GENETIC AND ENVIRONMENTAL DIFFERENCES IN IMPORTANT ECONOMIC TRAITS OF CROSSBRED SHEEP IN SPRING LAMB PRODUCTION

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INTRODUCTION

The dissimilarity of our many breeds of sheep is striking and noticeably obvious even to the casual observer. All of them, though of relatively recent origin, arose by the same process of choosing certain combinations of characters from the general inheritance pattern which makes animals alike, or as the case may be, unlike. Our breeds decended from an heterogeneous mixture of sheep types and as yet we have purified them mostly for their less intrinsically valuable traits, many of them being the only characters which do differentiate the breeds.

It was the purpose of many of the breed associations at the time of their inception to foster the identification of superior individuals as well as to promote their breeds. Nevertheless, many have deviated from their purpose to one of establishing and maintaining aesthetic characters at the expense of utility. The incorporation of the non-utility traits as primary criteria in breeding programs has attenuated the purifying of those traits which mean dollars and cents to the commercial man. Much of the early breed promotion work was based on superficialities largely perhaps because the real basis for animal improvement was unknown. Breeds were evaluated in terms of a few superlative accomplishments rather than in terms of their actual merit.

The rapid rate at which the so-called purebreds degenerate in the hands of unskilled breeders is evidence enough that purity, in such breeds, has not been attained in many of the traits which determine their utility. None the less, we must pay tribute to the efforts of the breeders of purebreds for having built for us a marvelous array of models on which to improve and develop livestock which will be notable both from an aesthetic and utilitarian view.

Breeding, at most, is an art to be learned only by practise, but a knowledge of the principles which accelerate or lessen its progress furnishes the only firm basis for its practise. The rules-of-thumb methods which have heretofore provided the basis for improvement of livestock have been expensive and slow, and many of them must pass into discard.

We are long past the point at which our concepts and applications of livestock breeding need new approaches and new techniques. It was written by Ritzman and Davenport (74, p.3), as early in the development of formal genetics as 1920, "that methods of a more analytical character must someday become the basis of animal breeding, as they have become the basis of plant breeding, soil culture, industrial chemistry, and other economic fields of endeavor, seems beyond question." Our breeding programs must of necessity be based on sound genetic and physiological principles and objective methods of measurements lest we lapse into a state of inertia or stagnation.

Fortunately, in the past three decades a great deal of knowledge has been accumulated concerning the complexity of inheritance in livestock. Many of the confounding factors which masked progress through use of hit-or-miss selection have been subdued. The inheritance of a majority of the traits which reflect economic value is quite different from and more complex than that of many of the aesthetic characters which can be categorized into easily identifiable, qualitative, discontinuous groups. Those characters which affect the production of meat and milk and wool are controlled by an indefinite number of genes of minor effect which do not arrange themselves in such obvious groups, but express themselves in a quantitative manner. Furthermore, they are subject in their expression to the effect of such environmental factors as climatic fluctuations, food supply and disease. An animal's appearance is not necessarily a direct reflection of his transmitting ability.

Genetically speaking, the correlation between the animal's phenotype and genotype may vary. The genotype remains static, but the effect of external agencies on total expression does vary. Where such a situation exists, the measurement of breeding worth becomes a problem too difficult for rules of thumb to evaluate. An excellent example of environmental effects is evident in every day sheep husbandry where lambs are born as twins, or born to young ewes not yet capable of maximum production, or born late in the season rather than early. These lambs suffer a distinct disadvantage which some of the other lambs in the flock do not receive. Although the outward appearance, phenotype, suffers from these environmental influences the germ plasm does not, and yet such phenotypically inhibited animals are often ostracized and excluded from the breeding flock. Herein lies a major fault of rules of thumb and the lack of objective measurement.

The methods developed through integration of statistical methodology and genetic reasoning enable us to measure the variation exhibited by animal phenotypes and to partition them into portions due to genetic causes and those due to nurture. Among the many parameters which statistical methodology furnishes us is that of genetic variation, upon which the possibilities of changing a population through selection depend. These methods are being employed quite extensively in poultry production and to a lesser extent with larger animals. They are the same underlying methods which formed the basis for plant improvement, and will be of great use to us with sheep and cattle when we are willing to set aside our laziness or conservativism and are willing to supplement the familiar methods with the new approaches.

We are not bound in commercial practises, however, to achieve purity of utility traits but may use the genetic variability in any manner which is to our advantage. Through crossing various breeds or strains within breeds several objectives may be accomplished; correct deficiencies of either breed or strain, utilize bound variation through crossing, or utilize genic interactions - of dominant or epistatic nature - which may occur. Thus it is possible to combine different genetic sources of metabolic and physiological pattern, maternal effects, body form and environmental adaptability to obtain an individual of maximum utility, or should we say optimum phenotype. Perhaps eventually our breed improvement will be based on the ability to outcross with specific breeds for producing a certain product for a particular market demand.

A characteristic of which we must never lose sight is the capability of animals to cope with the immediate environment. The development of the sheep breeds took place under a large variety of topographical climatic and forage conditions and each breed is not necessarily adapted to produce optimally in every environment. These genetic-environmental interactions are certainly utilized in sheep husbandry where varying amounts of emphasis are placed on the production of meat or wool, and thus different breeds are used in different localities, depending on existing conditions.

The object of this study was to compare the commercial value of various breed crosses of sheep in a specific environment, the Willamette Valley of Oregon. Its purpose was to measure genetic differences between various breed crosses in characters which reflect dollars and cents to the producer of spring lambs. The goal of the spring lamb producer, needless to say, is to produce a lamb of such size, form and fatness to command top price on the existing market and to do this in such a manner as to fully utilize pastures and maintain costs at a minimum.

Notwithstanding that this study was designed to study the economic merit of these breed crosses, it will yield information regarding the genetic and environmental entities which influence the economic aspects.

REVIEW OF LITERATURE

The production of spring lambs is a special type of enterprise which for success demands breeding for the right kind of lamb and possessing succulent, highly nutritive, cheap feed. The object is to provide, in lambs, a continuous fast rate of growth from birth to slaughter weight and simultaneously to produce a sufficient amount of fat to suit the public's demand. An understanding of the factors which influence the development and growth of sheep will initiate ideas as to what changes in the selection and management systems will minimize influences which reduce production efficiency. In order to integrate the findings of this thesis with those of other workers a review of pertinent literature is presented. It is categorized for convenience into various subheadings to avoid discontinuity.

Growth Changes in Relation to Lamb Production

Growth of animals is the basis of meat production. For our purpose of definition, growth is an increase in live weight (31, p.450). It is a well known fact that as an animal grows older growth velocity decreases. The most economical gains are therefore made when animals are very young (9, p.499).

Rate of growth is determined genetically according to

Bonsma (7, p.73), Dahmen and Bogart (19, 23p.) and Knapp and Clark (49, pp.174-181), however its expression is subject to environmental modification. Furthermore, certain breeds are more apt to produce fat at an early age than others. Weight at slaughter age is dependent upon growth rate, whereas market grade is determined largely by finish. Hirzel, cited by Bonsma (7, p.13), maintains that it is not so much the actual weight as the relation between bone, muscle and fat that is important. It is a combination of these factors and some emphasis on wool that dictates the preference of various sheepmen for different breeds of mutton sheep. Often these preferences are based on empericism or tradition rather than on the particular breed's ability to grow, fatten and produce wool.

Hankins and Titus (31, p.453) asserted "whereas the gains of young growing animals are composed largely of protein and water those of the mature or nearly mature animal consist mostly of fat. It usually is not possible, however, to fix any definite point as the one at which growth ceases and fattening begins. This is because the character of the gain varies during both the early and late stages of growth, and, normally, the change between the period when the gain is mostly protein and the period when it is mostly fat is not abrupt but gradual."

The greatest significance of the chemical composition and the changes in it associated with growth and fattening is that it acts as an index of nutritive value of the edible product (31, p.453).

Bonsma (7, p.12) in a most remarkable study of lamb growth and development, stated that hereditary breed differences in attaining maturity in respect to skeletal, muscular and fat development will determine the suitability of particular breeds to different nutritional and environmental conditions for production of fat lambs. Hammond and Murray (28, pp.233-249) contended that there appears to be, for every breed, an optimum carcass weight at which the fat, muscle and bone are in right proportion. Nevertheless, the market imposes a weight-maximum restriction with which some breeds cannot cope because their weight is too great when their condition becomes adequate. Hammond (27, p.307) was of the opinion that early maturity can be obtained in the proportion of meat to bone without reducing the size of animals.

The end point of lamb production is the carcass, or further yet its cuts. However, for the lamb producer the end point is the time when the lamb goes to market. The factors which determine income from lamb at marketing time are the sale weight (in this case weaning weight), condition or fatness and perhaps body form or conformation.

From an interest and investment standpoint, nevertheless, the production per ewe bred or the production per hundredweight of ewe bred provides the most efficient estimate (88, p.27).

Effect of Heredity, Environment and Their Interactions on Lamb Production

The magnitude of within-breed heritability estimates of lamb weaning weights varies from .08 reported by Hazel and Terrill (38, pp.370-377) to .42 reported by Nelson and Ven Katachalem (64, pp.607-608). Estimates within this range and chiefly in the neighborhood of .30 have been reported by Terrill and Hazel (82, p.358), Hazel and Terrill (34, pp.347-358), (38, pp.370-377), Karam, Chapman and Pope (46, pp.148-164) and Morley cited by Karam, et al. (46, pp.148-164). Likewise, heritability estimates of 0, .12 and .30 have been cited for calf weaning weights by Knapp and Nordskog (48, pp.62-70). Hazel and Terrill (38, pp.370-377) reported heritability estimates of .32 for Corriedale, .16 for Columbia and .08 for Targhee lambs indicating a difference between breeds in the extent to which environment and heredity influence weaning weights. Blunn (5, pp.306-310) indicated that 14.2 percent of the total variation exhibited by Navajo lambs was due to year differences while among Navajo crossbred lambs it was 37.4 percent, hence pointing out differences in environmental adaptability. His data indicated a breed-year interaction which further showed a difference in breed response to environment. Neale (62, 26p.) working with range lambs in New Mexico again found breed-year interactions. He declared that Hampshire-cross lamb weights varied directly with feed conditions and to a greater extent than did Rambouillet lamb weights.

Generally speaking, the reported estimates of the heritability of condition score within breeds have been low. They do show, however, that differences do exist between breeds in their inherent ability to fatten. Hazel and Terrill (36, pp.55-61) found the heritability of condition score to be .04 for Rambouillet lambs under Idaho range conditions, and they (38, pp.370-377) reported estimates of .13, .31 and .34 for Columbia, Targhee and Corriedale lambs, in that order.

Breed Comparisons in Lamb Production

The literature reveals a promiscuous array of sheep-cross comparisons. Each of these was devoted to testing sheep under specific environmental conditions. Generalizations regarding the producing abilities of various breeds can be made on the basis of these comparisons.

The superiority of crossbreeding for lamb production was reported by Miller and Dailey (60, pp.462-468) of

Minnesota. In a comparison of purebred Columbia, Hampshire and Shropshire ewes and all possible crosses of these breeds there was a 19-percent increase in lamb per hundredweight of ewe in favor of the crossbreds. The crossbreds also scored higher in condition. These authors suggested that the increase in weight of lamb per ewe was due to heterosis in lambing percentage and lamb survival. Carter and Henning (14, p.1023) were unable to demonstrate heterosis in birth weights, however.

Rambouillet ewes, when used in crossing, produced 27 percent more pounds of lamb at 140 days than did straightbred Shropshire ewes mated to Shropshire rams according to Miller and Dailey (60, pp.462-468). Greatest production from Rambouillet ewes was realized from Border Leicester sires, followed by the Columbia, Oxford and Hampshire breeds which exceeded the Shropshire sires by 20 percent. Cheviot sired lambs were small at weaning, but were easy to raise, had good livability, and were well finished.

Miller (59, 32p.) used rams of six breeds on Rambouillet ewes. Suffolk sired lambs were heaviest at weaning, followed by Hampshire and Shropshire, in that order, then Romney, Rambouillet and Southdown were equal. Nevertheless, the Southdown rams sired the fattest lambs, while Romney and Rambouillet sires had the least percentage of marketable lambs. Lambs from Romney x Rambouillet ewes were inferior both in weight and condition to those from straight-run Rambouillet ewes. Neale (62, 26p.) observed Romney-cross lambs to be very slow maturing, particularly under relatively adverse forage conditions. Romney sires produced 15.4 pounds less lamb per ewe bred than did Columbia sires, Grandstaff (24, p.478) attested.

In Kentucky, Hampshire ewes produced lambs which gained rapidly and were ready for market at an earlier age than any others. Cheviot lambs grew more rapidly than the Southdowns and produced a good quality carcass. The Cheviot ewes were hardy and were good mothers (41, 60p.).

According to Bonsma (7, p.29), in South Africa, the highest quality lamb was produced from Border Leicester-Merino x Southdown cross. The Border Leicester-Merino ewe possessed greater size, hybrid vigor, higher fertility and superior milking qualities especially when compared to the Merino ewe. The Southdown rams were capable of siring lambs which were fat at four to five months of age.

As a concluding statement, Neale (62, 26p.) asserted that in order to obtain advantage in feeder lamb weights it was necessary to use rams which were larger than the ewes. Such a case would be more applicable to range conditions in the production of feeder lambs; still, with maturing qualities being considered the contention may well apply to spring lamb production.

Nelson, et al. (63, 4p.) found that under Willamette Valley conditions, Hampshire rams sired lambs which were fat and heavy, Border Leicester sired lambs were large but only moderately fat, Cheviot-cross lambs excelled in finish but were of light weight, while those sired by Romney were lacking in finish though of adequate weight. From another trial, they reported the greatest lambing percentage and survival from Southdown sires with Romney sires producing the smallest lambing percent, having the lowest survival and the least percentage of fat lambs.

Concerning the Suffolk ram as a sheep for crossbreeding, Hammond (29, 10p.) wrote that "the Suffolk breed is unique for it combines early maturity, good milking qualities and high fertility to a marked degree." Burns and Johnston (10, 28p.) observed higher birth and weaning weights, greater survival and a greater percentage of marketable lambs sired by Suffolks than by Hampshire rams.

The excellence of Southdown rams as getters of quality lambs has been acknowledged by Sutton, Thomas and Davenport (79, pp.355-371), McLeroy (61, p.19), Stark (77, p.553), Hultz, Gorman and Wheeler (42, 20p.), Branaman (8, pp.473-486) and Nelson, et al. (63, 4p.). Branaman (8, pp.473-486) stated that "Southdown lambs of choice market finish give higher yields of dressed carcass, boneless meat and separable lean than Hampshires in similar finish and thus are worth a higher price as live lambs, in the carcass and in retail trade." Southdown-cross lambs had the highest appraised value per hundredweight of any of the breeds compared by Hultz, Gorman and Wheeler (42, 20p.).

Relation of Birth Weight, Survival, Weaning Weight and Subsequent Growth

Bonsma (7, p.78) found that crossbred lambs had a significant advantage in live weight at 12 and 18 weeks when compared with straight-bred Merinos. He found no difference in relative growth but that the crossbred lambs maintained the advantage in weight established at time of birth. On the basis of equal birth weights no breed differences were established. Donald and McLean (22, pp.497-519) reported a correlation of .495 between birth weight and 70-day weight; still, they found a difference in correlation of birth and weaning weights of .7 and .4 for English Leicester and Southdown lambs, respectively, denoting different relative growth rates. It may have been that the measurements were taken when the Southdown lambs were maturing and the Leicesters merely growing. Cadmus (13, 20p.) found that each pound increase of birth weight above the mean will result in 2.5 to 3.5 pounds increase above the mean weight at 20 weeks depending on the breed. Phillips and Dawson (67, pp.296-306) noticed that each pound increase in birth weight was associated with 4.3 pounds increased weight at three months. Regarding factors which affect birth weight per se, Hammond (30, p.95) asserted that the size and strength of lambs at birth can be affected by the state of nutrition of the ewe during the second half of pregnancy. The work of Phillips (66, 19p.) demonstrated that 32 percent of the lambs which weighed under 6 pounds at birth die soon after, and that single and twin lambs of the same size at birth have an equal chance for survival.

Dawson, Phillips and Black (20, pp.247-257) working with beef cattle found correlations of -.58 between birth weight and age at 500 pounds, and -.62 between birth weight and age at 900 pounds. Dahmen and Bogart (19, 23p.) found that 18% of the variation in economy of gains in beef calves was due to birth weight variations, and that the correlation of birth weight and economy of gains was .42. Bonsma (7, p.93) reported a correlation of .408 between birth and 12-week weights of lambs. Hammond and Appleton (27, p.81) found a .52 correlation of 20-week weight with 1-week weight of lambs, and a higher correlation still of weight at 61 weeks with weight at 20 weeks. High correlations of weights early in life on subsequent weights also have been reported in sheep by Henning and Kean (40, p.513), Terrill (80, pp.333-340) and Phillips (66, 19p.); in cattle by Knapp and Clark (49, pp.174-181) and Koger and Knox (52, 760-767). Krider and his associates (53, pp.3-15) working with pigs in Illinois found that the heritability of weight increased from 5 percent at birth to 24 percent at weaning.

Nelson and Ven Katachalam (64, pp.607-608) found the heritability of lamb birth weight to be .33. Chapman and Lush (16, pp.473-478) reported that 25 to 30 percent of the variance in birth weight was genetic. Estimates for birth weight heritability in beef cattle have been found to be .22 by Burris and Blunn (11, pp.34-41); .23, .42 and .34 by Knapp and Nordskog (48, pp.62-70); and .45 and 1.0 by Gregory, Blunn and Baker (26, pp.338-345). It seems unreasonable that birth weight should be 100 percent heritable as stated by the latter author since so many sources of variation could exert an outward influence on birth weight.

Lush, Hetzer and Culbertson (57, pp.329-343) claimed that 7.0 percent of the birth weight variance among pigs was due to sires. This was in accord with Kincaid (47, pp.152-156) who reported that 7.8 percent of lamb birth weight variation was due to breed of sire. Bonsma (7, p.48) attested that genetically, the birth weight of lambs as influenced by sire is determined by its hereditary size and earliness of maturity.

Relation of Weight of Dam to Production

Donald and McLean (22, pp.497-519) found that heavy ewes produce heavy lambs. Bonsma (7, p.48) stated that 24 percent of the variation in birth weight of lambs was due to variation in ewe weight. Hammond (27, p.53) supports this contention by writing that the dam has more influence in controlling size at birth than does the ram. Bonsma (7, p.72) further extended that 25 percent of the variation in milk yield of ewes within breeds is due to body weight differences. He reported a correlation of .317 between total milk yield and birth weight of lambs. In summary he stated that "improved efficiency of food utilization by individual ewes resulted in higher intra-uterine nutrition and heavier lambs at birth, and no doubt in improved development of mammary gland tissue. The association is a result of the same physiological functioning responsible for feed utilization efficiency whether before or after birth of lambs."

Terrill and Stoehr (81, pp.221-228), of the United States Sheep Breeding Experiment Station, asserted that, within breeds, ewes heavier as yearlings on the average weaned more pounds of lamb per ewe during their life-time regardless of breed. Sidwell (75, p.515) reported a repeatability of 21.7 percent for lamb production of

Navajo ewes. Koch (50, pp.768-775) working with Montana beef cattle data found a repeatability of 52 percent for weaning weights of calves from range cows. Perhaps Bonsma's feed efficiency-production efficiency hypothesis may be a permanent phenomenon.

Relation of Age of Dam to Production

Kincaid (47, p.152-156) found an increase of .63 of a pound in birth weight of lamb for each increase of one year in age of ewe. He observed the increase to be a linear one as did Burris and Blunn (11, pp.34-41) in beef cattle. Bonsma likewise found an increase of .62 of a pound in birth weight of a ewe's second lamb over that of her first, however he found no significance among subsequent lambs. Differences in weights and condition scores of lambs produced by mature ewes and young ewes are reported, also, by Nelson and Ven Katachalam (64, pp.607-608); Sidwell, Price and Grandstaff (76, pp.455-461); Hazel (35, pp.21-25); and Hazel and Terrill (33, pp.331-341), (34, pp.347-358), (36, pp.55-61) and (37, pp.318-325). In all cases there was a distinct advantage in favor of mature ewes. Koch (50, pp.768-775) declares that age of dam affects calf weaning weights through changes in udder development, milking ability and ability of the dam to withstand the rigors of environment. Bonsma (7, p.70) again agrees with these findings. His data showed a significant difference between the first and second lactations in ewes, and that there was a gradual increase in successive lactations up to the fifth. Ewes in their fifth lactation produced 83.5 percent more milk than they did in their first.

Birth Type as an Environmental Factor

Numerous workers have shown that type of birth (twins vs. singles) and rearing have a tremendous effect on growth rates of lambs. Range sheepmen generally run twins in bands separate from singles and afford them the better pastures. Stark (77, p.553) found that lambs born as singles are 20 percent heavier than twins. Hammond (27, p.27) similarly reported a 29-percent difference, and Nelson and Ven Katachalam (64, pp.607-608) 22-percent difference between weights of singles and twins. Price, Sidwell and Grandstaff (72, p.1029) found that type of birth influenced weanling traits more than did any of the other environmental factors studied. Differences in favor of lambs born as singles are cited as 6.2 pounds at 25 weeks by Karam, Chapman and Pope (45, p.606) under Wisconsin conditions; 13.4 by Hazel (35, pp.21-25); 6 pounds and 11 pounds by Hazel and Terrill (39, pp.382-388) and (37, pp.318-325), respectively. Phillips and Dawson (68, 18p.) showed differences due to birth type even when weaning weights were adjusted for birth weights, indicating that the lambs were not getting enough milk even though ewes nursing twins milk heavier than those with singles as was indicated by Wallace (86, p.112).

Price, et al. (71, pp.272-277) denoted that 14.3 percent of the total variation among lamb condition scores was accounted for by birth type. Sidwell, Price and Grandstaff (76, pp.455-461) declared that singles scored higher than twins. Hazel and Terrill (33, pp.331-341), also, reported a definite advantage in condition score for singles. Hammond (30, pp.95-108) claimed that whereas singles attain their maximum growth rate during their first week, it is the fifth week before twins can supplement their milk diet enough to grow maximally.

Sex as an Environmental Factor

The differences in maturity and growth rate which exist between the sexes impart an important environmental influence on the growth of animals and its evaluation. Dahmen and Bogart (19, 23p.) demonstrated that there are sex differences in rates and economy of gains in young beef animals. Bulls gained 2.3 pounds per day and heifers 2.0 pounds per day during test. Burris and Bogart (12, 6p.) were able to show differences in the thyrotropic hormone content of the anterior pituitary glands of heifers and steers, and that heifers and steers injected with testosterone gained more rapidly and efficiently than controls. Differences in weaning weights of beef calves in favor of the males are reported by Koger and Knox (51, pp.15-19) and Koch (50, pp.768-775), and in birth weights between sexes by Burris and Blunn (11, pp.34-41) and Dawson, Phillips and Black (20, pp.247-257), again the bulls being heavier. Karam, Chapman and Pope (45, p.606) of Wisconsin asserted that wethers were 3.5 pounds heavier than ewe lambs at 25 weeks. Ram lambs were 8.3, 10.8 and 13.4 pounds heavier at weaning than ewe lambs according to Hazel and Terrill (33, pp.331-341), (37, pp.318-325) and Hazel (35, pp.21-25), in that order. Sex differences at weaning were significant even when corrected for birth weights according to Phillips and Dawson (68, 18p.).

Hammond (27, p.50) presented evidence that ewes are earlier maturing than wethers. He continues (p.110), however, that rams dress a higher percentage than ewes. Females are fatter than males at the same weight according to Verges (85, 11p.). At the Doubois station (37, pp.318-325) and also under Wisconsin conditions as observed by Karam and his associates (45, p.606) ewe lambs scored higher in condition than did ram lambs.

<u>Importance of Milk Production</u>

Of all the factors affecting the growth rate of lambs, Hammond (30, p.96) claims that the milk supply of the ewe is the most important. Bonsma (7, p.96) asserted that a high level of milk secretion during the first few weeks after lambing is of greater importance than persistancy in milk secretion. Gains are more highly correlated with milk yield during the first 45 days of lactation than later. He noticed a 50-percent difference in weight increase in lambs from high versus low milk-producing dams. Wallace (86, p.153), working with ewes of similar breeding and similar ages in an extremely well controlled experiment observed 96 percent of the variation in gains from birth of lambs to 112 days of age to be due to differences in consumption of milk and supplemental feed. Bonsma (7, p.65) summarized that individual selection for high milk production is more important than choice of breed.

MATERIALS AND METHODS

Description of Data and Purpose for the Study

The data employed in this study were taken from the files of the Oregon State College Sheep Improvement Program. The study embodies two year's observations of crossing breeds of sheep in an attempt to seek out adaptable breeds and breed crosses which have the inherent ability of producing lamb and wool in the commercial hill pasture areas of Western Oregon. It is based on 224 matings and the resulting 280 lambs.

A major part of the commercial (non-purebred) sheep, which comprise at least 90 percent of Western Oregon sheep, produce a very light clip of wool and an unsatisfactory percentage of slaughter lambs when compared to commercial flocks in the range areas of Eastern Oregon. Johnson and Nelson (44, 10p.) stated that a production increase of 2 pounds of wool and 10 pounds of lamb per head in this area is not beyond the realm of possibility.

The climate of the Willamette valley where these trials were conducted may be described as a mild subcoastal type with moist, open winters, an early growing season and a dry harvest season. The ecological conditions of Western Oregon are basically similar to the commercial hill lands of the British Isles. Grass generally commences to grow in early March and begins to dry and mature in late June or early July, by which time it is desirable to have the lambs marketed grass fat. The pasture composition and weather conditions were thoroughly described by McLeroy (61, pp.5-7) and Livingston (56, pp. 13-30). In the quest for breeds to involve in these extended studies of sheep ecology, sheep research men from other areas of the United States and from the British Isles were asked to view the existing conditions. They advised that "arable land" sheep of the mutton breeds be included but also that at least two and preferably three of the "hill type" sheep breeds used commercially in the British Isles be used in the study (44, 10p.).

A basic flock of 120 Lincoln x Rambouillet ewes was available at the time of inception of the project in 1946. They had been retained on the basis of thrift, lamb and wool production and body conformation. These ewes were divided into four groups, a group to be bred to good rams of each of the Romney, Border Leicester, Cheviot and Hampshire breeds. The Romney represented a more popular breed of sheep in Western Oregon, the Border Leicester a long-wool hill breed, the Cheviot a medium-wool hill breed, and the Hampshire a mutton breed. The limitation of money and space prolonged the development of ewe-breed crosses and hence the objective of the project over a seven year period.

The original cross from the Lincoln x Rambouillet ewe and by each of the ram breeds derived what will be termed the First-cross ewes. The breeding of these ewes was 25% Lincoln, 25% Rambouillet and 50% of which ever ram breed (Hampshire, Border Leicester, Cheviot or Romney) was their sire. A representative First-cross ewe of each of the four breeds is shown in Figure 1. These First-cross ewes were then backcrossed to rams of their respective sire breed to derive the Second-cross ewes. A representative ewe of each of the Second-cross breed groups is shown in Figure 2. These ewes in turn were 75% of which ever breed of sire, 12½% Lincoln and 12½% Rambouillet. The period from 1946 through 1950 was devoted to developing these crosses. It was originally intended to compare the producing abilities of the First and Second-cross ewes, however, a two year age difference developed between them which could have ended in misinterpretation of results (21, p.11), thus they are not compared in this thesis. A comparison of the four ram breeds as sires of spring lambs was summarized by Nelson et al. (63, 4p.).

The First and Second-cross ewes were outcrossed during the fall of 1951 and that of 1952 to Suffolk and Southdown rams to determine the relative value of such crosses for commercial lamb production. The rams which sired the 1953 lamb crop are shown in Figure 3. The ewes were allotted by use of random numbers tables to each of two rams of the Suffolk and Southdown breeds by ages and by crosses. Different rams were used in consecutive years so that the results might reflect a more accurate picture of the ram breed merit.

The experiment was originally designed as a 2x4x4 factorial experiment, however the imposition of multiple births and sexes as variables deemed necessary the use of a least squares method of fitting constants (1, pp.190-203 and 278-284). This method is desirable for application of analysis of variance to data where multiple classification with unequal numbers in the different subclasses is encountered. The method consists in fitting constants for each of the independent variables which in this case are the measurable environmental factors, the different breeding groups and their interactions. It is unique in that discontinuous variables are expressed as deviations from a mean while continuous variables are expressed as regressions representing the average change in the dependent variate for each unit of change in each of the independent variables.

Because of the forementioned confounding of ages and crosses, and because of having used different rams in consecutive years, the analyses were conducted within ages

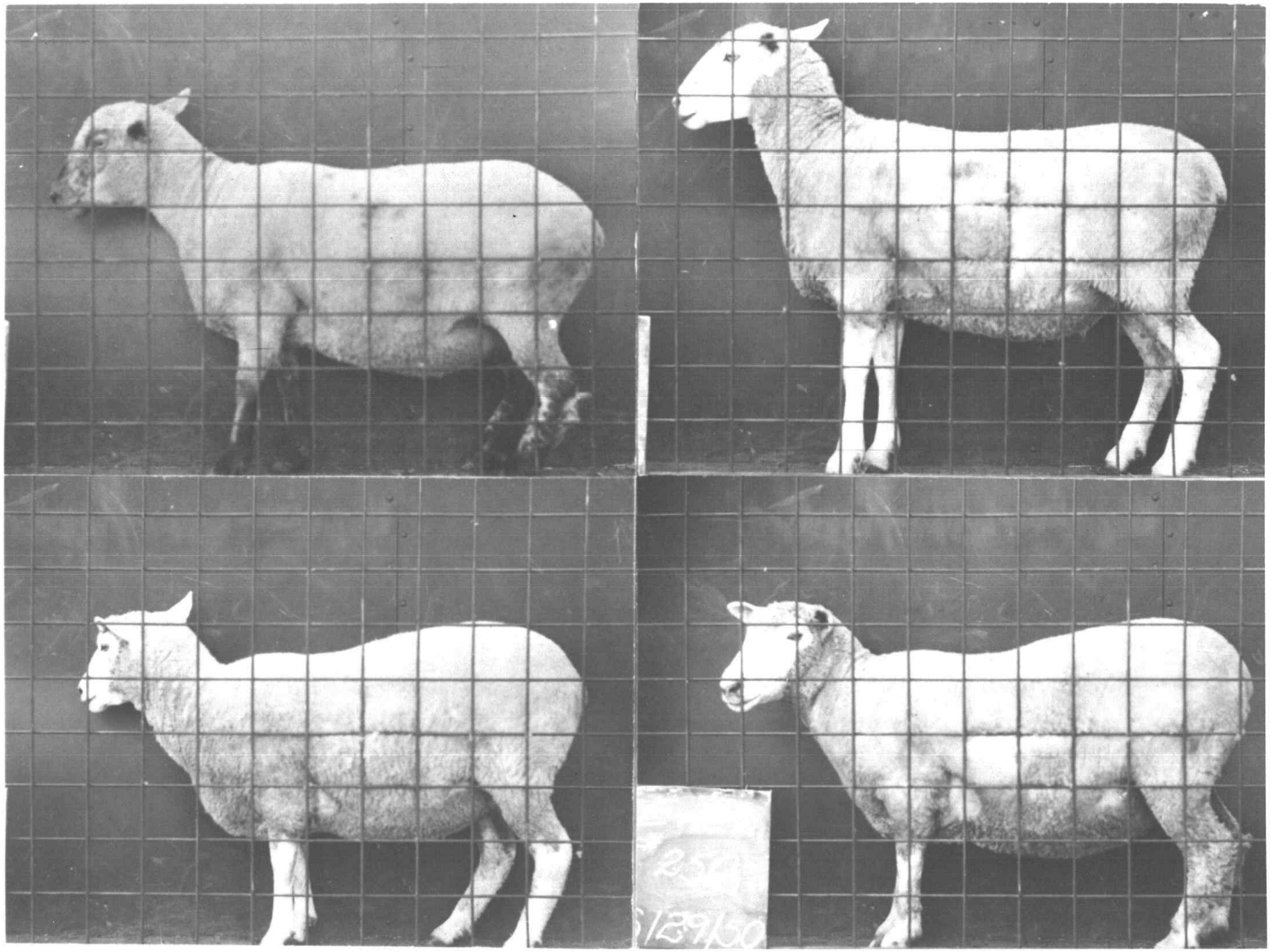


FIGURE 1 Representative Ewes of First Cross Hampshire (upper left), Border Leicester (upper right), Cheviot (lower left) and Romney (lower right) Breeding

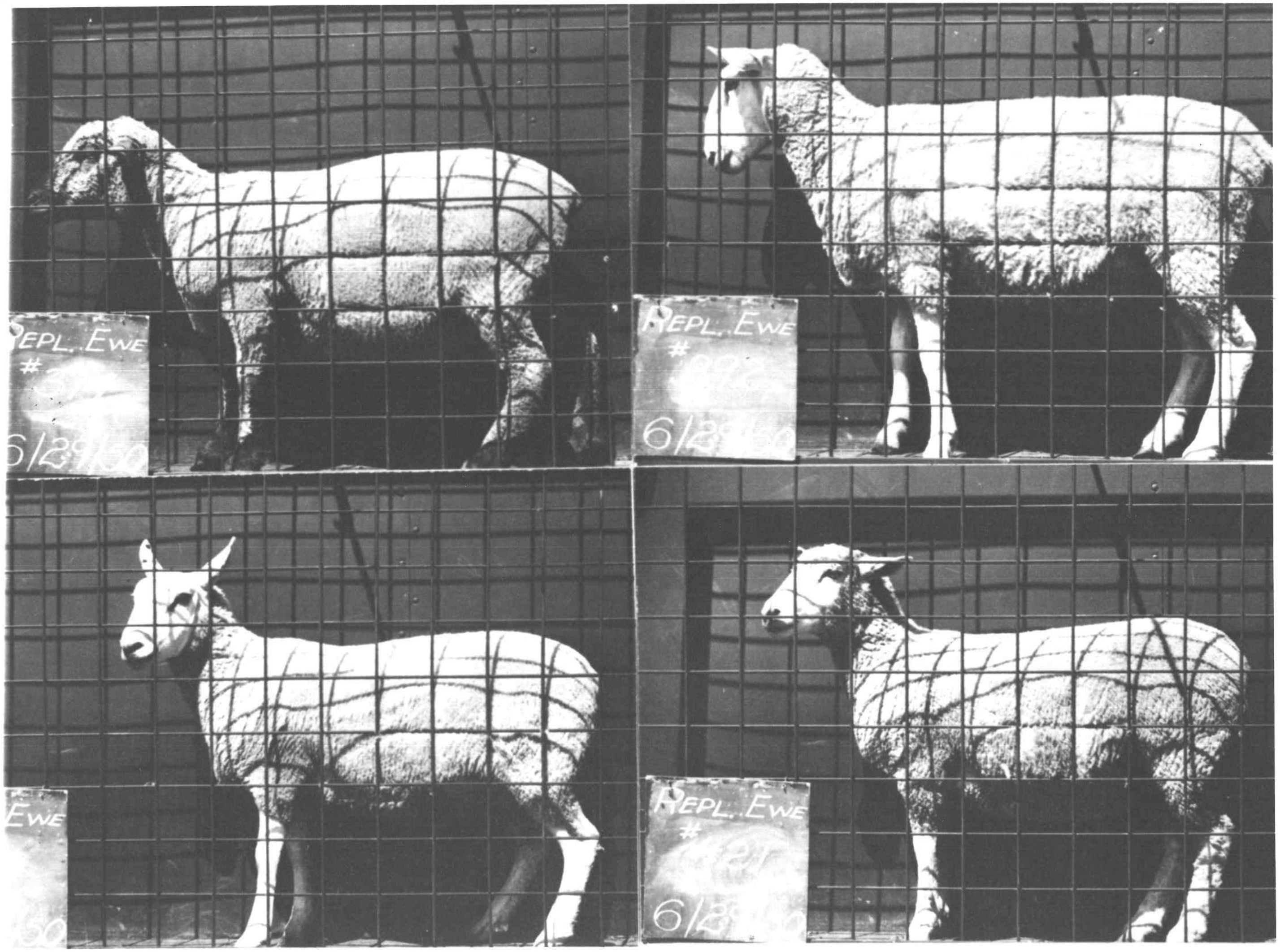


FIGURE 2 Representative Ewes of Second Cross Hampshire (upper left), Border Leicester (upper right), Cheviot (lower left) and Romney (lower right) Breeding

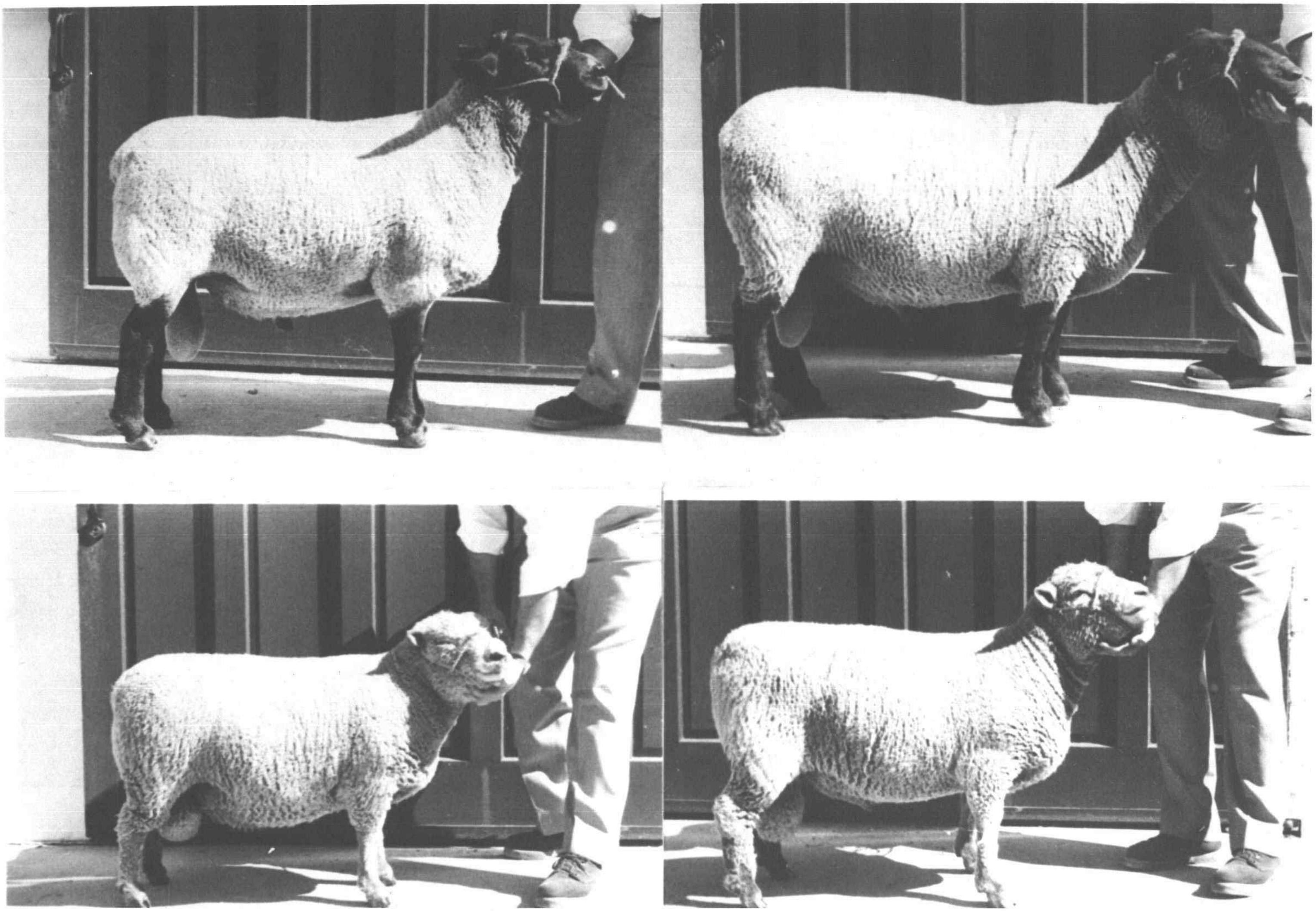


FIGURE 3 Representative Rams of the Suffolk (above) the Southdown (below) Breeds. These Are the Rams which Sired the 1953 Lambs

and within years. Differences between rams within breeds were not measured. Wherever possible, use has been made of graphs for elucidating the results obtained.

Management of the Experimental Flock

All the ewes were subject to the same nutritional and climatic conditions. They were run together at all times save during a short period during the latter part of the lambing season when ewes with older lambs were moved to pasture to alleviate barn space. The feeding and climatic conditions were considered random and free from bias, thus the differences exhibited by these sheep were differences due to breed, to individual ewe productivity and to such environmental factors as sex, type of birth and age.

The experimental year began on September 10 in both years with the beginning of the breeding season. The ewes had been flushed with one-third of a pound of an oats-barley mix prior to breeding and were fed thus during the breeding season. During the breeding season of 1951, pen breeding was practised. The ewes were allowed to pasture during the day and were turned in to their respective rams each evening. The Suffolk rams required 1.13 estrous periods per conception, while one Southdown ram though a proven sire failed to breed and the other required 2.3 estrous periods per conception. The latter Southdown was left with the flock 15 days longer than the Suffolks. The 40-day breeding season did not allow time to obtain another ram for valid comparison after the sterility of the one ram was confirmed. The ewes allotted to this ram were excluded from the experiment during that year's comparison.

During the breeding season of 1952, vasectomized rams were employed to observe ewes in heat and "controlled or hand" mating was practised. This provided an accurate observation of breeding behavior of the rams. The conception rate was similar and likewise the lambing dates of ewes bred to both breeds, however, generally speaking the Southdowns were slower breeders.

The ewes were tagged, or crutched, about six weeks prior to the beginning of lambing and were given grain and hay beginning about a month before the first lamb was expected. Feeding, thus, was continued until March 1 to March 15. In all, each ewe received from 30 to 45 pounds of the oat-barley mix and 225 pounds of hay per year in addition to natural pasture. A phenothiazine-salt mixture was available to the ewes at all times to minimize internal parasites.

Each ewe had a flock number and was identified by a metal tag in each ear. As soon as a ewe was observed to have lambed, the lamb was also ear-tagged, and its birth weight recorded to the nearest one-tenth of a pound.

Docking and castration of male lambs was then done with rubber rings, and the umbilical cord was disinfected. The ewe and her lamb(s) were confined to a 3 x 4 enclosure to "mother up" for a period of 12 to 36 hours depending on the strength of the lamb. Assistance was given in all cases of dystocia.

As soon as the lambs were deemed strong enough they were moved to pasture. The flock was rotated from pasture to pasture in such a manner that the lambs and ewes were on the most luxurient pastures at all times. During the growing season of 1952, the lambs were weighed on the portable scales described by McLeroy (61, p.47) each time they were moved from a pasture and at weaning. In 1953, the lambs were weighed as rapidly as possible each Saturday morning to obtain growth rates by weeks. It was felt that no deleterious effect was imposed on the lambs as they were weighed quickly and quietly. Rain disrupted the weighing schedule one Saturday during the latter weeks and consequently dissipated the data to be used in plotting growth curves past the thirteenth week.

The lambs were weaned as they reached top condition and/or heavy market weights. They were moved out in three groups at weekly intervals beginning June 1. A committee of three judges placed scores for condition and conformation on each lamb. Weaning weights were taken immediately prior to moving the lambs to market. Carcass grading was done by a Federal grader.

ANALYSIS AND RESULTS

The income from the lambs marketed from the experimental flock was found to comprise 86 percent of the total income as contrasted with 14 percent from wool. The analysis, therefore, concerns itself only with factors important to the production of lamb. The analysis of potential differences in growth rates was conducted on lambs alive at weaning with no regard for mortality within subgroups which may have occurred prior to weaning. Hence, the study is one of differences in relative growth, fatness and birth weight of lambs and of the effect of some environmental factors on these production characteristics.

The least squares method of estimation was used in the analysis of the data. Each observation for weaning weight, condition score and birth weight was assumed to be the sum of the influences or effects of the identifiable variables as follows in an example for weaning weight:

Weaning Weight = general mean + sire breed effect + ewe breed effect + sire breed x ewe breed interaction effect + birth type effect + sex effect + birth type x sex interaction effect + effect peculiar to each lamb.

This linear combination of effects is referred to hereafter as the mathematical model.

The general mean of the mathematical model includes in its basis the fundamental likeness of the observations, due to the fact that all animals were of the same genus and species and were grown in the same general environment. Superimposed upon the general mean are other factors which are not alike for all lambs. Potential breed effects are perhaps due to differences in metabolic and physiological patterns and, hence, to differences in rates of maturity. Type of birth affects lamb growth perhaps through limitation of intrauterine food supply and through limitation of milk supply so vital to growth after birth. Lambs were classified as wethers or ewes to measure sex differences in this study. The effects peculiar to the individual lamb included such effects as individual ewe productivity and accidents or other environmental incidents not measurable for analysis.

Restrictions are imposed upon the mathematical model, in that the effects of lambs which are from Suffolk sires, Hampshire, Border Leicester or Cheviot-cross ewes, wethers, or born as singles are indicated by constants representing deviations from the general mean. The effect of the continuous variable represents the average change in the dependent variable for each unit of change of the independent continuous variable. Furthermore, no constants were obtained to measure the effect of lambs which are from Southdown sires, Romney-cross dams, twins or ewe since the general mean includes the estimate of the average Southdown, Romney-cross, twin, ewe lamb, irrespective of birth weight which is the only continuous independent variable in this analysis. The constants estimated represent deviations from the general mean which must be added to or subtracted from it (depending on their sign) to estimate a given value. For example, the most efficient, unbiased estimate of the weaning weight of a Southdown sired, Romney-cross, twin, ewe lamb with a 7.5 pound birth weight would be as follows:

Estimated Weaning Weight = general mean + 7.5 (regression coefficient of weaning weight on birth weight);

whereas, the most efficient estimate of the weaning weight of a Suffolk sired, Border Leicester-cross, single, wether lamb with a 9.0 pound birth weight would be:

Estimated Weaning Weight = general mean + constant for Suffolk + constant for Border Leicester + constant for Suffolk x Border Leicester interaction + constant for single + constant for wether + constant for single x wether interaction + 9.0 (regression coefficient of weaning weight on birth weight).

A test of significance for each of the constants necessitated obtaining the standard errors of the estimates: whereas a test of significance of the differences between ewe breeds entailed finding the differences between estimates and also the standard errors of the differences between estimates. An understanding of the mathematical model is imperative for understanding this analysis. The number of lambs weaned are listed in table 1 according to their various classifications.

Weaning Weight

Lambs from each of the ewe-breed crosses and sired by Suffolk or Southdown rams are shown in figures 4 and 5. These lambs represented the more outstanding lambs from each group rather than an average lamb.

The average age of the lambs at weaning was approximately 120 days. The lambs were dropped over a 40-day period and were not weaned at a constant age. Previous plotting of individual lamb weights indicated that under the existing environmental conditions the lamb growth was linear up to 135 days. The individual lamb weight was corrected to 120 days of age by use of the following equation:

$$C.\ W.^{1} = \frac{(\text{Actual weight} - \text{Birth weight})120}{\text{Actual age}} + \text{Birth weight}$$

1 Corrected weight

Estimates of the deviations, from the mean weaning weight of the mathematical model, of the breed groups and environmental effects ignoring birth weight are

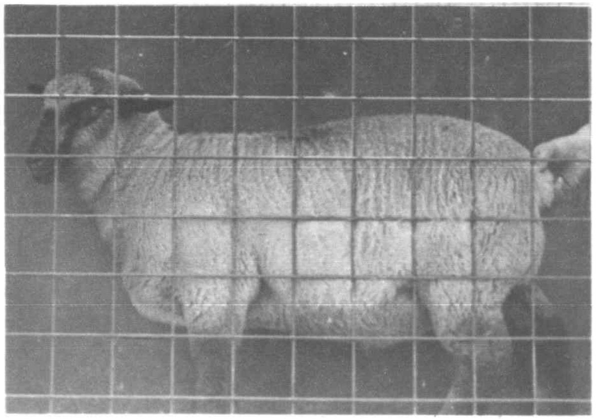
TABLE 1 Numbers of Lambs Weaned, Assembled According to Year, Breed and Top-cross of Ewe, Breed of Sire, Sex and Type of Birth

	Suffolk Sired	Southdown Sired	Wethers	Ewes	Twins	Singles
1952						
First Cross Ewes						
Hampshire	10	5	7	8	6	9
B. Leicester	11	6	8	9	10	7
Cheviot	10	7	9	8	8	9
Romney	10	7	6	11	10	7
Second Cross Ewes						
Hampshire	13	6	9	10	14	5
B. Leicester	10	3	4	9	6	7
Cheviot	10	4	5	9	4	10
Romney	9	2	4	7	2	9
1953						
First Cross Ewes						
Hampshire	12	12	11	13	17	7
B. Leicester	12	12	13	11	17	7
Cheviot	11	11	10	12	12	10
Romney	8	9	9	8	9	8
Second Cross Ewes						
Hampshire	10	9	5	14	10	9
B. Leicester	10	8	11	7	10	8
Cheviot	9	10	9	10	6	13
Romney	8	6	10	4	2	12

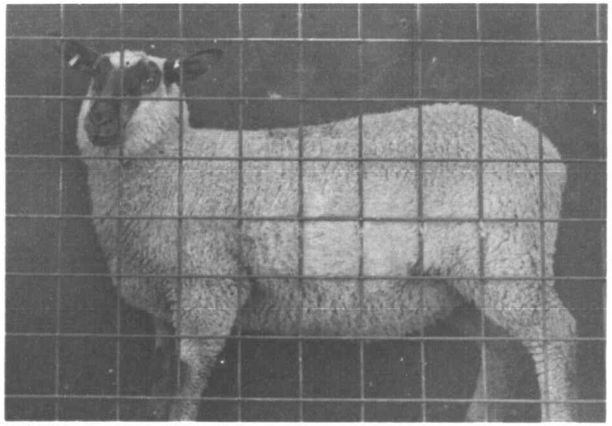
presented in table 2, and in table 3 with birth weight adjusted. The difference in weights between the Suffolk and Southdown sired lambs which was depicted in figure 6 was significant in one analysis of the four when birth weight was ignored and was significant within the second-cross ewe group when birth weights were adjusted. The overall tendency favored the Suffolk rams as sires of heavy lambs. This tendency was also apparent when the various breeds of ewe were mated to Suffolk sires. There was no difference in mortality of lambs nor lambing percentages of ewes bred to Suffolk rams from those bred to Southdowns. When a comparison was made of pounds of lamb marketed (uncorrected for age or other factors), the Suffolk-sired lambs averaged 15 pounds heavier than the Southdown-sired lambs. (figure 12, part 1)

The Hampshire and Border Leicester-cross ewes tended to produce somewhat faster growing lambs of the breeds compared (tables 2 and 3). The Hampshire crosses particularly produced faster growing lambs than did the Cheviot and Romney-cross ewes. There was no significant difference in the growth rates of Cheviot and Romney-cross lambs in any case.

The general tendency of the ewe breeds was to produce slightly heavier lambs at birth and weaning when mated to Suffolk rams. Nevertheless, these tendencies lacked

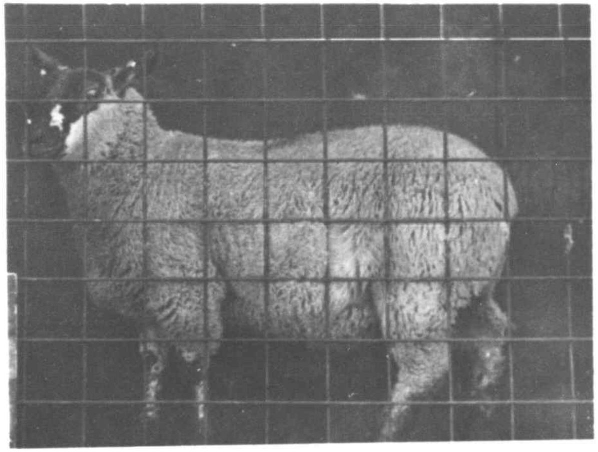


Hampshire-Cross



Border Leicester-Cross

Cheviot-Cross



Romney-Cross

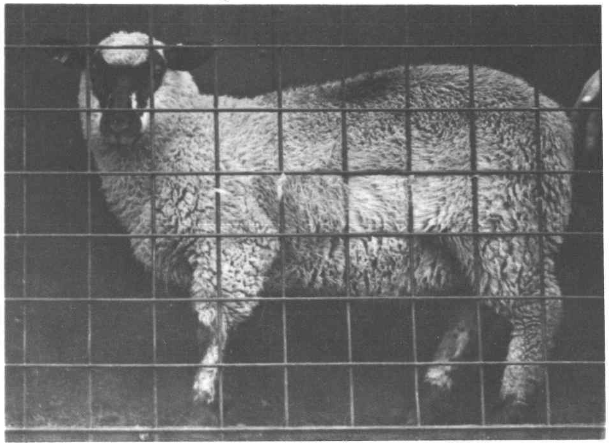
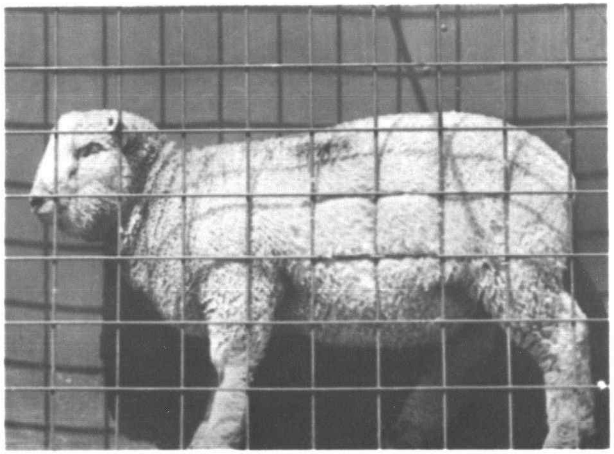
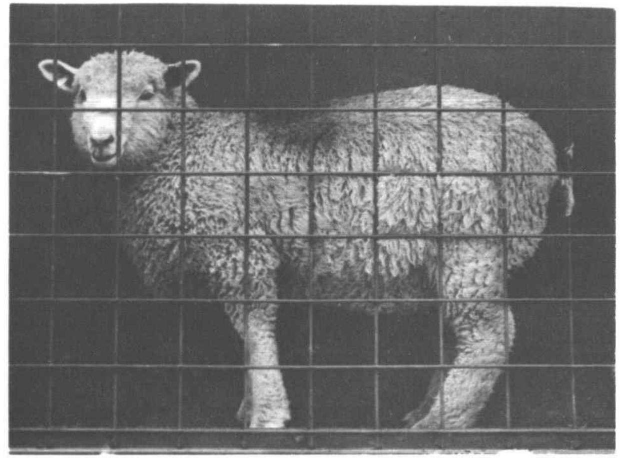


FIGURE 4 An Example of the More Outstanding Lambs from the Four Breed Crosses of Ewes Bred to Suffolk Rams

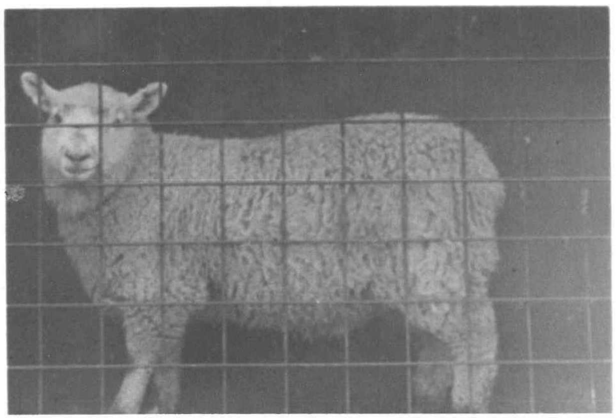


Hampshire-Cross



Border Leicester-Cross

Cheviot-Cross



Romney-Cross

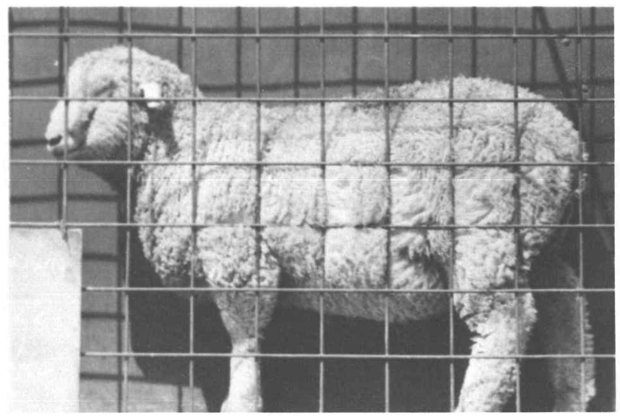


FIGURE 5 An Example of the More Outstanding Lambs from the Four Breed Crosses of Ewes Bred to Southdown Rams

TABLE 2 Summary of Analyses of Variance (1), Estimates (with other variables adjusted) of Deviations from the Mean Weaning Weight of the Mathematical Model Ignoring Birth Weight (2) and Differences Between Deviations, from the Mean, Among Ewe Breeds (3)

Source	1952				1953			
	First Cross		Second Cross		First Cross		Second Cross	
	Sum of Squares	Degrees of Freedom	Sum of Squares	Degrees of Freedom	Sum of Squares	Degrees of Freedom	Sum of Squares	Degrees of Freedom
(1)								
Total	17,311.	65	8,624.	56	12,101.	86	12,646.	69
Regression	10,670.	9	3,891.	9	7,710.	9	8,829.	9
Residual	6,642.	56	4,733.	47	4,391.	77	3,807.	60
R^2**	.61*		.45*		.64*		.70*	
(2)								
General Mean[2]	67.19*	± 4.90	65.11*	± 7.87	59.58*	± 2.84	46.74*	± 4.15
Suffolk	6.06	± 4.98	-1.88	± 7.88	2.69	± 3.55	12.53*	± 4.34
Hampshire	6.65	± 7.14	.98	± 8.56	6.52*	± 2.87	13.40*	± 4.49
B. Leicester	1.25	± 6.44	1.83	± 9.47	-.64	± 3.38	14.30*	± 4.48
Cheviot	4.09	± 5.45	-1.06	± 8.74	.38	± 3.40	.57	± 4.20
H[3]xS[4]	-.28	± 8.52	15.84	± 9.42	1.92	± 3.17	-5.51	± 5.79
BL[5]xS	3.47	± 7.73	9.67	± 10.58	8.62	± 4.85	-12.46*	± 5.74
C[6]xS	2.78	± 6.38	7.45	± 9.93	5.00	± 4.90	3.29	± 5.80
Singles	17.87*	± 4.52	15.70*	± 4.05	16.28*	± 2.44	17.83*	± 2.89
Wethers	-4.13	± 4.10	1.39	± 4.64	6.01*	± 2.06	4.93	± 3.29
Single Wethers	9.35	± 6.50	3.38	± 6.22	-1.38	± 3.38	3.04	± 4.16
(3)								
H minus BL	5.45	± 6.77	-.85	± 7.51	7.16*	± 2.52	0.90	± 4.04
H minus C	2.56	± 6.97	-.08	± 7.01	6.14*	± 2.61	12.83*	± 3.76
BL minus C	-2.84	± 6.42	-.77	± 8.19	1.02	± 3.20	13.73*	± 3.82
HxS minus BLxS	-3.75	± 8.47	6.17	± 9.13	-6.70*	± 2.49	6.95	± 5.34
HxS minus CxS	-3.06	± 8.24	8.39	± 7.97	-3.08	± 2.61	8.80	± 5.19
BLxS minus CxS	.69	± 7.85	2.22	± 9.58	3.62	± 4.51	-15.75*	± 5.34

* Significant at $P = 0.05$ ** Multiple correlation coefficient

2 Includes estimate for Southdown, Romney, twin, ewe lamb

3 Hampshire 4 Suffolk 5 Border Leicester 6 Cheviot

TABLE 3 Summary of Analyses of Variance (1), Estimates (with other variables adjusted) of Deviations from the Mean Weaning Weight of the Mathematical Model Adjusted for Birth Weight (2) and Differences Between Deviations, from the Mean, Among Ewe Breeds (3)

Source	1952				1953			
	First Cross		Second Cross		First Cross		Second Cross	
	Sum of Squares	Degrees of Freedom	Sum of Squares	Degrees of Freedom	Sum of Squares	Degrees of Freedom	Sum of Squares	Degrees of Freedom
(1)								
Total	17,311.	65	8,624.	57	12,101.	86	12,646.	69
Regression	11,788.	10	6,628.	11	8,428.	10	9,912.	10
Residual	100.	55	1,996.	46	3,673.	76	2,735.	59
R^2**	.68*		.77*		.70*		.78*	
(2)								
General Mean[2]	44.17*	± 7.96	9.02	± 8.85	40.20*	± 6.08	23.03*	± 6.02
Suffolk	-3.50	± 5.31	13.61*	± 5.54	-1.16	± 3.39	11.33*	± 3.72
Hampshire	-1.57	± 6.97	11.88*	± 5.79	2.11	± 3.11	12.83*	± 3.82
B. Leicester	-6.15	± 5.54	.76	± 6.22	-1.61	± 3.13	9.89*	± 3.93
Cheviot	-1.80	± 5.27	6.90	± 5.83	1.47	± 3.14	3.74	± 3.65
H[3]xS[4]	8.57	± 8.23	-5.42	± 6.76	12.28*	± 4.51	-5.64	± 4.95
BL[5]xS	8.22	± 7.23	.25	± 7.05	6.38	± 4.49	-10.46*	± 4.92
C[6]xS	10.02	± 6.22	-5.91	± 6.74	1.05	± 4.54	-.32	± 5.01
Singles	8.79	± 4.89	1.68	± 3.21	11.43*	± 2.57	11.96*	± 2.75
Wethers	-7.07	± 3.86	-2.59	± 3.09	3.83	± 1.99	2.36	± 2.86
Single Wethers	8.53	± 5.98	6.41	± 4.10	.57	± 3.16	2.89	± 3.56
Birth Weight	3.71*	± 1.05	5.96*	± .76	2.50*	± .65	3.05*	± .63
(3)								
H minus BL	4.58	± 6.24	11.12*	± 5.16	3.72	± 2.89	2.94	± 3.54
H minus C	.23	± 6.45	4.98	± 4.61	.64	± 2.93	9.09*	± 3.31
BL minus C	4.35	± 5.99	-6.14	± 5.50	3.08	± 2.99	6.15	± 3.61
HxS minus BLxS	.35	± 7.89	5.67	± 6.18	5.45	± 4.06	4.82	± 4.58
HxS minus CxS	-1.45	± 7.59	-.49	± 5.33	11.23*	± 4.10	-5.32	± 4.49
BLxS minus CxS	1.80	± 7.26	-5.66	± 6.31	5.78	± 4.15	-10.14*	± 4.71

* Significant at P = 0.05 ** Multiple correlation coefficient
2 ibid. 3 ibid. 4 ibid. 5 ibid. 6 ibid.

significance. One would expect little difference in the relative growth rates of lambs from the various ewe breeds after seeing their similarity in figure 7. This method of evaluation points out the merit of the average lamb of the breed rather than the breed merit since no account is made for lambing percentage, mortality, nor production per hundred weight of ewe. The growth rates of lamb based on pounds of lamb per ewe bred are shown in figure 8 for the various breeds of ewe. This graph takes into account differences in lambing percentage between breeds and if converted to dollars and cents would depict the relative differences in return per ewe. In figure 10 the lambing percentages and mortality percentages are shown. The lambing percentage was based on the ratio of lambs born to the number of ewes bred while mortality was figured on the percentage of total lamb drop. It is suggested that differences do exist between the breed crosses of ewe when lambing percentage and mortality are taken into consideration, which do not show when the measurement of production is made solely on the average live lamb. The pounds of marketable lamb produced by the various ewe breeds are shown in figure 11. These figures represent the actual pounds which would be marketed as returns to the producer. Death losses had been eliminated and lambing percentages were adequately accounted for prior to the lamb's reaching this point. The Hampshire-cross ewes produced the greatest number of pounds of lamb per ewe and the Romney-crosses produced the least of the breed crosses compared.

Perhaps the most efficient way of measuring differences in producing abilities of ewes would be on the basis of pounds of lamb produced per hundred-weight of ewe. This method would interpret production relative to units of cost. It would perhaps provide the most accurate measure of heterosis. Assuming that ewes consume feed in proportion to body weight or to a fractional power of body weight, the ewes which produced the most pounds of lamb per hundred weight (of ewe) would yield the greatest return per unit of cost. The production per hundred-weight of ewe from the various breed crosses is shown in figure 9. Not only are lambing percentages considered in these figures, but also efficiency of production is taken into account. The Cheviot-cross ewes out-produced all other breed-crosses, followed by Hampshire, Border Leicester, and Romney-cross when their production was measured as a ratio of their weight. A big portion of the difference between the breeds lies in differences in fecundity and lamb survival, however, the fact that the small Cheviot-cross ewe produced lambs comparable in size to those of the other breeds, in spite of her small size, indicates that her producing efficiency is superior.

Birth weight was the most influential of all the genetic variables affecting weaning weight which were studied. The regression of weaning weight on birth weight was, in all cases, high and significant. The range of increase in weaning weight varied from 2.50 ± .65 pounds to 5.96 ± .76 pounds for every pound of increase in birth weight. The lack of significance in relative growth rate of lambs of the various breeds, together with the inconsistency in the differences from one group to another and the effect which birth weight had on the breed constants indicate that the differences between breeds in weight at weaning are largely accounted for by differences in birth weights. The lambs were grouped according to birth weight, disregarding breed of ewe, sex, or type of birth for plotting figure 13. The effect of birth weight on subsequent weights is quite clearly illustrated. In no case was there an overlap in the weight increase of lambs of a given birth weight and those of another. There was no difference in relative growth of lambs of different birth weights. The advantage enjoyed by the lambs which were larger at weaning was one established at birth. The importance of birth weight on subsequent weights suggests that in order to get large lambs at weaning, the choice of breed may not be as important as the ability of the individuals within breeds to produce lambs which are large (within limits) at birth. The importance of birth weight was sufficient to eliminate the significance of the general mean in one instance (table 3).

Lambs born as singles weighed, on the average, 17 pounds more at weaning than did those born as twins. Birth type imparts the greatest barrier on growth of any of the measurable environmental factors studied. The comparative growth rates of lambs born as singles and as twins are illustrated in figure 14. The difference between singles and twins was significant in all cases when birth weight was ignored. Single lambs were heavier than twins in 1953 even when adjustments were made for differences in birth weights. When adjustment for birth weight was made on the 1952 data the difference between singles and twins was eliminated. The growing season of 1952 was more favorable for lamb growth than was that of 1953 as can be noted in the general mean of the two years (table 2). A large portion of the variation in weights between single and twin lambs is established at birth, denoting a limitation of intra-uterine food supply in the case of twins. Nevertheless, these data justify the opinion that in a year of good forage conditions a ewe can more adequately satisfy her maintenance requirements, produce a greater milk supply and do a better job of rearing twins than in a

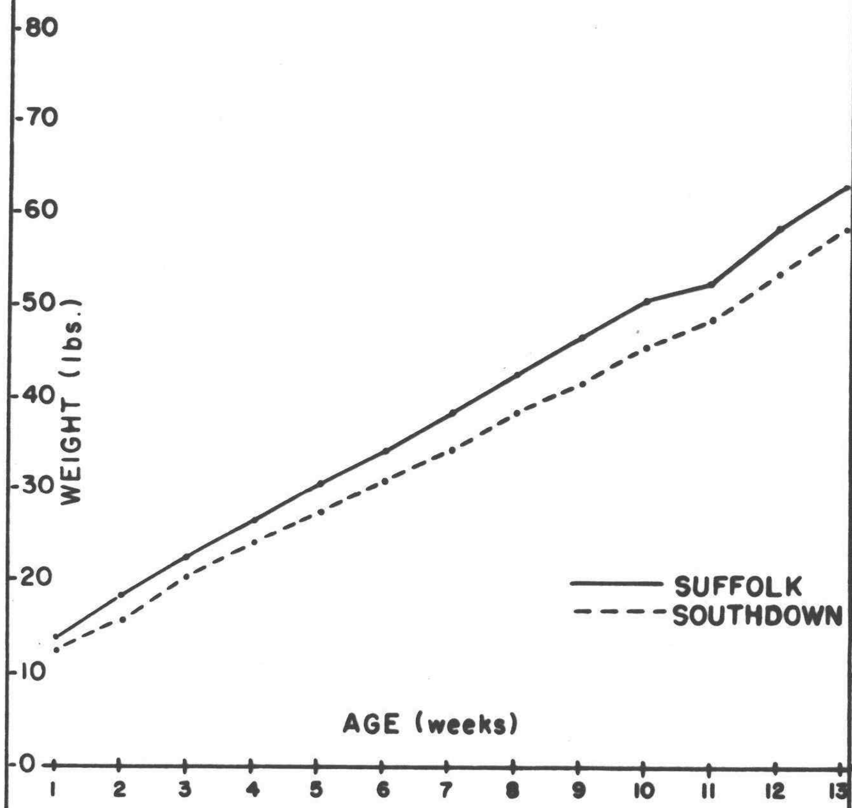


FIGURE 6. COMPARATIVE GROWTH RATES, BY WEEKS, OF THE AVERAGE SUFFOLK AND SOUTHDOWN SIRED LAMBS.

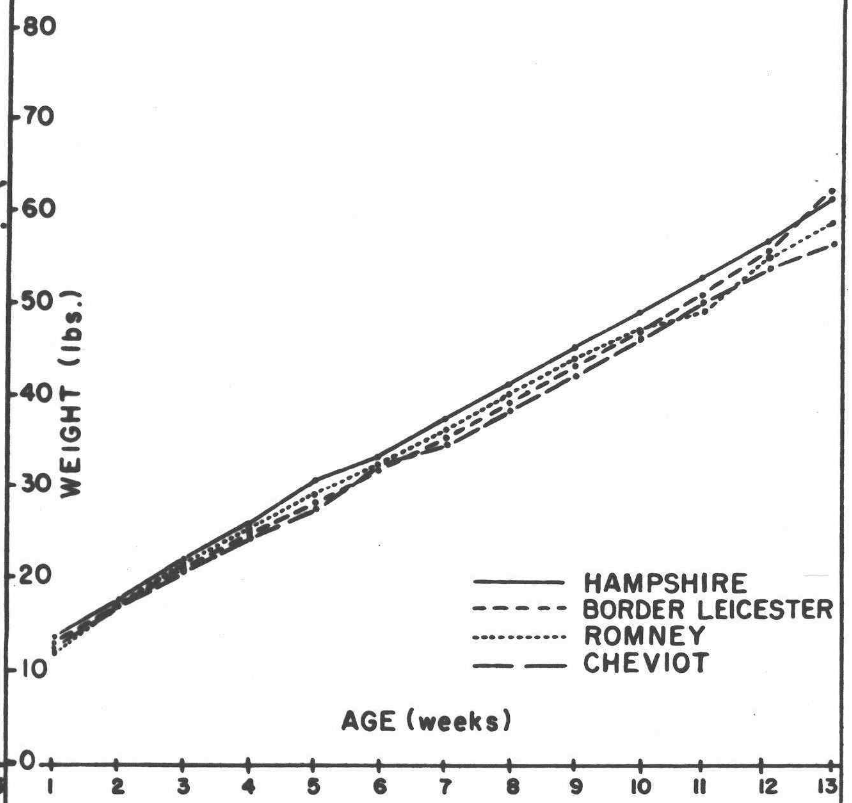


FIGURE 7. COMPARATIVE GROWTH RATES, BY WEEKS, OF THE AVERAGE LAMB FROM THE FOUR BREED CROSSES OF EWE.

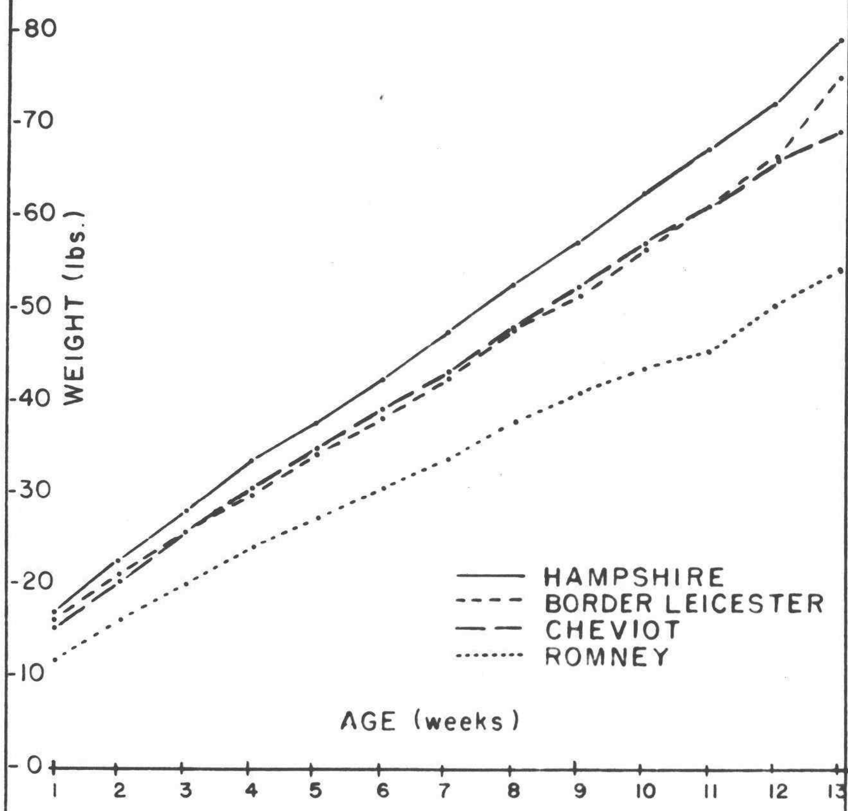


FIGURE 8. COMPARATIVE GROWTH RATES, BY WEEKS OF LAMB PER EWE BRED FROM THE FOUR BREED CROSSES OF EWE.

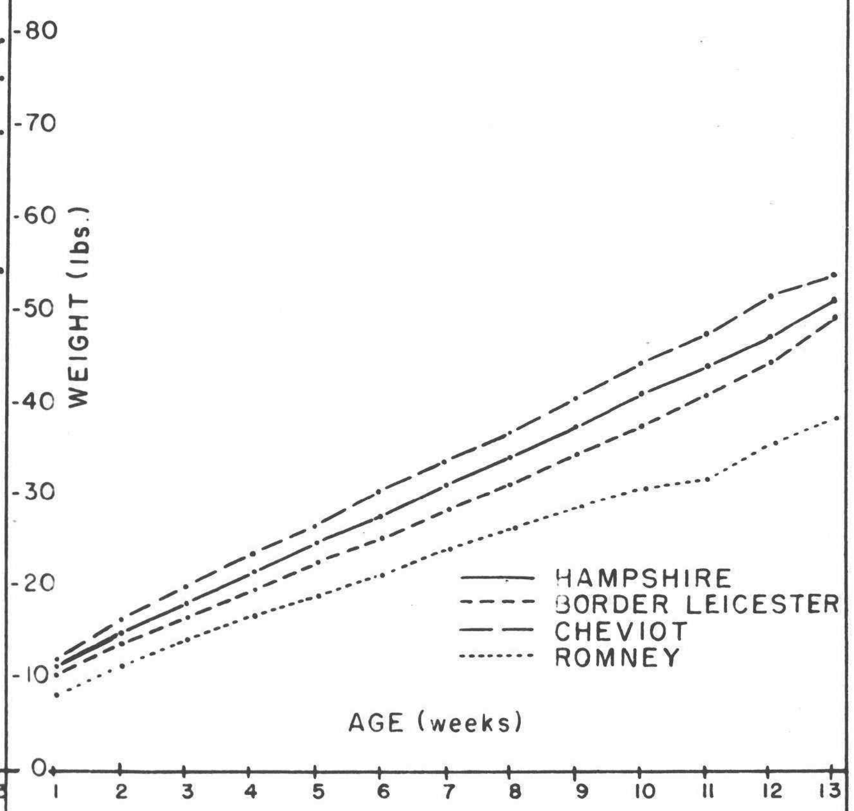


FIGURE 9. COMPARATIVE GROWTH RATES, BY WEEKS, OF LAMB PER CWT. OF EWE FROM THE FOUR BREED CROSSES OF EWE.

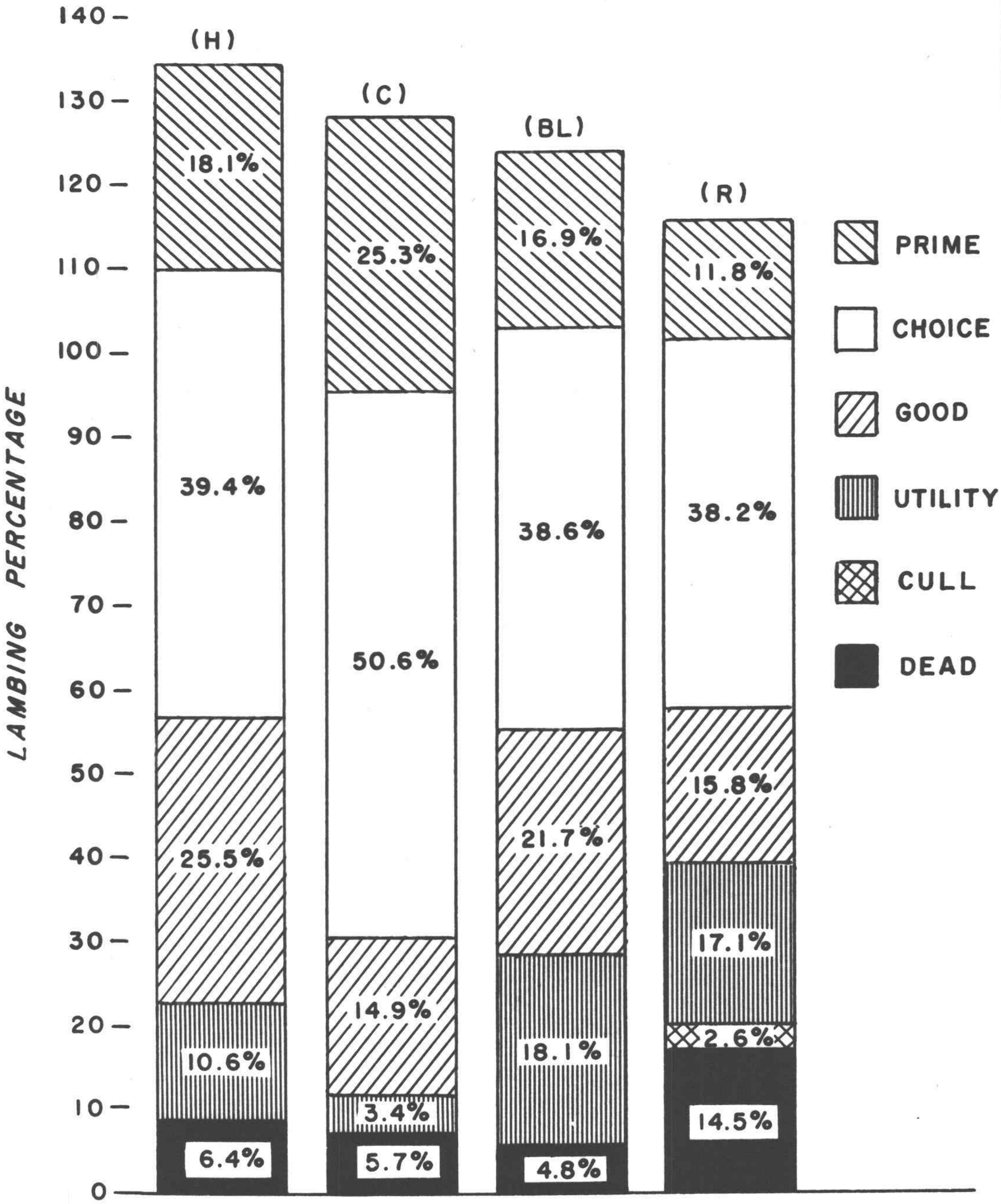


FIGURE 10. LAMBING PERCENTAGES OF HAMPSHIRE (H), CHEVIOT (C) BORDER LEICESTER (BL) AND ROMNEY (R) CROSS EWES AND THE PERCENTAGE OF LAMBS THEREOF IN THE VARIOUS MARKET GRADES OR DEAD.

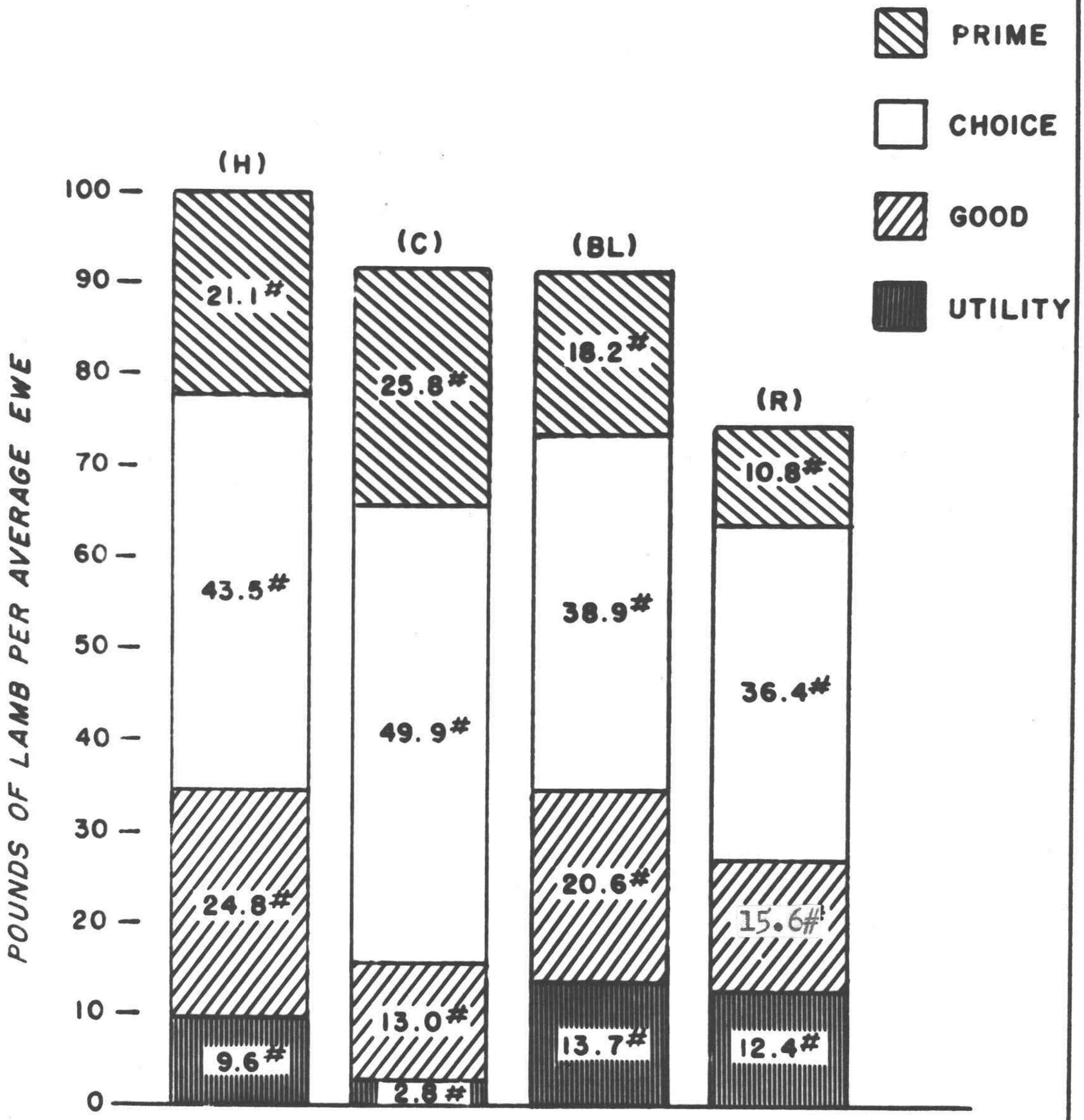


FIGURE 11. POUNDS OF MARKETABLE LAMB OF EACH MARKET GRADE PER AVERAGE EWE OF HAMPSHIRE (H), CHEVIOT (C), BORDER LEICESTER (BL) AND ROMNEY (R) BREED CROSSES.

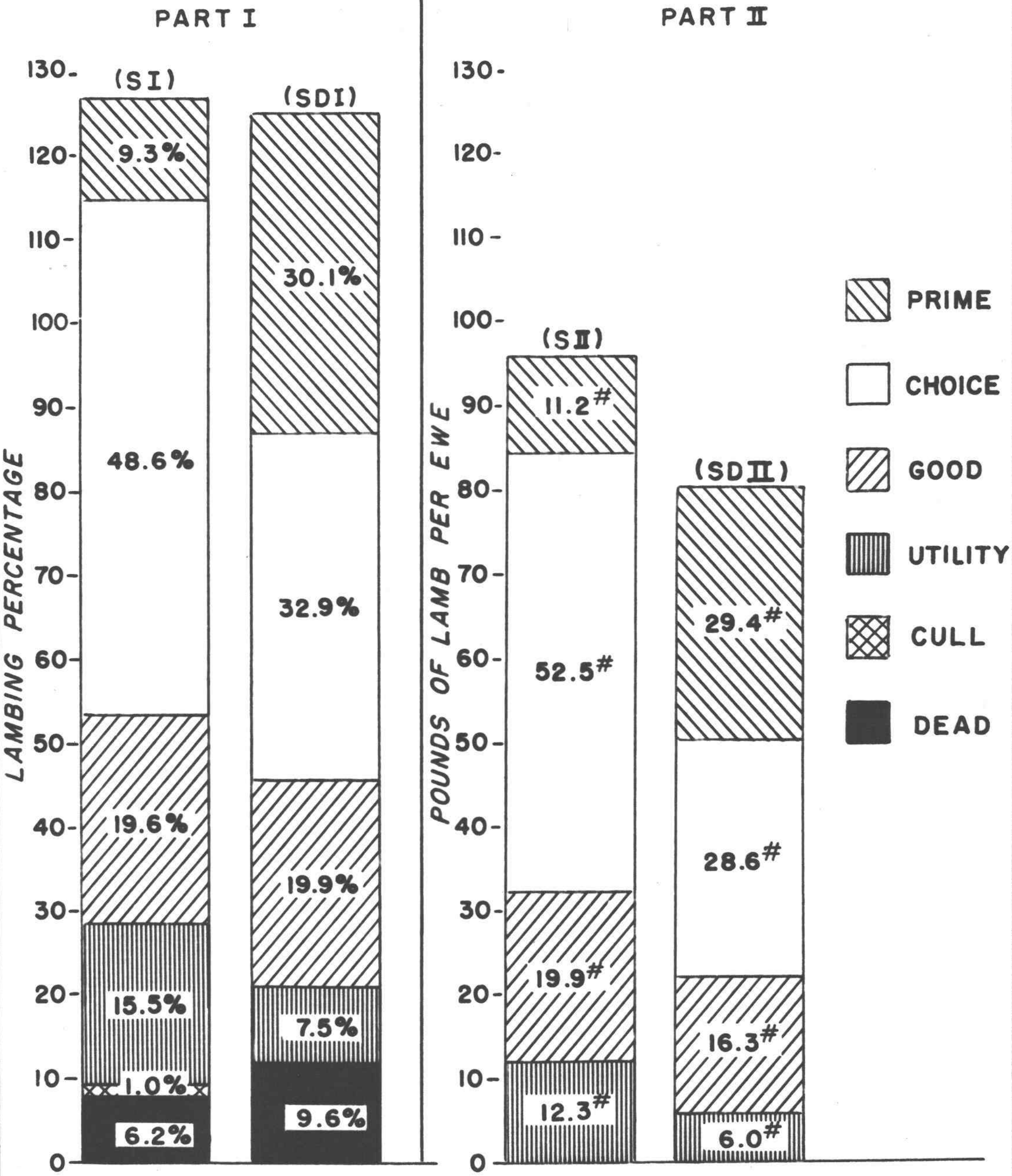


FIGURE 12. PART I: LAMBING PERCENTAGE OF EWES BRED TO SUFFOLK (SI) AND SOUTHDOWN (SDI) RAMS AND THE PERCENTAGE OF LAMBS THEREOF IN THE VARIOUS MARKET GRADES OR DEAD.

PART II: POUNDS OF MARKETABLE LAMB OF EACH MARKET GRADE PER AVERAGE EWE BRED TO SUFFOLK (SII) AND SOUTHDOWN (SDII) RAMS.

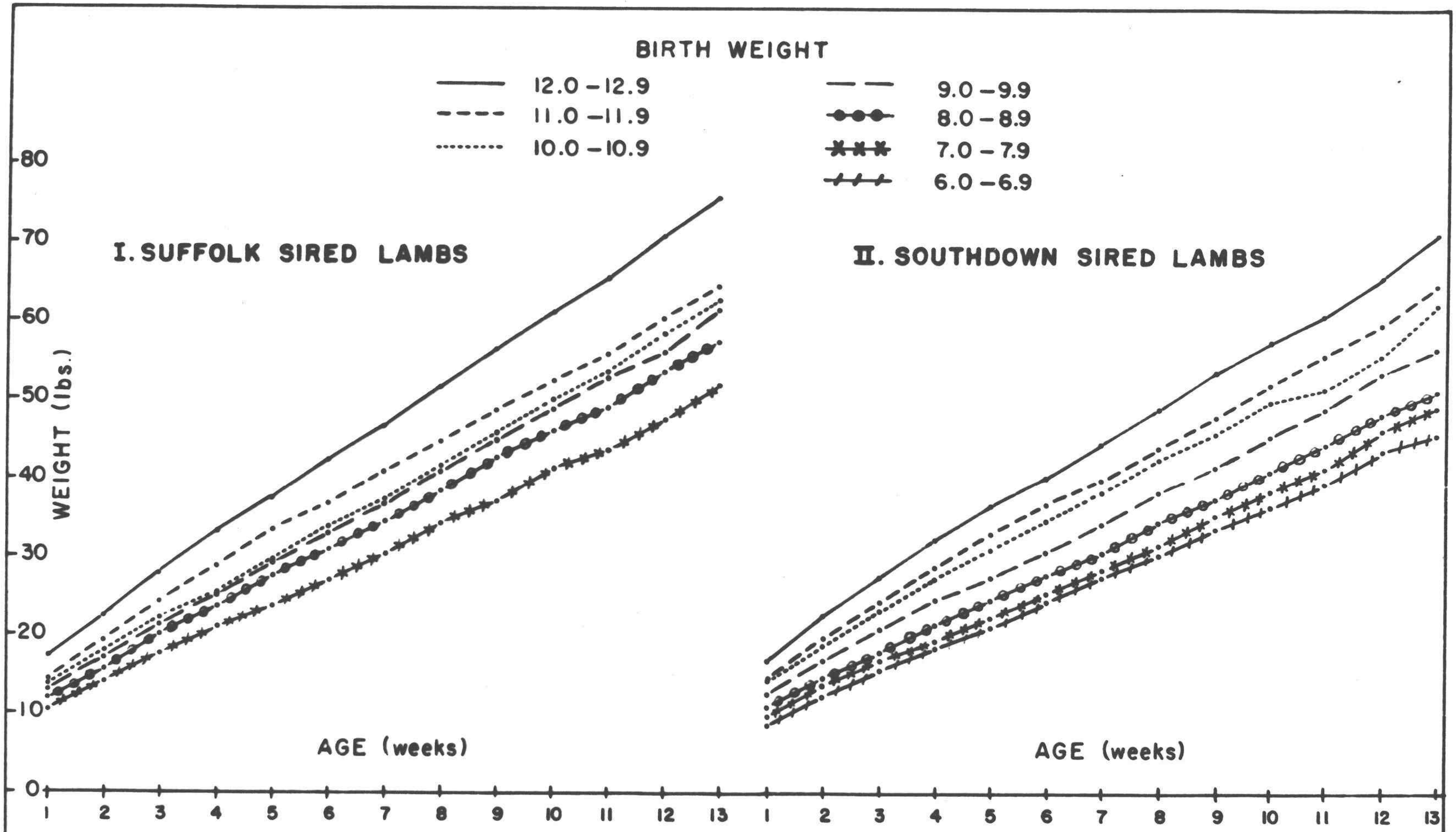


FIGURE 13. COMPARATIVE GROWTH RATES, BY WEEKS, OF SUFFOLK SIRED (I) AND SOUTHDOWN (II) SIRED LAMBS OF DIFFERENT BIRTH WEIGHTS

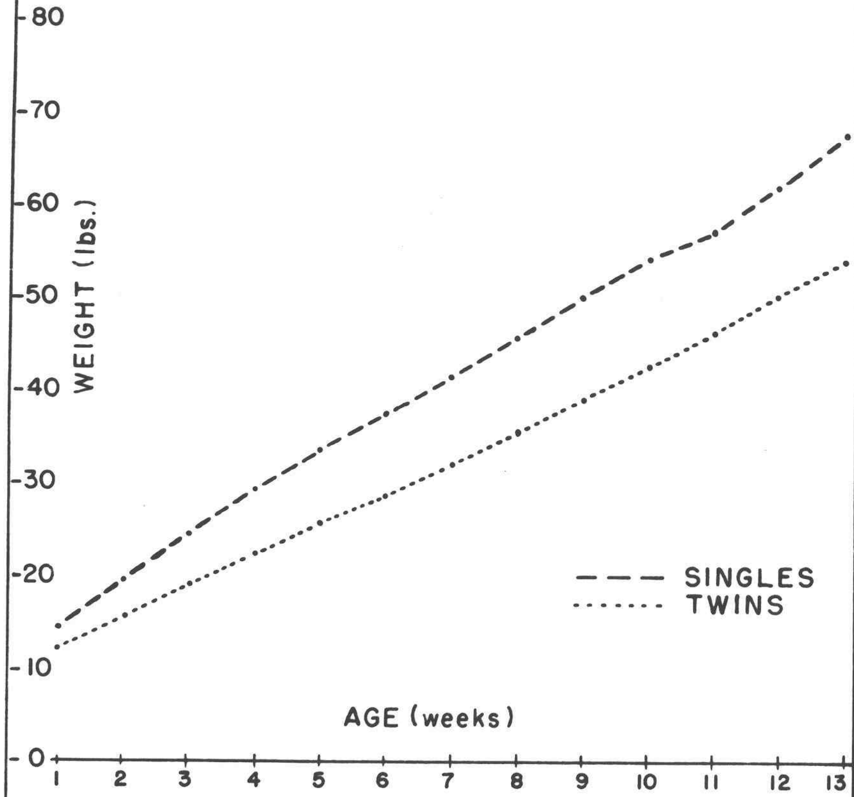


FIGURE 14. COMPARATIVE GROWTH RATES, BY WEEKS, OF THE AVERAGE TWIN AND SINGLE LAMB.

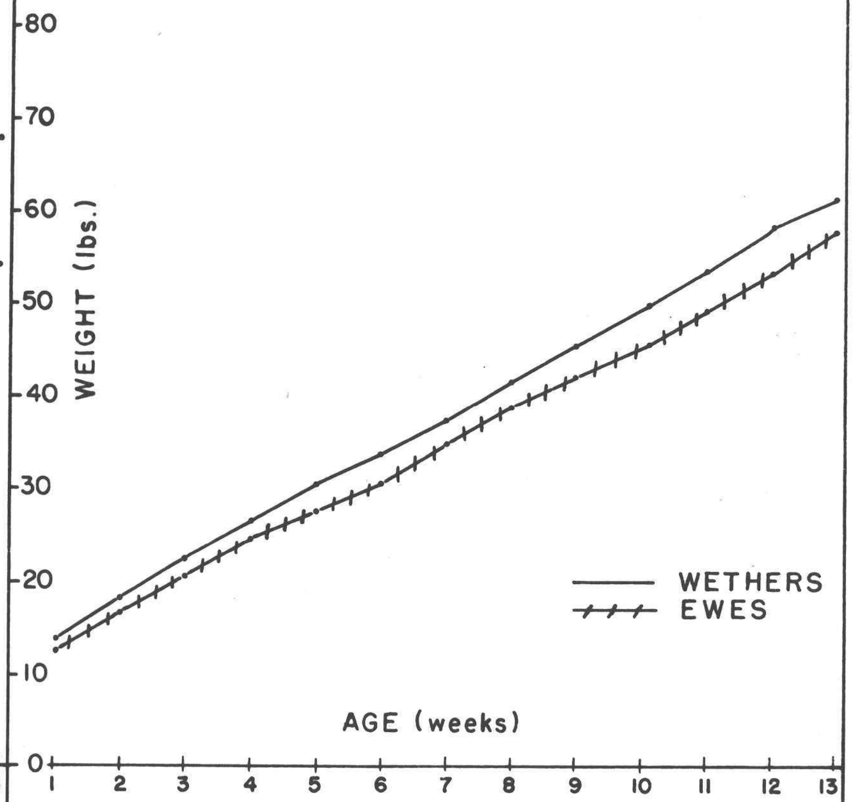


FIGURE 15. COMPARATIVE GROWTH RATES, BY WEEKS, OF THE AVERAGE WETHER AND EWE LAMB.

poor forage year.

The comparative growth rates of wether and ewe lambs are presented in figure 15. The difference in relative growth rate of wether and ewe lambs, when adjustment was made for birth weight was not significant. When birth weight was ignored, wether lambs were significantly heavier than ewes in one of four analyses, the significance perhaps being due to chance occurrence. Although a difference was graphically indicated between sexes (figure 15) the variation in the weights, from which the averages were obtained, was so great that the difference was not real. Furthermore, there was no interaction between birth type and sex in any instance.

<u>Condition</u>

Although the price realized from the sale of a spring lamb depends on a combination of weight and fatness, it is difficult to integrate both figures into one for purpose of analysis. This could be done by assigning a price to each of the market grades and conducting an analysis on the dollars and cents figures. It would be unreasonable to assume that the price spread between the grades would remain stable or that the answers would remain reasonable in the event of an economic change. Thus the analyses were conducted separately and the integration was done graphically.

Constants were fitted for condition score by the same method as for weaning weights. The mathematical model for the analysis of condition score was the same as the one for weaning weights. Each observation consisted of an average of the condition scores assigned each lamb by a committee of three scorers. The scores ranged from 0.0 to 5.0 and were converted to a percentage of 100. A score of 95 or above corresponded to a Prime lamb, 90 to 95 a Choice lamb, 85 to 90 a Good lamb, 75 to 85 a Utility lamb and below 75 a Cull lamb. The lamb carcasses were graded on the rail by a federal grader. The correlation of condition score and federal grade was high but not perfect.

The Southdown sired lambs scored significantly higher than Suffolk sired lambs only in one case when birth weight was ignored (table 4) and in one instance when scores were adjusted for differences in birth weights (table 5). The tendency, however, was in favor of Southdown sires. Ewes of the various breed-crosses tended to produce higher scoring lambs when bred to Southdown rams than when bred to Suffolks. Lambs from Hampshire, Romney and Border Leicester-cross ewes by Southdown sires scored higher than those by Suffolks, with the first two significant and the last lacking significance. Cheviot-crosses performed equally well when sired by either breed of ram.

In figure 12 (part 1), the percentage of lambs from

TABLE 4 Summary of Analyses of Variance (1), Estimates (with other variables adjusted) of Deviations from the Mean Condition Score of the Mathematical Model Ignoring Birth Weights (2) and Differences Between Deviations, from the Mean, Among Ewe Breeds (3)

Source	1952				1953			
	First Cross		Second Cross		First Cross		Second Cross	
	Sum of Squares	Degrees of Freedom	Sum of Squares	Degrees of Freedom	Sum of Squares	Degrees of Freedom	Sum of Squares	Degrees of Freedom
(1)								
Total	2,796.	65	1,833.	56	4,364.	86	3,260.	69
Regression	1,830.	9	1,001.	9	1,667.	9	1,401.	9
Residual	967.	56	832.	47	2,697.	77	1,859.	60
R^2**	.65*		.55*		.38*		.43*	
(2)								
General Mean[2]	74.34*	± 1.87	80.22*	± 3.30	89.35*	± 2.23	83.36*	± 2.90
Suffolk	1.70	± 1.90	-5.23	± 3.30	-9.67	± 2.78	.22	± 3.03
Hampshire	13.17*	± 2.75	4.20	± 3.59	.41	± 2.25	5.99	± 3.13
B. Leicester	7.94*	± 2.46	4.10	± 3.97	-5.04	± 2.65	2.73	± 3.13
Cheviot	9.77*	± 2.08	5.78	± 3.67	1.22	± 2.66	1.29	± 2.94
H[3]xS[4]	-8.85*	± 3.25	3.30	± 3.85	3.89	± 2.48	-8.46*	± 4.05
BL[5]xS	-8.78*	± 2.95	-1.76	± 4.43	7.80*	± 3.80	-7.83	± 4.01
C[6]xS	-5.97*	± 2.43	.93	± 4.16	3.32	± 3.84	-2.65	± 4.05
Singles	10.26*	± 1.72	5.22*	± 1.70	5.22*	± 1.91	7.10*	± 2.02
Wethers	-.53	± 1.56	-1.35	± 1.95	-.78	± 1.62	-1.47	± 2.26
Single Wethers	2.14	± 2.48	2.06	± 2.61	-1.06	± 2.65	-.26	± 2.91
(3)								
H minus BL	5.23*	± 2.58	.10	± 3.15	5.45*	± 1.98	3.26	± 2.82
H minus C	3.40	± 2.66	-1.58	± 2.94	-.81	± 2.05	4.70	± 2.63
BL minus C	-1.83	± 2.45	-1.68	± 3.34	-6.26*	± 2.51	1.44	± 2.67
HxS minus BLxS	-.07	± 3.23	5.06	± 3.83	-3.91*	± 1.95	-.63	± 3.73
HxS minus CxS	-2.88	± 3.14	2.37	± 3.34	.57	± 2.05	-5.81	± 3.62
BLxS minus CxS	-2.81	± 2.99	-2.69	± 4.02	4.48	± 3.53	-5.18	± 3.73

* Significant at P = 0.05 ** Multiple correlation coefficient

2 ibid. 3 ibid. 4 ibid. 5 ibid. 6 ibid.

TABLE 5 Summary of Analyses of Variance (1), Estimates (with other variables adjusted) of Deviations from the Mean Condition Score of the Mathematical Model Adjusted for Birth Weight (2) and Differences Between Deviations, from the Mean, Among Ewe Breeds (3)

Source	1952				1953			
	First Cross		Second Cross		First Cross		Second Cross	
(1)	Sum of Squares	Degrees of Freedom	Sum of Squares	Degrees of Freedom	Sum of Squares	Degrees of Freedom	Sum of Squares	Degrees of Freedom
Total	2,796.	65	1,833.	56	4,363.	86	3,260.	69
Regression	1,633.	10	1,270.	10	1,684.	10	1,370.	10
Residual	1,163.	55	563.	46	2,679.	76	1,890.	59
R^2**	.58*		.69*		.39*		.42*	
(2)								
General Mean[2]	76.29*	± 3.62	65.98*	± 4.70	93.05*	± 5.19	81.00*	± 5.01
Suffolk	2.27	± 2.42	-1.30	± 2.94	-10.41*	± 2.89	.11	± 3.09
Hampshire	13.69*	± 3.17	6.96*	± 3.07	-.98	± 2.66	5.88	± 3.18
B. Leicester	8.10*	± 2.83	3.83	± 3.30	-4.87	± 2.67	2.29	± 3.27
Cheviot	9.99*	± 2.36	7.80*	± 3.09	1.09	± 2.68	1.60	± 3.03
H[3]xS[4]	-9.55*	± 3.74	-2.90	± 3.59	7.18	± 3.85	-8.47*	± 4.12
BL[5]xS	-8.68*	± 3.29	-4.15	± 3.75	8.06*	± 3.83	-7.63	± 4.09
C[6]xS	-6.52*	± 2.93	-2.46	± 3.58	3.61	± 3.88	-3.01	± 4.17
Singles	10.96*	± 2.23	1.66	± 1.70	6.01*	± 2.20	6.52*	± 2.29
Wethers	-.30	± 1.76	-2.36	± 1.64	-.45	± 1.70	-1.72	± 2.38
Single Wethers	-2.80	± 2.72	2.82	± 2.18	-1.39	± 2.70	-.28	± 2.96
Birth Weight	-.29	± .48	1.51*	± .41	-.40	± .55	.30	± .52
(3)								
H minus BL	5.59	± 2.86	3.13	± 2.74	3.89	± 2.47	3.59	± 2.94
H minus C	3.70	± 2.96	-.84	± 2.45	-2.07	± 2.51	4.70	± 2.75
BL minus C	-1.89	± 2.75	-3.97	± 2.92	-5.96	± 2.56	.69	± 3.00
HxS minus BLxS	-.87	± 3.62	2.06	± 3.28	.88	± 3.47	-.84	± 3.81
HxS minus CxS	-3.03	± 3.48	.37	± 2.83	3.57	± 3.50	-5.46	± 3.73
BLxS minus CxS	-2.16	± 3.33	-1.69	± 3.35	4.45	± 3.54	-4.62	± 3.92

* Significant at P = 0.05 ** Multiple correlation coefficient

2 ibid. 3 ibid. 4 ibid. 5 ibid. 6 ibid.

Suffolk and Southdown sires which were classified into the various carcass grades are presented. These graphs represent the actual figures without correction for any of the measurable variables. The Southdown sires produced 30.1 percent Prime lambs as compared to 9.3 percent for Suffolk sires. In view of the fact that there is no price differential on the existing market between Prime and Choice lambs, these two grades can be combined for comparison. Southdown sires produced 63.0 percent lambs grading Prime and Choice while Suffolk sires produced 57.6 percent Prime and Choice. A big difference between the breeds lies in the percentage of Utility lambs; ie. those not fat enough for slaughter and needing to be carried through the feed lot. Suffolk and Southdown sires produced 15.5 and 7.5 percent Utility lambs, respectively.

As was pointed out above, a comparison of either weaning weight or condition without an integration of the two fails to give the full view of actual worth of the breed. In figure 12 (part 2), the pounds of lamb (per ewe bred) in each market grade are given for the two sire breeds. Suffolk sires produced 5.7 pounds more Choice and Prime lamb, 3.6 pounds more Good lamb and 6.3 pounds more Utility lamb on the per lamb basis than did the Southdown sires. Whereas the greater percentage of

Southdown sired lambs graded higher than the Suffolk sired lambs, the Suffolks had sufficient added pounds to give them superiority.

In 1952, lambs from first cross Border Leicester, Hampshire and Cheviot ewes and the second-cross Hampshire and Cheviot ewes scored higher than lambs from Romney-cross ewes regardless of birth weight. Lambs from Hampshire and Cheviot-cross ewes in turn scored higher in condition than those from Border Leicester-cross ewes. In 1953 there was no significant difference between lambs from the various breed crosses. However, the general tendency favored the lambs from Hampshire and Cheviot-cross ewes.

The percentages of lambs from the various ewe-breed crosses are presented, according to market grades or dead, in figure 10. The percentages of marketable lambs were 83.0, 90.0, 77.1 and 65.8 for the Hampshire, Cheviot, Border Leicester and Romney crosses, in that order. The Hampshire-cross ewes had the greatest number of twins and consequently produced the highest percentage of Good lambs. Nevertheless, the Border Leicester-cross ewes produced the most Utility lambs (18.1 percent) of any of the breeds. The highest mortality rate was in the Romney-cross group which lost 14.5 percent of the total drop and produced 17.1 percent Utility lambs giving them a lower return per ewe.

The pounds of lamb per ewe in each market grade from the various ewe-breed crosses are presented in figure 11. The production of marketable pounds of lamb per ewe was 88.4, 88.7, 77.7 and 62.8 for the Hampshire, Cheviot, Border Leicester and Romney-cross ewes, respectively. The total production including Utility or feeder lambs for Hampshire, Cheviot, Border Leicester and Romney-cross ewes was 98.0, 91.5, 91.4 and 75.2 pounds per ewe, in that order. The production per ewe was highest for the Hampshire crosses. Although the total weight of lamb per ewe from Cheviot and Border Leicester-cross ewes was the same, the value of the Cheviot-cross production per ewe was higher since they produced 10 pounds more marketable lamb than did the Border Leicesters.

Lambing percentage accounted for a large portion of the difference between the breeds in pounds of lamb per ewe bred, and mortality accounted for another large part. Ewes of Cheviot and Hampshire breeding reared more pounds of marketable lamb in the same period of time than did the Border Leicester and Romney-crosses. Cheviot-cross ewes were the most efficient producers, on the basis that they produced more pounds of fat lamb per unit of their own weight than did any of the other breeds.

Only in one instance, was the effect of birth weight on condition score at weaning significant. Among the second-cross ewes in 1952, there was an increase of 1.51 ± .41 points in condition score for each pound increase in birth weight. This could have been due to chance occurrence or to the fact that these ewes were 2 and 3 year olds, and that those young ewes which were capable of producing lambs which were heavy at birth were capable of supplying them adequate milk for finishing. In all other instances birth weight had no effect on condition score at weaning.

Birth type had more influence on condition score than did any other single factor studied. Single lambs scored from 5.22 ± 1.71 points to 10.26 ± 1.72 points higher than twin lambs, when birth weight was ignored. With condition score adjusted for differences in birth weights there was a significant difference between singles and twins in all cases except one. The magnitude of the differences correspond to a superiority among singles of 1 to 2 market grades. The effect of birth type undoubtedly accounts for the increased pounds of lower grade lambs from the Hampshire-cross ewes which had the greatest number of twins.

There was no significant difference in the condition scores of wether and ewe lambs. The general tendency, in all cases, was a slightly higher condition score for the females. In no case, moreover, was there an interaction between birth type and sex in condition scores.

Birth Weight

Estimates of deviations from the mean birth weight of a mathematical model similar to that used for weaning weight and condition score were obtained. Each observation consisted of a weight taken to the nearest one-tenth of a pound very soon after birth of the lamb. The constants obtained for each of the measurable variables are shown in table 6.

The difference between birth weights of lambs sired by rams of Suffolk and Southdown breeds lacked significance in three analyses. A significant difference occurred in the fourth analysis in which Southdown sired lambs were heavier at birth than those sired by Suffolk rams. This situation seems unlikely and may have been due to chance. The only other instance of consistent breed differences in birth weight were those in which lambs from Border Leicester-cross ewes were repeatedly heavier at birth than lambs from Cheviot-cross ewes, and lambs from Hampshire-cross ewes were heavier than the lambs from Cheviot-cross ewes when all lambs were sired by Suffolk rams.

Birth type, again, contributed the most consistent of all effects on birth weights. Singles were from $1.92 \pm .48$ to $2.40 \pm .60$ pounds heavier at birth than were the twins. The differences and standard errors

TABLE 6 Summary of Analyses of Variance (1), Estimates (with other variables adjusted) of Deviations from the Mean Birth Weight of the Mathematical Model (2) and Differences Between Deviations, from the Mean, Among Ewe Breeds (3)

Source	1952				1953			
	First Cross		Second Cross		First Cross		Second Cross	
	Sum of Squares	Degrees of Freedom	Sum of Squares	Degrees of Freedom	Sum of Squares	Degrees of Freedom	Sum of Squares	Degrees of Freedom
(1)								
Total	267.88	65	162.49	57	198.08	86	226.55	69
Regression	151.31	9	88.13	10	177.63	9	121.14	9
Residual	116.57	56	74.36	47	20.45	77	105.41	60
R^2**	.56*		.54*		.90*		.53*	
(2)								
General Mean[2]	7.42*	± .65	9.42*	± .97	8.31*	± .19	7.77*	± .69
Suffolk	.68	± .66	-2.60*	± .99	.32	± .24	.40	± .72
Hampshire	1.04	± .94	-1.83	± 1.07	.33	± .20	.22	± .74
B. Leicester	.79	± .85	.18	± 1.19	.43	± .73	1.44	± .74
Cheviot	.73	± .72	-1.34	± 1.10	-.40	± .23	-1.04	± .69
H[3]xS[4]	-.46	± 1.13	3.57*	± 1.18	.31	± .23	.05	± .96
BL[5]xS	.70	± 1.02	1.58	± 1.33	.71	± .45	-.66	± .96
C[6]xS	-.52	± .85	2.24	± 1.24	.76*	± .33	1.18	± .97
Singles	2.40*	± .60	2.35*	± .51	1.93*	± .33	1.92*	± .48
Wethers	.55	± .54	.67	± .58	.87*	± .17	.84	± .55
Single Wethers	.47	± .86	-.51	± .78	-.77*	± .14	.05	± .69
(3)								
H minus BL	.25	± .90	-2.01*	± .94	.10	± .17	-1.22	± .67
H minus C	.31	± .92	-.49	± .88	.73*	± .18	1.25	± .63
BL minus C	.06	± .85	-1.52	± 1.03	.83*	± .22	1.48*	± .64
HxS minus BLxS	-1.16	± 1.12	1.99	± 1.14	.40*	± .17	.69	± .89
HxS minus CxS	.06	± 1.09	1.33	± 1.00	.45*	± .18	-1.83*	± .86
BLxS minus CxS	1.22	± 1.04	.66	± 1.20	.05	± .31	2.54*	± .89

* Significant at P = 0.05 ** Multiple correlation coefficient
2 ibid. 3 ibid. 4 ibid. 5 ibid. 6 ibid.

between singles and twins were remarkably similar among ewes of various top-crosses within years. An emperical explanation (solely from recollection) is that the ewes were in higher condition prior to the lambing season of 1953 than in that of 1952; consequently, the intra-uterine environment must have been superior in 1953. It was pointed out above, in contrast, that the growing season of 1953 was the poorer of the two and that the lamb weights in that year were below those of 1952. The feed during the pre-lambing season included fall-growth forage and supplementary hay and grain while the post-lambing feed consisted of green grass alone after March 15.

No consistent differences existed between the birth weights of ram and ewe lambs. The trend in all cases was for ram lambs to be heavier. Significance existed in one case only. The interactions between birth type and sex were likewise inconsistent and unimportant.

GENERAL DISCUSSION

The ewes used in this study were unselected representative crossbred individuals predominantly of Hampshire, Border Leicester, Cheviot and Romney breeding. The variations among breed crosses were more apparent than between first and second-crosses within breeds so that in most instances reference was made to the breed-crosses per se rather than to the top-cross within the breed. Largely, there was no difference in relative growth of lambs produced by ewes of the various breeds, thus these data substantiate the findings of Bonsma of South Africa (7, p.78). A large part of the difference among these breeds, as was the case among those studied by Miller and Dailey (60, pp.462-468), lies in the lambing percentage which they produced and in the survival rate which they maintained to weaning. The growth rate of the average lamb and/or pounds of lamb per ewe bred fails to adequately show the relative merit of the various breeds. The vast difference in the size of the Border Leicester and Cheviot cross ewes, for example, is ignored in both cases. The conclusion that their lambs were of equal weight at weaning or that the pounds of lamb per ewe were equal is no indication that their producing abilities were alike. If one were to assume that the ewes of the various breed crosses consumed equal amounts of feed, rather than consuming feed in proportion to body weight or to a power thereof, the above comparisons alone would be sufficient. It was shown above that Border Leicester and Hampshire-cross lambs were somewhat heavier at weaning than Cheviot-cross lambs but that the Cheviot-cross ewes produced a greater amount of lamb per unit of body weight than did any other breed. One is led to believe that the superior production of the small-sized Cheviot-cross ewe is due to non-linear effects beyond those measured in these analyses. Analysis of data taken on a basis of pounds of lamb per hundred weight of ewe might yield measurements of effects of hybrid vigor in these data in spite of a lack of comparison with the original parents. Winters and co-workers (88, 28p.) have likewise asserted that production per hundred pounds of ewe is the most practical method of evaluating production.

The magnitude of the unmeasured portion of variation in these analyses is noteworthy. The ages of dams were completely randomized among the rams and their effect was not removed from experimental error, nor was the effect of the individual ewe removed. A certain portion of the unmeasured variation perhaps was due to ewe age and to an extent the incorporation of this variation in experimental error impairs the reliability of the estimates. Nevertheless, the similarity of the relative growth of lambs from the various breed-crosses together with the large variation due to individuals is evidence enough that selection of the individual high-producing ewes within breeds is just as important as the choice of a particular breed. Bonsma (7, p.65) found this to be the case, and; furthermore, he asserted that "this selection could be effected by recording the weight growth of lambs from individual ewes." This is in line with the suggestions of Cadmus (13, 20p.) relative to the value and use of a record system in the practical livestock program.

The differences among weights of individual lambs from Suffolk and Southdown, and of individual lambs from the various breed-crosses of ewe were largely accounted for by differences in birth weights. These figures are, again, in accordance with the figures of Bonsma (7, p.78) who ascertained that no difference existed between the various breeds on the basis of equal birth weights, nor when weight gains were expressed as a percentage of birth weight. The rate of change of 2.50 to 5.96 pounds in weaning weight for each pound change in birth weight, regardless of breed or environmental factors, which were obtained from these analyses are distinctly in line with the findings of Cadmus (13, 20p.) and Phillips and

Dawson (67, pp.296-306). Birth weight, with reference to the effect it imparts on subsequent weights, was one of the most influential characters studied. It is assumed that this character is at least in part under genetic control. Its effect was of greater importance than that attributed to breed differences, therein again denoting the importance of the indivdauls within breeds. In order to obtain heavy weaning weights in lambs, another criterion besides the use of larger breeds is to use parental material which, regardless of breed, will produce larger lambs at birth. Various workers, Bonsma (7), Hammond (27) and Terrill and Stoehr (81) among others, have indicated that the larger ewes are likely to produce the heavier lambs at birth. The effects of weight of ewe were removed in these analyses only inasmuch as they were confounded with those of breeds.

A certain basic efficiency difference disregarding size must, of necessity, exist among breeds and among individuals within breeds in their ability to provide an adequate intra-uterine environment for their lambs. Undoubtedly, livability and strength are inherited to some extent and perhaps are dependent on the efficiency complex, as is weight at birth. The small Cheviot-cross ewes were capable of producing a greater percentage of heavier lambs with greater livability than were the larger

Romneys. The use of progeny tests, of adequate selection based on heritabilities, of individual selection based on standard deviations or of selection based on specific combining merit should add consistency to the identification of desirable parental material.

Real differences exist among breeds in the fatness which the lambs attain at comparable ages. Specific breeds of ewes produce fatter lambs from Southdown than from Suffolk rams. In these trials, specific ewe-breed crosses, in themselves, tended to produce fatter lambs at weaning than did others. Cheviot-cross ewes produced the greatest percentage of marketable lambs followed by Hampshire, Border Leicester and Romney-cross, in that order. This pattern of breed-fattening tendencies exhibited by the ewe crosses are in perfect accordance with the figures of Nelson, et al. (63, 4p.) concerning the same breeds as sires of fat lambs, and with those of an early study by Horlacher in Kentucky (41, pp.140-199).

Whereas a comparison of Southdown and Suffolk breeds would indicate that early fattening is an attribute of smaller animals, this is not consistently so among the ewe-breed crosses. Moreover, birth weight imparted no significant effect on condition score. The Border Leicester-cross ewes were the largest but produced late maturing lambs particularly from Suffolk sires. The

Cheviot-cross ewes were the smallest and produced the fattest lambs. Nevertheless, Hampshire-cross ewes were second in weight and ranked close to Cheviots in fatness of lambs when no corrections were made. The Hampshire-crosses were penalized in condition because of their large proportion of twins, and on the basis of equal lambing percent were not different from Cheviots. This disadvantage in condition which was suffered by the Hampshire-cross lambs because of the high lambing percentage is excusable. However, the Romney-cross, the second smallest breed, proved to be the slowest maturing. Their lambs should have been fat since their lambing percentage was low, but their lambs possessed the lowest scores.

Bonsma (7, p.85) asserted that milk supply of the dams was one of the most important limiting factors retarding potential growth of lambs, and the amount of food intake exerts a very marked influence on fattening at a young age. Even while one keeps in mind that breed differences in earliness of maturity are existent, as it was shown by Wallace (86) that these differences are apparent in foetal life, individual ewes within breed-crosses were capable of producing high scoring lambs. Such was the case, most notably, when specific breeds of ewes were mated to particular ram breeds; ie, Border Leicester-cross ewes produce fatter lambs when bred to

Southdown than when bred to Suffolk rams. Similar to the statement of Hammond and Murray (28, pp.243-249) "there is a particular weight for every breed at which the fat, muscle and bone are in right proportion," there is a right breed of sire for each breed of ewe. Specific combining ability is important in fat lamb production as shown by fatter lambs from Border Leicester and Romney-cross ewes when bred to Southdown rams. A general combining ability was shown by the Hampshire and Cheviot-cross ewes to the extent that their lambs were adequately fat whether sired by Southdown or Suffolk rams.

The genetic contributions of the sire to his lambs are those of hereditary size and maturity. The role of the ewe is more extensive in that she is responsible for half the genetic size and maturity rate, for multiple ovulation, for maintenance of pregnancy and for provision of an adequate pre-natal environment and post-natal milk supply. Whereas the sire and dam equally contribute to potential size and maturity, the continuation of potential growth is highly dependent on the dam. While specific combination of breeds is important in growth and fattening, the role of the individual within breeds is of no little consequence. Rigorous culling of ewes, within breeds, which consistently produce thin lambs, should eventually be rewarded with uniformly high-scoring lambs. Substantiation of this lies in Bonsma's (7, p.103) assertion that lambs reared by high producing ewes were in a position to promote fattening simultaneously with growth.

The difference of 17 pounds in weaning weight and of 5 to 10 points in condition score which was exhibited between singles and twins would impose a considerable restriction on the producer who is interested in a high proportion of twin lambs. There is an actual difference in relative growth between single and twin lambs which is largely due to limitations in the environment of the twin. The enormity of the restriction among twins is such that they do not reach maximum growth rate until five weeks of age, according to Hammond (30) whereas singles attain maximum growth rate during their first week of age. Moreover, a large portion of the variation between twins exists already at birth. In commercial practice an added advantage should be obtained through supplemental (creep) feeding twin lambs. The gain should be three-fold: weight gain should be increased; a higher degree of finish should be reached resulting in a higher market grade; and a portion of the feed would be saved which, of necessity, would be required to fatten some that would not be fat enough to slaughter and would require feeding after weaning.

Although there was a slight tendency for male lambs to be heavier at birth and weaning than females such as have been reported by Karam, et al. (45, p.606), Bonsma (7, p.85) and Phillips and Dawson (68, 18p.), the differences were not significant. Relative growth was alike for wether and ewe lambs. Castration of males, perhaps, lessened the chance for real differences between sexes as have been shown in sheep by Hazel and Terrill, (32) and (36). The tendencies for ewe lambs, in all analyses, to score higher in condition than ram lambs were not significant.

One of the difficulties that arises with improving sheep through selection is the interaction of such factors as birth weight and twinning on weaning weight and score. Obviously, if one is to improve his sheep for fertility, mothering ability of the ewe, growthiness and fattening tendency of the lambs, a selection index must be employed. Care must be exercised to make necessary corrections for differences in environmental influences such as age of ewe, but one must avoid correcting out differences of a genetic nature which are factors which we are striving to concentrate in the flock.

SUMMARY AND CONCLUSIONS

1. Mating to Suffolk rams resulted in a greater number of pregnancies in the 1952 trials than did those to Southdown rams. Fewer services per conception were necessary, in both years, from Suffolk rams; consequently, the average weaning-age of Suffolk sired lambs was greater than that of Southdown sired lambs. Ewes mated to Suffolk rams marketed 15 pounds more lamb per ewe bred than those bred to Southdowns. On a basis of equal ages, the tendency for heavy weaning weights of lambs favored the Suffolk sires, but the difference between Suffolk and Southdown sires was not significant. Likewise, there was a non-significant tendency for ewes within the various breed-crosses to produce heavier lambs (on an equal age basis) from Suffolk than from Southdown rams.

2. Southdown sired lambs showed a tendency to score higher than those sired by Suffolk rams. More apparent was the effect of these breeds on specific crosses. Combination of specific breeds is extremely important in spring lamb production. Nevertheless, among Southdown-sired lambs 30.1 percent graded Prime; 63.0 percent Prime and Choice, combined; 19.6 percent Good; and 7.5 percent Utility. Comparable figures for Suffolk sired lambs were 9.3, 57.6, 19.9, and 15.5 percent, respectively. When

market grade and lamb weight were integrated, Suffolk sires produced 5.7 pounds more of Prime and Choice, 3.6 pounds more of Good and 6.3 pounds more of Utility lamb per average ewe than did Southdown sires.

3. The average lambs from Hampshire and Border Leicester-cross ewes were heavier than those from Cheviot and Romney-cross ewes. The lambing percentages were 134, 127, 124, and 115 for Hampshire, Cheviot, Border Leicester, and Romney-cross ewes, respectively. Mortality was 6.4, 5.7, 4.8 and 14.8 percent for Hampshire, Cheviot, Border Leicester and Romney-cross ewes, in that order. A reflection of gross production from the various crosses may be expressed in terms of pounds of lamb per ewe bred. Mortality, lambing percentage and growth rate of lambs are thus considered. The production per ewe bred for each breed cross was Hampshire 98.0 pounds, Cheviot 91.5 pounds, Border Leicester 91.4 pounds and Romney 75.2 pounds. By expressing production as pounds of lamb weaned per hundred weight of ewe, a net production estimate, which accounts for mortality, lambing percentage, growth rate and efficiency of production, is forthcoming. The rank of the ewe-breed crosses, thus, was Cheviot, Hampshire, Border Leicester and Romney-cross, in that order.

4. In the 1953 trials there were no differences

in the average score of lambs from the various breed crosses of ewes. However in 1952, the lambs from Hampshire and Cheviot-cross ewes scored higher than those from Border Leicester-cross which in turn scored higher than those from the Romney-cross. Overall, the percentage of marketable lambs (Good or higher) of the total lambs dropped were Cheviot 90.9, Hampshire 83.0, Border Leicester 77.1 and Romney 65.8. The remainder of the total lambs within crosses either graded Utility or died before weaning time. Hampshire, Border Leicester and Romney-cross lambs scored higher when sired by Southdown rams. Cheviot-cross ewes performed equally when bred to either breed of ram, and despite the Hampshire-cross lambs being superior from Southdown sires, the Suffolk sired lambs out of Hampshire-cross ewes were above average. The total pounds of marketable lamb per average ewe bred were 88.7, 88.4, 77.7, and 62.8 for Cheviot, Hampshire, Border Leicester and Romney-cross ewes, repsectively.

5. Birth weight, with regard to the effect it imparts on weaning weight, was one of the most influential characters studied. There was an increase of 2.50 to 5.96 pounds in weaning weight for every pound increase in birth weight. The differences in weaning weights which existed among breeds were largely accounted for by

differences in birth weight. Birth weight imparted no significant effect on condition score at weaning. A large portion of the variation, moreover, was attributable to differences among individuals. Therefore, selection of ewes, within breeds, which are capable of producing lambs that are heavy at birth and of affording them an adequate milk supply, is equally as important as choice of breed.

6. Lambs born as singles were from 1.92 to 2.40 pounds heavier at birth and weighed 17 pounds more at weaning than those born as twins. The limitation of nutrient supply which apparently is imposed pre-natally and the limitation in milk supply post-natally is responsible for these differences. Methods of management should be practised to provide more suitable environment to the twins so that they may express their full growth potential.

7. No significant differences were apparent between sexes in any of the traits studied. Tendencies were, however, for wether lambs to be heavier at birth and weaning than ewe lambs, and for ewe lambs to score higher in condition at weaning than wether lambs.

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