained more ($P<.05$) from birth to weaning than 118 Hampshire x Shropshire lambs. These results indicated that Hampshire ewes provided a more favorable environment pre- and postpartum to weaning for their lambs than did Shropshire ewes.

Holtman and Bernard (1969) found that Oxford x Suffolk lambs were similar in weight at birth, heavier ($P<.05$) at 28 days and heavier ($P<.05$) at 120 days than Suffolk x Oxford lambs. These data indicated that Suffolk ewes provided a more favorable environment for their lambs from birth to weaning than did Oxford ewes.

Bradley et al. (1972) found the maternal effects for 120 day lamb weight to be 1.2 kilograms for Suffolk ewes, .4 kilograms for Targhee ewes and -1.8 kilograms for Shropshire ewes. These results agreed with the two papers cited previously in which Suffolk ewes were found to excel in maternal performance (Holtman and Bernard, 1969) and Shropshire ewes were poorer (Sidwell et al., 1964).

Hohenboken et al. (1976b) reports maternal effects for Hampshire, Suffolk and Willamette ewes of .01, -.15 and .14 kilograms, respectively for birth weight and -.90, .31 and .59, respectively for weaning weight. The Willamette breed which is a synthetic developed under the conditions under which the trial was conducted had positive maternal effects for both traits.

Weiner and Hayter (1974) have used the Scottish Blackface, Cheviot and Welsh breeds and all possible reciprocals to evaluate maternal effects on body weights from birth (546 lambs) to 282 weeks of age (150 ewes). Maternal effects were significantly different among breeds to approximately one year of age with lambs born from Blackface ewes being the heaviest. From one year of age until 222 weeks of age maternal effects were small and nonsignificant.

Similar results as those reported by Weiner and Hayter (1974) have been found by Karihaloo and Combs (1971). Body weights were evaluated on 87 Southdown x Lincoln and 77 Lincoln x Southdown lambs from birth to 190 days of age. The two parental breeds differ greatly in respect to mature size with mature Lincoln ewes averaging 80 to 100 kilograms and mature Southdown ewes averaging 55 to 70 kilograms in body weight. At birth, 40, 90, 150 and 190 days of age, lambs from Lincoln ewes exceeded those from Southdown ewes in body weight by .69, 2.31, 2.70, 1.75 and 3.12 kilograms, respectively. However, the differences at 150 and 190 days of age were not significantly different from zero indicating that maternal effects for body weight are more important early in life than later.

## Recombination Effects

The effects of genetic recombination is termed recombination loss since it is felt that it results in a reduction or "loss" in performance. The theory behind recombination loss is that through evolution, our breeds of livestock have built-up desireable non-allelic gene interactions (epistatic effects). As long as we are purebreeding, these desirable epistatic effects remain intact. These desirable epistatic effects are even maintained in the $F_1$ who receives one set of chromosomes, with their desirable non-allelic gene interactions, from each of the two purebreds. However, when the $F_1$ individual undergoes meiosis in the formation of gametes, these desirable interactions may be broken-up by crossing-over between the maternal and paternal chromosomes at pachytene. Therefore, recombination loss is a potential problem whenever crossbred individuals are used in a mating scheme.

The importance of epistatic recombination loss has not been estimated in large farm animals, but Dickerson (1969) points out that it has been demonstrated to exist in Drosophila (Wallace and Vetukhiv, 1955; King, 1955), in corn (Sprague et al., 1962) and in fowls (Dickersone, 1961, 1965). Current experimentation is underway at the United States Meat Animal Research Center, Clay Center, Nebraska with both cattle and sheep to determine the effect of genetic recombination on performance traits.

## Summary of Literature Review

In all spring-lambing trials reviewed, ewes containing Finnish Landrace breeding have reached sexual maturity at an earlier age and had higher ovulation rates and/or larger litter sizes than the breeds or crossbreeds that they were compared with. Fertility rates of ewes two years and older at lambing have generally been similar among Finn and non-Finn ewes. Finn ewes shear lighter fleeces than non-Finn ewes.

Finn lambs are lighter at birth and generally lighter at weaning than non-Finn lambs. Reports of lamb livability from birth to weaning have been varied with some studies reporting increased mortality among

Finn lambs and others reporting decreased mortality.

Data from The United Kingdom and Europe would indicate that the Finnish Landrace breed has the potential for use in accelerated lambing programs by being able to mate and conceive during lactation or shortly after weaning of the lambs. However, one study completed in the United States indicates a very long anestrous period of five months for Finn-cross ewes which would make successful accelerated lambing programs almost impossible.

Both Dorsets and Rambouillets have extended breeding seasons which makes them adaptable to accelerated or out-of-season lambing programs. Dorset ewes have been shown to have a higher fertility and lambing rate than Rambouillet ewes under both spring and fall lambing programs. Rambouillet ewes, on the other hand, shear heavier grease fleeces than do Dorset ewes.

Rambouillet lambs are heavier at all ages than Dorset lambs. One study suggests that under rather severe rearing conditions, livability to weaning may be higher in Rambouillet than Dorset lambs.

It is apparent from the preceding review that individual and maternal heterosis exist for reproduction, survival and growth in sheep. The average of the estimates of individual and maternal heterosis obtained from this review are presented in Table II. There seems to be little evidence for the existence of grand-maternal heterosis for reproduction.

Maternal breed effects estimated by the difference between reciprocal crossbreds do not seem to be important for reproductive traits, fleece weights and body weights late in life. They are, however, very important for lamb growth to weaning and in some cases to one year of age.

TABLE II

AVERAGE OF THE HETEROSIS ESTIMATES OBTAINED FROM THE STUDIES REVIEWED

| Trait | Percent Heterosis | |
|---|---|---|
| | Individual | Maternal |
| Fertility | 4.1 (3)[a] | 8.9 (3) |
| Prolificacy | 5.4 (4) | 12.0 (4) |
| Lamb Survival | 6.0 (4) | -1.7 (3) |
| Weight of Lamb Weaned per Ewe Mated | 17.1 (3) | 26.3 (2) |
| Birth Weight | 3.9 (7) | 3.8 (2) |
| A.D.G.-Birth to Weaning | 5.1 (3) | 7.3 (1) |
| Weaning Weight | 5.3 (8) | 6.9 (3) |
| Fleece Weight | 24.2 (2) | + (1) |

[a]Number in parenthesis is the number of studies from which the estimates were taken.

# CHAPTER III

# MATERIALS AND METHODS

## Experimental Animals and Their Management

During March and April of 1971 and 1972, 198 crossbred ewes representing four combinations of Finnsheep (F), Dorset (D) and Rambouillet (R) breeding were born at the Southwestern Livestock and Forage Research Station, El Reno, Oklahoma. The four crossbred ewe groups represented were: 1/2D1/2R, 1/4D3/4R, 1/4F1/2D1/4R and 1/4F1/4D1/2R. Table III presents the matings and number of sires and dams used to produce the ewes and the number born each year. The Rambouillet, Dorset and 1/2D 1/2R dams and the Dorset sires were purchased from a number of flocks in Oklahoma and Texas. The 1/2 Finnsheep sires and one Rambouillet sire were purchased from the Meat Animal Research Center, Clay Center, Nebraska. The remaining Rambouillet sire originated in Missouri.

The crossbred ewe lambs were raised in drylot with their dams and allowed access to a creep which contained a ground ration comprised of 45 percent sorghum grain, 40 percent alfalfa hay, 10 percent soybean meal and 5 percent sugarcane molasses. Dams were allowed a few hours daily grazing of either small grain or bermuda grass pasture. The ewe lambs were weaned at approximately 70 days of age and fed a finishing ration similar to the creep ration but with the 10 percent soybean meal replaced by 5 percent sorghum grain and 5 percent alfalfa hay. Upon reaching 34 kilograms in body weight, the ewe lambs were removed from

TABLE III

MATINGS AND NUMBER OF SIRES AND DAMS USED TO PRODUCE THE EWES AND NUMBER PRODUCED EACH YEAR

| Ewe Breeding[a] | Sires | | Dams | | No. Ewes Produced | | |
|---|---|---|---|---|---|---|---|
| | Breed[a] | No. | Breed[a] | No. | 1971 | 1972 | Total |
| 1/D1/2R | D | 8 | R | 43 | 26 | 25 | 51 |
| 1/4D3/4R | R | 2 | 1/2D1/2R | 38 | 28 | 24 | 52 |
| 1/4F1/2D1/4R[b] | 1/2F1/2D | 6 | 1/2D1/2R | 28 | 14 | 17 | 31 |
| | 1/2F1/2R | 4 | D | 11 | 9 | 4 | 13 |
| 1/4F1/4D1/2R[b] | 1/2F1/2D | 6 | R | 25 | 8 | 18 | 26 |
| | 1/2F1/2R | 5 | 1/2D1/2R | 19 | 14 | 11 | 25 |
| | | | | | 99 | 99 | 198 |

[a]D=Dorset, R=Rambouillet, F=Finnsheep.

[b]The 1/4 Finnsheep ewes were each produced from two types of matings.

the drylot and placed on clean pastures to develop and await breeding.

It was desired to measure the performance of these ewes when lambing at approximately one year of age in the spring and when lambing in the late winter-early spring and the fall of the year at ages greater than one year of age. In order to realize these objectives, the ewes were mated in the falls of 1971, 1972 and 1973 for late winter-early spring lambing and in the springs of 1974 and 1975 for fall lambing. Dates of the breeding seasons and average ewe age at the start of the breeding seasons from 1971 to 1975 are presented in Table IV. In addition to the 198 ewes born in the springs of 1971 and 1972, 23 ewes (5 to 7 in each of the four crossbred ewe groups) were born in October and November of 1971. These ewes were mated for the first time during the September 15 to November 6, 1972 breeding season and thus did not lamb at one year of age in the spring. For this reason, the performance of these ewes was not included in any of the late winter-early spring lambing results. Their performance was included, along with that of the ewes born in the spring of 1971, when lambing in the falls of 1974 and 1975.

In addition to the breeding seasons in Table IV, a "clean-up" breeding was conducted in 1974. Following the May 15 to July 2, 1974 breeding season, a ram was reintroduced into the ewe flock on August 20, 1974 and alternated daily with another ram until September 24, 1974. The purpose of this breeding season was to mate ewes that had not settled to the spring, 1974 mating. Sixty-one ewes conceived to this mating and lambed in January and February of 1975. Performance at this lambing is not included in the study since all ewes were not given an opportunity to lamb during this period.

TABLE IV

NUMBER OF EWES EXPOSED, MEAN BREEDING AGE AND BREEDING SEASON DATES FROM 1971 TO 1975

| Year | Year of Ewe's Birth | No. Ewes Exposed | Age (Months)[a] Mean | Age (Months)[a] S.D. | Breeding Dates |
|---|---|---|---|---|---|
| 1971 | 1971 | 99 | 6.5 | .46 | Oct. 18 - Dec. 22 |
| 1972 | 1971 | 95 | 17.6 | .44 | Sept. 15 - Nov. 6 |
| | 1972 | 99 | 6.8 | .60 | Oct. 20 - Dec. 22 |
| 1973 | 1971 | 94 | 29.0 | .47 | Aug. 23 - Oct. 19 |
| | 1972 | 95 | 17.0 | .60 | Aug. 23 - Oct. 19 |
| 1974 | 1971 | 93+23[b] | 36.0 | 2.73 | May 15 - July 2 |
| | 1972 | 93 | 25.5 | .60 | May 15 - July 2 |
| 1975 | 1971 | 91+23[b] | 48.0 | 2.75 | May 14 - July 3 |
| | 1972 | 91 | 37.5 | .61 | May 14 - July 3 |

[a]Age at the start of the breeding season.

[b]23 ewes were born in October-November, 1971 and not included in the study until the 1974 mating season.

Prior to mating each year, the ewes were weighed and divided into single-sire groups of equal size. The number of ewes in a group varied from 29 to 37 over the years included in this study. Each mating group was equalized as closely as possible for ewe age, crossbred ewe group and number of lambs reared at the previous lambing. All rams used were of Hampshire, Suffolk, Hampshire x Suffolk or Suffolk x Hampshire breeding. Prior to the start of each breeding season, all rams were electroejaculated and only those rams with normal appearing semen, as evaluated by microscopic exmaination, were used in the breeding pastures. Rams which appeared to be slow breeders in the mating pastures were replaced with a reserve ram. Table V presents the number of rams used each breeding season.

The Hampshire and Suffolk sires used for the fall matings were purchased from breeders in Oklahoma and were of various ages when used. The rams used for the two spring matings were produced in two separate years by two purebred sheep breeders; Mr. Clifford Sloan (Suffolk) and Mr. Clyde Bachtel (Hampshire) of Hamilton, Missouri. By exchanging some females at breeding time, these breeders produced purebred Hampshire and Suffolk and reciprocal cross rams. The same ram that sired purebreds of either breed also sired some of the crossbreds. Therefore, the Suffolk and Suffolk x Hampshire and the Hampshire and Hampshire x Suffolk rams were half brothers. Each ram was used one year when approximately 16 months of age. As indicated in Table IV, the breeding season lasted approximately 50 days each year.

Following the breeding season each year, ewes grazed bermuda or native pastures and were supplied alfalfa hay when grass became scarce or covered with snow.

TABLE V

NUMBER OF RAMS OF EACH BREED OR CROSS USED EACH BREEDING SEASON

| Breed of Ram | Fall Mating 1971 | 1972 | 1973 | Spring Mating 1974 | 1975 | Total No. of Diff. Sires |
|---|---|---|---|---|---|---|
| Hampshire | 2 | 5(2)[a] | 2(2) | 2 | 2 | 9 |
| Suffolk | 1 | 4(1) | 8(4) | 2 | 2 | 12 |
| Hampshire x Suffolk[b] | - | - | - | 2 | 3 | 5 |
| Suffolk x Hampshire | - | - | - | 2 | 1 | 3 |

[a]Number in parenthesis indicates the number of rams which had been used in a previous breeding season.

[b]Breed of sire of the ram is listed first.

From four weeks prior to lambing until lambing, the ewes were fed approximately .2 kilograms of sorghum grain per head daily. Ewes were lambed inside a large enclosed shed or outside in an adjoining pasture if weather permitted. Shortly after parturition, the lambs were identified and weighed, and the ewe and her lamb(s) were placed in an individual lambing pen where they remained for approximately three days. All lambs were docked and all ram lambs born in the late winter or early spring of 1972, 1973 and 1974 were castrated at approximately three days of age. Half of the ram lambs born in the fall of 1974 were castrated while half were left intact, and all ram lambs born in the fall of 1975 were left intact.

When the lambs were approximately five days of age, they were moved with their dams to a feedlot located adjacent to several small-grain pastures. Late winter or early spring born lambs remained in drylot at all times while the ewes were allowed daily grazing of the small-grain pastures. Fall born lambs were allowed to graze with their dams. Lambs born in both seasons had continuous access to a ground creep ration comprised of 45 percent sorghum grain, 40 percent alfalfa hay, 10 percent soybean oil meal and 5 percent sugarcane molasses.

Prior to the oldest lamb reaching 66 days of age, unshrunk weights were taken on all lambs. Biweekly unshrunk weights were taken from this point in time until market on all lambs. At each weighing, any lambs that were 66 days of age or older had their dams removed from the lot and were weaned. Thus, weaning ages of the lambs ranged from 66 to 79 days of age. No minimum weight was required to be reached before weaning took place. When a majority of the lambs had been weaned, the 10 percent soybean oil meal was deleted from the creep ration and replaced with 5 percent sorghum grain and 5 percent alfalfa hay. This new ration served as the feedlot ration. Late winter and early spring lambs were marketed when they reached 43.1 kilograms in body weight while fall born lambs were marketed when they reached a weight of 45.5 kilograms.

Following the weaning of their lambs, ewes were run as one group on bermuda or native pasture and kept in thrifty body condition to await the next breeding season.

Ewes were shorn by professional shearers over a two day period each year during the last week of April or the first week of May. Throughout the year, routine sheep management chores such as foot trimming and drenching were carried out on the ewe flock. The overall health status of the flock was very good throughout the entire study and was a credit to the shepherd and his assistants.

## Traits Studied

Traits which determine weight of lamb weaned per ewe maintained in the flock (ewe productivity) and those traits which characterize lamb growth from birth to market were of primary interest in this study. The measure of ewe productivity used was kilograms of lamb weaned per ewe mated. This is a complex trait determined by many other traits; namely: ewe fertility, ewe prolificacy, lamb survival from birth to weaning and lamb weaning weight. Ewe fertility was defined as the proportion of ewes mated and surviving at lambing that lambed, and ewe prolificacy was the average number of lambs born per ewe lambing. Lamb survival from birth to weaning was the proportion of lambs born that were present with their dams at weaning. Lamb losses from birth to weaning included still-births, lambs that died during the period and lambs taken from their dams and either fostered to another ewe or placed on milk replacer. Ewes were given an opportunity to raise all lambs delivered and lambs were taken from a ewe only when it was obvious that the ewe could not raise them. Lamb weaning weight was the adjusted 70 day weight of each lamb present with its dam at weaning where adjustment had been made for lamb age (using each lambs own birth to weaning average daily gain) and sex, adjusted to a female basis (using least squares constants generated from the lamb growth analysis. For late winter-early spring born lambs, 1.4 kilograms was subtracted from the 70 day weight of each wether lamb. For fall born lambs, 2.5 and 2.8 kilograms were subtracted from the 70 day weights of each wether and ram lamb, respectively). Kilograms of lamb weaned by each ewe was the sum of the adjusted 70 day weights of all of a ewe's weaned progeny. Ewes that did not lamb or that lambed but did not wean a lamb had a zero recorded for this value.

Traits that were used to characterize lamb growth were birth weight, average daily gain from birth to 70 days of age, 70 day weight, average daily gain from 70 days to market and age at 43.1 kilograms. Age at 43.1 kilograms was calculated using the following formula:

Age at 43.1 kg. = 70 + ((43.1 kg. - 70 Day Weight)/ A.D.G. from 70 days to Market).

Since ewe, wether and ram lambs were present in the fall of 1974 and only ewe and ram lambs were present in the fall of 1975, preliminary analysis of the 1974 data was done in order to generate least square sex constants for each of the growth traits after birth. These constants were used to adjust the rams in both 1974 and 1975 to a wether basis. Each ram's average daily gain from birth to 70 days, 70 day weight, average daily gain from 70 days to market and age at 43.1 kilograms was reduced by .0068 kilograms, .32 kilograms, .0544 kilograms and increased by 10.43 days, respectively.

In addition to the above mentioned traits, grease fleece weights were obtained each year and in 1974 a quality grade was placed on each fleece by the personnel of the Mid-States Wool Marketing Cooperative, Hutchinson, Kansas. Breeding weights were also recorded prior to the beginning of each breeding season.

## Breed Group Comparisons

Represented in the four crossbred ewe groups are two levels of Finnsheep breeding (one-quarter and zero) and two levels of Dorset breeding (one-quarter and one-half). These levels of Finnsheep and Dorset breeding are arranged factorially across the four crossbred ewe groups; i.e. each level of Finnsheep breeding occurs with each level of Dorset breeding. In each crossbred ewe group, Rambouillet breeding is present in the proportion needed to gain unity (see Figure 1).

| | | Level of Dorset Breeding | | |
|---|---|---|---|---|
| | | 1/2 | 1/4 | |
| Level of Finnsheep Breeding | 1/4 | 1/4F1/2D1/4R[a] | 1/4F1/4D1/2R | 1/4 Finnsheep $\bar{x}$ |
| | 0 | 1/2D1/2R | 1/4D3/4R | 0 Finnsheep $\bar{x}$ |
| | | 1/2 Dorset $\bar{x}$ | 1/4 Dorset $\bar{x}$ | |

[a]F=Finnsheep, D=Dorset and R=Rambouillet

Figure 1. Factorial Arrangement of Two Levels of Finnsheep and Dorset Breeding in the Ewes

For traits measured on the ewes, the 1/4 Finnsheep mean minus the 0 Finnsheep mean is an estimate of the main effect of increasing Finnsheep breeding from 0 to 1/4 at the expense of Rambouillet breeding. Likewise, the 1/2 Dorset mean minus the 1/4 Dorset mean is an estimate of the main effect of increasing Dorset breeding from 1/4 to 1/2 at the expense of Rambouillet breeding. The failure of the two simple effects of increasing Finnsheep breeding from 0 to 1/4 to be equal and of increasing Dorset breeding from 1/4 to 1/2 to be equal (interaction between level of Finnsheep and Dorset breeding) is estimated by subtracting diagonal means; i.e. (1/2D1/2R + 1/4F1/4D1/2R)/2 - (1/4F1/2D1/4R + 1/4D3/4R)/2.

For traits measured on the lambs of these ewes, such as lamb survival and growth traits, a similar factorial arrangement of Finnsheep and Dorset breeding exists except that the levels of Finnsheep and Dorset breeding in the lambs is one-half that in the ewes. One-half of the breeding of each lamb is of black-face breeding (1/2 Hampshire, 1/2 Suffolk or 1/4 Hampshire - 1/4 Suffolk) with Rambouillet breeding present in the proportion needed to gain unity. Adjusting lamb traits for breed of sire effects, gives four crossbred lamb groups arranged factorially as to level of Finnsheep and Dorset breeding as shown in Figure 2.

| | | Level of Dorset Breeding | | |
|---|---|---|---|---|
| | | 1/4 | 1/8 | |
| Level of Finnsheep Breeding | 1/8 | 1/8F1/4D1/8R1/2B[a] | 1/8F1/8D1/4R1/2B | 1/8 Finnsheep $\bar{x}$ |
| | 0 | 1/4D1/4R1/2B | 1/8D3/8R1/2B | 0 Finnsheep $\bar{x}$ |
| | | 1/4 Dorset $\bar{x}$ | 1/8 Dorset $\bar{x}$ | |

[a]F=Finnsheep, D=Dorset, R=Rambouillet and B=Blackface

Figure 2. Factorial Arrangement of Two Levels of Finnsheep and Dorset Breeding in the Lambs

Estimates of main effects and interaction are estimated in the same manner as for the ewes. However, with the lambs, estimates of the effect of increasing Finnsheep or Dorset breeding by 1/8 at the expense of Rambouillet breeding is obtained.

In order to determine the genetic parameters being estimated by the above mentioned main effects, it is first necessary to express the expected performance of each of the four crossbred ewe and lamb groups in terms of the following genetic components expressed as a deviation from the parental purebred mean (Dickerson, 1969):

1. deviation due to average direct effects of the individual's own genes ($g^I$)
2. deviation due to increased average heterozygosity of $F_1$ crossbreds including any non-allelic interaction of parental gametes (individual heterosis effects, $h^I$)
3. deviation due to change in non-allelic gene interactions effects in $F_2$ individuals, relative to those of the $F_1$, from gametic recombinations between chromosomes of the parent breeds (individual recombination effects, $r^I$)
4. deviation due to average effects of the dam's genes for maternal traits (maternal effects, $g^M$)
5. deviation due to increased heterozygosity of $F_1$ crossbred dams (maternal heterosis effects, $h^M$).

Table VI presents the expected performance of the four crossbred ewe groups in terms of the above components as calculated from examples given by Dickerson (1969).

Table VII presents the expected values of the 1/4 Finnsheep and 1/4 Dorset main effects and the interaction between level of Dorset and Finnsheep breeding of the ewes in terms of the genetic components. As can be seen from Table VII, for traits measured in the ewe such as

## TABLE VI

## EXPECTED PERFORMANCE OF THE CROSSBRED EWE GROUPS

| Breed Group[b] | Mating | Parameters[a] | | | | |
|---|---|---|---|---|---|---|
| | | $g^I$ | $h^I$ | $r^I$ | $g^M$ | $h^M$ |
| 1/2D1/2R | D·R | .50(D+R) | DR | 0 | R | 0 |
| 1/4D3/4R | R·(DR) | .25(D+ R) | .50DR | .50DR | .50(D+R) | DR |
| 1/4F1/2D1/4R | (FD)·(DR) | .25(F+2D+R) | .25(FD+FR+DR) | .50(FD+DR) | .50(D+R) | DR |
| | (FR)·D | .25(F+2D+R) | .50(FD+RD) | .50FR | D | 0 |
| | Weighted Ave.[c] | .25(F+2D+R) | .175(1.86FD+1.86DR+FR) | .15(2.33FD+2.33DR+FR) | .35(1.86D+R) | .70DR |
| 1/4F1/4D1/2R | (FD)·R | .25(F+D+2R) | .50(FR+DR) | .50FD | R | 0 |
| | (FR)·(DR) | .25(F+D+2R) | .25(FD+FR+RD) | .50(FR+DR) | .50(D+R) | DR |
| | Weighted Ave.[c] | .25(F+D+2R) | .125(3FR+3DR+FD) | .25(FR+DR+FD) | .25(3R+D) | .50DR |

[a] Parameters are defined in the text.

[b] F=Finnsheep, D=Dorset and R=Rambouillet.

[c] The two 1/4 Finnsheep groups were produced from two types of matings which yield different expectations. The weights used to calculate the weighted average of the two mating types within each group were the proportion of ewes from each mating type that started the study.

TABLE VII

EXPECTED VALUES OF THE MAIN EFFECTS OF INCREASING FINNSHEEP AND DORSET BREEDING BY ONE-QUARTER AT THE EXPENSE OF RAMBOUILLET BREEDING AND THE INTERACTION BETWEEN LEVELS OF FINNSHEEP AND DORSET BREEDING IN THE EWES

| Main Effect[c] | Parameter[a,b] | | | | |
|---|---|---|---|---|---|
| | $g^I$ | $h^I$ | $r^I$ | $g^M$ | $h^M$ |
| 1/4F - 0F | .25(F-R) | .10 | .55 | .20(D-R) | .10 |
| 1/2D - 1/4D | .25(D-R) | .23 | -.20 | -.05(D-R) | -.40 |
| Interaction | .00 | .27 | -.30 | -.45(D-R) | -.60 |

[a]Parameters are defined in the text.

[b]Heterosis and recombination effects are assumed to be equal for all crosses.

[c]F=Finnsheep, D=Dorset and R=Rambouillet.

fleece grade, body weight, fertility, prolificacy and kilograms of lamb weaned per ewe exposed, the main effect of increasing Finnsheep breeding from 0 to 1/4 at the expense of Rambouillet breeding is equal to .25 of the difference between the direct effects of the genes possessed by the Finnsheep and Rambouillet breeds plus .10 of the individual heterosis plus .55 of the individual recombination effects plus .20 of the difference in maternal effects between Dorset and Rambouillet dams plus .10 of the maternal heterosis for a given trait. It would be nice if the main effect of increasing the level of Finnsheep breeding was due solely to .25 of the difference between the direct effects of the genes possessed by the Finnsheep and Rambouillet breeds. It is evident from Table VII that this is not the case, but if the effects other than direct genetic are small, it may be close.

Prolificacy can be used as an example. Donald and Read (1967) have reported average litter sizes of straightbred Finnsheep of two years of age or greater to be 3.2 while Dickerson and Glimp (1975) have reported average litter sizes of straightbred Rambouillet ewes to be 1.4. Using these means and the percent individual and maternal heterosis for prolificacy reported in Table II (5.4 and 12.0, respectively), a rough estimate of the extent to which the direct genetic effects are confounded with the other effects can be obtained. With an individual heterosis estimate of 5.4 percent for prolificacy, $h^I$=2.3 x .054=.12. With a maternal heterosis estimate of 12.0 percent, $h^M$=2.42 x .12=.29. No estimates for recombination effects are available, but they are generally thought to be negative and maternal effects have little effect on reproductive traits. Therefore, the main effect of increasing the level of Finnsheep breeding from 0 to 1/4 at the expense of Rambouillet breeding as estimated from the literature is: .25(3.2 - 1.4) + .10(.12) + .55 (-?) + .20(0) + .10(.29)≃.491. Of this amount, only .041 (8.4 percent) was estimated to be due to effects other than direct genetic. This example shows that a majority of the main effect for this trait is probably due to one-quarter of the difference in direct genetic effects between the Finnsheep and Rambouillet breeds. The use of the reported difference in litter size between the Finnsheep and Rambouillet breeds as an estimate of the difference in direct genetic effects between the two breeds assumes that the difference between maternal effects for the two breeds for litter size is small. This is probably valid since maternal effects are of little consequence for reproductive and other traits measured late in life. Likewise, for the ewe traits other than prolificacy, the majority of the main effect of increasing Finnsheep breeding form 0 to 1/4 is also probably due to one-quarter the difference in direct effects of the genes possessed by the Finnsheep and Rambouillet breeds. However, the 1/4 Finnsheep main effect will always be somewhat of an over-estimate of .25 of the difference in direct genetic effects of the Finnsheep and Rambouillet breeds due to positive individual and maternal heterosis for ewe traits.

As can be seen from Table VII, a greater proportion of both individual and maternal heterosis are involved in the main effect of increasing Dorset breeding from 1/4 to 1/2 than was the case with the 1/4 Finnsheep main effect. Fortunately the signs on the coefficients are opposite for these two parameters which will result in the partial cancellation of one with the other. The ultimate result will be that the main effect of increasing Dorset breeding from 1/4 to 1/2 will be a slight over or under-estimate of one-quarter the difference in direct genetic effects between Dorset and Rambouillet breeds depending on the relative magnitude of individual and maternal heterosis for the trait being examined.

An interaction term of small magnitude indicates one of two things: (1) the effects of individual heterosis, recombination effects, maternal effects and maternal heterosis are all very small or (2) these effects are large but the opposite signs of their coefficients cause their effects to be partially cancelled. A significantly large interaction term would imply that at least one of these effects is large.

Table VIII presents the expected performance of the lambs produced by the four crossbred ewe groups when mated to black-face sires in terms of the same genetic parameters used previously for ewe traits. Table IX presents the expected values of the 1/8 Finnsheep and 1/8 Dorset main effects and the interaction between level of Dorset and Rambouillet breeding in terms of the genetic components. From Table IX, it can be seen that the main effect of increasing Finnsheep breeding from 0 to 1/8 at the expense of Rambouillet breeding in the lambs is approximately equal to .125 of the difference between the direct effects of the genes possessed by the Finnsheep and Rambouillet breeds plus .25 of the difference between maternal effects of Finnsheep and Rambouillet dams plus .10 of the maternal heterosis plus .05 of the recombination effects. The maternal heterosis estimates for lamb growth traits presented in Table II vary from about 4 to 7 percent. One-tenth of these figures is rather small. No estimates are available for recombination effects. Therefore, the 1/8 Finnsheep main effect is probably a slight over-estimate of .125 of difference in direct genetic effects plus .25 of difference in maternal effects between the Finnsheep and Rambouillet breeds. A similar interpretation can be given to the main effect of

## TABLE VIII

## EXPECTED PERFORMANCE OF THE CROSSBRED LAMB GROUPS

| Breed Group[b] | Mating | Parameters[a] | | | | |
|---|---|---|---|---|---|---|
| | | $g^I$ | $h^I$ | $r^I$ | $g^M$ | $h^M$ |
| 1/2B1/4D1/4R | B·(DR) | .25(2B+D+R) | .50(BD+BR) | .50DR | .50(D+R) | DR |
| 1/2B1/8D3/8R | B·(R DR) | .125(4B+D+3R) | .25(3BR+BD) | .25DR | .25(D+3R) | .50DR |
| 1/2B1/8F1/4D1/8R | B·(FD DR) | .125(4B+F+2D+R) | .25(BF+2BD+BR) | .125(FD+FR+DR) | .25(F+20+R) | .25(FD+FR+DR) |
| | B·(FR D) | .125(4B+F+R+2D) | .25(BF+BR+2BD) | .25(FD+RD) | .25(F+2D+R) | .50(FD+RD) |
| | Weighted Ave.[c] | ,125(4B+F+R+2D) | .25(BF+BR+2BD) | .088(1.86FD+FR+1.86RD) | .25(F+2D+R) | .175(1.86FD+1.86DR+FR) |
| 1/2B1/8D1/4R | B·(FD R) | .125(4B+R+D+2R) | .25(BF+BD+2BR) | .25(FD+FR) | .25(F+D+2R) | .50(FR+DR) |
| | B·(FR DR) | .125(4B+F+D+2R) | .25(BF+2BR+BD) | .125(FD+FR+RD) | .25(F+D+2R) | .25(FD+FR+RD) |
| | Weighted Ave.[c] | .125(4B+F+D+2R) | .25(BF+BD+2BR) | .062(3FD+3FR+RD) | .25(F+D+2R) | .125(3FR+3DR+FD) |

[a]Parameters are defined in the text.

[b]F=Finnsheep, D=Dorset, R=Rambouillet and B=Blackface.

[c]Weighted by the proportion of ewes of each mating type that started the study.

TABLE IX

EXPECTED VALUES OF THE MAIN EFFECTS OF INCREASING FINNSHEEP AND DORSET BREEDING BY ONE-EIGHTH AT THE EXPENSE OF RAMBOUILLET BREEDING AND THE INTERACTION BETWEEN LEVELS OF FINNSHEEP AND DORSET BREEDING IN THE LAMBS

| Main Effect[c] | Parameter[a,b] | | | | |
|---|---|---|---|---|---|
| | $g^I$ | $h^I$ | $r^I$ | $g^M$ | $h^M$ |
| 1/8F - 0F | .125(F-R) | .00 | .05 | .25(F-R) | .10 |
| 1/4D - 1/8D | .125(D-R) | .00 | .12 | .25(D-R) | .23 |
| Interaction | .00 | .00 | .13 | .00 | .27 |

[a]Parameters are defined in the text.

[b]Heterosis and recombination effects are assumed to be equal for all crosses.

[c]F=Finnsheep, D=Dorset and R=Rambouillet.

increasing Dorset breeding from 1/8 to 1/4 at the expense of Rambouillet breeding except that this main effect has a larger maternal heterosis component than the 1/8 Finnsheep main effect. The existence of a significantly large interaction term would indicate that maternal heterosis was very important for the trait under study and that both the 1/8 Finnsheep and 1/8 Dorset main effects were probably significant over-estimates of .125 of the difference in direct genetic effects plus .25 of the difference in maternal effects between the Finnsheep and Rambouillet breeds.

## Statistical Analysis

A major portion of the statistical analysis of the data was accomplished through the use of the computer program package entitled Statistical Analysis System (SAS) developed by Barr and Goodnight (1972) at North Carolina State University. All traits were analyzed by least squares analysis of variance, and all reported means are least square means. Significance levels of the main effects of increasing Finnsheep and Dorset breeding at the expense of Rambouillet breeding and the interaction between levels of Finnsheep and Dorset breeding were determined by a t-test with the residual mean square from the least squares analysis of variance being used as the estimate of $\sigma^2$. The study is divided into three general areas and the model used in the statistical analysis of data in each area will be treated separately.

### Late Winter - Early Spring Ewe Productivity

Through the late winter lambing of 1974, the ewes born in 1971 had had an opportunity to lamb at approximately one, two and three years of age, and the ewes born in 1972 had had an opportunity to lamb at one and two years of age. The analysis of each trait was done within age of dam. The model used for ewe productivity traits of one and two year old ewes was:

$$Y_{m(ijkl)} = \mu + A_i + B_j + C_k + d_{l(ik)} + (AB)_{ij} + (AC)_{ik} + (BC)_{jk} + (ABC)_{ijk} + e_{m(ijkl)}$$

where:

$Y_{m(ijkl)}$ = the observed value of the mth individual in the lth ram, kth breed of service ram, jth breed of ewe and ith year.

$\mu$ = overall mean.

$A_i$ = the fixed effect of the ith year.

$B_j$ = the fixed effect of the jth breed of ewe.

$C_k$ = the fixed effect of the kth breed of service ram.

$d_{l(ik)}$ = the random effect of the lth ram nested in ith year and kth breed of service ram.

$(AB)_{ij}$, $(AC)_{ik}$, $(BC)_{jk}$ and $(ABC)_{ijk}$ = the fixed effects of the two and three-way interactions among the above mentioned main fixed effects.

$e_{m(ijkl)}$ = residual.

It was not possible to fit the "breed of ewe x ram/year/breed of service ram" interaction due to some cells with missing values. However, when this interaction was fit to that portion of the data in which values were present in all cells, it was found that it was a nonsignificant (P>.10) source of variation for a majority of the traits.

"Ram/year/breed of service ram" was tested with the "residual" mean square. If it was found to be significant (P<.10), the "ram/year/

breed of service ram" mean square was used to test both "year" and "breed of service ram". If it was found to be nonsignificant (P> .10), both "year" and "breed of service ram" were tested with the "residual". All other effects were tested with the "residual" mean square.

The model for breeding weights, fleece weights and fleece grades of ewes lambing at one and two years of age was similar to the one given above for ewe productivity traits except that the effect of "ram/year/breed of service ram", "breed of service ram" and any interaction containing these effects were deleted.

The models used for traits of the ewes when lambing at approximately three years of age were similar to those used for one and two-year-old ewes except that the effects of "year" and any interactions containing "year" were deleted. This was necessary since data on the three-year-old ewes was available in 1974 only.

Least squares analysis of variance tables for traits of the one, two and three-year-old ewes can be found in Tables XXII through XXVI of the appendix.

Fall Ewe Productivity

All ewes have had an opportunity to lamb in the falls of 1974 and 1975. Ewe productivity traits have been analyzed within year (1974 and 1975) using the following model:

$$Y_{m(ijkl)} = \mu + A_i + B_j + C_k + d_{l(k)} + (AB)_{ij} + (AC)_{ik} + (BC)_{jk} + (Ad)_{il(k)} + (Bd)_{jl(k)} + e_{m(ijkl)}$$

where:

$Y_{m(ijkl)}$ = the observed value of the mth individual in the lth ram, kth breed of service ram, jth breed of ewe and ith age of ewe.

$\mu$ = overall mean.

$A_i$ = the fixed effect of the ith age of ewe.

$B_j$ = the fixed effect of the jth breed of ewe.

$C_k$ = the fixed effect of the kth breed of service ram.

$d_{l(k)}$ = the random effect of the lth ram nested in the kth breed of service ram.

$(AB)_{ij}$, $(AC)_{ik}$ and $(BC)_{jk}$ = the fixed effects of the two-way interactions among the above mentioned main fixed effects.

$(Ad)_{il(k)}$ and $(Bd)_{jl(k)}$ = the random effects of the two-way interactions among the above mentioned main fixed and random effects.

$e_{m(ijkl)}$ = residual.

It was not possible to fit the "age x breed of ewe x breed of service ram" and "age of ewe x breed of ewe x ram/breed of service ram" interactions due to some cells with missing values. However, when these interactions were fit to that portion of the data in which values were present in all cells, it was found that they were a nonsignificant ($P>.10$) source of variation for a majority of the traits.

Since the "age of ewe x ram/breed of service ram" and "breed of ewe x ram/breed of service ram" interactions were generally nonsignificant ($P>.10$) when tested with the "residual" mean square, "ram/breed of service ram" was tested with the "residual" mean square instead of the two interaction mean squares. If the "ram/breed of service ram" effect was found to be significant ($P<.10$), its mean square was used to test "breed of service ram", otherwise, "breed of service ram" was tested with the "residual" mean square. All other effects were tested with the "residual" mean square.

Breeding weights and fleece weights following each fall lambing were analyzed using a similar model as that used for the ewe productivity traits except that the effects of "breed of service ram", "ram/ breed of service ram" and all interactions containing either of these effects were deleted.

Least squares analysis of variance tables for traits of the fall lambing ewes can be found in Tables XXVII through XXIX of the appendix.

Lamb Growth Traits

Lamb growth traits were analyzed within season of birth (late winter-early spring and fall). Only birth weights of single and twin lambs and growth traits after birth of single born-single reared and twin born-twin reared lambs were analyzed. The following model was used:

$$Y_{o(ijklmn)} = \mu + A_i + B_j + C_k + D_l + E_m + f_{n(ik)} + (AB)_{ij} + (AC)_{ik} + (AD)_{il} + (AE)_{im} + (BC)_{jl} + (BD)_{jl} + (BE)_{jm} + (CD)_{kl} + (CE)_{km} + (DE)_{lm} + e_{o(ijklmn)}$$

where:

$Y_{o(ijklmn)}$ = the observed value of the oth lamb in the nth sire, mth sex, lth type of birth (or birth-rearing), kth breed of sire, jth breed of dam and ith year-age of dam subclass.

$\mu$ = overall mean.

$A_i$ = the fixed effect of the ith year-age of dam subclass.

$B_j$ = the fixed effect of the jth breed of dam.

$C_k$ = the fixed effect of the kth breed of sire.

$D_l$ = the fixed effect of the lth type of birth (or birth-rearing).

$E_m$ = the fixed effect of the mth sex.

$f_{n(ik)}$ = the random effect of the nth sire nested in the ith year-age of dam subclass and kth breed of sire.

$(AB)_{ij} \ldots (DE)_{lm}$ = the fixed effects of all the two way interactions among the above mentioned fixed effects.

$e_{o(ijklmn)}$ = residual.

Due to the large number of main effects included in the model, no attempt was made to fit all possible interactions.

If the "sire/year-age of dam subclass/breed of sire" effect was found to be significant ($P<.10$) when tested with the "residual" mean square, its mean square was used to test both "year-age of dam subclass" and "breed of sire". If the "sire/year-age of dam subclass/breed of sire" was found to be nonsignificant ($P>.10$), the latter effects were tested with the "residual" mean square. All other effects were tested with the "residual" mean square.

Least squares analysis of variance tables for lamb growth traits can be found in Tables XXX and XXXI of the appendix.

# CHAPTER IV

# RESULTS AND DISCUSSION

This chapter will be divided into three major sections: 1) ewe performance when lambing in the late winter-early spring, 2) ewe performance when lambing in the fall and 3) growth from birth to market of late winter-early spring and fall born lambs. The main effects of increasing Finnsheep and Dorset breeding at the expense of Rambouillet breeding, as defined in the previous chapter, will be discussed for each trait. These two effects will simply be termed the Finnsheep effect and the Dorset effect throughout this chapter.

## Ewe Performance When Lambing In The Late Winter-Early Spring

### Breeding Weights

Weights of the four crossbred ewe groups taken prior to the breeding season at approximately 7, 18 and 29 months of age are presented in Table X. The 1/4 Finnsheep effect for breeding weight was negative at all three ages but only approached significance at the start of the first breeding season (-.8 kilograms) when the ewes were approximately seven months of age. The 1/4 Dorset effect, on the other hand, resulted in a significant decrease in breeding weight at all three ages (-1.6, -3.0 and -4.3 kilograms, respectively). These results indicate that increasing Finnsheep breeding by 1/4 at the expense of Rambouillet breed-

TABLE X

LEAST SQUARE MEANS AND 1/4 FINNSHEEP AND 1/4 DORSET MAIN EFFECTS FOR BREEDING WEIGHTS OF LATE WINTER-EARLY SPRING LAMBING EWES

| | Approximate Age at Breeding (months) | | | | | |
|---|---|---|---|---|---|---|
| | 7 | | 18[d] | | 29 | |
| Ewe Breeding[a] | No.[b] | Wt.[c] | No. | Wt. | No. | Wt. |
| 1/2D1/2R | 51 | 38.2±.48 | 25 | 51.4±1.02 | 25 | 58.6±1.25 |
| 1/4D3/4R | 52 | 40.5±.48 | 24 | 55.0±1.04 | 27 | 63.9±1.20 |
| 1/4F1/2D1/4R | 44 | 38.1±.52 | 20 | 50.7±1.14 | 21 | 59.0±1.37 |
| 1/4F1/4D1/2R | 51 | 38.9±.50 | 26 | 53.0±1.00 | 21 | 62.3±1.37 |
| Main Effects and Interaction | | | | | | |
| 1/4F-0F | | -.8±.49† | | -1.3±1.05 | | -.7±1.30 |
| 1/2D-1/4D | | -1.6±.49** | | -3.0±1.05** | | -4.3±1.30** |
| Interaction | | -.7±.49 | | -.7±1.05 | | -1.0±1.30 |

[a]F=Finnsheep, D=Dorset, R=Rambouillet.

[b]No.=Number of ewes weighed prior to breeding season.

[c]Wt.=Mean ewe weight in kilograms.

[d]Weights were only taken on the ewes born in 1972.

†P<.10, **P<.01.

ing will have little effect on the breeding weights of young ewes and that the increasing of Dorset breeding by 1/4 at the expense of Rambouillet breeding will result in a significant reduction in breeding weights. Laster et al. (1972) has reported breeding weights of Rambouillet, 1/2R 1/2F and 1/2R1/2D ewe lambs to be 40.4, 40.8 and 38.9 kilograms, respectively, which also indicates little change in breeding weight by increasing Finnsheep breeding at the expense of Rambouillet breeding and a decrease in breeding weight by increasing Dorset breeding at the expense of Rambouillet breeding. Thus, infusion of 1/4 Finnsheep breeding into commercial flocks (which are in many cases, of predominately Rambouillet breeding) should have little or no effect on body weights.

## Fleece Weights and Grades

Late April or early May grease fleece weights of the four crossbred ewe groups following lambing at approximately one, two and three years of age and quality grades of fleeces from the 1974 clip are presented in Table XI. The 1/4 Finnsheep effect resulted in a decrease ($P<.01$) in grease fleece weights of one- and two-year-old ewes (-.31 and -.45 kilograms, respectively) and a non-significant decrease in the three-year-old ewes (-.19 kilograms). The 1/4 Dorset effect caused a decrease ($P<.01$) in grease fleece weights at all three ages (-.21, -.45 and -.44 kilograms, respectively). A significant interaction between level of Finnsheep and Dorset breeding is present for grease fleece weight of three-year-old ewes. This interaction is caused by the mean fleece weight of the 1/4F1/4D1/2R ewes being far heavier, relative to the other groups, at three years of age than at the two preceding ages. From the expected value of this interaction term presented in Table VII,

TABLE XI

LEAST SQUARES MEANS AND 1/4 FINNSHEEP AND 1/4 DORSET MAIN EFFECTS FOR EWE FLEECE WEIGHTS AND FLEECE GRADES FOLLOWING LATE WINTER-EARLY SPRING LAMBING

| Ewe Breeding[a] | Approximate Age at Lambing (years) | | | | | | Fleece Grade | |
|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | | 3 | | | |
| | No.[b] | Wt.[c] | No. | Wt. | No. | Wt. | No.[d] | Grade[e] |
| 1/2D1/2R | 50 | 3.25±.074 | 49 | 4.07±.099 | 25 | 4.54±.134 | 49 | 2.92±.082 |
| 1/4D3/4R | 52 | 3.34±.073 | 52 | 4.42±.097 | 27 | 4.60±.101 | 51 | 2.27±.080 |
| 1/4F1/2D1/4R | 44 | 2.82±.079 | 40 | 3.52±.110 | 20 | 3.98±.150 | 38 | 3.55±.090 |
| 1/4F1/4D1/2R | 49 | 3.14±.075 | 47 | 4.06±.101 | 21 | 4.80±.146 | 47 | 3.12±.084 |
| **Main Effects and Interaction** | | | | | | | | |
| 1/4F-0F | | -.31±.075** | | -.45±.102** | | -.19±.140 | | .74±.084** |
| 1/2D-1/4D | | -.21±.075** | | -.45±.102** | | -.44±.140** | | .54±.084** |
| Interaction | | .11±.075 | | .10±.102 | | .38±.140** | | .11±.08 |

[a] F=Finnsheep, D=Dorset, R=Rambouillet.

[b] No.=Number of fleeces weighed.

[c] Wt.=Mean fleece weight in kilograms.

[d] No.=Number of fleeces from 1974 clip that were graded.

[e] Fleece grade code: 1=fine, 2=half-blood, 3=three-eights-blood, 4=quarter blood.

**P<.01.

one might surmise that individual heterosis has a greater effect on three-year-old fleece weight than it does on one- or two-year-old fleece weights. This seems rather improbable, and the fleece weight of three-year old 1/4F1/4D1/2R ewes (4.80 kilograms) is probably an overestimate of the true value.

Grease fleece grades indicate that both the 1/4 Finnsheep and 1/4 Dorset effect (.74 and .54, respectively) result in coarser, poorer grading (P<.01) fleeces.

The detrimental effects on both grease fleece weight and grade observed in this study for the 1/4 Finnsheep and 1/4 Dorset effects are to be expected. The Rambouillet breed is noted for its heavy, high grading fleeces and one would predict that the increasing of the germ plasm of almost any breed at the expense of Rambouillet breeding would be detrimental to fleece traits. Probably of greater significance is that the 1/4 Finnsheep effect was generally no more detrimental than the 1/4 Dorset effect for these fleece traits.

Productivity at One Year of Age.

Presented in Table XII are the least square means for lamb productivity traits of the four crossbred ewe groups and the 1/4 Finnsheep and 1/4 Dorset effects when lambing at approximately one year of age.

The 1/4 Finnsheep effect resulted in an increase (P<.01) of 24 percent in fertility and the 1/4 Dorset effect resulted in a nonsignificant increase of 7.1 percent. The ability of Finnsheep crossbred ewes to reach sexual maturity, conceive and lamb at a relatively young age has been previously documented by many authors. Two such studies have been conducted in the United States. Laster et al. (1972) found an 11 percent

TABLE XII

LEAST SQUARE MEANS AND 1/4 FINNSHEEP AND 1/4 DORSET MAIN EFFECTS FOR PRODUCTIVITY OF EWES LAMBING AT ONE YEAR OF AGE IN THE EARLY SPRING

| Ewe Breeding[a] | No. Ewes Exposed | Fertility (%) | Prolificacy | Lamb Survival (%) | Lamb Weaning Weight (kg) | Kg. Lamb Weaned Per Ewe Exposed |
|---|---|---|---|---|---|---|
| 1/2D1/2R | 51 | 60.2±6.42 | 1.11±.066 | 88.8±6.42 | 24.9±.84 | 13.3±1.90 |
| 1/4D3/4R | 52 | 52.9±6.40 | 1.05±.066 | 92.0±6.44 | 25.3±.83 | 12.6±1.86 |
| 1/4F1/2D1/4R | 44 | 84.0±6.93 | 1.16±.057 | 77.4±5.30 | 24.2±.78 | 16.0±2.05 |
| 1/4F1/4D1/2R | 51 | 77.1±6.57 | 1.18±.057 | 84.5±5.13 | 23.1±.68 | 17.0±1.90 |
| Main Effects and Interaction | | | | | | |
| 1/4F-0F | | 24.0±6.58** | .09±.061 | -9.5±5.77 | -1.5±.78[†] | 3.5±1.86[†] |
| 1/2D-1/4D | | 7.1±6.58 | .02±.062 | -5.2±5.91 | .3±.79 | -.1±1.87 |
| Interaction | | .2±6.59 | .04±.061 | 1.9±5.78 | -.7±.77 | .9±1.85 |

[a]F=Finnsheep, D=Dorset, R=Rambouillet.

[†]P<.10, **P<.01.

advantage of 1/2 Finnsheep ewe lambs over 1/2 Rambouillet ewe lambs in percent ewes lambing of ewes exposed and Dickerson and Laster (1975) showed that 1/2 Finnsheep ewe lambs reached puberty 19 days earlier than 1/2 Rambouillet ewe lambs (219 vs. 238 days, respectively).

Dickerson and Laster (1975) also presented some limited data that suggested that individual heterosis (a portion of which is included in the 1/4 Finnsheep effect) may be very important for the early sexual maturity observed in Finn-cross ewes. Based on a limited number of 3/4 Finn crosses, the mean superiority of 1/2 Finn over 3/4 Finn crosses in percentage reaching puberty by November 10 was 41.4±11.7 percent. The 3/4 Finn crosses contain 25 percent more Finn genes but would be expected to express one-half the heterosis of the 1/2 Finn crosses. The fact that the 1/2 Finns were superior to the 3/4 Finns suggests that much of the Finn effect on percentage of Finn-cross lambs reaching puberty early in life may be due to heterosis rather than to average direct effects for earlier puberty in purebred Finns. If this is in fact true, the 1/4 Finnsheep effect in this study of 24 percent may be a sizable overestimate of 1/4 the difference in average gene effects between the Finnsheep and Rambouillet breeds for fertility at one year of age.

Both the 1/4 Finnsheep and 1/4 Dorset effects were positive but nonsignificant for prolificacy. However, the value of .09 reported for the the 1/4 Finnsheep effect is of economic significance and if real, would suggest that commercial sheepmen could easily increase lambing rate of one-year-old ewes by increasing Finnsheep breeding by 1/4 at the expense of Rambouillet breeding.

The 1/4 Finnsheep and 1/4 Dorset effects for lamb survival to weaning were negative (-9.5 and -5.2 percent, respectively) but determined to be not significantly different from zero. It is however, interesting to note that the signs on these effects are opposite those for prolificacy suggesting that an increase in prolificacy may also result in an increase in lamb mortality. Hohenboken and Cochran (1976) have reported increased lamb losses from lambs born from crossbred ewe lambs which had higher lambing rates than from purebred ewe lambs which had lower lambing rates. This resulted in a negative maternal heterosis estimate for lamb survival. Under some rather adverse environmental conditions, Smith (1977) reported that preweaning mortality in twin born lambs was 1.7 times greater than that observed for single born lambs.

Sex adjusted weaning weights of lambs produced by the four crossbred ewe groups were lowest for the ewe groups with the greatest prolificacy and greatest for the ewe groups with the lowest prolificacy. This is in part due to the fact that twin born lambs weigh less at 70 days of age than single born lambs (Gould and Whiteman, 1971). The 1/4 Finnsheep effect was negative (-1.5 kilograms) and tended toward significance. Dickerson et al. (1975) has reported that Finn-crosses and Rambouillet-crosses have similar 10-week weights. Therefore, the negative 1/4 Finnsheep effect observed here may be due to greater prolificacy of 1/4 Finnsheep ewes and the failure of the ewes to provide an optimum maternal environment for the additional lambs rather than average gene effects for decreased growth in 1/8 Finnsheep lambs. The 1/4 Dorset effect was small and not significantly different from zero.

Kilograms of lamb weaned per ewe exposed is an overall measure of productivity of the ewe flock. The effect of increasing Finnsheep breeding by 1/4 at the expense of Rambouillet breeding was to increase ($P<.10$) kilograms of lamb weaned per ewe exposed by 3.5 kilograms. This is a sizable increase of substantial economic value and indicates that productivity of ewe lambs can be greatly enhanced by infusion of 1/4 Finnsheep germ plasm into commercial flocks of predominately Rambouillet breeding.

It has been known for many years that ewes lambing for the first time at approximately one year of age will have a higher lifetime production rate than those which lamb for the first time as two-year-olds (Briggs, 1936). However, the frequency of ewes that will conceive at seven months of age in most of our domestic breeds has been too low to warrant the increased expenditure necessary to manage ewe lambs for lambing at one year of age. This study indicates that approximately 80 percent of 1/4 Finnsheep ewes will lamb at one year of age which would definitely make the lambing of ewe lambs like these economically feasible.

Productivity at Two and Three Years of Age

Tables XIII and XIV present the productivity of the four crossbred ewe groups and the 1/4 Finnsheep and 1/4 Dorset effects when lambing in the late winter-early spring as two- and three-year-olds, respectively.

At both ages, both the 1/4 Finnsheep and 1/4 Dorset effects were positive but not significantly different from zero for kilograms of lamb weaned per ewe exposed. The reduced increase for this trait observed for the 1/4 Finnsheep effect at two and three years of age versus that observed at one year of age is due primarily to the smaller difference observed between 1/4 Finnsheep and 0 Finnsheep ewes for fertiltiy at two and three years of age than at one year of age. Other studies that have reported increased fertility of Finn-crosses over domestic-

TABLE XIII

LEAST SQUARE MEANS AND 1/4 FINNSHEEP AND 1/4 DORSET MAIN EFFECTS
FOR PRODUCTIVITY OF EWES LAMBING AT TWO YEARS OF AGE
IN THE LATE WINTER-EARLY SPRING

| Ewe Breeding[a] | No. Ewes Exposed | Fertility (%) | Prolificacy | Lamb Survival (%) | Lamb Weaning Weight (kg) | Kg. Lamb Weaned Per Ewe Exposed |
|---|---|---|---|---|---|---|
| 1/2D1/2R | 50 | 89.4±5.26 | 1.53±.094 | 94.9±3.86 | 23.4±.56 | 29.9±2.51 |
| 1/4D3/4R | 52 | 83.1±5.88 | 1.54±.098 | 89.6±4.14 | 24.9±.61 | 27.3±2.50 |
| 1/4F1/2D1/4R | 41 | 82.2±5.82 | 1.72±.110 | 89.0±4.35 | 23.2±.67 | 29.5±2.81 |
| 1/4F1/4D1/2R | 47 | 86.7±5.58 | 1.53±.101 | 90.6±4.16 | 25.6±.62 | 29.8±2.66 |
| Main Effects and Interaction | | | | | | |
| 1/4F-0F | | -1.8±5.36 | .09±.098 | -2.5±4.02 | .2±.61 | 1.0±2.56 |
| 1/2D-1/4D | | .9±5.37 | .09±.097 | 1.9±3.96 | -1.9±.59** | 1.2±2.57 |
| Interaction | | 5.4±5.39 | -.11±.098 | 3.5±3.99 | .5±.59 | 1.5±2.57 |

[a]F=Finnsheep, D=Dorset, R=Rambouillet.

**P<.01.

TABLE XIV

LEAST SQUARE MEANS AND 1/4 FINNSHEEP AND 1/4 DORSET MAIN EFFECTS FOR PRODUCTIVITY OF EWES LAMBING AT THREE YEARS OF AGE IN THE LATE WINTER

| Ewe Breeding[a] | No. Ewes Exposed | Fertility (%) | Prolificacy | Lamb Survival(%) | Lamb Weaning Weight (kg) | Kg. Lamb Weaned Per Ewe Exposed |
|---|---|---|---|---|---|---|
| 1/2D1/2R | 25 | 96.0±8.85 | 1.66±.164 | 85.6±7.31 | 24.0±1.06 | 32.6±4.42 |
| 1/4D3/4R | 27 | 77.5±7.97 | 1.51±.161 | 78.3±7.52 | 28.1±1.19 | 25.8±3.98 |
| 1/4F1/2D1/4R | 21 | 95.4±9.87 | 1.62±.184 | 71.7±7.99 | 25.9±1.21 | 29.0±4.93 |
| 1/4F1/4D1/2R | 21 | 85.0±8.35 | 1.71±.164 | 82.9±7.47 | 26.9±1.01 | 31.2±4.17 |
| | | Main Effects and Interaction | | | | |
| 1/4F-0F | | 3.4±8.04 | .08±.155 | -4.6±6.60 | .3±.89 | .9±4.01 |
| 1/2D-1/4D | | 14.5±8.25† | .03±.160 | -2.0±6.70 | -2.5±.88** | 2.3±4.12 |
| Interaction | | 4.0±8.03 | .12±.155 | 9.3±6.59 | -1.5±.91 | 4.5±4.01 |

[a]F=Finnsheep, D=Dorset, R=Rambouillet

†P<.10, **P<.01.

crosses at one year of age have also found little difference between the two groups at older ages (Donald et al., 1968; Barker, 1975). Even though they were not significantly different from zero, the differences observed by Barker (1975) between Finn-cross and domestic-cross ewes for fertility at two and three to four years of age (-2.0 and 2.5 percent, respectively) are very similar to the 1/4 Finnsheep effects observed with similar age ewes in this study (-1.8 and 3.4 percent, respectively). Results from this study and others reported in the literature would indicate that the increased proportion of Finn-cross ewes lambing at one year of age is due primarily to earlier sexual maturity and not increased fertility per se. At ages older than one year, when ewes of most breeds have reached sexual maturity, the Finnsheep advantage is generally not present.

The 1/4 Dorset effect was positive for fertility at both ages and approached significance at three years of age (.9 and 14.5 percent, respectively). The 1/4 Dorset effect at three years of age seems extremely high in light of the 6.0 percent advantage of purebred Dorset ewes over purebred Rambouillet ewes reported by Dickerson and Glimp (1975) and the 7.7 percent advantage of 1/2D1/2R ewes over Rambouillet ewes reported by Thrift and Whiteman (1969a).

The 1/4 Finnsheep and 1/4 Dorset effects resulted in positive but nonsignificant increases in prolificacy at both two and three years of age. However, the consistent nature of the 1/4 Finnsheep effect to be .08 and .09 for prolificacy at all three ages would suggest that increasing Finnsheep breeding by 1/4 at the expense of Rambouillet breeding will result in an increase of eight to nine lambs born per 100 ewes lambing in young, late winter-early spring lambing ewes. The 1/4 Dorset effect was less consistent across the three ages.

The 1/4 Finnsheep and 1/4 Dorset effects for lamb survival were nonsignificant at both ages. The effects for sex adjusted lamb weaning weights were nonsignificant for the 1/4 Finnsheep effect at both ages but strongly negative ($P<.01$) for the 1/4 Dorset effect in both two- and three-year-old ewes (-1.9 and -2.5 kilograms, respectively). These results may suggest that increasing Dorset breeding by 1/4 at the expense of Rambouillet breeding results in ewes that provide a poorer maternal environment to their lambs and/or that increasing Dorset breeding by 1/8 in the lamb at the expense of Rambouillet breeding results in slower growth due to the substitution of genes with average effects for growth less than those that they replaced. There is some evidence for one or both of these ideas from Dickerson et al. (1972) who observed that straightbred Rambouillet lambs weighed 3.6 kilograms more than Dorset lambs at ten weeks of age.

In summary, increasing Finnsheep breeding by 1/4 at the expense of Rambouillet breeding resulted in no significant change in breeding weight, a significant decrease in grease fleece weight and grade, a large ($P<.10$) increase in kilograms of lamb weaned per ewe exposed in one-year-old ewes and no significant change in kilograms of lamb weaned per ewe exposed in two- and three-year-old ewes when lambing in the late winter-early spring. Under the same conditions, increasing Dorset breeding by 1/4 at the expense of Rambouillet breeding significantly decreased breeding weights, fleece weights and fleece grades but had little effect on kilograms of lamb weaned per ewe exposed at any of the three ages.

## Ewe Performance When Lambing In The Fall

In order to take advantage of winter wheat pasture and high seasonal lamb prices in the spring, most of the commercial sheepmen in Oklahoma lamb in the fall of the year (October and November). Therefore, the performance of the four crossbred ewe groups under a fall lambing program is of special regional interest. Accelerated lambing programs of lambing twice a year or three times in two years require lambing ewes in the fall at sometime in the cycle, so these results might also suggest how these four crossbred ewe groups would perform under such a system.

### Breeding Weights

Table XV presents the least square means and 1/4 Finnsheep and 1/4 Dorset effects for breeding weights prior to the May 1974 and 1975 breeding seasons. As observed previously with the late winter-early spring lambing ewes, the 1/4 Finnsheep effect results in little change in breeding weight and the 1/4 Dorset effect results in a significant decrease in breeding weight in both seasons (-3.7 and -4.4 kilograms, respectively). However, the interaction between level of Finnsheep and Dorset breeding is also highly significant which was not the case with breeding weights of the late winter-early spring lambing ewes.

A plausible explanation may exist to explain this significant interaction. An approximate weight of the four crossbred ewe groups when mated for the last late winter-early spring lambing can be obtained by averaging the 18 and 29 month weights in Table X. This gives breeding

TABLE XV

LEAST SQUARE MEANS AND 1/4 FINNSHEEP AND 1/4 DORSET MAIN EFFECTS FOR BREEDING WEIGHTS OF FALL LAMBING EWES

| | Year of Mating | | | |
|---|---|---|---|---|
| | 1974 | | 1975 | |
| Ewe Breeding[a] | No.[b] | Wt.[c] | No. | Wt. |
| 1/2D1/2R | 53 | 56.6±1.08 | 53 | 57.7± .99 |
| 1/4D3/4R | 57 | 65.6±1.04 | 56 | 64.7± .97 |
| 1/4F1/2D1/4R | 45 | 59.5±1.17 | 43 | 61.0±1.10 |
| 1/4F1/4D1/2R | 52 | 61.2±1.08 | 51 | 62.7±1.01 |
| | Main Effects and Interaction | | | |
| 1/4F-OF | | -.7±1.09 | | .7±1.02 |
| 1/2D-1/4D | | -5.3±1.09** | | -4.4±1.02** |
| Interaction | | -3.7±1.09** | | -2.7±1.02** |

[a]F=Finnsheep, D=Dorset, R=Rambouillet.

[b]No.=Number of ewes weighed prior to breeding season.

[c]Wt.=Mean ewe weight in kilograms.

**P<.01.

weights of 55.0, 59.4, 54.8 and 57.6 kilograms for the 1/2D1/2R, 1/4D 3/4R, 1/4F1/2D1/4R and 1/4F1/4D1/2R ewes, respectively. When these weights, which give a nonsignificant interaction term are compared with the fall breeding weights in Table XV, it is found that the weight gain of the 1/2D1/2R ewes is one half or less the weight gain of the other three ewe groups. The decreased weight gain of the 1/2D1/2R ewes relative to the other three groups resulted in the significant interaction for fall breeding weights. The 1/2D1/2R ewes may have gained less weight during 1974 because they were the most productive ewe group as measured by kilograms of lamb weaned per ewe exposed during the January - February lambing of 1974 (see Table XIV). The high level of production during this period probably resulted in a higher weight loss in the 1/2D1/2R ewes than in the other ewe groups, and the rebreeding in May, 1974 for fall lambs didn't allow the 1/2D 1/2R ewes adequate time to regain all condition lost. The 1/2D1/2R ewes were again the most productive ewes at the fall 1974 lambing (see Table XVIII). This continued high level of performance again prevented their breeding weights from gaining at the same rate as those of the other three crossbred ewe groups and resulted in their lighter weights in 1975.

From the expected value of the interaction in terms of the genetic parameters presented in Table VII, one would probably expect the breeding weight interaction to be positive since individual heterosis is thought to be positive for body weight (Fahmy and Bernard, 1973) and the other parameters are probably of little importance to body weights measured late in life. However, the stressful environmental effects (increased lamb production and fast rebreeding) have probably masked these genetic effects and resulted in the significant, negative interactions for fall breeding weights.

Fleece Weights

Least square means and 1/4 Finnsheep and 1/4 Dorset effects for grease fleece weights following each of the two fall lambings are presented in Table XVI. As was the case with fleece weights of the ewes at younger ages, both the 1/4 Finnsheep and 1/4 Dorset effects resulted in decreased ($P<.01$) fleece weights both seasons. The interaction of level of Finnsheep breeding with level of Dorset breeding tended toward significance for fleece weights following the 1974 lambing. This, most likely, is an indication that individual heterosis is rather large and positive for fleece weight. The fact that the fleece weight interaction is positive for all fleece weight analyses (Tables XI and XVI) is added evidence for this conclusion. Positive heterosis estimates of 31.4 and 17.1 percent for fleece weight have been reported by Galal et al. (1972) and Fahmy and Bernard (1973), respectively.

Productivity of Fall Lambing Ewes

Tables XVII and XVIII present the least square means and 1/4 Finnsheep and 1/4 Dorset effects for lamb productivity traits of the four crossbred ewe groups when lambing in the falls of 1974 and 1975.

The 1/4 Finnsheep effect resulted in lowered fertility in both 1974 (-14.1 percent, $P<.05$) and 1975 (-24.9 percent, $P<.01$). This would indicate that the Finnsheep breed is less able to conceive to May-June mating than is the Rambouillet breed and that an increase of Finnsheep

TABLE XVI

LEAST SQUARE MEANS AND 1/4 FINNSHEEP AND 1/4 DORSET MAIN EFFECTS FOR FLEECE WEIGHTS FOLLWOING FALL LAMBING

| Ewe Breeding[a] | Year of Fall Lambing | | | |
|---|---|---|---|---|
| | 1974 | | 1975 | |
| | No.[b] | Wt.[c] | No. | Wt. |
| 1/2D1/2R | 54 | 3.89±.094 | 50 | 4.34±.110 |
| 1/4D3/4R | 57 | 4.16±.092 | 55 | 4.86±.106 |
| 1/4F1/2D1/4R | 45 | 3.44±.103 | 42 | 3.88±.120 |
| 1/4F1/4D1/2R | 52 | 4.03±.096 | 51 | 4.64±.109 |
| **Main Effects and Interaction** | | | | |
| 1/4F-0F | | -.28±.096** | | -.34±.111** |
| 1/2D-1/4D | | -.43±.096** | | -.64±.111** |
| Interaction | | .16±.096† | | .12±.111 |

[a]F=Finnsheep, D=Dorset, R=Rambouillet

[b]No.=Number of fleeces weighed.

[c]Wt.=Mean fleece weight in kilograms.

†P<.10, **P<.01.

TABLE XVII

LEAST SQUARE MEANS AND 1/4 FINNSHEEP AND 1/4 DORSET MAIN EFFECTS FOR PRODUCTIVITY OF EWES LAMBING IN THE FALL OF 1974

| Ewe Breeding[a] | No. Ewes Exposed | Fertility (%) | Prolificacy | Lamb Survival (%) | Lamb Weaning Weight (kg.) | Kg. Lamb Weaned Per Ewe Exposed |
|---|---|---|---|---|---|---|
| 1/2D1/2R | 54 | 79.2±5.81 | 1.51±.087 | 90.8±4.06 | 23.5±.61 | 25.2±2.35 |
| 1/4D3/4R | 57 | 70.6±6.01 | 1.37±.094 | 94.3±4.47 | 25.9±.64 | 22.5±2.33 |
| 1/4F1/2D1/4R | 45 | 61.9±6.80 | 1.73±.117 | 85.6±5.20 | 23.5±.77 | 21.9±2.63 |
| 1/4F1/4D1/2R | 52 | 59.7±6.35 | 1.56±.111 | 90.9±5.19 | 24.1±.75 | 20.7±2.42 |
| Main Effects and Interaction | | | | | | |
| 1/4F-0F | | -14.1±6.23* | .20±.103† | -4.3±4.82 | -.9±.70 | -2.5±2.44 |
| 1/2D-1/4D | | 5.4±6.27 | .15±.100 | -4.4±4.65 | -1.5±.68* | 2.0±2.42 |
| Interaction | | 3.2±6.23 | -.02±.100 | -.9±4.70 | -.9±.68 | .7±2.44 |

[a]F=Finnsheep, D=Dorset, R=Rambouillet.

†P<.10, *P<.05.

TABLE XVIII

LEAST SQUARE MEANS AND 1/4 FINNSHEEP AND 1/4 DORSET MAIN EFFECTS FOR PRODUCTIVITY OF EWES LAMBING IN THE FALL OF 1975

| Ewe Breeding[a] | No. Ewes Exposed | Fertility (%) | Prolificacy | Lamb Survival (%) | Lamb Weaning Weight (kg.) | Kg. Lamb Weaned Per Ewe Exposed |
|---|---|---|---|---|---|---|
| 1/2D1/2R | 53 | 85.6±6.62 | 1.45±.086 | 86.8±4.37 | 22.1±.72 | 22.6±2.47 |
| 1/4D3/4R | 57 | 87.1±6.47 | 1.27±.086 | 91.8±4.64 | 26.4±.74 | 26.1±2.42 |
| 1/4F1/2D1/4R | 43 | 64.3±8.26 | 1.48±.130 | 91.2±6.48 | 22.6±.87 | 18.8±2.88 |
| 1/4F1/4D1/2R | 51 | 58.7±6.55 | 1.67±.110 | 87.9±5.17 | 20.8±.84 | 17.0±2.46 |
| | | Main Effects and Interaction | | | | |
| 1/4F-0F | | -24.9±6.96** | .22±.103* | .2±5.11 | -2.6±.84** | -6.4±2.55** |
| 1/2D-1/4D | | 2.1±7.05 | -.01±.106 | -.8±5.30 | -1.3±.88 | -.9±2.59 |
| Interaction | | -3.6±7.03 | .18±.105† | -4.1±5.26 | -3.0±.87** | -2.6±2.57 |

[a]F=Finnsheep, D=Dorset, R=Rambouillet.

†P<.10, *P<.05, **P<.01.

genes at the expense of Rambouillet genes will result in a decreased percent ewes lambing. Although no report can be found in the literature where performance of Finnsheep or Finn-cross ewes has been evaluated under a fall lambing program, some estrus detection work done by Shelton and Klindt (1976) in Texas would tend to support the fertility results of this study. In that study, none of 20 1/2F1/2R ewes were detected in estrus in April, May or June of 1973 or 1974. During these same months, 35 to 45 percent of straightbred Rambouillet ewes are known to exhibit estrus (Hulet et al., 1974). On the other hand, there is some information available from field data collected in Finland (Maijala and Kangasniemi, 1972) and studies conducted in West Germany and The United Kingdom (Nitter, 1975a and Land, 1971; respectively) that would suggest that the Finnsheep breed has the ability to lamb out-of-season. In both seasons, the 1/4 Dorset effect was positive but not significantly different from zero (5.4 and 2.1 percent, respectively).

In contrast to the late winter-early spring lambing results, the 1/4 Finnsheep effect resulted in a sizable increase in prolificacy in both the falls of 1974 (.20, $P<.10$) and 1975 (.22, $P<.05$). These increases in prolificacy compare favorably with those observed by Bradford (1976) from California with spring lambing ewes. In that study, 1/4 Finn 3/4 Whiteface ewes, ranging in age from two to five years, gave birth to .22 more lambs per ewe lambing than whiteface ewes. The Whiteface ewes were of Targhee and Corriedale breeding. Both of these breeds have some genetic background in common with the Rambouillet breed.

In 1974, the 1/4 Dorset effect was positive and of economical significance (.15) but was determined to be not statistically significant ($P<.20$). In 1975, the 1/2 Dorset effect was very small and the interaction between level of Finnsheep and Dorset breeding approached statistical significance. The reason for this discrepancy from 1974 to 1975 was a switch in prolificacy between the 1/4F1/2D1/4R and 1/4F1/4D1/2R ewes from one season to the next.

Neither the 1/4 Finnsheep nor the 1/4 Dorset effect were significant for lamb survival in either season. In both 1974 and 1975, both the 1/4 Finnsheep and 1/4 Dorset effects were negative for lamb weaning weight. These effects were judged to be significantly different from zero in the case of the 1/4 Dorset effect in 1974 and the 1/4 Finnsheep effect in 1975. The significant interaction in 1975 for weaning weight probably arose due to the switch in prolificacy between the two 1/4 Finnsheep ewe groups from one season to the next since these weaning weights are strongly related to the proportion of multiple reared lambs.

The 1/4 Finnsheep effect on kilograms of lamb weaned per ewe exposed was negative in both seasons but significant only in 1975 (-2.5 and -6.5 kilograms, respectively). The 1/4 Dorset effect was nonsignificant in both seasons. These data suggest that increasing Finnsheep breeding by 1/4 at the expense of Rambouillet breeding may result in decreased productivity of fall lambing flocks such as those found in the southwestern United States.

In summary of the fall lambing results, increasing Finnsheep breeding by 1/4 at the expense of Rambouillet breeding resulted in little change in ewe breeding weight, a significant decrease in ewe fleece weight and a decrease in kilograms of lamb weaned per ewe exposed. It should be noted that the 1/4 Finnsheep ewes had very desirable lambing rates and that the main reason for the low weight of lamb weaned per ewe exposed for these ewes was that a high proportion of them failed to lamb. These ewes would be very desirable for fall lambing if through selection or management, the proportion of ewes lambing could be improved.

The 1/4 Dorset effect resulted in significantly decreased ewe breeding and fleece weights but resulted in little change in kilograms of lamb weaned per ewe exposed.

## Lamb Growth From Birth to Market

Presented in Table XIX are the number of lambs from each crossbred dam group that were used in the analysis of lamb growth traits. Only single and twin lambs born alive were included for birth weight. Only single born-single reared and twin born-twin reared lambs were included for the remaining four traits.

Table XX and XXI present the least square means and 1/8 Finnsheep and 1/8 Dorset effects for growth traits of the late winter-early spring and fall born lambs, respectively. In both seasons, some of the traits show a significant interaction between level of Finnsheep and Dorset breeding. The expected value of this interaction, in terms of genetic components (Table IX), is .13 of the individual recombination effects plus .27 of the maternal heterosis for each of the respective growth traits. Since maternal heterosis has gnerally been shown to exist for lamb growth traits, one might expect the interaction terms in Tables XX and XXI to be significant. However, reported maternal heterosis estimates for growth traits have almost always been positive. All of the interaction terms in Tables XX and XXI are negative (except those for age at 43.1 kilograms where a positive sign indicates slower growth) and opposite in sign of what they are expected to be assuming positive

TABLE XIX

NUMBER OF LATE WINTER-EARLY SPRING AND FALL BORN LAMBS FROM EACH CROSSBRED DAM GROUP AVAILABLE FOR ANALYSIS OF GROWTH TRAITS

| Growth Trait[b] | Dam's Breeding[a] | | | | | | | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1/2D1/2R | | 1/4D3/4R | | 1/4F1/2D1/4R | | 1/4F1/4D1/2R | | | |
| | Spring | Fall | Spring | Fall | Spring | Fall | Spring | Fall | Spring | Fall |
| Birth Weight | 122 | 124 | 113 | 115 | 112 | 86 | 126 | 87 | 473 | 412 |
| A.D.G. from Birth to 70 Days | 114 | 108 | 99 | 100 | 105 | 73 | 113 | 77 | 431 | 358 |
| 70 Day Weight | 114 | 108 | 99 | 100 | 105 | 73 | 113 | 77 | 431 | 358 |
| A.D.G. from 70 Days to Market | 110 | 105 | 98 | 100 | 101 | 73 | 109 | 76 | 418 | 354 |
| Age to 43.1 Kilograms | 110 | 105 | 98 | 100 | 101 | 73 | 109 | 76 | 418 | 354 |

[a]F=Finnsheep, D=Dorset, R=Rambouillet.

[b]Only single and twin born lambs were included for birth weight. All other traits included single born-single reared and twin born-twin reared lambs only.

TABLE XX

LEAST SQUARE MEANS AND 1/8 FINNSHEEP AND 1/8 DORSET MAIN EFFECTS FOR GROWTH TRAITS OF LATE WINTER-EARLY SPRING BORN LAMBS

| Lamb's Breeding[a] | Birth Weight[b] | A.D.G. From Birth to 70 Days | 70 Day Weight | A.D.G. From 70 Days to Market | Age at 43.1 Kg. |
|---|---|---|---|---|---|
| 1/4D1/4R | 4.15±.068 | .290±.0051 | 24.44±.382 | .223±.0061 | 162.8±2.75 |
| 1/8D3/8R | 4.49±.071 | .297±.0052 | 25.27±.387 | .239±.0066 | 151.3±2.96 |
| 1/8F1/4D1/8R | 3.96±.073 | .290±.0056 | 24.32±.420 | .239±.0066 | 155.3±2.99 |
| 1/8F1/8D1/4R | 4.12±.063 | .290±.0052 | 24.46±.387 | .233±.0063 | 157.5±2.82 |
| | | Main Effects and Interaction | | | |
| 1/8F-0F | -.28±.062** | -.003±.0048 | -.46±.357 | .005±.0057 | -.6±2.58 |
| 1/4D-1/8D | -.25±.062** | -.004±.0047 | -.48±.351 | -.005±.0056 | 4.6±2.52† |
| Interaction | -.09±.062 | -.003±.0046 | -.35±.344 | -.011±.0055* | 6.9±2.47** |

[a]F=Finnsheep, D=Dorset, R=Rambouillet. Only the dam's contribution is represented. All lambs are 1/2 blackface.

[b]All weights are in kilograms.

†P<.10, *P<.05, **P<.01.

TABLE XXI

LEAST SQUARE MEANS AND 1/8 FINNSHEEP AND 1/8 DORSET MAIN EFFECTS FOR GROWTH TRAITS OF FALL BORN LAMBS

| Lamb's Breeding[a] | Birth Weight[b] | A.D.G. From Birth to 70 Days | 70 Day Weight | A.D.G. From 70 Days to Market | Age at 43.1 Kg. |
|---|---|---|---|---|---|
| 1/4D1/4R | 3.59±.069 | .293±.0049 | 23.97±.375 | .255±.0061 | 146.9±2.22 |
| 1/8D3/8R | 4.03±.072 | .323±.0050 | 26.61±.384 | .284±.0061 | 132.1±2.22 |
| 1/8F1/4D1/8R | 3.59±.096 | .310±.0065 | 25.27±.503 | .287±.0080 | 136.8±2.91 |
| 1/8F1/8D1/4R | 3.71±.086 | .294±.0059 | 24.29±.453 | .281±.0072 | 140.1±2.62 |
| | | Main Effects and Interaction | | | |
| 1/8F-OF | -.16±.080* | -.006±.0055 | -.51±.423 | .010±.0067 | -1.0±2.45 |
| 1/4D-1/8D | -.28±.080** | -.007±.0055 | -.83±.422* | -.016±.0068* | 5.7±2.46* |
| Interaction | -.16±.081* | -.023±.0055** | -1.81±.421** | -.013±.0068† | 9.1±2.45** |

[a]F=Finnsheep, D=Dorset, R=Rambouillet. Only the dam's contribution is represented. All lambs are 1/2 blackface.

[b]All weights are in kilograms.

†P .10, *P .05, **P .01.

maternal heterosis and minimal recombination effects for growth traits.

The existence of these significant, negative interactions is very difficult to explain. In these data, the interactions generally result from the difference between lambs produced by the 1/4D3/4R and 1/2D1/2R ewes being greater than the difference between lambs produced by the 1/4F1/4D1/2R and 1/4F1/2D1/4R ewes. The high level of performance of lambs produced by 1/4D3/4R ewes may be due to the breed sampling done in the production of these test ewes. In Table III, it can be seen that only two Rambouillet rams were used to produce all of the 1/4D3/4R ewes. One quarter of the genes possessed by the lambs produced from the 1/4D 3/4R ewes are expected to have come from the two original Rambouillet sires. If the breeding values of these two rams for growth traits were much higher than the average of the Rambouillet breed, the performance of the lambs from the 1/4D3/4R ewes would be greater than expected. The above explanation seems to be the most plausible one available for explaining the significant negative interactions for growth traits found in Tables XX and XXI.

In both seasons, the main effect of increasing Finnsheep breeding by 1/8 at the expense of Rambouillet breeding resulted in a significant decrease in birth weight (-.28 and -.16 kilograms for spring and fall born lambs, respectively) and no significant change in any of the other growth traits. Most other studies (Donald et al., 1968; Barker, 1975 and Nitter, 1975b) have also reported lighter birth weights of Finn-cross lambs but have in addition, also reported lighter weaning weights of Finn-cross lambs which was not the case with the present study. In these studies, no Rambouillet breeding was present.

In agreement with the results of the present study, Dickerson *et al*. (1975) found that Finn-cross lambs were lighter than Rambouillet-cross lambs at birth and that the two groups were similar in weight at 10 weeks of age. The results of the present study and the study reported by Dickerson et al.(1975) would indicate that increasing Finnsheep breeding at the expense of Rambouillet breeding in commercial flocks will have little effect on the growth traits of the lambs produced other than reducing birth weights.

The 1/8 Dorset effect for late winter-early spring born lambs resulted in a significant decrease in birth weight (-.25 kilograms), nonsignificant but negative changes in average daily gain from birth to 70 days, 70 day weight and average daily gain from 70 days to market and an increase (P<.10) of 4.6 days to reach 43.1 kilograms. For the fall born lambs, the 1/8 Dorset effect resulted in a significant decrease in birth weight, 70 day weight and average daily gain from 70 days to market (-.28, -.83 and -.016 kilograms, respectively), a nonsignificant but negative change in average daily gain from birth to 70 days and a significant increase of 5.7 days to reach 43.1 kilograms. These data suggest that increasing Dorset breeding by 1/8 at the expense of Rambouillet breeding in lambs will result in slower growth rates. This detrimental effect seems to be greater with fall born than with late winter-early spring born lambs. Gould and Whiteman (1971) have reported that lambs produced by Dorset dams and blackfaced sires have poorer growth rates than lambs produced by Rambouillet dams and blackfaced sires which also shows the detrimental effect of Dorset breeding on growth traits. In this same study reported by Gould and Whiteman (1971), the difference between lambs from Dorset and Rambouillet dams for all growth traits was greater with fall born than with spring born lambs which is similar to the results noted here. Dickerson et al. (1972) also reports that Rambouillet lambs are significantly heavier than Dorset lambs at 0, 10 and 22 weeks of age.

In summary, the 1/8 Finnsheep effect resulted in a significant reduction in birth weights of both late winter-early spring and fall born lambs but resulted in little change in growth traits measured from after birth to market. The 1/8 Dorset effect resulted in a significant reduction in birth weight and an increased number of days to reach 43.1 kilograms in both seasons. The 1/8 Dorset effects were generally of larger magnitude in the fall born than the late winter-early spring born lambs. Numerous significant interactions in both seasons indicated that the effects of increasing both Finnsheep and Dorset breeding were dependent upon the respective level of Dorset and Finnsheep breeding present.

## CHAPTER V

## SUMMARY

This study involves the performance of 198 crossbred ewes representing four combinations of Finnsheep (F), Dorset (D) and Rambouillet (R) breeding under both late winter-early spring and fall lambing conditions from 1972 through 1975 and the growth performance to market of their terminal sired lambs. The four crossbred ewe groups represented were: 1/2D1/2R, 1/4D3/4R, 1/4F1/2D1/4R and 1/4F1/4D1/2R.

The four breed groups allowed the estimation of the main effect of increasing Finnsheep breeding by 1/4 at the expense of Rambouillet breeding (1/4 Finnsheep effect = (1/4F1/2D1/4R + 1/4F1/4D1/2R)/2 - (1/2D1/2R + 1/4D3/4R)/2), the main effect of increasing Dorset breeding by 1/4 at the expense of Rambouillet breeding (1/4 Dorset effect = (1/2D1/2R + 1/4F1/2D1/4R)/2 - (1/4D3/4R + 1/4F1/4D1/2D/2) and the interaction between level of Finnsheep and Dorset breeding (Interaction = (1/2D1/2R + 1/4F1/4D1/2R)/2 - (1/4D3/4R + 1/4F1/2D1/4R)/2) for ewe performance traits. The main effects are not clean estimates of 1/4 the difference between the average effects of the genes possessed by the Finnsheep (or Dorset) and Rambouillet breeds but are confounded with portions of the individual heterosis, individual recombination effects, maternal effects and maternal heterosis expressed for the trait under question. Similar effects were estimated for lamb growth traits, but in this case they are a 1/8 Finnsheep or a 1/8 Dorset effect versus the 1/4 effects for ewe traits.

With both late winter-early spring and fall lambing, the 1/4 Finnsheep effect resulted in little change in breeding weight, a significant decrease in grease fleece weight and a significant decrease in fleece quality grade. During these same periods, the 1/4 Dorset effect resulted in a significant decrease in all three traits.

When lambing in the early spring at one year of age, the 1/4 Finnsheep effect resulted in a large ($P<.10$) increase in kilograms of lamb weaned per ewe exposed (3.5 kilograms) due primarily to a greater ($P<.01$) proportion of the 1/4 Finnsheep ewes lambing (24 percent). When lambing at approximately two and three years of age, the 1/4 Finnsheep effect resulted in no significant change in kilograms of lamb weaned per ewe exposed. At one, two and three years of age, the 1/4 Dorset effect had little effect on kilograms of lamb weaned per ewe exposed.

Two seasons of fall lambing indicated that the 1/4 Finnsheep effect resulted in a significant reduction in fertility, a significant increase in prolificacy and overall, a reduction in kilograms of lamb weaned per ewe exposed. During this same time, the 1/4 Dorset effect resulted in little change in kilograms of lamb weaned per ewe exposed.

Lamb growth data from both late winter-early spring and fall born lambs showed that the 1/8 Finnsheep effect resulted in decreased birth weights and no significant change in growth traits measured from after birth to market. The 1/8 Dorset effect resulted in decreased birth weights and increased days to reach 43.1 kilograms in both seasons. Many growth traits in both seasons had significant interaction terms indicating that the magnitude of the 1/8 Finnsheep and 1/8 Dorset effects were dependent upon the respective level of Dorset or Finnsheep breeding present. The differences in growth traits tended to be greater between lambs produced from 1/2D1/2R and 1/4D3/4R dams than between lambs produced by the two 1/4 Finnsheep dam groups.

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APPENDIX

TABLE XXII

LEAST SQUARES ANALYSIS OF VARIANCE AND MEAN SQUARES FOR BREEDING WEIGHTS (KG.) OF SPRING LAMBING EWES

| | | Approximate Age at Breeding (Months) | | |
|---|---|---|---|---|
| Source | df | 48 | 18[a] | 29 |
| Year (Y) | 1 | 567.65** | | |
| Breed of Ewe (E) | 3 | 60.55** | 84.63* | 163.08* |
| Y x E | 3 | 26.39† | | |
| Residual[b] | | 11.99 | 25.84 | 39.14 |
| $R^2$ | | .26 | .10 | .12 |

[a]Breeding weights were only available for the ewes born in 1972.

[b]df for "residual" is 190, 91 and 90 for the respective traits from left to right.

†P<.10, *P<.05, **P<.01.

TABLE XXIII

LEAST SQUARES ANALYSIS OF VARIANCE AND MEAN SQUARES FOR FLEECE WEIGHTS AND FLEECE GRADES OF SPRING LAMBING EWES

| | | Fleece Weight (Kg.) at Different Ages: | | | |
|---|---|---|---|---|---|
| Source | df | 1 yr. | 2 yr. | 3 yr. | Fleece Grade[a] |
| Year (Y) | 1 | 246.37** | 2116.66** | | .756 |
| Breed of Ewe (E) | 3 | 238.89** | 608.76** | 253.54** | 12.959** |
| Y x E | 3 | 43.26 | 22.21 | | .485 |
| Residual[b] | | 27.29 | 48.07 | 44.88 | .326 |
| $R^2$ | | .18 | .32 | .16 | .42 |

[a]Fleece Grade Code: 1 = Fine, 2 = Half-blood, 3 = Three-eighths-blood and 4 = Quarter-blood.

[b]df for "Residual" is 187, 180, 89 and 177 for the respective traits from left to right.

**P<.01.

TABLE XXIV

LEAST SQUARES ANALYSIS OF VARIANCE AND MEAN SQUARES FOR EWE PRODUCTIVITY TRAITS WHEN LAMBING AT APPROXIMATELY ONE YEAR OF AGE

| Source | df | Trait | | | | |
|---|---|---|---|---|---|---|
| | | Fertility | Prolificacy | Lamb Survival | Lamb Weaning Weight (Kg) | Kg. Lamb Weaned Per Ewe Exposed |
| Year (Y) | 1 | .648 | .027 | .997** | 43.25† | 1843.66† |
| Breed of Ewe (E) | 3 | .948* | .104 | .131 | 25.86 | 201.70 |
| Breed of Ram (R) | 1 | .011 | .017 | .036 | 64.39* | 23.88 |
| Ram/Y/R | 7 | .397† | .101 | .085 | 8.49 | 375.14* |
| Y x E | 3 | .229 | .331* | .087 | 17.59 | 264.04 |
| Y x R | 1 | .111 | .056 | .000 | 0.91 | 279.97 |
| E x R | 3 | .058 | .151 | .189 | 12.00 | 138.63 |
| Y x E x R | 3 | .193 | .388* | .511** | 14.42 | 498.15* |
| Residual[a] | | .198 | .109 | .108 | 15.42 | 156.31 |
| $R^2$ | | .20 | .21 | .24 | .21 | .22 |

[a]df for "Residual" is 175, 111, 127, 106 and 175 for the respective traits from left to right.

†P<.10, *P<.05, **P<.01.

TABLE XXV

LEAST SQUARES ANALYSIS OF VARIANCE AND MEAN SQUARES FOR EWE PRODUCTIVITY TRAITS WHEN LAMBING AT APPROXIMATELY TWO YEARS OF AGE

| | | Trait | | | | |
|---|---|---|---|---|---|---|
| Source | df | Fertility | Prolificacy | Lamb Survival | Lamb Weaning Weight (Kg.) | Kg. Lamb Weaned Per Ewe Exposed |
| Year (Y) | 1 | .466 | .138 | .358 | 4.46 | 280.23 |
| Breed of Ewe (E) | 3 | .066 | .263 | .039 | 57.17** | 65.68 |
| Breed of Ram (R) | 1 | .378 | .479 | .001 | 30.05 | 339.73 |
| Ram/Y/R | 13 | .524** | .302 | .121† | 20.53 | 913.83** |
| Y x E | 3 | .102 | .122 | .057 | 4.92 | 588.94† |
| Y x R | 1 | .092 | .068 | .005 | 18.18 | 83.55 |
| E x R | 3 | .061 | .202 | .164† | 7.21 | 104.68 |
| Y x E x R | 3 | .042 | .025 | .103 | 20.90 | 82.54 |
| Residual[a] | | .113 | .312 | .079 | 15.72 | 257.87 |
| $R^2$ | | .36 | .16 | .16 | .17 | .28 |

[a]df for "Residual" is 161, 127, 222, 198 and 161 for the respective traits from left to right.

†P<.10, **P<.01.

TABLE XXVI

LEAST SQUARES ANALYSIS OF VARIANCE AND MEAN SQUARES FOR EWE PRODUCTIVITY TRAITS WHEN LAMBING AT APPROXIMATELY THREE YEARS OF AGE

| | | Trait | | | | |
|---|---|---|---|---|---|---|
| Source | df | Fertility | Prolificacy | Lamb Survival | Lamb Weaning Weight (Kg.) | Kg. Lamb Weaned Per Ewe Exposed |
| Breed of Ewe (E) | 3 | .145 | .109 | .107 | 75.17** | 174.18 |
| Breed of Ram (R) | 1 | .323 | .145 | .204 | .77 | 20.65 |
| Ram/R | 7 | .506** | .315 | .161 | 33.40† | 1035.17** |
| E x R | 3 | .020 | .685 | .093 | 22.72 | 79.36 |
| Residual[a] | | .118 | .387 | .119 | 17.58 | 294.19 |
| $R^2$ | | .33 | .19 | .10 | .26 | .27 |

[a]df for "Residual" is 79, 62, 117, 99 and 79 for the respective traits from left to right.

†P<.10, **P<.01.

TABLE XXVII

LEAST SQUARES ANALYSIS OF VARIANCE AND MEAN SQUARES FOR BREEDING WEIGHTS AND FLEECE WEIGHTS OF EWES LAMBING IN THE FALLS OF 1974 AND 1975

| | | Breeding Weight (kg.) | | Fleece Weight (kg.)[a] | |
|---|---|---|---|---|---|
| Source | df | 1974 | 1975 | 1974 | 1975 |
| Age of Ewe (A) | 1 | 1998.00** | 513.29** | .014 | 0.009 |
| Breed of Ewe (E) | 3 | 766.70** | 468.33** | 4.620** | 8.162** |
| A x E | 3 | 15.42 | 11.21 | .282 | .487 |
| Residual | | 61.59 | 52.47 | .477 | .608 |
| $R^2$ | | .27 | .18 | .14 | .19 |

[a]Fleece weights were from the spring 1975 and 1976 shearings following the fall lambings of 1974 and 1975, respectively.

[b]df for "Residual" is 199, 195, 200 and 190 for the respective traits from left to right.

**P<.01.

TABLE XXVIII

LEAST SQUARES ANALYSIS OF VARIANCE AND MEAN SQUARES FOR EWE PRODUCTIVITY TRAITS WHEN LAMBING IN THE FALL OF 1974

| | | Trait | | | | |
|---|---|---|---|---|---|---|
| Source | df | Fertility | Prolificacy | Lamb Survival | Lamb Weaning Weight (Kg.) | Kg. Lamb Weaned Per Ewe Exposed |
| Age of Ewe (A) | 1 | .945* | .000 | .038 | 43.48 | 1145.10* |
| Breed of Ewe (E) | 3 | .373 | .533 | .047 | 52.70* | 184.39 |
| Breed of Ram (R) | 3 | .799 | .480 | .070 | 12.45 | 471.38 |
| Ram/R | 4 | .405† | .073 | .004 | 15.44 | 852.19* |
| A x E | 3 | .275 | .303 | .119 | 22.55 | 642.28† |
| A x R | 3 | .571* | .369 | .056 | 20.95 | 754.21† |
| E x R | 9 | .256 | .130 | .144 | 28.30 | 396.99 |
| A x Ram/R | 4 | .242 | .645† | .019 | 30.29 | 671.61† |
| E x Ram/R | 12 | .150 | .188 | .057 | 21.24 | 231.20 |
| Residual | | .175 | .281 | .088 | 17.18 | 287.83 |
| $R^2$ | | .31 | .32 | .22 | .36 | .30 |

[a]df for "Residual" is 165, 102, 175, 153 and 165 for the respective traits from left to right.

†P<.10, *P<.05.

TABLE XXIX

LEAST SQUARES ANALYSIS OF VARIANCE AND MEAN SQUARES FOR EWE PRODUCTIVITY TRAITS WHEN LAMBING IN THE FALL OF 1975

| | | Trait | | | | |
|---|---|---|---|---|---|---|
| Source | df | Fertility | Prolificacy | Lamb Survival | Lamb Weaning Weight (Kg.) | Kg. Lamb Weaned Per Ewe Exposed |
| Age of Ewe (A) | 1 | .006 | .004 | .125 | 45.47 | 27.12 |
| Breed of Ewe (E) | 3 | .860** | .769* | .025 | 221.04** | 695.48* |
| Breed of Ram (R) | 3 | .183 | .197 | .076 | 12.99 | 228.95 |
| Ram/R | 4 | .208 | .416 | .141 | 48.41† | 257.71 |
| A x E | 3 | .167 | .164 | .135 | 54.50† | 409.20 |
| A x R | 3 | .180 | .237 | .049 | 11.56 | 156.45 |
| E x R | 9 | .200 | .209 | .081 | 52.48* | 191.64 |
| A x Ram/R | 4 | .024 | .282 | .250* | 32.82 | 157.38 |
| E x Ram/R | 12 | .142 | .314 | .098 | 30.16 | 169.51 |
| Residual | | .183 | .273 | .097 | 22.06 | 258.97 |
| $R^2$ | | .25 | .28 | .21 | .43 | .21 |

[a]df for "Residual" is 161, 108, 175, 150 and 161 for the respective traits from left to right.

†P<.10, *P<.05, **P<.01.

TABLE XXX

LEAST SQUARES ANALYSIS OF VARIANCE AND MEAN SQUARES FOR GROWTH TRAITS OF LATE WINTER-EARLY SPRING BORN LAMBS

| Source | df | Birth Weight | A.D.G. From Birth to 70 Days | 70 Day Weight | A.D.G. From 70 Days to Market | Days to 43.1 Kg. |
|---|---|---|---|---|---|---|
| Year-Age of Dam (Y) | 4 | 4.000** | .0158** | 98.55** | .0437** | 13617.3** |
| Breed of Dam (D) | 3 | 4.278** | .0009 | 13.32 | .0045 | 1771.1* |
| Breed of Sire (B) | 1 | .005 | .0037 | 22.67 | .0383** | 10184.9** |
| Type of Birth (T)[a] | 1 | 67.824** | .1919** | 1385.31** | .0062 | 35295.0** |
| Sex (S) | 1 | 5.001** | .0186** | 150.88** | .0426** | 16020.2** |
| Sire/Y/B | 26 | .579* | .0015 | 10.35 | .0030 | 626.5 |
| Y x D | 12 | .679* | .0035* | 20.96* | .0011 | 761.6† |
| Y x B | 4 | .153 | .0057* | 31.47* | .0008 | 2050.6** |
| Y x T | 4 | .139 | .0011 | 6.53 | .0027 | 609.0 |
| Y x S | 4 | .206 | .0024 | 14.36 | .0050† | 732.5 |
| D x B | 3 | .390 | .0022 | 11.15 | .0013 | 634.3 |
| D x T | 3 | .604 | .0021 | 5.87 | .0031 | 349.9 |
| D x S | 3 | .354 | .0017 | 9.62 | .0033 | 603.7 |
| B x T | 1 | .236 | .0015 | 5.67 | .0000 | 719.3 |
| B x S | 1 | .110 | .0000 | .19 | .0001 | 278.0 |
| T x S | 1 | .840 | .0003 | .06 | .0172** | 369.9 |
| Residual[b] | | .361 | .0018 | 9.84 | .0024 | 485.1 |
| $R^2$ | | .54 | .49 | .54 | .50 | .58 |

[a]"Type of Birth-Rearing" for traits other than birth weight.

[b]df for "Residual" is 400, 358, 358, 345 and 345 for the respective traits from left to right.

†P<.10, *P<.05, **P<.01.

TABLE XXXI

LEAST SQUARES ANALYSIS OF VARIANCE AND MEAN SQUARES FOR GROWTH TRAITS OF FALL BORN LAMBS

| Source | df | Birth Weight | A.D.G. From Birth to 70 Days | 70 Day Weight | A.D.G. From 70 Days to Market | Days to 43.1 Kg. |
|---|---|---|---|---|---|---|
| Year-Age of Dam(Y) | 3 | 3.574** | .0114* | 86.61* | .0045 | 2142.0* |
| Breed of Dam (D) | 3 | 3.679** | .0153** | 105.16** | .0132** | 2947.8** |
| Breed of Sire (B) | 3 | 1.236* | .0033 | 22.24 | .0060† | 620.2 |
| Type of Birth (T)[a] | 1 | 47.865** | .2566** | 1708.15** | .0073 | 13924.0** |
| Sex (S) | 1 | .575 | .0424** | 277.83** | .0708** | 19167.3** |
| Sire/Y | 16 | .564 | .0030† | 17.95† | .0041 | 546.8† |
| Y x D | 9 | .929* | .0031† | 20.26† | .0022 | 204.1 |
| Y x B | 9 | .502 | .0034† | 17.81 | .0059* | 741.7* |
| Y x T | 3 | .202 | .0027 | 14.22 | .0008 | 228.0 |
| Y x S | 3 | .674 | .0031 | 19.94 | .0030 | 719.8 |
| D x B | 9 | .489 | .0037* | 23.07* | .0058* | 774.3* |
| D x T | 3 | 1.177† | .0130** | 83.87** | .0040 | 2440.9** |
| D x S | 3 | .675 | .0029 | 16.78 | .0021 | 680.5 |
| B x T | 3 | .700 | .0018 | 11.90 | .0026 | 230.9 |
| B x S | 3 | .108 | .0012 | 6.91 | .0077* | 669.3 |
| T x S | 1 | 1.481† | .0264** | 140.11** | .0010 | 429.2 |
| Residual[b] | | .454 | .0018 | 10.87 | .0028 | 362.6 |
| $R^2$ | | .53 | .65 | .67 | .38 | .56 |

[a]"Type of Birth-Rearing" for traits other than birth weight.

[b]df for Residual is 338, 284, 284, 280 and 280 for the respective traits from left to right.

†P<.10, *P<.05, **P<.01.

VITA

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Doctor of Philosophy

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