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Eight purebred rams (four Suffolk and four Panama) previously selected as high and low on the basis of post-weaning performance feed test of 84 days were used each of three years. Each of the rams was mated to approximately 25 grade Panama ewes each year. One ram and 25 ewes representing the high and low performance of each of the breeds were kept continuously in drylot while the other comparable group was grazed on pasture during the summer and fed in drylot during the winter. Thus, a total of four groups were in drylot, the drylot groups, and four groups were on pasture, the pasture groups. The data on birth and weaning weights of the lambs, the fleece weights and body weights of the ewes were analyzed by the method of least squares.

There was evidence for heterosis because the Suffolk-sired lambs exceeded the Panama-sired lambs by 0. 9 pound at birth and 7. 8 pounds at weaning. The lambs sired by the rams having a high

post-weaning rate of gain were no larger at weaning than those sired by rams having a low rate of gain. Post-weaning rate of gain does not reflect itself in pre-weaning gains which might indicate that gains in the two periods are not controlled by the same genes. The drylot ewes produced lambs that weighed more at birth and at weaning than the pasture ewes, produced fleeces equal to the pasture ewes, and had heavier body weights than the pasture ewes.

There were significant yearly variations in body weights of the ewes and weaning weights of the lambs. Also, the age of the ewe affected her body weight, fleece weight, and the birth weight and weaning weight of the lambs. Fleece weights corresponded closely with body weight because two-year-old ewes and those seven years old or over were lower in body weight and fleece weight than mature ewes in the peak of production. Weaning weights of lambs were highest for three- and four-year-old ewes, intermediate for ewes five years of age or older and lowest for two-year-old ewes. Single lambs were heavier at birth and at weaning than each member of a set of twin lambs. Male lambs exceeded females in birth weight, and wether lambs exceeded ewe lambs in weaning weight. Ewes nursing twin lambs were lower in body weight than those nursing singles, and those raising single lambs were lower in body weight than non-nursing ewes.

SOME GENETIC AND ENVIRONMENTAL FACTORS AFFECTING WEANING WEIGHTS OF LAMBS

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TABLE OF CONTENTS

LIST OF TABLES

SOME GENETIC AND ENVIRONMENTAL FACTORS AFFECTING WEANING WEIGHTS OF LAMBS

INTRODUCTION

Idaho is one of the ten leading sheep producing states in the United States. Approximately 70 percent of the sheep in Idaho are dependent on Federal ranges for a major portion of their spring, summer and fall grazing. There is an increasing demand for use of these areas by other interests, and the range available for grazing is growing smaller.

The number of farm flock sheep has been on an increase in Idaho, and the production of early spring lambs is of considerable importance on many irrigated farms along the Snake River. Except for purebred flocks, most farm and range lambs raised are the offspring of whitefaced crossbred ewes mated to Suffolk, and less frequently, to Hampshire rams. When blackfaced rams are used, the entire lamb crop goes to market and the grower buys replacements from whiteface breeders. Sheepmen occasionally breed part of their ewes to a crossbred ram of Panama, Columbia or other whiteface breeding to raise their own replacements.

Except for spring range lambing, many range and most farm lambs are "shed" lambed in January and February and reach market by June or July. There are several reasons for the production of early lambs. More labor is available during the early lambing season; there usually is a favorable market for early lambs; and the lambs make better gains while the grass is green and "lush" and the weather is cool.

Both range and farm sheep have the dual function of producing meat and wool; hence traits which reflect capacity to produce these in quantity and quality have economic value in breeding for sheep improvement. Weaning weight of lambs is important because income from meat production largely comes from the sale of lambs at weaning.

The object of lamb production is to provide a rapid rate of growth from birth to slaughter while at the same time, produce a lamb with desirable finish. A more thorough understanding of the factors which influence the growth and development of sheep will undoubtedly suggest changes in breeding and management systems to minimize influences which reduce production efficiency.

The goal in lamb production is obtaining the greatest income possible from each individual ewe per year. Thus one must consider the extent to which heredity and environment influence weights of lambs prior to weaning. For the lamb producer, the endpoint is the time when the lamb goes to market. That the endpoint of lamb production is the carcass must not be overlooked. Weaning weight, above all else, plays a large part in the determination of income from lamb production.

The ability of a ewe to provide care and nourishment for her lamb varies from one year to another, depending upon the environmental circumstances which influence both the ewe and the lamb. These environmental circumstances may prevail during prenatal or postnatal stages, and may influence the ewe only, the lamb only, or both the ewe and the lamb. The effects which some environmental factors have upon weaning weight can be measured.

Animals with the inherited capacity for a rapid rate of growth usually require less feed per unit of production and are therefore more efficient than those which gain less rapidly. It has been well established that differences in rate and efficiency of gain are inherited. It can be demonstrated that this is a quantitative type of inheritance where many pairs of genes are presumed to influence the attributes which contribute to such differences.

During recent years the growing importance of performance in the breeding of sheep for meat has placed a great deal of emphasis on the weaning weight of lambs. When corrected to a standard age, the extreme variations observed in weaning weights indicate that the potentials for heavy weaning weights are great and have not been fully realized.

There are three main reasons why rapid growth is highly desirable in fat lamb production: (1) The market usually favors spring lambs that reach the market early. (2) Rate of gain is correlated with efficiency of feed utilization. (3) Costs per each unit of gain are reduced when lambs are ready for market in a short length of time. Rate of gain is usually positively associated with condition, which is the most important single criterion in determining market grade. From an economic standpoint, a knowledge of the conditions essential for most rapid growth of lambs is of utmost importance. One of the most important factors in determining the total pounds of lamb weaned or marketed from a flock of sheep is the weight of each lamb at weaning.

The purpose of the present research was to determine the merits of specific breeding, feeding and management practices for fat lamb production under limited acreages of farm lands. The objectives were:

1. To compare breeding performance of ewes kept continuously in the drylot with those grazed on irrigated farm pastures during the summer months and kept in the drylot for the remainder of the year.
2. To compare wool production under the two systems of management.
3. To compare lamb production under the two systems of management.
4. To compare the performance of Panama- and Suffolk-sired

lambs.

5. To determine if selecting for the most rapidly gaining rams on a post-weaning test will increase the pre-weaning growth rate of their offspring.

REVIEW OF LITERATURE

The production of early spring lambs is a special type of enterprise. In order to be successful, one must breed the right kind of lamb and provide favorable environmental conditions for its growth. An understanding of the factors which influence the development and growth of lambs may call for changes in breeding and management systems to increase production efficiency.

Growth of animals is the basis of meat production. According to Hankins and Titus (1939) growth is an increase in live weight. 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 (Brody, 1945).

Rate of growth in sheep is genetically controlled according to Bonsma (1939), 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 (1939) maintains that it is not so much the actual weight as the relation between bone, muscle and fat that is important. With some emphasis on wool, it is a combination of the above mentioned factors that dictates the preference of various sheepmen for different breeds of mutton sheep.

Bonsma (1939), from a study of lamb growth and development, reported 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 (1934) contended that for every breed there appears 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 and Appleton (1932) were of the opinion that early maturity can be obtained in the proportion of meat to bone without reducing the size of animals.

Both induced and natural environmental factors operate to conceal genetic merit, thereby confusing the breeder and obstructing his efforts to select those animals having the greatest breeding value. In many instances variations in environment can be eliminated or controlled, but in others only adjustment or correction is capable of placing animals on a comparable basis. For example, two animals which have equal breeding value may differ widely in phenotype because of a difference in time of birth with attendant more or less favorable conditions of development, age of dams, twinning and other factors.

In earlier research, Donald and McLean (1935) studied the factors which influence the growth rate of purebred and crossbred lambs of mutton breeds in New Zealand. Their findings indicated that generally ram lambs, single lambs and lambs from mature ewes were superior in growth rate to ewe lambs, twin lambs and lambs from two-year-old ewes, respectively. Phillips and Dawson (1937) found that the selection of Hampshire, Shropshire and Southdown lambs under farm conditions in the Eastern United States was affected by type of birth and birth weight of lambs. Bonsma (1939) found that sex and number of parturitions affected growth and development of Merino and crossbred lambs in South Africa. Hazel and Terrill (1945a) reported research results on Rambouillet lambs at the Western Sheep Breeding Laboratory, Dubois, Idaho. The effects of sex, age of dam, year, breeding group, type of birth, age at weaning, and percent inbreeding were studied on range Rambouillet lambs born in 1941 and 1942. The effects of sex, age of dam, type of birth and rearing on weaning weight were highly significant. Differences between years and between groups were not large enough to be significant.

According to Blunn (1944) growth of lambs raised on the range is directly related to the amount and quality of forage available for their consumption. The amount and quality of range forage is in turn governed to a large degree by weather conditions which vary from year to year. Consequently, as pointed out by Phillips, Stoehr and

Brier (1940), differences in rates of growth between seasons are inevitable when animals are raised on the range where feed is dependent upon weather conditions. Blunn (1944) studied groups of Navajo lambs in New Mexico and found highly significant differences between the mean weights at intervals of four weeks from birth to weaning age (20 weeks) for all of the four years studied. Analysis of variance showed that whenever significant differences between the mean weights occurred, the variance between the years was responsible for most of the variations in weights. In further work, Blunn (1945) studied Navajo and Navajo-cross lambs (the Navajo sheep having had about 400 years in which to become adapted to their region), and found large yearly variations and breed-year interactions for weaning weights of the lambs. In studies at Beltsville, Sidwell, Everson and Terrill (1948) found that considerable differences were evident between years for three traits: birth weight, weaning weight, and gain from birth to weaning. In the ten year study under Beltsville conditions, improved nutrition and management for the last four years resulted in birth weights that were one pound greater, weaning weights that were 17 pounds greater, and gain from birth to weaning that was 16 pounds greater than corresponding values during the previous six years. According to Phillips et al. (1940) when lambs being compared are not born in the same year, the first problem to be studied is the effect of different years on the characters for which comparisons are being made. If differences between years are of no importance, they may be disregarded in continuing the analysis, but if significant yearly differences are found, they must be considered in carrying out each succeeding step of the problem (Phillips et al. 1940).

It is generally recognized that males tend to be heavier than ewe lambs at the same age (Winters et al., 1946). Males gain more rapidly than females (Sidwell, Everson and Terrill, 1964). Botkin (1955) found that ram lambs gained more rapidly and were more efficient than ewe lambs. Karem, Chapman and Pope (1949) asserted that wethers were 3.5 pounds heavier than ewe lambs at 25 weeks of age. Ram lambs were 8.3 (Hazel and Terrill, 1945a), 10.8 (Hazel and Terrill, 1946b) and 13.4 (Hazel, 1946) pounds heavier at weaning than ewe lambs. Field et al. (1963) found that the carcass weight per day of age for ewe lambs was 0.03 pound less than for wether lambs. These findings were similar to those reported by deBaca et al. (1956). Furthermore, Shelton and Campbell (1962) reported that range Rambouillet male lambs grew 7.2 percent faster than females. Sex differences at weaning were significant even when corrected for birth weights (Phillips and Dawson, 1940).

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 grazing. Hammond (1952) claimed that whereas single lambs attain their maximum growth rate during their first week of life, it is the fifth week before twin lambs can supplement their milk diet enough to grow maximally. Sidwell, Everson and Terrill (1964) reported that single lambs were significantly heavier than twin lambs at birth and at weaning. Twin lambs raised as singles were significantly lighter at weaning age than singles and heavier than twins raised as twins. deBaca et al. (1956) asserted that birth type imparted the greatest effect on lamb growth of any of the environmental factors studied. Single lambs weighed 17 pounds more at weaning than did twin lambs. Shelton and Campbell (1962) found that single lambs grew 4.6 percent faster than twins raised as singles and ten percent faster than twins raised as twins. Stark (1944) found that lambs born as singles are 20 percent heavier than twins at birth. Hammond and Appleton (1932) reported a 29 percent difference, and Nelson and Ven Katachalam (1949) 22 percent difference between weights of singles and twins. Price, Sidwell and Grandstaff (1951) found that type of birth influenced weanling traits more than did any of the other environmental factors studied. Sidwell and Grandstaff (1949) reported that single lambs averaged 11.2 pounds heavier at weaning than twins and 2.9 pounds heavier than twins raised as singles. Single lambs tend to be heavier for age than twins; in this study they averaged five pounds heavier at 23 weeks (Winters et al. 1946). Other differences in favor of lambs born as singles are cited as 6.2 pounds at 25 weeks by Karem, Chapman and Pope (1949) under Wisconsin conditions; 13.4 by Hazel (1946); six pounds by Hazel and Terrill (1946d); and 11 pounds by Hazel and Terrill (1946b). Phillips and Dawson (1940) showed differences due to birth type even when weaning weights were adjusted for birth weights; this indicated that the lambs were not getting sufficient milk even though ewes nursing twins produce more milk than ewes with single lambs. Similar results were reported by Wallace (1948).

Most of the experiments reported in the literature concerning the various aspects of lamb production have been conducted under as uniform environmental conditions as possible. Unfortunately, little experimental data are available concerning the merits and limitations of the more intensified systems of sheep production. The literature lacks information concerning the production of ewes kept continuously in drylot as compared with those grazed on irrigated farm pastures during the summer months and kept in drylot for the remainder of the year.

Jordan and Hanke (1963) of Minnesota reported on three experiments involving 358 Rambouillet ewes. In all three trials all the ewes were kept in the drylot during the summer months and maintained on harvested feeds. Frequency of feeding (three times per week) had no significant effect on ewe weight gains, fleece weights, lambing percent, lamb birth weights and 30-day lamb weights. Feeding non-lactating ewes during the summer with alfalfa-brome hay at levels which permit them to lose five to ten percent of their body weight, to maintain their body weight, or to increase body weight ten percent had no significant effect on conception, fleece production or lambing percent. About the same amount of TDN was required to increase the weight of non-lactating ewes ten percent (0.06 - 0.08 pounds daily) as is required for gestating ewes. About 1.0 to 1.1 pounds TDN per 100 pounds body weight were required to maintain body weight. Ewes fed to lose about ten percent of their body weight consumed about 60 percent as much TDN as ewes that maintained their body weight. The low level of energy supplied these ewes resulted in an appreciable saving in feed without adversely affecting their production of wool and lambs (Jordan and Hanke, 1963).

Donald and McLean (1935) found that heavy ewes produce heavy lambs. Bonsma (1939) stated that 24 percent of the variation in birth weight of lambs was due to variations in ewe weight. Hammond and Appleton (1932) support this contention by writing that the dam has more influence in controlling size at birth than does the ram. Bonsma (1939) further extended that 25 percent of the variation in milk yield of ewes within breeds is due to body weight differences. In summary Bonsma (1939) stated that "improved efficiency of food utilization by individual ewes resulted in higher intrauterine 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 (1942) asserted that ewes that were heavier as yearlings weaned more pounds of lamb per ewe during their lifetime regardless of breed. An increase in productivity of ewes as they reached maturity was noted by deBaca et al. (1956) and Brown, Bougers and Sabin (1961). Sidwell and Grandstaff (1949) and Hazel and Terrill (1945a) reported that mature ewes weaned lambs that were from four to nine pounds heavier than lambs from two-year-olds. Sidwell, Everson and Terrill (1964) reported that lambs born from dams four years old and older were significantly heavier at birth than lambs from three-year-old dams, and these in turn were significantly heavier than lambs from two-year-old dams. At weaning age, lambs from dams three to six years of age were significantly heavier than those from dams seven years of age and older, and these were also significantly heavier than lambs from two-year-old dams (Sidwell, Everson and Terrill, 1964). Similarly Shelton and Campbell (1962) reported that two-year-old dams and those eight years and older, produced lambs significantly lighter than the relatively constant production of ewes three through seven years of age. Furthermore, Kincaid (1943) found an increase of 0. 63 pound in birth weight of lamb for each increase of one year in age of ewe. Kincaid (1943) observed the increase to be a linear one. Bonsma (1939) likewise found an increase of 0. 62 of a pound in birth weight of a second lamb over that of the first from a ewe; however, he found no significant differences among subsequent lambs. Mature ewes produced lambs with heavier weaning weights than lambs produced by two-year-old ewes (Nelson and Ven Katachalam, 1949; Sidwell, Price and Grandstaff, 1951; Hazel, 1946; Hazel and Terrill, 1945a, b, 1946 a, b).

The literature concerning the effect of age of dam on weaning weight of lambs is generally in agreement except that Blackwell and Henderson (1955) reported the age of the dam to have no significant effect on the weaning weight of Dorset lambs under farm conditions. However, Blackwell and Henderson (1955) reported that the effect of age of ewe on the weaning weight of lambs for the Corriedale, Hampshire and Shropshire breeds which lambed early in the spring was in agreement with studies of range sheep.

Crossbreeding to improve market lamb production is common practice in the sheep industry of this country. Heterosis, or hybrid vigor, in which the crossbred population shows more vigor than either of the parental stocks used in making the cross, may be associated with crossbreeding (Bogart, 1959). In comparison of purebred Columbia, Hampshire and Shropshire ewes and all possible crosses of these breeds there was a 19 percent increase in lamb weight per hundred weight of ewe in favor of the crossbreds (Miller and Daily, 1951). These authors suggested that the increase in weight of lamb per ewe was due to the expression of heterosis in lambing percentage and lamb survival.

When considering the Suffolk ram as a sheep for crossbreeding, Hammond (1947) wrote that "the Suffolk breed is unique because it combines early maturity, good milking qualities and high fertility to a marked degree." Burns and Johnston (1950) observed higher weaning weights, greater survival and a greater percentage of marketable lambs sired by Suffolk than by Hampshire rams.

Miller (1935) used rams of six breeds on Rambouillet ewes. Suffolk-sired lambs were heaviest at weaning, followed by Hampshire and Shropshires, in that order, with the Romney, Rambouillet and Southdown rams being the lowest and equal to one another.

Bradford, Weir and Torell (1960) reported 120-day lamb weights of 71.3 and 59.3 pounds respectively for Suffolk- and Southdown-sired lambs from western white-face ewes. The lambs sired by rams of the larger breed returned approximately 16 percent more income per ewe. Coop and Clark (1958) compared lambs sired by Suffolk, Border Leicester, Hampshire, Dorset and Southdown rams when crossed on Corridale ewes. Suffolk and Border Leicester rams increased weaning weights by eight pounds at 110 days of age, while the Hampshire and Dorset rams increased weaning weights by six pounds at 110 days when compared to the weaning weight of the lambs sired by Southdown rams.

Neville, Chapman, and Pope (1958) used rams of four Down breeds, Suffolk, Hampshire, Oxford and Shropshire, on Montana ewes largely of Rambouillet and Columbia breeding. They reported differences in 120-day weights of lambs very similar to those obtained by Miller (1935) for the same breeds of sire. In both studies, Suffolk-and Hampshire-sired lambs weighed significantly more than those sired by Shropshires.

In Miller's work (1935) which was done under good conditions for fat lamb production, the lambs sired by Down rams were 3.0 to 8.0 pounds heavier at weaning than those sired by the fine wool rams. Under range conditions, however, Neale (1943) found the Down-Rambouillet lambs weighed no more at weaning than straight bred Rambouillet lambs.

Carter et al. (1958) mated rams of the Hampshire, Southdown, Shropshire, Dorset, Columbia, Corriedale breeds and Hampshire x Southdown crossbreds to grade native Virginia and western ewes. The most rapid daily gain from birth to weaning was made by the Columbia-sired lambs, 0.65 pounds per day, followed by those sired by Hampshire rams, 0.62 pound per day. Lambs sired by Southdown, Dorset and Corriedale rams averaged 0.59 pound per day; those sired by Hampshire x Southdown crossbred rams averaged 0.58 pound per day and those sired by Shropshire rams were last at 0.57 pound per day. At the Wyoming station, Hultz, Gorman and Wheeler (1935) compared Hampshire, Lincoln, Rambouillet, Southdown, and Corriedale rams, mated to grade range ewes. Lambs by Hampshire rams were heaviest at weaning. They exceeded the Lincolns by 0.4 pound, Rambouillets by 1.6 pounds, Southdowns by 2.9 pounds, and Corriedales by 4.8 pounds. In gains from birth to weaning, however, the Lincolns and Rambouillets were first, followed by Hampshire, Corriedale and Southdown. These findings were similar to those of Neale (1943).

Foster and Hostetler (1939) compared Hampshire and Shropshire rams mated to eastern North Carolina ewes. The Hampshire crosses gained more rapidly than did the Shropshire crosses, but they were lower in carcass quality.

Nelson, et al. (1950) reported a comparison of Romney, Border Leicester, Southdown and Cheviot rams mated to Lincoln x Rambouillet ewes for fat lamb production in Western Oregon in two trials (1942-1950). In the first trial ewes bred to Southdown and Hampshire rams were about equal in pounds of lamb produced per ewe and exceeded the Romneys. In the second trial, lambs by Hampshire rams were heaviest at weaning with the highest percentage of fat lambs sold and greatest return per ewe. Romney lambs were no larger than the

Cheviots and were lowest in percentage of fat lambs. In a more recent Oregon study, deBaca *et al.* (1956) found that Suffolk rams tended to sire lambs which were heavier at weaning than did Southdown rams, although the differences were not significant.

Shelton (1964) reported that as a group crossbred lambs weighed 0. 6 pounds more than straight Rambouillet lambs at birth, and that birth weight was positively correlated with post-weaning gains. Sidwell, Everson and Terrill (1964) stated that advantages of all crossbred lambs over purebred lambs involving the same breeds were seven pounds for weaning weight and 6. 5 pounds for gain from birth to weaning. The increases in weaning weight of the crossbreds over that of the purebreds were 5. 2 pounds for two-breed crosses, 9. 5 pound for three-breed crosses, and 10. 4 pounds for four-breed crosses. Many workers such as Rae (1953), Terrill (1958) and others have reported studies concerned with crossbreeding, and most of these studies have shown that crossbreeding does lead to increased weaning weights of the lambs.

There is little research information in the literature to determine if selecting for high gaining rams will increase the growth rate of their offspring. Field *et al.* (1963) of the University of Kentucky selected 12 rams (three per year for four years) from the same flock. They weighed approximately 75 pounds and were approximately 180 days of age when the 120-day test was initiated. Each year a slow, average, and rapid gaining ram from the same group was selected and the following fall they were bred to similar groups of western blackfaced ewes. Lambs sired by rapid gaining rams gained faster and had leaner carcasses. There was 0.009 pound per day increase in carcass weight per day of age or approximately 0.018 pound increase per day in live weight for every 0.10 pound increase in average daily gain of rams. Partial correlation coefficients which show correlations between dependent variables and average daily gain of rams were calculated. A relationship of 0.16 ($P < .05$) between carcass weight per day of age and average daily gain of rams was obtained. Thus Field et al. (1963) state that selecting for high gaining rams will increase the growth rate of their offspring.

MATERIALS AND METHODS

Description of Data and Purpose for the Study

The data were collected over a period of three years beginning on July 15, 1960. Five hundred fifty-nine matings were made. Six hundred and twenty-five lambs were weaned.

The study involves data from research at the Caldwell Branch Station to determine the feasibility of maintaining sheep the year around with harvested feeds in drylot. The performance of ewes confined in drylot throughout the year was compared with the performance of ewes grazed on irrigated pasture during summer months and wintered on hay and grain. The ewes that were confined to the drylots and fed only harvested feeds will be referred to as "drylot" ewes in the subsequent presentations, and the ewes that were grazed on irrigated pasture during the summer months and ate harvested feeds during the winter months will be referred to as "pasture" ewes in subsequent presentations.

A breeding study involving the comparison of lambs sired by purebred Suffolk and Panama rams was superimposed upon the management study. Eight rams per year (four Suffolk and four Panama rams) were used each year of the study. The Suffolk rams were selected on the basis of their performance on feed test from the purebred ram lambs raised at the Moscow Station. The Panama rams were selected on the basis of their performance on feed test from the purebred Panama lambs raised at the Caldwell Station.

The design of the experiment to compare performance of dry-lot and pasture managed ewes when mated to high gaining or low gaining Panama or Suffolk rams is presented for the three years, 1960, 1961, 1962, in Tables 1, 2, and 3.

Table 1. Allotment of ewes to treatments and breeding plans for 1960[1]

Pasture	Drylot
46 Panama ewes (Caldwell) 40 yearling ewes (purchased)	46 Panama ewes (Caldwell) 40 yearling ewes (purchased)
86 Ewes	86 Ewes
Sub-flock No. 1 -- 22 ewes Bred to Panama ram #59-27 with the most rapid gain on test	Sub-flock No. 1 -- 22 ewes Bred to Panama ram #59-94 with the most rapid gain on test
Sub-flock No. 2 -- 22 ewes Bred to Suffolk ram #3180 with the most rapid gain on test	Sub-flock No. 2 -- 22 ewes Bred to Suffolk ram #3155 with the most rapid gain on test
Sub-flock No. 3 -- 21 ewes Bred to Panama ram #59-23 with the least rapid gain on test	Sub-flock No. 3 -- 21 ewes Bred to Panama ram #59-47 with the least rapid gain on test
Sub-flock No. 4 -- 21 ewes Bred to Suffolk ram #3177 with the least rapid gain on test	Sub-flock No. 4 -- 21 ewes Bred to Suffolk ram #3055[2] with the least rapid gain on test

[1] The length of the breeding season was 52 days.

[2] This ram proved to be sterile.

Table 2. Allotment of ewes to treatments and breeding plans for 1961[1]

Pasture	Drylot
78 mature ewes 17 yearling ewes	80 mature ewes 17 yearling ewes
95 Ewes	97 Ewes
Sub-flock No. 1 -- 24 ewes Bred to Panama ram #59-94 with the most rapid gain on test	Sub-flock No. 1 -- 25 ewes Bred to Panama ram #59-27 with the most rapid gain on test
Sub-flock No. 2 -- 24 ewes Bred to Suffolk ram #3496 with the most rapid gain on test	Sub-flock No. 2 -- 24 ewes Bred to Suffolk ram #3180 with the most rapid gain on test
Sub-flock No. 3 -- 24 ewes Bred to Panama ram #59-47 with the least rapid gain on test	Sub-flock No. 3 -- 24 ewes Bred to Panama ram #59-23 with the least rapid gain on test
Sub-flock No. 4 -- 23 ewes Bred to Suffolk ram #3328 with the least rapid gain on test	Sub-flock No. 4 -- 24 ewes Bred to Suffolk ram #3451 with the least rapid gain on test

[1] The length of the breeding season was 60 days.

Table 3. Allotment of ewes to treatments and breeding plans for 1962[1]

Pasture	Drylot
76 ewes 26 yearling ewes	76 ewes 26 yearling ewes
102 Ewes	102 Ewes
Sub-flock No. 1 -- 26 ewes Bred to Panama ram #61-98 with the most rapid gain on test	Sub-flock No. 1 -- 26 ewes Bred to Panama ram #61-60 with the most rapid gain on test
Sub-flock No. 2 -- 26 ewes Bred to Suffolk ram #3407 with the least rapid gain on test	Sub-flock No. 2 -- 26 ewes Bred to Suffolk ram #3496 with the least rapid gain on test
Sub-flock No. 3 -- 25 ewes Bred to Panama ram #61-80 with the most rapid gain on test	Sub-flock No. 3 -- 25 ewes Bred to Panama ram #61-43 with the most rapid gain on test
Sub-flock No. 4 -- 25 ewes Bred to Suffolk ram #3451 with the least rapid gain on test	Sub-flock No. 4 -- 25 ewes Bred to Suffolk ram #3328 with the least rapid gain on test

[1] The length of the breeding season was 45 days.

Twenty-five ram lambs which met the registration requirements of the Panama Breed Association were selected at weaning time from the offspring of the purebred flock of approximately 100 ewes at the Caldwell Station. The ram lambs were maintained on a growing ration of alfalfa hay and one-half pound of oats daily from weaning. In late summer these rams were placed on a standard 84-day individual feeding test. The ration was 50 percent chopped alfalfa hay and 50 percent concentrate mixture.

At the Moscow Station approximately the same number of Suffolk ram lambs were selected at weaning time from the offspring of the purebred flock of 75 ewes. These ram lambs were maintained on pasture for about one month following weaning. The ram lambs were then placed on the standard 84-day individual feeding test at the Moscow Station. The two most rapidly and the two least rapidly gaining rams were selected from both the Panama and Suffolk rams that had been tested. The four rams that were selected from the tested rams were trucked to the Caldwell Station early the following spring. The following summer these eight rams were bred to similar groups of grade Panama and crossbred Panama type western whiteface ewes.

There were 92 grade Panama ewes of various ages from two to eight years old in the original flock at the Caldwell Station. Another 80 head of crossbred whiteface yearling ewes of similar breeding were purchased in the eastern part of Idaho. Thus, a total of 172 ewes was available for the study at the beginning of the first breeding season. The number of breeding ewes was increased each year until approximately 200 ewes were available at the beginning of the third breeding season.

Management of the Experimental Flock

The ewes were allotted by use of a table of random numbers to each of the four Suffolk and four Panama rams on July 15, which was the beginning of the breeding season for each year of the experiment. However, both the drylot and pasture ewes were retained in their respective management groups throughout the entire experiment. The allotment of the ewes to sub-flocks within the drylot and pasture flocks for 1960, 1961, and 1962 respectively is shown in Tables 1, 2 and 3.

All ewes were subject to similar climatic conditions, although the nutritional management was not the same for all of the ewes. Only two irrigated pastures were available during the breeding season. The sub-flocks were rotated each morning and evening, which allowed each sub-flock to be on pasture for 12 out of every 24 hours. The sequence of rotation was changed periodically to provide an equal number of days and nights on pasture for all four sub-flocks. A small grove of trees provided shade during the day for the ewes.

The ewes were confined in separate enclosures where they were provided with fresh water, salt and shade during the intervals of rotation when they were not on pasture. The four drylot sub-flocks were confined in separate lots which were provided with fresh water, salt and shade during the breeding season.

One ram was kept with his assigned ewes in the same lot during the entire breeding season the first year of the experiment. The management of the rams was changed the following year. All of the eight assigned rams were turned in with their respective sub-flocks in the evening and in the morning the rams were separated from the ewes. During the daytime all of the rams were confined together in a small pen containing a grove of shade trees where feed, salt and fresh water were provided.

After the breeding season 50 drylot ewes were confined in each corral which was 40 feet wide and 95 feet long. Each corral was provided with covered feed bunks and shade. The pasture managed ewes were allowed to continue grazing on irrigated pasture until approximately November 15th each year at which time they were confined to winter quarters.

The ewes were tagged, or crutched, about six weeks prior to the beginning of lambing. Each ewe had a flock number and was identified by a tattoo in one ear and a metal tag in the other ear.

As soon as a ewe had lambed, the ewe and her lamb(s) were brought into the lambing shed. Here, the ewe numbers, the sex and the birth dates of all lambs were recorded. The birth weight of each lamb was recorded to the nearest one-tenth of a pound, and the umbilical cord was disinfected. The ewe and her lamb(s) were confined to a 4 x 6 foot enclosure to "mother up" for a period of 12 to 36 hours depending on the strength of the lamb(s). Assistance was given to individual lambs requiring help to nurse. As soon as the lambs were deemed strong enough they were tagged and removed from the enclosures (jugs) with their mothers and placed in larger enclosures. Usually, at first, only two ewes with their lambs were placed in each pen. Later on these pairs of ewes and lambs were progressively moved into larger groups until they were outside in the large pens where a maximum of 25 ewes with lambs were kept until weaning time.

All ewes were sheared on or near April 1 of each experimental year. Each fleece was identified and weighed to the nearest tenth of a pound. The fleece weight and the shorn body weight of each ewe was recorded.

The lamb weaning dates were April 17, 1961, April 16, 1962 and April 22, 1963. The ewes were culled immediately after the lambs were weaned. At weaning time all lambs were weighed individually and their wool and body characteristics were evaluated on a uniform scoring system.

The replacement ewe lambs were selected from lambs which were sired by Panama rams. All of the ewe lamb replacements from both management flocks were maintained in the drylot on harvested feeds until needed as yearling replacements for the following summer. After the lambs were weaned from the ewes, the pasture ewes were turned out to pasture but the drylot ewes remained in confinement where they were fed two pounds of alfalfa hay per ewe per day.

During the gestation period the ewes were allowed to gain in weight by having their hay consumption gradually increased. One-half pound of dried molasses beet pulp per ewe per day was added to the ration of both flocks one month prior to lambing. The ewes which had lambed and were nursing lambs were fed one-half pound of barley (whole) daily in addition to the one-half pound of dried molasses beet pulp and alfalfa hay until the lambs were weaned. The lambs were provided with hay and grain creeps.

After the first year of the experiment, no grain was fed to either flock of ewes until after the ewes had lambed and had been moved out of the lambing shed into the larger corrals with their lambs. One pound of grain per ewe per day was fed for the first three weeks after lambing. No more grain was fed to the ewes after the three week period had ended. The ewes were fed ample amounts of alfalfa hay until their lambs were weaned.

ANALYSIS AND RESULTS

In the first analysis, a preliminary examination of the data was made. A total of 559 ewes were studied. For the two traits measured on the ewes, shorn body weight April 1 and fleece weight, the following mathematical model was fit:

$$Y_{ijklm} = \mu + p_i + t_j + m_k + a_l + (pt)_{ij} + (pm)_{ik} + (pa)_{il}$$

$$+ (tm)_{jk} + (ma)_{kl} + e_{ijklm}$$

Y_{ijklm} is the record of either shorn ewe weight or ewe fleece weight of the m^{th} ewe of the l^{th} age of the k^{th} management of the j^{th} type of rearing and of the i^{th} year.

μ is the overall mean

p_i is the effect of the i^{th} year - 1961, 1962 or 1963

t_j is the effect of the j^{th} type of rearing--barren, single or twins

m_k is the effect of the k^{th} management class--pasture or drylot

a_l is the effect of the l^{th} age of ewe--2, 3, 4, 5 or 6, 7 + years

e_{ijklm} is the random error.

Five of the six possible interactions of the main effects are as noted above.

Least squares normal equations were set up. The reduced matrix was inverted, and the least squares constants were computed. Portions of the inverse were re-inverted to obtain the sums of squares for the main effects and interactions as outlined by Harvey (1960).

Tests of significance for differences between individual means were also made. These tests were the multiple range tests devised by Duncan (1955) and extended by Kramer (1957). In tables where the results of these tests are presented, those means followed by the same letter do not differ significantly from one another. Those means not followed by the same letter do differ significantly from one another.

The lamb data were adjusted to a basis of 100 days of age for each lamb prior to the analysis by least squares. The lambs were dropped over a 50-day period and were weaned at a constant date. Thus, it was necessary to adjust the individual lamb weight to 100 days of age by use of the following equation:

$$\text{Adjusted weight} = \frac{(\text{actual weaning weight} - \text{birth weight})}{\text{actual weaning age in days}} 100 + \text{birth weight}$$

The second analysis was set up after a preliminary examination of the data was made. For the two traits measured on the lambs, birth weight and weaning weight, the following mathematical model was fit:

$$Y_{ijklmno} = \mu + s_i + p_j + t_k + m_l + d_m + r_n + (sp)_{ij} + (pt)_{jk} + e_{ijklmno}$$

$Y_{ijklmno}$ = record of the ijklmnoth lamb

μ is the overal mean

s_i is the effect of the ith sex

p_j is the effect of the jth year (61, 62, 63)

t_k is the effect of the kth type of rearing (single or twin)

m_l is the effect of the lth management (pasture or drylot)

d_m is the effect of the mth age of dam

r_n is the effect of the nth ram

$e_{ijklmno}$ is the random error.

An analysis of variance was run prior to the final analysis on the two lamb traits, birth weight and adjusted weaning weight, which included the following interactions: year x type of rearing, year x management, year x age of ewe, type of rearing x management and age of ewe x management. Sex was not included as a main effect in the preliminary analysis of variance.

Only the year x type of rearing was significant, so this interaction along with sex x year was included in the final least squares analysis.

As explained by Harvey (1960) in the selection of the model for the analysis, it is important to exclude from the model sets of effects which are known not to affect the variability. At the same time, however, it is important to include in the model all effects which really do affect the variability of Y in order that the estimates obtained in the analysis will be unbiased. This places the investigator in somewhat of a quandary. One rule to follow is to place a set of effects in the model when some doubt exists concerning whether such effects are really zero or not. Methods are available for deleting a set of effects after it has been found that the constants for the effects within the set probably equal zero.

Classification of the ewes according to the age of the ewe and the type of rearing of the lambs during a period of three years is presented in Table 4.

Table 4. Classification of ewes according to age of ewe and type of rearing of their lambs during a period of three years.

Type of rearing	Number	
Barren	83	
Singles	280	
Twins raised as singles	7	196
Twins raised as twins	189	
Age of ewe	**Number**	
2	185	
3	143	
4	118	
5	36	70
6	34	
7	21	
8	14	43
9	2	
10+	6	

Note: The same ewe could have a record in more than one year.

Twins raised as singles were combined with the twins raised as twins since there were only seven lambs in the first class. Small numbers such as these will yield very inefficient estimates of constants. In like manner, ewes five and six years of age were combined into one class, and ewes seven years of age and above were combined into another class.

The partial confounding of year and age class of ewe is shown very vividly in Table 5.

Table 5. The partial confounding of year and age class of ewe.

Year	Age Class of Ewe					Year sum
	2	3	4	5 & 6	7 & above	
1961	101	18	17	22	14	172
1962	34	99	15	24	19	191
1963	50	26	86	24	10	196

If the year means were not adjusted for age of ewe, it is easy to see that the preponderance of mature ewes in the third year would confound the estimate for age of ewe with year. The effects of year, type of lamb rearing, type of management and age of ewe were studied on 559 possible matings. The least squares constants for shorn ewe weight and ewe fleece weight for all ewes according to years, type of lamb rearing, management, and age of ewe for the two traits measured on ewes, shorn body weight and fleece weight, are shown in Table 6.

Table 6. Least squares constants by years, type of rearing of lamb(s), type of management, age of ewes and interactions for the two traits measured on ewes--shorn body weight and fleece weight.

Classification		Least Squares Constants	
		Shorn ewe weight (pounds)	Ewe fleece weight (pounds)
Overall mean		140.44	11.62
Year			
1961		-6.58	0.31
1962		7.25	-.23
1963		-.67	-.08
Type of rearing			
Barren		11.06	0.09
Single		-3.06	0.11
Twin		-8.00	-.20
Management			
Pasture		-3.61	-.05
Drylot		3.61	0.05
Age of ewe			
2		-14.59	0.11
3		3.53	1.11
4		2.85	0.83
5 and 6		10.54	0.13
7 and above		-2.33	-2.18
Year x Type of rearing			
1961	Barren	-3.36	-.37
	Single	0.17	0.19
	Twin	3.19	0.18
1962	Barren	9.46	0.27
	Single	-2.61	-.02
	Twin	-6.85	-.25
1963	Barren	-6.10	0.09
	Single	2.44	-.17
	Twin	3.66	0.08

Table 6. Continued

Classification		Least Squares Constants: Shorn ewe weight (pounds)	Least Squares Constants: Ewe fleece weight (pounds)
Year x Management			
1961	Pasture	2.52	-.51
1962	Pasture	1.62	0.70
1963	Pasture	-4.14	-.19
1961	Drylot	-2.52	0.51
1962	Drylot	-1.62	-.70
1963	Drylot	4.14	0.19
Year x Age of ewe			
1961	2	-2.84	-.04
	3	2.58	0.71
	4	0.00	0.34
	5 and 6	-1.62	-.62
	7 and above	1.88	-.39
1962	2	3.82	0.52
	3	-6.97	-.92
	4	-1.51	0.27
	5 and 6	1.57	0.14
	7 and above	3.09	-.01
1963	2	-.98	-.48
	3	4.39	0.21
	4	1.51	-.61
	5 and 6	0.05	0.48
	7 and above	-4.97	0.40

The least squares means were derived from the least squares constants by algebraically adding the constants for the effects to the overall mean. The least squares means for shorn ewe weight and ewe fleece weight for all ewes according to years, type of lamb rearing, management, age of ewe and interactions are shown in Table 7.

Table 7. Least squares means for shorn ewe weight and ewe fleece weight covering the three-year period by years, type of rearing of lamb(s), management, age of ewe, and interactions.

Classification		Number of ewes	Least Squares Means: Shorn ewe weight (pounds)	Least Squares Means: Ewe fleece weight (pounds)
Overall mean		599	140.44	11.62
Year				
1961		172	133.86 b	11.93a
1962		191	147.69a	11.39a
1963		196	139.77 b	11.54a
Type of rearing				
Barren		83	151.50a	11.71a
Single		280	137.38 b	11.73a
Twin		196	132.44 c	11.42a
Management				
Pasture		280	136.83 b	11.57a
Drylot		279	144.05a	11.67a
Age of ewe				
2		185	125.85 c	11.72 b
3		143	143.97 b	12.73a
4		118	143.29 b	12.45a
5 and 6		70	150.98a	11.75 b
7 and above		43	138.11 b	9.44 c
Year x Type of rearing				
1961	Barren	57	141.56	11.65
	Single	71	130.97	12.23
	Twin	44	129.05	11.91
1962	Barren	11	168,21	11.76
	Single	111	142.02	11.48
	Twin	69	132.84	10.94
1963	Barren	15	144.73	11.72
	Single	98	139.15	11.48
	Twin	83	135.43	11.41

Table 7. Continued

Classification		Number of ewes	Least Squares Means: Shorn ewe weight (pounds)	Least Squares Means: Ewe fleece weight (pounds)
Year x Management				
1961	Pasture	86	132.77	11.37
1962	Pasture	95	145.70	12.04
1963	Pasture	99	132.07	11.30
1961	Drylot	86	134.95	12.49
1962	Drylot	96	149.68	10.75
1963	Drylot	97	147.52	11.77
Year x Age of ewe				
1961	2	101	116.43	11.99
	3	18	139.97	13.75
	4	17	136.71	13.10
	5 and 6	22	142.78	11.45
	7 and above	14	133.41	9.36
1962	2	34	136.92	12.02
	3	99	144.25	11.59
	4	15	149.03	12.50
	5 and 6	24	159.80	11.67
	7 and above	17	148.45	9.20
1963	2	50	124.20	11.16
	3	26	147.69	12.86
	4	88	144.13	11.76
	5 and 6	24	150.36	12.15
	7 and above	10	132.47	9.75

Those means within a column and within a particular sub-class followed by the same letter do not differ significantly from one another. All others differ significantly ($P < .05$).

The data on ewes (Table 7) showed that the ewes were significantly heavier in 1962 than in 1961 and 1963. However, there was no significant difference between 1961 and 1963 in weight of the ewes.

The pasture ewes were significantly lighter than the drylot ewes

(Table 7). The lower weights of the pasture ewes in 1963 likely resulted from restricted feed because they were on pasture until November 12 with no supplemental feed and were subsequently fed poor quality hay until lambing time.

There was no significant difference in fleece weights between the drylot and the pasture ewes (Table 7). From an examination of Table 7, one notes that the shorn ewe weight was affected by the type of rearing of the lamb(s) the ewes were nursing. That is, the barren ewes were heavier than the ewes which were nursing either twins or singles. Ewes nursing single lambs were heavier than those nursing twins.

The shorn ewe weight was affected by the age of the ewe (Table 7). The two-year-old ewes and those seven and above were lighter than the three-, four-, five- and six-year-old ewes. The fleece weights of the ewes for each of the three years 1961, 1962 and 1963 were not significantly different (Table 7). The fleece weight means correspond rather closely with the weight of the ewe (Table 7). Two-year-old ewes and ewes seven years old and above were lower in body weight and fleece weight than mature ewes in their peak of production. The analysis of variance for the factors affecting shorn ewe weight and fleece weight is shown in Table 8.

Table 8. The analysis of variance by years, type of rearing, management, age of ewe and interactions for shorn ewe weight and fleece weight (mean squares only).

		Mean Squares	
Source of variation	D. F.	Shorn ewe weight April 1	Ewe fleece weight
Years	2	3,735.97**	6.479
Type of rearing	2	6,667.58**	4.941
Management	1	3,964.94**	0.720
Age of ewe	4	9.396.18**	79.741**
Year x Type of rearing	4	1,044.27	3.476
Year x Management	2	1,852.92**	52.313**
Year x Age of ewe	8	597.26	13.554
Type of rearing x Management	2	479.50	1.851
Management x Age of ewe	4	672.74	8.191
Residual	529	380.15	3.540
Total	558		

*Significant (P < .05)

**Highly significant (P < .01)

The year x age of ewe interaction on fleece weight (Table 8) is not readily explained. According to the ewe data (Table 7) the 1962 three-year-old, the 1963 two-year-old and the 1963 four-year-old ewe fleece weights were low for young ewes. The 1961 three-year-old ewes have a heavy fleece weight.

The year x management interaction concerning ewe fleece weight is brought about because of the low fleece weight for the dry-lot ewes in 1962 (Table 7). The reason for the low fleece weight of the drylot ewes in 1962 is unexplained.

In the second analysis by least squares, the effects of sex, year, type of rearing, management, age of dam, and sire (whether Suffolk or Panama or the most rapidly gaining or the least rapidly gaining) were studied using 625 lambs. The analysis is concerned only with the factors important to the production of lamb. The study is one of difference in relative growth of lambs and of the effect of some genetic and environmental factors on the weaning weight of lambs. The lambs were classified as wethers or ewes to measure the effects of sex. The least squares constants for birth weights and weaning weights for all lambs by sex, year, type of rearing, management, age of dam, ram effect and interactions are shown in Table 9. The least squares means for birth weights and weaning weights of all lambs according to sex, year, type of rearing, management, age of dam, ram effect and interactions are shown in Table 10.

Table 9. Least squares constants for birth weights and weaning weights of all lambs by sex, year, type of rearing, management, age of dam, ram effect and interactions.

Classification	Least Squares Constants	
	Birth weight (pounds)	Adjusted weaning weight (pounds)
Overall mean	10. 42	73. 40
Sex		
Male	0. 23	2. 01
Female	-. 23	-2. 01

Table 9. Continued

Classification	Least Squares Constants: Birth weight (pounds)	Adjusted weaning weight (pounds)
Year		
1961	-.14	-1.47
1962	0.14	-.86
1963	-.00	2.33
Type of rearing		
Single	0.96	6.42
Twin	-.96	-6.42
Management		
Pasture	-.26	-1.40
Drylot	0.26	1.40
Age of dam		
2	-.34	-2.15
3	-.12	2.53
4	0.12	1.13
5 and 6	-.19	-.76
7 and above	0.53	-.75
Ram		
2	0.95	6.44
3	0.11	3.03
4	1.01	5.55
5	-.97	-3.94
6	-.56	-3.03
7	-.60	-4.52
8	-.06	-2.16
9	0.94	5.70
10	0.33	5.33
11	-.04	0.07
12	0.22	3.42
13	0.22	-.51
14	-.44	-3.13
15	-.85	-4.92
16	-.28	-7.32

Table 9. Continued.

Classification	Least Squares Constants	
	Birth weight (pounds)	Adjusted weaning weight (pounds)
Sex x Year		
Male - 1961	-.24	0.07
1962	0.10	0.56
1963	0.14	-.63
Female - 1961	0.24	-.07
1962	-.10	-.56
1963	-.14	0.63
Type of rearing x Year		
Single - 1961	-.21	0.03
1962	0.13	0.52
1963	0.09	-.54
Twin - 1961	0.21	-.03
1962	-.13	-.52
1963	-.09	0.54

Table 10. Least squares means for birth weights and weaning weights of all lambs by sex, year, type of rearing, management, age of dam, ram effect and interactions.

Classification	Number of lambs	Least Squares Means	
		Birth weight (pounds)	Adjusted weaning weight (pounds)
Overall mean	625	10.42	73.40
Sex			
Male	310	10.65 b	75.41 b
Female	315	10.19a	71.40a
Year			
1961	149	10.28a	71.94a
1962	221	10.56a	72.54a
1963	255	10.42a	75.74 b

Table 10. Continued.

Classification	Number of lambs	Least Squares Means: Birth weight (pounds)	Least Squares Means: Adjusted weaning weight (pounds)
Type of rearing			
Single	268	11.38 b	79.83 b
Twin	357	9.46a	66.98a
Management			
Pasture	335	10.16a	72.01a
Drylot	290	10.68 b	74.80 b
Age of dam			
2	169	10.08a	71.25a
3	163	10.30ab	75.94 c
4	148	10.54 b	74.53 bc
5 and 6	84	10.23ab	72.65ab
7 and above	61	10.95 c	72.66ab
Ram			
2	8	11.37	79.84
3	22	10.53	76.43
4	45	11.43	78.96
5	51	9.45	69.46
6	49	9.86	70.38
7	58	9.82	68.89
8	56	10.36	71.24
9	40	11.36	79.10
10	61	10.75	78.74
11	62	10.38	73.47
12	38	10.64	76.82
13	33	10.64	72.89
14	33	9.98	70.27
15	34	9.57	68.48
16	35	10.14	66.08
Sex x Year			
Male - 1961	75	10.26	74.01
1962	116	10.89	75.11
1963	119	10.79	77.10
Female - 1961	74	10.30	69.86
1962	105	10.24	69.98
1963	136	10.05	74.36

Table 10. Continued.

Classification	Number of lambs	Least Squares Means Birth weight (pounds)	Least Squares Means Adjusted weaning weight (pounds)
<u>Type of rearing x Year</u>			
Single - 1961	66	11.02	78.39
1962	105	11.64	79.48
1963	97	11.46	81.62
Twin - 1961	83	9.54	69.91
1962	116	9.48	65.60
1963	158	9.37	69.85

Those means within a column and within a particular sub-class followed by the same letter do not differ significantly from one another. All others differ significantly ($P < .05$).

The male lambs exceeded the female lambs in both birth weight and weaning weight (Table 10). There was no significant difference among the year means for the birth weight of the lambs (Table 10). The weaning weight of the lambs for 1963 significantly exceeded that of the lambs in both 1961 and 1962 (Table 10). Single lambs exceeded twin lambs in both birth weight and weaning weight (Table 10). The lambs from the drylot ewes exceeded the lambs from the pasture ewes in both birth weight and weaning weight (Table 10).

The birth weights of the lambs from the two-year-old ewes were significantly lighter than the birth weights of the lambs from the four- and seven-year-old ewes (Table 10). The lambs from the three-year-old ewes were significantly lighter at birth than were the lambs from the seven-year-old and above class of ewes. The birth weights of the lambs from the four-, five- and six-year old classes of ewes were lighter than the birth weights of the lambs from the seven-year-old and above class of ewes.

The two-year-old dams produced lambs which were significantly lighter at weaning than the lambs from either the three- or four-year-old dams. All of the ewes that were five years of age and older produced lambs which were lighter at weaning time than the lambs from the three-year-old ewes.

The data on the rams were analysed to determine the effects of the rams on their offspring. The means of all sires for their pre-weaning gains and post-weaning test gains are shown in Table 11.

The rams had been selected according to breed and whether they were the most rapidly or the least rapidly gaining on a post-weaning rate of gain test. The rams were selected (Table 11) on the basis of their performance on a post-weaning rate of gain test. However, the evaluation of their offspring was based on a different criterion, gain in weight from birth to weaning.

The data (Table 11) show that the pre-weaning average daily gains of the Suffolk rams which were selected by the post-weaning test as the most rapidly gaining and the least rapidly gaining are nearly the same 0. 68 pounds and 0. 64 pounds respectively. Similarly, the Panama rams had a difference of only 0. 11 pound in average daily gain from birth to weaning between the most rapidly and least

Table 11. The means of all sires for their pre-weaning gains and post-weaning test gains.

Ram	Average daily gain from birth to weaning (pounds)	Average daily gain on post-weaning test (pounds)
The least rapidly gaining Panama rams		
5	0.74	0.44
7	0.60	0.43
13	0.50	0.71
15	0.57	0.70
Mean	0.60	0.57
The most rapidly gaining Panama rams		
6	0.74	0.68
8	0.61	0.68
14	0.74	0.94
16	0.75	0.92
Mean	0.71	0.81
The least rapidly gaining Suffolk rams		
3	0.70	0.51
10	0.62	0.41
11	0.61	0.33
Mean	0.64	0.42
The most rapidly gaining Suffolk rams		
2	0.70	0.89
4	0.73	0.76
9	0.69	0.73
12	0.60	0.58
Mean	0.68	0.74

rapidly gaining rams as selected by the post-weaning test.

The least squares means for birth weights and adjusted weaning weights of lambs sired by the most rapidly and least rapidly gaining Suffolk and Panama rams during a post-weaning test period are shown in Table 12.

Table 12. Least squares means of birth weights and adjusted weaning weights for lambs sired by the most rapidly and the least rapidly gaining Suffolk and Panama rams.

Ram	Birth weight (pounds)	Adjusted weaning weight (pounds)
The least rapidly gaining Panama rams		
5	9.45	69.4
7	9.82	68.9
13	10.64	72.9
15	9.57	68.5
Mean	9.87	69.9
The most rapidly gaining Panama rams		
6	9.86	70.4
8	10.36	71.2
14	9.98	70.3
16	10.14	66.1
Mean	10.08	69.5
The least rapidly gaining Suffolk rams		
3	10.53	76.4
10	10.75	78.7
11	10.38	73.5
Mean	10.55	76.2
The most rapidly gaining Suffolk rams		
2	11.37	79.8
4	11.44	79.0
9	11.36	79.1
12	10.64	76.8
Mean	11.20	78.7

There was a breed difference for both birth weight and weaning weight of the lambs (Table 12). The Suffolk-sired lambs exceeded the Panama-sired lambs by 0. 9 pound at birth and continued to maintain an advantage until weaning at which time the Suffolk-sired lambs exceeded the Panama-sired lambs by 7. 8 pounds. Although the lambs sired by the most rapidly gaining Suffolk rams exceeded the lambs sired by the least rapidly gaining Suffolk rams in weaning weight by 2. 5 pounds, this was not reflected in the lambs sired by Panama rams.

Furthermore, the data (Table 12) show that the Panama rams which were selected as the most rapidly gaining by post-weaning test sired lambs which had an adjusted weaning weight of 69. 5 pounds as compared to 69. 9 pounds for the lambs which were sired by the least rapidly gaining rams on test. Therefore, the post-weaning test to select the most rapidly gaining rams was not a satisfactory method for increasing the pre-weaning gains of their lambs.

The analysis of variance for the effects of sex, year, type of rearing, management, age of dam and the most rapidly or least rapidly gaining Suffolk or Panama sires upon birth weight and weaning weight of lambs is shown in Table 13. Orthogonal comparisons were made by matrix multiplication as outlined by Harvey (1960) to apportion the differences among sires to that between Suffolk and Panama breeds, the most rapidly and least rapidly gaining on test and interaction (Table 13). The sex x year and year x type of rearing interactions were not significant, so no mean separation procedure was run on these subclass means. The remainder mean square with 11 degrees of freedom is the appropriate error term for these comparisons.

Table 13. The analysis of variance of sex, year, type of rearing, management, age of dam, breed of ram, gaining ability of sire and interaction effects for birth weight and weaning weight of lambs (mean squares only).

		Mean Squares	
Source of variation	D. F.	Birth weight	Adjusted weaning weight
Sex	1	29.09*	2,303.5**
Years	2	2.46	199.7
Type of rearing	1	445.56**	20,059.6**
Management	1	27.64**	780.0**
Age of dam	4	9.19**	441.2**
Ram	(14)	(14.60)**	(760.8)**
Panama vs. Suffolk	1	81.26	6,527.0**
High vs. Low	1	26.92	251.2
Interaction	1	7.39	443.4
Remainder	11	8.08	311.7
Sex x Year	2	7.56	62.9
Year x Type of rearing	2	5.38	60.2
Residual	597	2.38	69.7
Total	624		

*Significant ($P < .05$)

**Highly significant ($P < .01$)

Upon examination of the ram data for effect of ram on offspring (Table 13), one observes no significant interaction of breed x selection for gaining ability. The lambs sired by Suffolk rams had significantly heavier weaning weights than the lambs sired by Panama rams (Table 13). For either birth weight or weaning weight there was no significant difference between lambs sired by the most rapidly gaining and the least rapidly gaining rams (Table 13).

It appears that heterosis was important in giving an increase in gains of the Suffolk-sired lambs when compared with the Panama lambs. However, selection for increased post-weaning rate of gain in the sires did not increase the pre-weaning rate of gain of their offspring. This might suggest that the genes affecting pre-weaning growth are not the same as those affecting post-weaning growth.

DISCUSSION

Crossbreeding

Growth of animals is the basis of meat production. Rate of growth in sheep is controlled genetically; however, its expression is subject to environmental modification. Both induced and natural environmental factors operate to conceal genetic merit. Although growth in lambs is in part under additively controlled inheritance, it also responds to crossbreeding. Crossbreeding is an established practice among commercial sheep producers to improve market lamb production in Idaho. The chief reason for crossbreeding is to bring about an increase in vigor. Vigor is used in this connection to cover almost everything that pertains to desirability. The desirable items are rate of gain, economy of gain, fertility and general strength (Winters, 1959).

Heterosis, or hybrid vigor, in which the crossbred population shows more vigor than either of the parental stocks used in the making of the cross, may be associated with crossbreeding (Bogart, 1959). There are several hypotheses concerning the aspects of heterosis. No attempt will be made to discuss these aspects.

The literature previously cited indicates that Suffolk and Hampshire rams are superior to Shropshire, Romney, Rambouillet and Southdown rams for crossing on western whiteface ewes. Miller (1935) states, "Sires of the larger breeds, namely, the Hampshire and Suffolk, produce lambs weighing from 6 to 8 pounds more at 3 1/2 to 4 months of age than sires of the smaller breeds such as the Shropshire and Southdown". Furthermore, Miller (1935) found the Hampshire to be exceeded only by Suffolk rams in weaning weight of lambs sired when bred to Rambouillet ewes. de Baca (1956) found that ewes mated to Suffolk rams produced 15 pounds more lamb per ewe bred than those bred to Southdown rams. Both Suffolk and Hampshire rams have compared very favorably for crossbreeding purposes in several experiments. However, in Idaho there has been a definite objection to the Hampshire ram as a crossing sheep because of the contention that a Hampshire ram transmits to his lambs a large, broad head which makes delivery difficult. It is said that this causes a certain amount of trouble at parturition, particularly in yearling ewes. This is, perhaps, the main reason why the Suffolk ram is very popular in Idaho for crossing on western whiteface ewes. The results obtained in the present experiment are in agreement with most of the findings that have been reported. Crossbreeding was beneficial as shown by the fact that the Suffolk-sired lambs weighed significantly more at birth and at weaning than the Panama-sired lambs. The Suffolk-sired lambs exceeded the Panama-sired lambs by 0.9 pound at birth and continued to maintain an advantage until weaning at which time the Suffolk-sired lambs exceeded the Panama-sired lambs by 7.8 pounds. It appears that heterosis was important in giving an increase in gains of the Suffolk-sired lambs when compared with the Panama-sired lambs.

Under some conditions, however, crossing does not show any value. Neale's work (1943) shows that under rigorous conditions of the New Mexico range country, pure or grade Rambouillets gave better results when mated to Rambouillet rams than when mated to Hampshire rams. He stated that Hampshire cross lamb weights varied directly with feeding condition and to a greater extent than did weights of Rambouillet lambs. The Rambouillets used by Neale were apparently much better adapted to the conditions under which they were raised, and crossing them to breeds obviously not adapted to such conditions failed to show an advantage.

Selection for the Most Rapidly Gaining Rams

Growth during the nursing period and weaning weight result from a combination of the animal's genetic capacity to grow and the milk provided by its dam. Rate of growth from birth to weaning is very important in the production of lambs for market because it is the general practice to market them at or soon after weaning. The relationship between weaning weight and growth following weaning is not as clearly understood in sheep as it is in beef cattle and swine.

Very little information is available to indicate whether or not selecting for high gaining rams will increase the growth rate of their lambs from birth to weaning. Field et al. (1963) selected rams on the basis of their post-weaning rate of gain test. Each year a slow, an average, and a rapidly gaining ram from the same group was selected, and the following fall they were bred to randomly selected groups of western blackfaced ewes. There was 0.009 pound per day increase in lamb carcass weight per day of age or approximately 0.018 pound increase per day in live weight for every 0.10 pound increase in average daily gain of rams. Thus, lambs sired by rapidly gaining rams gained more rapidly from birth to weaning than the lambs sired by slowly gaining rams.

The data from the present study do not agree with the results obtained by Field et al. (1963). The rams had been selected (Table 11), whether they were the most rapidly or the least rapidly gaining, on a post-weaning rate of gain test. However, the evaluation of their offspring was based on a different criterion: gain in weight from birth to weaning. The pre-weaning average daily gains of the Suffolk rams which were selected by the post-weaning test (Table 11) as the most rapidly gaining and the least rapidly gaining are the same. Similarly, the Panama rams showed only a small difference in average daily gain from birth to weaning between the most rapidly and the least rapidly gaining rams as selected by the post-weaning test. Although the lambs sired by the most rapidly gaining Suffolk rams exceeded the lambs sired by the least rapidly gaining Suffolk rams in weaning weight by 2.5 pounds, this was not reflected in the lambs sired by Panama rams. For either birth weight or weaning weight there was no significant difference between lambs sired by the most rapidly gaining and the least rapidly gaining rams (Table 13). In the present experiment, selection for increased post-weaning rate of gain of the sires did not increase the pre-weaning rate of gain of their offspring. This might suggest that the genes affecting pre-weaning growth are not the same as those affecting post-weaning growth.

Drylot vs. Pasture

Very little information is available concerning the merits and limitations of the more intensified systems of sheep production. The literature lacks information concerning the productive capacity of ewes kept continuously in drylot as compared with those grazed on irrigated pastures during the summer months and kept in drylot for the remainder of the year.

Jordan and Hanke (1963) reported on three experiments in which all the ewes were kept in the drylot during the summer months and maintained on harvested feeds. Feeding non-lactating ewes during the summer with alfalfa-brome hay at levels which permitted them to lose five to ten percent of their body weight, or to increase body weight ten percent, had no significant effect on rate of conception, fleece production or lambing percent. About 1.0 to 1.1 pounds TDN per 100 pounds body weight was required to maintain body weight. The low level of energy supplied these ewes resulted in an appreciable saving in feed without adversely affecting their production of wool and lambs. The conditions under which the present experiment was carried out were such that the performance of ewes confined in drylot throughout the year was compared with the performance of ewes grazed on irrigated pasture during summer months and wintered on hay and grain. The data on ewes (Table 7) show that the pasture ewes were significantly lighter than the drylot ewes. The lower weights of the pasture ewes in 1963 likely resulted from restricted feed because they were on pasture until November 12 with no supplemental feed and were subsequently fed poor quality hay until lambing time. There was no significant difference in fleece weights between the drylot and pasture ewes (Table 7).

The lambs from the drylot ewes exceeded the lambs from the pasture ewes in both birth weight and weaning weight (Table 10). The lambs from the drylot ewes seemed to be stronger than those from the pasture ewes. This was noticeable when the lambs were brought into the lambing shed from the drop pens soon after they were born. The advantage in weight carried on through to weaning for the drylot lambs were 0.46 pound heavier at birth and 2.8 pounds heavier at weaning than the pasture lambs.

Yearly Variations

Both induced and natural environmental factors operate to conceal genetic merit, and thereby confuse the breeder and obstruct his efforts to select those animals having the greatest breeding value. In many instances variations in environment can be eliminated or controlled, but in others only adjustment or correction is capable of placing animals on a comparable basis. A good example of seasonal or yearly variation is that which affects range lambs.

In studies at Beltsville, Sidwell, Everson and Terrill (1964) found that considerable differences were evident between years for three traits: birth weight, weaning weight, and gain from birth to weaning. According to Blunn (1944) growth of lambs raised on the range is directly related to the amount and quality of forage available for their consumption. The amount and quality of range forage is in turn governed to a large degree by weather conditions which vary from year to year.

In the present study it was found that we do have true seasonal effects as well as variations from one year to another. The ewes in drylot should have shown no yearly variation if year effects are the result of variations in seasons on forage production; however, this group of ewes showed the same yearly variation as the pasture ewes.

It appears that factors which affect the sheep directly are operating to bring about yearly variability.

Age of Dam

An increase in productivity of ewes as they reached maturity was noted by deBaca et al. (1956) and Brown, Bougers and Sabin (1961). Sidwell and Grandstaff (1949) and Hazel and Terrill (1945a) reported that mature ewes weaned lambs that were from four to nine pounds heavier than lambs from two-year-olds. At weaning age, lambs from dams three to six years of age were significantly heavier than those from dams seven years of age and older, and these were also significantly heavier than lambs from two-year-old dams (Sidwell, Everson and Terrill, 1964). Shelton and Campbell (1962) reported similar results. Numerous other research workers have reported similar findings that mature ewes produced lambs with heavier weaning weights than lambs produced by two-year-old ewes.

The present research findings are in agreement with the literature, and it is common knowledge that age affects the productivity of ewes. The shorn ewe weight was affected by the age of the ewe (Table 7). The two-year-old ewes and those seven and above were lighter than the three-, four-, five- and six-year-old ewes. The fleece weight means corresponded rather closely with the weight of the ewe (Table 7). Two-year-old ewes and ewes seven years old and above were lower in body weight and fleece weight than mature ewes in their peak of production.

The birth weights of the lambs from the two-year-old ewes were significantly lighter than the birth weights of the lambs from the four- and seven-year-old ewes (Table 10). The lambs from the three-year-old ewes were significantly lighter at birth than were the lambs from the seven-year-old and above class of ewes. The birth weights of the lambs from the four-, five- and six-year-old classes of ewes were lighter than the birth weights of the lambs from the seven-year-old class of ewes. Probably the main reason why the seven-year-old and above class of ewes produced heavier lambs at birth than the four-, five- and six-year-old ewes is that they were retained because of previous outstanding production. Thus, this is a highly selected class in comparison with other classes not selected at all for lamb production (two-year-old) or selected with much lower pressure than the older ewes.

The two-year-old dams produced lambs which were significantly lighter at weaning than the lambs from either the three- or four-year-old dams. All of the ewes that were five years of age and older produced lambs which were lighter at weaning than the lambs from the three-year-old ewes.

Type of Rearing

Numerous workers have shown that type of birth (twins vs. singles) and rearing have a tremendous effect on growth rates of lambs. Hammond (1952) claimed that whereas single lambs attain their maximum growth rate during their first week of life, it is the fifth week before twin lambs can supplement their milk diet enough to grow maximally. Sidwell, Everson and Terrill (1964) reported that single lambs were significantly heavier than twin lambs at birth and at weaning. Twin lambs raised as singles were significantly lighter at weaning age than singles and heavier than twins raised as twins. deBaca et al. (1956) asserted that birth type imparted the greatest effect on lamb growth of any of the environmental factors studied. Price, Sidwell and Grandstaff (1951) found that type of birth influenced weanling traits more than did any of the other environmental factors studied. Sidwell and Grandstaff (1949) reported that single lambs averaged 11.2 pounds heavier at weaning than twins.

The single lambs of the present study exceeded the individual twin lambs in both birth weight and weaning weight (Table 10). The single lambs were 1.9 pounds heavier than individual twin lambs at birth and 12.9 pounds heavier than individual twins at weaning. Type of rearing also affected the weights of the ewes. All ewes were weighed each year approximately two weeks prior to weaning of the lambs. Ewes raising twins were lighter than those raising single lambs and those raising single lambs were lighter than non-nursing ewes. It is interesting to note that the demand was greater on the ewes which were raising twins in comparison to those ewes raising single lambs.

Sex

It is generally recognized that males tend to be heavier at any given age than females. This is true in sheep as well as in other farm animals. It is common knowledge that male lambs gain more rapidly than females. Ram lambs gained more rapidly and were more efficient than ewe lambs (Botkin, 1955). Chapman and Pope (1949) asserted that wethers were 3.5 pounds heavier than ewe lambs at 25 weeks of age. Ram lambs were 8.3 (Hazel and Terrill, 1945a) 10.8 (Hazel and Terrill, 1946b) and 13.4 (Hazel, 1946) pounds heavier at weaning than ewe lambs. Numerous other research workers have reported similar findings.

The present research findings concerning sex are in agreement with the literature. The male (wether) lambs exceeded the female lambs in both birth weight and weaning weight (Table 10). The male (wether) lambs weighed 0.46 pound more at birth and 4.0 pounds more at weaning than females.

SUMMARY AND CONCLUSIONS

From the results of the present study the following conclusions appear warrented:

1. There was a breed difference for both birth weight and weaning weight of the lambs. The Suffolk-sired lambs exceeded the Panama-sired lambs by 0.9 pound at birth and continued to maintain an advantage until weaning at which time the Suffolk-sired lambs exceeded the Panama-sired lambs by 7. 8 pounds.

2. It appears that heterosis was important in giving an increase in gains of the Suffolk-sired lambs when compared with the Panama lambs.

3. Although the lambs sired by the most rapidly gaining Suffolk rams exceeded the lambs sired by the least rapidly gaining Suffolk rams in weaning weight by 2. 5 pounds, this was not reflected in the lambs sired by Panama rams. Thus, for either birth weight or weaning weight there was no significant difference between lambs sired by the most rapidly gaining and the least rapidly gaining rams.

4. In this experiment selection for increased post-weaning rate of gain in the sires did not increase the pre-weaning rate of gain of their offspring. This might suggest that the genes affecting pre-weaning growth are not the same as those affecting post-weaning growth.

5. The pasture ewes were significantly lighter than the drylot ewes. The lower weights of the pasture ewes in 1963 likely resulted from restricted feed because they were on pasture until November 12 with no supplemental feed and were subsequently fed poor quality hay until lambing time.

6. There was no difference between the drylot and pasture managed ewes or among the years for fleece weight.

7. The lambs from the drylot ewes exceeded the lambs from the pasture ewes in both birth weight and weaning weight but there were no differences among the year means for birth weights of the lambs.

8. The ewes were significantly heavier in 1962 than in 1961 and 1963. However, there was no significant difference between 1961 and 1963 in weight of ewes.

9. The weaning weight of the lambs for 1963 exceeded that of the lambs in 1961 and 1962 which were not different.

10. Two-year-old ewes and ewes seven years old and above were lower in body weight and fleece weight than mature ewes in their peak of production.

11. The birth weights of the lambs from the two-year-old ewes were significantly lighter than the birth weights of the lambs from the four- and seven-year-old ewes. The lambs from the three-year-old ewes were significantly lighter at birth than were the lambs from the

seven-year-old and above class of ewes. The birth weights of the lambs from the four-, five- and six-year-old classes of ewes were lighter than the birth weights of the lambs from the seven-year-old and above class of ewes.

12. The two-year-old dams produced lambs which were significantly lighter at weaning than the lambs from either the three- or four-year-old dams. All of the ewes that were five years of age and older produced lambs which were lighter at weaning time than the lambs from the three-year-old ewes.

13. Single lambs exceeded the individual twin lambs in both birth weight and weaning weight. The single lambs were 1.9 pounds heavier than individual twins at birth and 12.9 pounds heavier than individual twins at weaning.

14. Ewes raising twins were lighter than those raising single lambs and those raising single lambs were lighter than non-nursing ewes.

15. The male (wether) lambs exceeded the female lambs in both birth weight and weaning weight. The male (wether) lambs weighed 0.46 pound more at birth and four pounds more at weaning than females.

BIBLIOGRAPHY

1. Blackwell, R. L. and C. R. Henderson. Variation in fleece weight, weaning weight and birth weight of sheep under farm conditions. Journal of Animal Science 14:831-843. 1955.

2. Blunn, C. T. The influence of seasonal differences on the growth of Navajo lambs. Journal of Animal Science 3:41-49. 1944.

3. _______________. Yearly differences in growth of Navajo and crossbred ewe lambs. Journal of Animal Science 4:306-310. 1945.

4. Bogart, Ralph. Improvement of livestock. New York, MacMillan, 1959. 436 p.

5. Bonsma, F. N. Factors affecting the growth and development of lambs with special reference to cross-breeding of Merino sheep for fat lamb production in South Africa. Pretoria, South Africa, 1939. 214 p. (University of Pretoria Publication Series I. Agriculture No. 48).

6. Botkin, M. P. Selection for efficiency of gain in lambs. (Abstract) Journal of Animal Science 14:1176. 1955.

7. Bradford, G. E., W. C. Weir and D. T. Torell. Growth rate, carcass grades and net returns of Suffolk and Southdown-sired lambs under range conditions. Journal of Animal Science 19:493-501. 1960.

8. Brody, Samuel. Bioenergenetics and growth with special reference to the efficiency complex in domestic animals. Baltimore, Reinhold, 1945. 1023 p.

9. Brown, C. J., C. A. Bougers and S. W. Sabin. Evaluation of factors affecting the growth of spring lambs. Fayetteville, University of Arkansas, 1961. 19 p. (Arkansas. Agricultural Experiment Station. Station bulletin no. 646).

10. Burns, Robert H. and Alexander Johnston. Relation of wool type of ewes and breed of rams to lamb and wool production. Laramie, University of Wyoming, 1950. 28 p. (Wyoming. Agricultural Experiment Station. Station bulletin no. 296).

11. Carter, R. C. et al. Breeds of rams for spring lamb production. Blacksburg, Virginia Polytechnic Institute, 1958. 16 p. (Virginia. Agricultural Experiment Station. Bulletin no. 492.)

12. Coop, I. E. and R. V. Clark. Breeds of rams for fat lamb production. New Zealand Journal of Science and Technology 38:928-946. 1957.

13. deBaca, R. C. et al. Factors affecting weaning weights of crossbred spring lambs. Journal of Animal Science 15:667-677. 1956.

14. Donald, H. P. and J. W. McLean. The growth rate of lambs in Canterbury. New Zealand Journal of Science and Technology 17:497-519. 1935.

15. Duncan, D. B. Multiple range and multiple F tests. Biometrics 11:1-42. 1955.

16. Field, R. A. et al. Carcass evaluation of lambs from selected sires. Journal of Animal Science 22:364-367. 1963.

17. Foster, J. E. and E. H. Hostetler. Changes in meat and wool characteristics resulting from the use of purebred mutton rams on native ewes. Raleigh, University of North Carolina, 1939. 23 p. (North Carolina. Agricultural Experiment Station. Technical bulletin no. 60.)

18. Hammond, John. The Suffolk ram as a crossing sheep. Reprint from Suffolk Sheep Society Yearbook, 1947. 10 p.

19. ________________. Farm animals: their breeding, growth, and inheritance. London, Edward Arnold, 1952. 266 p.

20. Hammond, John and A. B. Appleton. Growth and the development of mutton qualities in the sheep. Edinburgh, Oliver and Boyd, 1932. 597 p.

21. Hammond, John and G. N. Murray. Grading meat: the prices given for carcasses of different weights and qualities. Journal of Agricultural Science 24:233-249. 1934.

22. Hankins, O. G. and Harry W. Titus. Growth, fattening and meat production. In: U. S. Department of Agriculture Yearbook, 1939. p.450-468.

23. Harvey, Walter R. Least squares analysis of data with unequal subclass numbers. Washington, 1960. 157 p. (U.S. Department of Agriculture. Agricultural Research Service. ARS-20-8).

24. Hazel, L. N. The covariance analysis of multiple classification tables with unequal subclass numbers. Biometrics 2:21-25. 1946.

25. Hazel, L. N. and Clair E. Terrill. Effect of some environmental factors on weanling traits of range Rambouillet lambs. Journal of Animal Science 4:331-341. 1945.

26. ________________. Heritability of weaning weight and staple length of range Rambouillet rams. Journal of Animal Science 4:347-358. 1945.

27. ________________. Heritability of type and condition in range Rambouillet rams. Journal of Animal Science 5:55-61. 1946.

28. ________________. Effects of some environmental factors on weanling traits of range Columbia, Corriedale and Targhee lambs. Journal of Animal Science 5:318-325. 1946.

29. ________________. Effects of some environmental factors on fleece and body characteristics of range Rambouillet yearling ewes. Journal of Animal Science 5:382-388. 1946.

30. Hultz, Fredric S., J. A. Gorman and S. S. Wheeler. Crossbreeding with western ewes. Laramie, University of Wyoming, 1935. 20 p. (Wyoming. Agricultural Experiment Station. Bulletin no. 210).

31. Jordon, R. M and H. E. Hanke. Frequency of feeding, roughage-concentrate ratio for pregnant ewes and summer drylot feeding of non-lactating ewes. Journal of Animal Science 22:679-685. 1963.

32. Karam, H. A., A. B. Chapman, and A. L. Pope. Some of the sources of variation in body weight, rate of gain, type and condition of lambs raised under farm conditions. (Abstract) Journal of Animal Science 8:606. 1949.

33. Kincaid, C. M. Influence of the sire on the birth weight of lambs. Journal of Animal Science 2:152-156. 1943.

34. Kramer, C. Y. Extension of multiple range tests to group correlated adjusted means. Biometrics 13:13-18. 1957.

35. Miller, K. P. and D. L. Dailey. A study of crossbreeding sheep. Journal of Animal Science 10:462-468. 1951.

36. Miller, Robert F. Crossbreeding investigation in the production of California spring lambs. Davis, University of California, 1935. 32 p. (California. Agricultural Experiment Station. Bulletin no. 598.)

37. Neale, P. E. Production of wool and lamb from different types of ewes and breeds of rams. State College, New Mexico A. and M., 1943. 26 p. (New Mexico. Agricultural Experiment Station. Bulletin no. 305).

38. Nelson, O. M. et al. Importance of ram breed in fat lamb production. Corvallis, Oregon State College, 1950. 4 p. (Oregon. Agricultural Experiment Station. Bulletin no. 489).

39. Nelson, R. H. and G. Ven Katachalam. Estimates of the heritability of birth weight and weaning weight of lambs. (Abstract) Journal of Animal Science 8:607-608. 1949.

40. Neville, W. E., Jr., A. B. Chapman and A. L. Pope. Comparison of lambs from Western (Columbia-Rambouillet) ewes and sired by 4 down breeds. Journal of Animal Science 17:763-773. 1958.

41. Phillips, Ralph W. and W. M. Dawson. The relation of type and time of birth and birth weight of lambs to their survival, growth and suitability for breeding. Record of proceedings of the American Society of Animal Production 30:296-306. 1937.

42. ________________. Some factors affecting survival, growth and selection of lambs. Washington, 1940. 18 p. (U. S. Department of Agriculture. Circular no. 538).

43. Phillips, Ralph W. et al. Some factors affecting the progeny testing of rams. Washington, 1940. 17 p. (U. S. Department of Agriculture. Circular no. 580).

44. Phillips, Ralph W., J. A. Stoehr and G. W. Brier. Growth in Corriedale and Rambouillet sheep under range conditions. Proceedings of the American Society of Animal Production 33:173-181. 1940.

45. Price, Donald A., James O. Grandstaff and George M. Sidwell. Lamb production of Navajo ewes bred to Columbia and Romney rams, and Navajo crossbred ewes bred to Lincoln and Cotswold rams. Journal of Animal Science 10:272-277. 1951.

46. Price, Donald A., G. M. Sidwell and J. O. Grandstaff. Genetic and environmental factors affecting yearling traits of Navajo and Navajo cross bred ewes. (Abstract) Journal of Animal Science 10:1029. 1951.

47. Rae, A. L. The advantages and disadvantages of crossbreeding sheep in New Zealand. Sheepfarming Annual 6:147-156. 1953.

48. Shelton, Maurice. Relation of birth weight to death losses and to certain productive characters of fall-born lambs. Journal of Animal Science 23:355-359. 1964.

49. Shelton, Maurice and and Fred Campbell. Influence of environmental adjustments on heritability of weaning weight of range Rambouillet lambs. Journal of Animal Science 21:91-94. 1962.

50. Sidwell, G. M., D. O. Everson and C. E. Terrill. Lamb weights in some pure breeds and crosses. Journal of Animal Science 23:105-110. 1964.

51. Sidwell, G. M. and J. O. Grandstaff. Size of lambs at weaning as a permanent characteristic of Navajo ewes. Journal of Animal Science 8:373-380. 1949.

52. Sidwell, G. M., D. A. Price and J. O. Grandstaff. Genetic and environmental factors affecting type and condition in Navajo and Navajo crossbred weanling lambs. Journal of Animal Science 10:455-461. 1951.

53. Stark, J. S. Grade Southdown sires for sucker-lamb production. Farming in South Africa 19:533. 1944.

54. Terrill, C. E. Selection of range Rambouillet ewes. Proceedings of the American Society of Animal Production 32:333-340. 1939.

55. ______________. Fifty years of progress in sheep breeding. Journal of Animal Science 17:944-959. 1958.

56. Terrill, Clair E. and John A. Stoehr. The importance of body weight in selection of range ewes. Journal of Animal Science 1:221-228. 1942.

57. Wallace, L. R. The growth rate of lambs before and after birth in relation to the level of nutrition. Journal of Agricultural Science 38:93-152, 243-300. 1948.

58. Winters, Laurence M. Animal breeding. 5th ed. New York, Wiley, 1959. 420 p.

59. Winters, L. M. et al. Factors affecting productivity in breeding sheep. St. Paul, University of Minnesota, 1946. 28 p. (Minnesota. Agricultural Experiment Station. Technical bulletin no. 174).