AN INVESTIGATION OF WOOL CHARACTERISTICS, GROWTH AND SKIN FOLDS IN A CROSS BETWEEN RAMBOUILLET AND BLACK TOP DELAINE SHEEP

By

YOUSSEF SALAH ELDIN GHANEM

A THESIS

Submitted to the School of Graduate Studies of Michigan
State College of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Animal Husbandry

1951

ACKNOWLEDGMENTS

The investigator wishes to express his indebtedness to Professor R. H. Nelson, head of the Animal Husbandry Department, for his helpful suggestions and criticism during the preparation of this manuscript, and for his constructive guidance.

The great concern with which Professor H. R. Hunt, head of the Zoology Department, has planned this experiment, collected the data and actually taken part in measuring the wool characteristics, was indispensable for the successful completion of the experiment. This, together with reviewing the manuscript, constant supervision and kind suggestions are deeply appreciated by the author.

He is also thankful to Professor W. D. Baten of the Mathematics Department for his valuable assistance in the statistical analysis of the results.

Grateful mention is hereby made of the Egyptian Government Scholarship, which made it possible for the author to complete this investigation.

VITA

Youssef Salah Eldin Ghanem was born in Cairo, Egypt on November the 13th, 1924. He completed his primary and secondary school education in Egyptian Government Schools. In June, 1946, he obtained the B.V.Sc. degree from the Veterinary College of Fouad I University, Gizah. He was employed as a demonstrator in that college in August, 1946, and was later appointed as a member of its Educational Mission to the U. S. A. In this country, he entered Cornell University, Ithaca, N. Y. where he obtained his M.S. degree in Animal Psychobiology in September, 1949. He then entered Michigan State College, East Lansing, Michigan as a candidate for the Ph.D. degree, with Animal Breeding as major and Genetics and Statistics as minor subjects. After returning to Egypt, the author will teach Animal Breeding and Genetics at the Veterinary College of Fouad I University.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Crossbreeding in sheep has been extensively practiced for different purposes. Experimental crosses have been carried out to discover the mode of inheritance of various traits (Tomhave and McDonald, 1920, Ritzman, 1923, Jones, et al., 1946, etc.). New breeds of sheep have been developed through the crossing of the older breeds, while occasional outcrossing has been practiced for improving the breeds in general. Crossbreeding has also been used widely by sheepmen for commercial lamb production. However, the crosses that have been studied and reported were mostly between fine-wool and mutton-type breeds or between two mutton-type breeds.

The present study deals with a cross between two fine-wool breeds, the American Rambouillet and the Improved Black Top Delaine Merino.

The American Rambouillet Breed was derived largely from the French Rambouillet sheep imported into this country as early as 1840. The French Rambouillets were developed from Spanish Merinos brought to Rambouillet, France, in 1786 and 1801 from Spain (Dickson and Lush, 1933).

The Rambouillet is a very popular breed in the United States, especially in the western states where it is used in the range flocks because it combines good wool characteristics with mutton qualities unparalleled by any of the other Merino breeds. Mature Rambouillet rams weigh on the average about 225 pounds, and mature ewes, about 155 pounds. The fleece of the Rambouillet is similar to that of the Delaine Merino (Vaughan, 1948), but has slightly coarser fibers, and the length of a twelve months growth of staple is about 2½ to 3 inches. The Rambouillets also have smooth bodies, with two or three neck folds and an apron.

The Improved Black Top Delaine breed was developed in Washington County, Pennsylvania, from the American Merino, which in turn originated from the Spanish Merino. The "Improved Black Top Delaine Merino Sheep Breeders' Association" was established in 1885. The rams of this breed weigh on the average about 180 pounds and the ewes, about 130 pounds. The Improved Black Top sheep have smooth bodies and long, or "Delaine," wool. These and other strains of the Delaine Merinos are becoming less popular than they were at the time this experiment was started.

THE PROJECT[1]

The objective of the project was to learn more concerning inheritance in the sheep, and if possible to improve the Rambouillet breed. The traits studied were wool characters (fiber length, crimp, fiber diameter and unscoured fleece weight), skin folds, and growth during the first year of life. The animal breeding point of view was to improve the wool bearing qualities of the Rambouillet, and to secure a type that combines the long wool of the Delaine with the growth qualities of the Rambouillet.

The experiment was started in 1929 by crossing a registered yearling Rambouillet ram with 15 Black Top Delaine ewes of varying ages (from 2 to 7 years old). Later, in 1931, another registered Rambouillet ram was crossed with four Black Top Delaine ewes. Two of these ewes were from the 15 ewes crossed in 1929. Twenty F_1 sheep were raised. Ten were males and ten were females.

---

[1] Professor H. R. Hunt, the head of the Zoology Department at M. S. C., started the experiment in 1929, in collaboration with Prof. G. A. Brown, the previous head of the Animal Husbandry Dept., for the Michigan Agricultural Experiment Station. All the wool samples, fleece and body weights and photographs were collected by Prof. H. R. Hunt. Measurements of the samples were made by Prof. H. R. Hunt, Prof. C. A. Lawson and the author. The statistical analysis was performed by the author.

Five of the males were castrated[1] and sold after weaning. Thus it was possible to obtain yearling data on five F_1 males and 10 F_1 females. Figure 1 shows the parental crosses and the F_1's.

One crossbred (F_1) ram was mated to the 10 crossbred females during the period from 1931 to 1937. Another F_1 ram was mated to four F_1 females. The total number of F_2's produced was 45, 27 males and 18 females. Data were obtained on 22 male and 15 female F_2 individuals. Figure 2 shows the F_1 matings and the F_2's produced.

Control sheep were used during the experiment. However, they were all born between 1933 and 1937, inclusive, during which period the F_2 animals were born. There were no control sheep in 1930 and 1932 when the F_1 animals were born. The control sheep represented the two parental breeds, _i.e._, the Rambouillet and the Black Top Delaine. There were 16 Rambouillet controls (4 males and 12 females) and 18 Black Top Delaine controls (7 males and 11 females).

All the animals used during the experiment belonged to Michigan State College, and the facilities of its Department of Animal Husbandry were used for raising and feeding the sheep.

---

[1] Castration was not desirable, but was necessary due to lack of space in the barn.

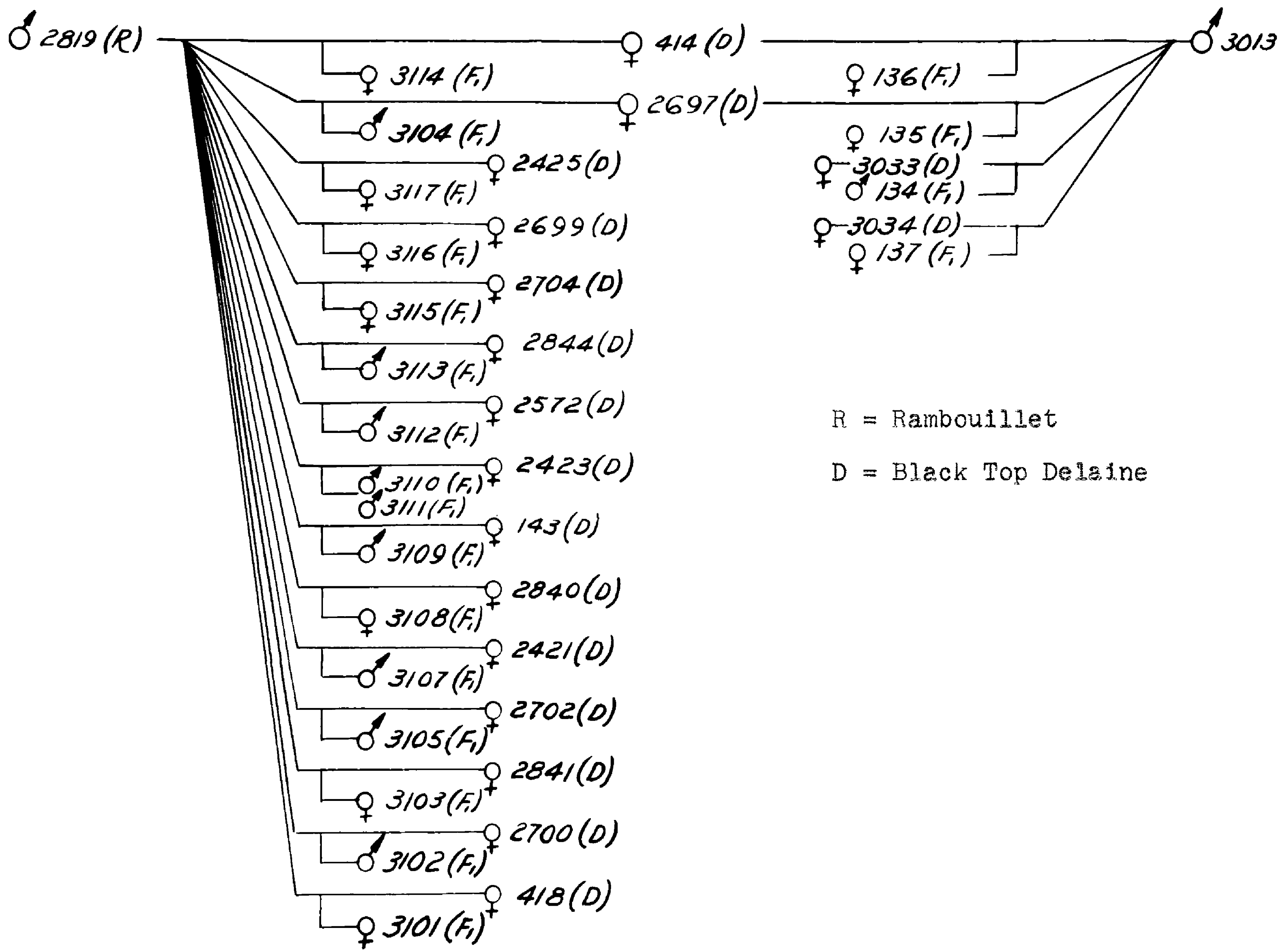

Figure 1. Crosses in the Parental Generation

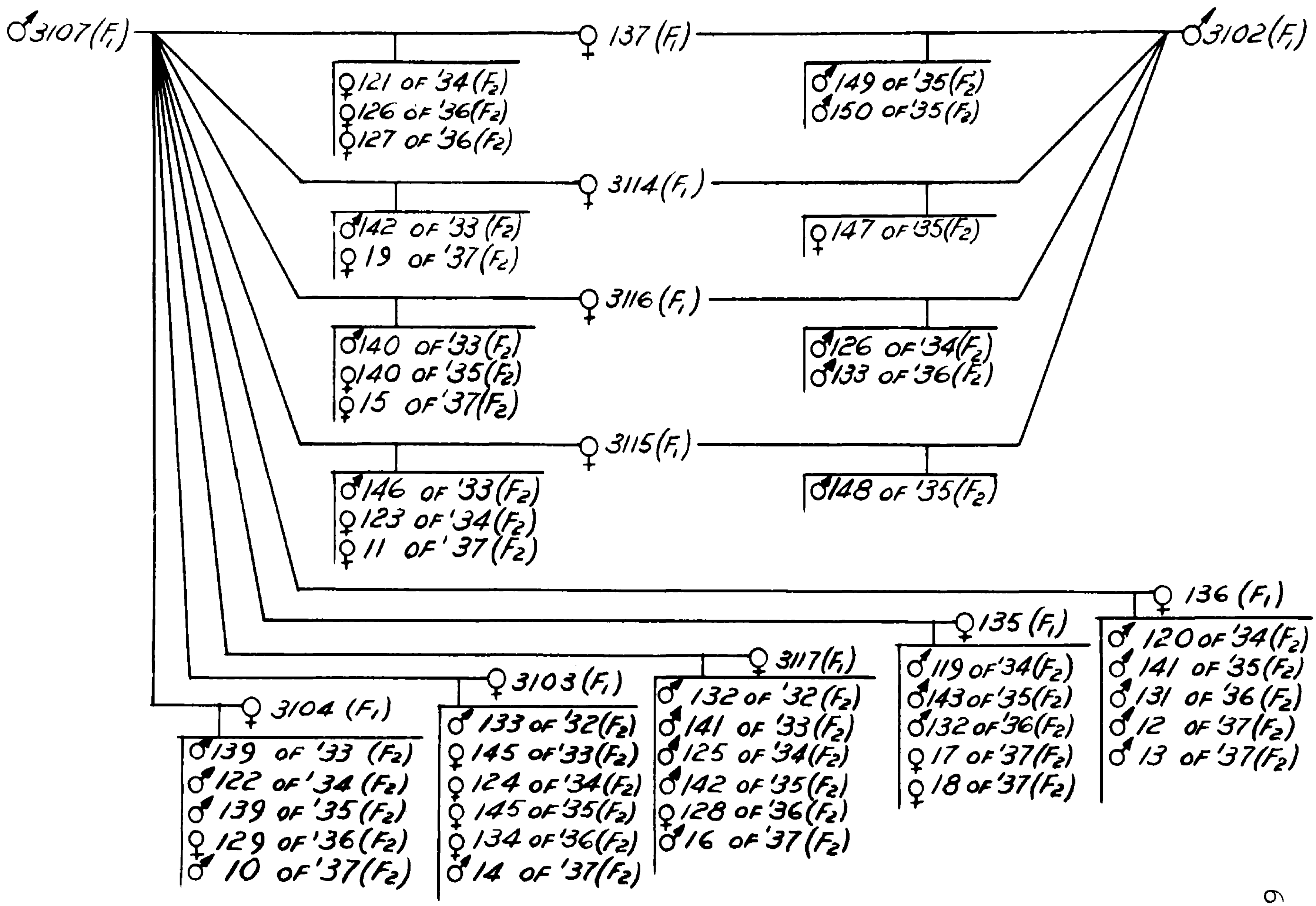

Figure 2. Matings in the F_1 Generation

The lambs were docked shortly after birth and stayed with their mothers until weaning time at about 120 days of age. They were raised under barn conditions until about the end of May, when they were put to pasture. They stayed on pasture until toward the end of November, when they were returned to the barn to stay until the next pasture season. Conditions in the barn were kept constant from year to year as much as possible. The pasture, however, varied from year to year due to different precipitation during different years. Table I shows the annual precipitation and the precipitation from April to November in Lansing during the years 1930 to 1937, inclusive.

TABLE I

ANNUAL PRECIPITATION AND PRECIPITATION FROM APRIL TO NOVEMBER IN LANSING, MICH. (1930-1937)*

	1930	1931	1932	1933	1934	1935	1936	1937
Annual Precipitation	18.50**	28.63	34.22	31.66	21.00	31.28	27.65	33.60
Precipitation from April to November	11.22	17.06	23.62	22.21	35.28	18.87	20.77	25.53

* After the "Annual Meteorological Summary With Comparative Data, 1937" of the U. S. D. A. Weather Bureau, Lansing, Michigan.

** This was the least annual total precipitation in Lansing, Michigan between the years 1874 and 1937.

SKIN FOLDS

Literature

Most sheep of the fine-wool type are characterized by having skin folds or wrinkles. These are caused by faster growth of the skin in proportion to the other components of the body during the early stages of life.

Studies on the inheritance of skin folds have been conducted by various workers. Jones, et al. (1936, 1937, 1938, 1939 and 1940) reported on the inheritance of skin folds in the Rambouillet sheep. Their reports indicate that the number of genes involved is relatively small, and that the genes for freedom from skin folds appear to be dominant. Similarly, Jones, et al. (1946) in a study of a cross between Rambouillet and Corriedale (smooth) sheep, concluded that the lack of skin folds is due to dominant multiple genes. Madsen, Esplin and Phillips (1943) in a report on skin folds in the Rambouillet showed a relationship between the number of folds on the dams and on their offspring. The correlation between dams and daughters at yearling age, with the sire held constant, was + 0.17. In another study of neck folds in Rambouillet lambs by Terrill and Hazel (1946), the average heritability was 0.39 ± 0.05. They found significant variations in neck folds between inbred lines. In the yearling ewes, the same authors (Terrill and Hazel, 1943) found that heritability was 0.26 for neck folds and 0.32 for body folds.

The effects of some environmental factors on skin folds have also been reported. Carter (1941) found that the development of neck and body folds in the Australian Merino sheep was reduced on a low plane of nutrition and augmented on a high plane. Burns (1935) observed a three to three and a half times increase of skin area between the ages of one month and twelve months. Madsen, Esplin and Phillips (1943) also found an increase in skin folds as the sheep matured. Hazel and Terrill observed that folds were more extensive on single sheep and those from mature dams than on twins and those from 2-year-old dams respectively, both at weaning (1945) and yearling (1946) ages. They also found that ram lambs had more extensive folds than ewe lambs. Jones, *et al*. (1946) also found that males had significantly greater skin-fold values than females.

Skin folds are in many ways related to wool production. However, the older view that the greater the folds, the heavier the fleece, has been proved misleading. Fleece from the more wrinkly sheep shrinks more than fleece from the smoother type according to a study by Jones, *et al*. (1944). They did not find a significant difference in clean (scoured) wool produced by the wrinkly and smooth type Rambouillet sheep. In the same study, Jones, *et al*. found a small but significant difference in staple length in favor of the smooth type. They indicated that there is greater uniformity of fineness of fibers in the smoother type. The smoother type sheep are also easier to shear (Madsen, Esplin and Phillips, 1943) and are less susceptible to blow flies, than the wrinkly type (Jones, *et al*., 1937).

Material and Methods

Photographic pictures of the F_1's, the F_2's and the controls were taken when they were about one year old, shortly after shearing. Yearling pictures of the parents were not available since these were at variable ages when the experiment started. The only pictures of the parents that were available were taken at different times before and during the experiment. Some of the parents were never photographed, and a few were photographed before shearing, thus hiding the extent of wrinkling.

An objective method of measuring the skin folds from the photographs was adopted. The basis for this method was the length and number of the folds. The length of every wrinkle was expressed as a fraction of the dorso-ventral dimension of the body at that level. The numerator of this fraction was the length of the wrinkle on the photograph, and the denominator, the body width at the region of the wrinkle. This fraction was called the "fold value". The fold values representing the folds in the neck region as far back as the shoulder were added together and the sum was called the "neck value." The "fold values" from the shoulder to the thigh were added and the sum of these fractions was called the "body value." The folds on the rump, the tail-head and the thigh ran in different directions and thus could not be evaluated with reference to the width of the parts showing the folds. The neck value and body value represented wrinkles on one side of the animal (the side which appeared in the photograph).

Results

Neck Values:

Table II shows the averages and standard deviations of the neck values of the different groups of animals for which photographs were available. The Rambouillet controls, the Black Top Delaine Controls, the F_1's and the F_2's averaged 5.61 ± 1.43, 4.82 ± 2.06, 5.93 ± 0.77 and 5.44 ± 1.52 respectively.

TABLE II

AVERAGES AND STANDARD DEVIATIONS
OF NECK FOLD VALUES AT
YEARLING AGE

Groups	Number of Animals	Average	Standard Deviation
Rambouillet controls	10	5.61*	±1.43
Black Top Delaine controls	12	4.82	±2.06
F_1's	14	5.93	±0.77
F_2's	32	5.44	±1.52

* Equivalent to 5.61 complete folds.

NOTE: Neck fold values signify skin folds on the neck.

The method used to obtain the standard deviation as described by Snedecor (1946, page 91) was:

$Sx^2 = SX^2 - (SX)^2/n$

Standard deviation $s = \sqrt{Sx^2/(n - 1)}$

Sx^2 = the sum of squared deviations from the mean

SX = the sum of the items (neck values in this case)

SX^2 = the sum of the squared items

n = the number of items.

The method used in analyzing the neck fold values will be described under "Body Values." As seen in Table II-A, the difference between the means of the different groups was found not to be significant. Also the difference between sexes was not significant.

Body Values:

Table III shows the average body values for the different groups of sheep used in the experiment. The averages were: 4.30 ± 2.46 for the Rambouillet controls, 5.92 ± 3.56 for the Black Top Delaine controls, 7.81 ± 2.39 for the F_1's, and 5.13 ± 2.33 for the F_2's.

For analysis, the technique used was that for disproportionate subclass numbers (Snedecor, 1946, page 289). The second variable introduced was sex. The method used in this analysis and others that will follow

TABLE II-A

ANALYSIS OF VARIANCE OF NECK VALUES

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares
Groups	3	7.8781	2.63
Sexes	1	0.0313	0.03
Interaction	3	5.0759	1.69
Individuals	60		2.16

NOTE: Neck values signify skin folds on the neck.

TABLE III

AVERAGES AND STANDARD DEVIATIONS
OF BODY FOLD VALUES AT
YEARLING AGE

Group	Number of Animals	Average	Standard Deviation
Rambouillet controls	10	4.30	±2.46
Black Top Delaine controls	12	5.92	±3.56
F_1's	14	7.81	±2.39
F_2's	32	5.13	±2.33

NOTE: Body fold values signify skin folds on the body from the shoulder to the hip.

in this paper (including also the analysis of neck values) was as follows:

The data were combined in a 4 X 2 table (Table III-A). Two variables were considered: sexes (males and females) and groups (Rambouillet controls, Black Top Delaine controls, F_1's and F_2's).

Correction term = $(387.57)^2/68$ = 2208.9780

Total sum of squares = 2738.0291 - 2208.9780

= 529.0511

Sum of squares between subclasses

= $[(7.07)^2/3] + \ldots + [(73.09)^2/14]$ - correction term

= 2328.481 - 2208.9780 = 119.5031

Sum of squares within subclasses

= 529.0511 - 119.5031 = 409.5480

Mean square within subclasses

= 409.5480/60 = 6.83 (this is to be used as the error term for the F-test)

Then a table containing the numbers and means of both sexes in the four groups of sheep was made (Table III-B).

k_1 = number of males

k_2 = number of females

$\overline{x}_1$ = mean body value of males

$\overline{x}_2$ = mean body value of females

TABLE III-A

NUMBERS AND BODY VALUES OF GROUPS AND SEXES

Sex	Rambouillet		Black Top Delaine		F_1		F_2		Sums	
	Number	Total	Number	Total	Number	Total	Number	Total	Number	Total
Male	3	7.07	4	28.43	4	33.41	18	91.08	29	159.99
Female	7	35.96	8	42.57	10	75.96	14	73.09	39	227.58
Sums	10	43.03	12	71.00	14	109.37	32	164.17	68	387.57

NOTE: Body values signify skin folds on the body from the shoulder to the hip.

TABLE III-B

NUMBERS AND MEAN BODY VALUES IN BOTH SEXES OF THE FOUR GROUPS

Group	Male		Female		W	D	WD
	k_1	$\bar{x}_1$	k_2	$\bar{x}_2$			
Rambouillet	3	2.357	7	5.137	2.1000	-2.780	-5.838
Black Top Delaine	4	7.108	8	5.321	2.6667	1.787	4.765
F_1	4	8.352	10	7.596	2.8571	0.756	2.160
F_2	18	5.060	14	5.221	7.8750	-0.161	-1.268
					15.4988		-0.181

NOTE: Body values signify skin folds on the body from the shoulder to the hip.

$W = (k_1 k_2)/(k_1 + k_2)$

$D = \bar{x}_1 - \bar{x}_2$

Sum of squares for sexes

$= (SWD)^2/SW = (-0.181)^2/15.4988 = 0.0021$

Sum of squares of sexes from Table III-A

$= (159.99)^2/29 + (227.58)^2/39$ - correction term = 1.6871

Correction for interaction

$= 1.6871 - 0.0021 = 1.6850$

Sum of squares of groups from Table III-A

$= (43.03)^2/10 + \ldots + (164.17)^2/32$ - correction term = 92.9209

Corrected sum of squares for groups = sum of squares of groups from the table - correction for interaction = 92.9209 - 1.6850 = 91.2359

Interaction sum of squares = $SWD^2 - (SWD)^2/SW$

$= 26.5820 - 0.0021 = 26.5799$

Then the complete analysis of variance table was constructed (Table III-C)

The individuals mean square was used as an error term for testing the mean squares for groups, sexes and interaction.

The following is an example of the procedure used in the F-test:

$$F_{groups} = \frac{\text{groups mean square}}{\text{individuals mean square}} = \frac{30.41}{6.83} = 4.45$$

TABLE III-C

COMPLETED ANALYSIS OF VARIANCE OF BODY VALUES

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Groups	3	91.2359	30.41**
Sexes	1	0.0021	0.0021
Interaction	3	26.5799	8.86
Individuals	60		6.83

** Indicates significance at 1% level.

NOTE: Body values signify skin folds on the body from the shoulder to the hip.

At 3 and 60 degrees of freedom 4.45 is found to exceed the F value (4.13 according to F-table) needed for reaching significance at the one-per cent level. It is to be concluded that variance caused by the differences between group means is significant at the one-per cent level. This means that only once in every 100 times can one expect to obtain an F value of 4.13 by chance alone.

When the sums of squares for sexes and interaction were tested they were found not to be significant.

The next step was to test the differences between each two group means. As an illustrative example the difference between the Rambouillet and F_1 group means is tested as follows:

The numbers and means of the Rambouillet and F_1 groups in both sexes are put in a table (Table III-D) as mentioned by Snedecor (1946, page 290).

Weighted mean difference

$$= SWD/SW = 20.3825/5.83 = 3.50$$

Variance of weighted mean difference

$$= (\text{Individuals mean square})/(SW)$$

$$= 6.83/5.83 = 1.172$$

$$s = \sqrt{1.172} = 1.08$$

$$t = 3.50/1.08 = 3.24^{**}$$

At 60 degrees of freedom the t value of 3.24 is found to be significant at the one-per cent level (look

TABLE III-D

CALCULATING THE WEIGHTED MEAN DIFFERENCE BETWEEN THE RAMBOUILLET AND F_1 GROUPS

Sex	Rambouillet		F_1		W	D	WD
	k_1	$\bar{x}_1$	k_2	$\bar{x}_2$			
Male	3	2.357	4	8.352	1.71	-5.995	-10.2514
Female	7	5.137	10	7.596	4.12	-2.459	-10.1311
					5.83		20.3825

t-table). By performing similar tests, it was found that the difference between F_1's and F_2's was also significant at 1% level. Other differences were found not to be significant.

Combined Neck and Body Values:

The neck values were combined with the body values and averaged. The averages and standard deviation as shown in Table IV were: 9.92 ± 3.42 for the Rambouillet controls, 10.74 ± 4.85 for the Black Top Delaine controls, 13.74 ± 2.59 for the F_1's and 10.57 ± 3.30 for the F_2's.

By using the method of analysis described on page 14, the information in Table IV-A was obtained. The groups mean square was found to be significant at the 5-per cent level. The sexes and interaction mean square were found not to be significant.

Then the t-tests were performed (see page 22) and the following results were obtained: The differences between the Rambouillet controls and the F_1's and between the F_1's and F_2's were found to be significant at the one-per cent level. The difference between the Black Top Delaine controls and the F_1's was significant at 5-per cent level, while the differences between the Rambouillet controls and Black Top Delaine controls, between

TABLE IV

AVERAGES AND STANDARD DEVIATIONS OF COMBINED NECK AND BODY VALUES AT YEARLING AGE

Group	Number of Animals	Average	Standard Deviation
Rambouillet controls	10	9.92	±3.42
Black Top Delaine controls	12	10.74	±4.85
F_1's	14	13.74	±2.59
F_2's	32	10.57	±3.30

NOTE: Combined neck and body values signify skin folds on the neck and body.

TABLE IV-A

COMPLETED ANALYSIS OF VARIANCE OF COMBINED NECK AND BODY VALUES

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Groups	3	118.7643	39.59*
Sexes	1	0.3618	0.36
Interaction	3	16.7630	5.59
Individuals	60		12.85

* significant at 5 per cent level.

NOTE: Combined neck and body values signify skin folds on the neck and body.

the Rambouillet controls and the F_2's and between the Black Top Delaine controls and the F_2's were found not to be significant. It is worth mentioning at this stage that there is an indication of heterosis in the F_1's, as evidenced by a significantly higher average combined neck and body value than either one of the parental breeds (the Rambouillet and the Black Top Delaine).

WOOL CHARACTERISTICS

Literature

Fiber Length:

The length of the wool fiber is one of its most important characteristics. Wools of the same grade are classed into combing and clothing wools according to their staple lengths. The manufacture of fine worsted material depends on wools of the longer combing classes. Woolen fabrics are usually made from the shorter clothing wools. In this classification, staple length is used in reference to the length of the wool fibers. Staple length, as differentiated from fiber length, is measured without stretching the fibers. In measuring the fiber length, the fibers are stretched to remove the crimps. According to Hultz (1927), the length of the stretched fibers are directly related to the length of the staple. He found that, on an average, the staple lengths of the Rambouillet, were 66.54 per cent of their fiber lengths.

Like most of the other economic characters, staple length is thought to be transmitted from parent to offspring through multiple-factor inheritance (Ritzman and Davenport, 1926). Hazel and Terrill (1945a) measured heritability of staple length in range Rambouillet weanling lambs and found it to be 0.40. In the yearling Rambouillet ewes, they found heritability of staple length to be 0.36.

Staple length is directly correlated with fleece weight, according to studies by Spencer (1925), Spencer, Hardy and Brandon (1928), Lambert, Hardy and Schott (1938), Pohle and Keller (1943) and Jones et al. (1944).

Staple length differs according to the part of the body in which the measurement is taken. Hultz and Paschal (1930) found that staple length in the shoulder region was slightly more than staple length in the thigh region of Rambouillet sheep. Similar studies by Ensminger (1942) revealed that there was an inherent gradient in length from the fore to the rear part of the body, with the longest wool on the britch and the shortest on the head.

Certain factors such as age, sex, plane of nutrition and type of birth tend to influence staple length. At the age of one year, staple length was found to be significantly greater than at any of the subsequent ages up to eight years (Jones, et al., 1944). Lambert, Hardy and Schott (1938) reported that the correlation between weanling length of fleece and yearling length was +0.65. Wilson (1930) found that staple length was greater on a high than on a low plane of nutrition. Hazel and Terrill

(1945) observed that ewe-lambs at weanling age had longer staple than ram lambs, while at yearling age (Terrill, Sidwell and Hazel, 1948), rams had greater staple length than ewes. Hazel and Terrill (1946) found that yearling ewes from two-year-old dams had shorter staple length than those from mature dams. They also found that staples of ewes from single births were longer than staples of twins and twins raised singly.

Fiber Diameter and Crimp:

Fiber diameter is the most important of all wool characteristics. The fine-wool breeds of sheep have smaller fiber diameters than the medium-wool or the long-wool breeds. The systems of standardizing wool grades are based on the relative fineness (or diameter) of wool fibers. In the American system, the finest grade is called "fine," while the coarsest is called "braid." Fineness is associated with crimp, which causes the wool to have a wavy appearance. There is a negative correlation between crimp and fiber diameter according to studies by Hultz (1927) and Darlow (1930).

Different methods for measuring fiber diameter have been studied by Barker and King (1926), Burns and Kochler (1925), Grandstaff (1940), Hardy (1935), Hardy and Wolf (1939), McNicholas and Curtis (1931), Pohle

(1940), Phillips, Schott, Hardy and Wolf (1940) and others.

The exact mode of inheritance of fiber diameter is, so far, unknown, but is believed to be through multiple factors (Ritzman and Davenport, 1926). Crosses between fine-wool and medium-wool breeds of sheep produce blending in the progeny (Burns, 1924).

Fiber diameter differs according to the location from which the sample is taken. Hultz and Paschal (1930) obtained a higher average fiber diameter from thigh samples than from shoulder samples of Rambouillet sheep. Ensminger (1942 and 1942a) reported that, in Shropshire and Southdown sheep, wool ranked from the finest on the head to the coarsest on the rump and britch. Similar results were obtained by Pohle and Schott (1942 and 1943) with Rambouillet sheep. Their results indicated a trend in average fineness from the smallest average diameter on the wither, shoulder, back and side to larger average diameters on the rump and belly, to the coarsest fibers on the thigh.

Certain factors as age and plane of nutrition affect fiber diameter. According to Pohle, Keller and Hazel (1945), fiber diameter decreases between six and eleven months of age, showing a slight increase thereafter. Lambert, Hardy and Schott (1938) found that in the Rambouillet, the correlation between weanling and yearling fineness of wool was +0.40. Jones, *et al.* (1944) reported that the yearling fleece was slightly finer than fleeces at older ages. Wilson (1930) observed that wool fibers were 26.5 per cent coarser at the base on a fattening ration than on a submaintenance ration.

Fiber diameter is directly related to fleece weight, according to studies by Spencer (1925), Spencer, Hardy and Brandon (1928), Jones, *et al.* (1944) and Slen (1949).

Fleece Weight:

Fleece weight is a composite character that depends on other wool characters and is affected by a number of environmental conditions. While its inheritance, like the inheritance of other wool characters, is not clear, it is believed to be transmitted through multiple factors. The heritability of unscoured fleece weights was found to be 0.28 by Terrill and Hazel (1943) in Rambouillet ewes. They estimated heritability of clean fleece weight at 0.38. Rasmussen (1942) estimated the coefficient of repeatability at 0.56 in range Rambouillet sheep.

Age, sex, type of birth, body weight and plane of nutrition are some of the factors that influence fleece weight. In the Rambouillet sheep, Spencer (1925) and Spencer, Hardy and Brandon (1928) observed that the average fleece weights increased with the age of the sheep from yearling age up to three years, and then showed a decline after three years. Lambert, Hardy and Schott (1938) found a positive correlation of 0.43 between the weanling and yearling clean fleece weights of range sheep. Correlation between fleece weight at one shearing and the fleece weight of the same sheep at the subsequent shearing was found by Lush (1922) to be +0.6149. Yearling Rambouillet rams produce heavier unscoured fleeces than yearling ewes, according to Terrill, Sidwell and Hazel (1948). In the same study, it was found that single rams had heavier fleeces than twins and twins raised singly. Rams from mature dams also produced heavier fleeces than rams from two-year-old dams. Similar results were obtained earlier by Hazel and Terrill (1946) in yearling Rambouillet ewes. On a high plane of nutrition, Wilson (1930) found that the grease fleece weight was 343 per cent greater than on a low plane of nutrition.

Beside being influenced by fiber length and fiber diameter (as stated above), fleece weight is affected by body weight, with which it is positively correlated (Spencer, Hardy and Brandon, 1928 and Jones, *et al.*, 1944).

Material and Methods

Two samples of wool were taken from each sheep at yearling age.[1] One sample was clipped from the middle of the shoulder, while the other sample was clipped from the area directly behind the point of the hip. Care was taken to clip close to the skin. Each of the two samples was labeled and inserted in a dry bottle. The bottles containing the samples were stored in a dry storage room until they were taken out for measurement.

The lengths of individual fibers were measured. The wool sample was first soaked in xylol (a fat solvent) until the grease was dissolved. After drying the sample, twenty-five fibers were drawn individually at random. Every fiber was stretched between the jaws of two pairs of forceps until the crimps barely disappeared, and then the length, in millimeters, was measured with a ruler on a black piece of velvet material. The average fiber length of the sample was then obtained by computing the mean of the twenty-five measurements. This was corrected to a 365-days growth by using linear interpolation. The following is an example of the method used:

---

[1] None of the parents was less than two years old at the beginning of the experiment; thus yearling samples were not available for the parents.

If the age of the animal at the time the sample was taken was 406 days, and the average length of twenty-five fibers from the sample was found to be 87.5 millimeters, the corrected 365-day fiber length would be

87.5 x 365/406 = 78.7 mm, approximately.

The fiber diameters were then measured. After dissolving the grease with xylol, the sample was divided into 10 subsamples. A wisp was taken from each subsample, and all the wisps were put together to form a combined sample. An attempt was made with each sample to measure the diameters of those sections of the fibers that grew during the month of January. It was assumed that conditions during the month of January in successive years were more constant than pasture conditions during the grazing season. The method can be illustrated by the following concrete example:

Suppose a sample of wool had a staple length of 75 mm. This length of wool grew during about 12 months; so, the monthly growth was about 6 mm. Suppose the wool sample was taken from the sheep about the middle of March. The most proximal section of each fiber must have grown in March; immediately distal to this was the section grown in February, followed by January growth. If 9 millimeters ($1\frac{1}{2}$ months x 6 mm. = 9 mm.) were cut from the proximal end of the sample, the cut surface of the sample would belong to wool that grew in January. A section of this January growth was cut off with scissors, immersed in xylol, placed under a cover glass, and the diameters measured. A microscope equipped with a filar micrometer was standardized and used to measure the fiber diameters. The diameters of fifty fibers were measured at random. The average fiber diameter of the sample was then obtained by computing the mean of the fifty measurements and converted from micrometer units to microns.

The number of crimps (or curls) per two centimeters were obtained from four different places in the wool sample. The four measurements were then averaged to represent the average "crimp" of the sample.

The weights of the unscoured yearling fleeces of the F_1's, F_2's and controls were obtained. For statistical analysis, the fleece weights were adjusted to a 365-days growth by using linear interpolation which can be illustrated by the following example:

If the fleece weight was 10.5 pounds and the age of the animal at shearing time was 400 days, the adjusted 365-days fleece weight would be:

$$10.5 \times 365/400 = 10.36 \text{ lbs., approximately.}$$

Results

Fiber Length:

Average fiber lengths of the shoulder and hip samples were computed for each of the four groups of sheep used in the experiment. Table V shows the averages obtained. The average fiber lengths of the shoulder samples were 82.86 ± 10.82 mm for the Rambouillet controls, 103.54 ± 7.58 mm for the Black Top Delaine controls, 82.49 ± 15.09 mm for the F_1's and 92.65 ± 9.86 mm for the F_2's. The average fiber lengths of the hip samples were 64.53 ± 9.82 mm for the Rambouillet controls, 83.42 ± 11.66 mm for the Black Top Delaine controls, 61.37 ± 11.84 mm for the F_1's and 74.17 ± 10.73 mm for the F_2's.

An analysis of variance was performed (see page 14) and an F test revealed significant differences among groups in both the shoulder and hip samples (Table V-A).

By using the t test on the weighted mean differences (page 22) it was found that, in case of the shoulder samples, the differences between any two of the four group means, except that between the Rambouillet controls and the F_1's, were significant at the one per cent level. The difference between the Rambouillet controls and the F_1's was found not to be significant. In case of the hip sample the results were similar, as far as significance of differences is concerned, except in case of the difference

TABLE V

AVERAGE FIBER LENGTHS OF THE SHOULDER AND HIP SAMPLES OF A 365 DAYS WOOL GROWTH

Groups	Number of Animals	Shoulder		Hip	
		Average Fiber Length in mm	Standard Deviation	Average Fiber Length in mm	Standard Deviation
Rambouillet controls	16	82.86	±10.82	64.53	± 9.82
Black Top Delaine controls	18	103.54	± 7.58	83.42	±11.66
F_1's	15	82.49	±15.09	61.37	±11.84
F_2's	37	92.65	± 9.86	74.17	±10.73

TABLE V-A

COMPLETED ANALYSIS OF VARIANCE OF AVERAGE FIBER LENGTHS OF SHOULDER AND HIP SAMPLES

Source of Variation	Degrees of Freedom	Shoulder		Hip	
		Sum of Squares	Mean Square	Sum of Squares	Mean Square
Groups	3	5025.9097	1675.30**	4794.7781	1598.26**
Sex	1	1.4574	1.46	436.7923	436.79
Interaction	3	321.7300	107.27	440.7393	146.91
Individuals	78		116.64		112.56

** significant at one-per cent level

between the F_2's and the Black Top Delaine controls, which was found to be significant only at the five per cent level.

<u>Fiber Diameter</u>:

The average fiber diameters of the shoulder samples (as shown in Table VI) were: $18.11 \pm 2.98\mu$ for the Rambouillet controls, $17.57 \pm 3.24\mu$ for the Black Top Delaine controls, $20.61 \pm 1.59\mu$ for the F_1's and $18.86 \pm 2.91\mu$ for the F_2's. For the hip samples, the averages were $19.24 \pm 3.61\mu$ in the Rambouillet controls, $18.95 \pm 3.19\mu$ in the Black Top Delaine controls, $21.80 \pm 1.35\mu$ in the F_1's, and $20.48 \pm 3.46\mu$ in the F_2's.

An analysis of variance was performed in the manner described above (page 14). The F test revealed a significant difference only among group means of the shoulder samples (Table VI-A).

A t test was performed for the shoulder sample only and a significant difference was obtained between the F_1's and any of the control groups or the F_2's. Other differences were found not to be significant.

<u>Crimp</u>:

The average number of crimps per two centimeters was computed for the shoulder and hip samples (Table VII). The average crimp in the shoulder samples of the

TABLE VI

AVERAGE FIBER DIAMETERS OF THE SHOULDER AND HIP SAMPLES DURING JANUARY APPROXIMATELY

Group	Number of Animals	Shoulder		Hip	
		Average Fiber Diameter in Micra	Standard Deviation	Average Fiber Diameter in Micra	Standard Deviation
Rambouillet controls	16	18.11	±2.98	19.24	±3.61
Black Top Delaine controls	18	17.57	±3.24	18.95	±3.19
F_1's	15	20.61	±1.59	21.80	±1.35
F_2's	37	18.86	±2.91	20.48	±3.46

TABLE VI-A

COMPLETED ANALYSIS OF VARIANCE OF AVERAGE FIBER DIAMETERS OF SHOULDER AND HIP SAMPLES

Source of Variation	Degree of Freedom	Shoulder		Hip	
		Sum of Squares	Mean Square	Sum of Squares	Mean Square
Groups	3	83.8882	27.96*	80.7847	26.93
Sex	1	2.9040	2.90	18.9487	8.95
Interaction	3	6.1941	2.06	63.2974	21.10
Individuals	78		7.91		11.23

* significant at 5 per cent level

TABLE VII

AVERAGE NUMBER OF CRIMPS PER TWO CENTIMETERS IN THE SHOULDER AND HIP SAMPLES

Group	Shoulder			Hip		
	Number of Animals	Average Number of Crimps per 2 cms.	Standard Deviation	Number of Animals	Average Number of Crimps per 2 cms.	Standard Deviation
Rambouillet controls	16	15.0	±1.41	13	13.0	±1.55
Black Top Delaine controls	18	14.7	±1.82	18	12.6	±2.64
F_1's	15	13.6	±1.26	5	12.1	±1.44
F_2's	37	14.1	±1.83	35	12.4	±2.27

Rambouillet controls was 15.0 ± 1.41, in the Black Top Delaine control it was 14.7 ± 1.82, in the F_1's, 13.6 ± 1.26 and in the F_2's it was 14.1 ± 1.83. In the hip samples, the average number of crimps per two centimeters was 13.0 ± 1.55 for the Rambouillet controls, 12.6 ± 2.64 for the Black Top Delaine controls, 12.1 ± 1.44 for the F_1's, and 12.4 ± 2.27 for the F_2's.

An analysis of variance was performed (see page 14) and the F test showed no significance of difference in either the shoulder or the hip samples (Table VII-A).

Grease Fleece Weight:

The difference due to sex was found to be significant in case of grease fleece weight as will be shown later. Thus Table VIII shows the averages and standard deviations in both sexes. In the males, the average unscoured fleece weight was 7.58 ± 2.21 pounds in the Rambouillet controls, 12.95 ± 3.21 pounds in the Black Top Delaine controls, 15.49 ± 1.79 pounds in the F_1's and 12.71 ± 3.27 pounds in the F_2's. In the females, the average grease fleece weight was 8.76 ± 1.44 pounds in the Rambouillet controls, 9.78 ± 2.29 pounds in the Black Top Delaine controls, 12.96 ± 1.91 pounds in the F_1's and 9.48 ± 1.77 pounds in the F_2's.

TABLE VII-A

COMPLETED ANALYSIS OF VARIANCE OF AVERAGE NUMBER OF CRIMPS PER TWO CENTIMETERS IN THE SHOULDER AND HIP SAMPLES

Source of Variation	Shoulder			Hip		
	Degrees of Freedom	Sums of Squares	Mean Square	Degrees of Freedom	Sums of Squares	Mean Square
Groups	3	20.593	6.86	3	3.897	1.30
Sex	1	0.763	0.76	1	10.567	10.57
Interaction	3	1.152	0.38	3	7.732	2.58
Individuals	78		2.91	63		4.28

TABLE VIII

AVERAGE UNSCOURED FLEECE WEIGHTS OF A 365 DAYS WOOL GROWTH

Group	Male			Female		
	Number of Animals	Average in lbs.	Standard Deviation	Number of Animals	Average in lbs.	Standard Deviation
Rambouillet controls	3	7.58	±2.21	12	8.76	±1.44
Black Top Delaine controls	7	12.95	±3.21	11	9.78	±2.29
F_1's	5	15.49	±1.79	10	12.96	±1.91
F_2's	22	12.71	±3.27	15	9.48	±1.77

An analysis of variance (see page 14) was performed and by applying the F test the mean squares for groups and sexes were found to be significant at the one per cent level (Table VIII-A).

By applying the t test, it was found that the differences between the F_1's and any of the control groups or the F_2's were significant at the one per cent level. The differences between the Rambouillet controls and the Black Top Delaine controls and between the Rambouillet controls and the F_2's were significant at the five per cent level, while the difference between the F_2's and the Black Top Delaine controls was found not to be significant.

TABLE VIII-A

COMPLETED ANALYSIS OF VARIANCE OF UNSCOURED FLEECE WEIGHTS

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square
Groups	3	188.6349	62.88**
Sex	1	121.5595	121.56**
Interaction	3	39.1560	13.05
Individuals	77		6.13

** significant at one per cent level

GROWTH

Literature

Growth in sheep is a very important trait. It is only second in importance to wool production in the fine-wool breeds. Body weight and height are the two measurements generally used as indicators of growth. In this experiment, body weight only was used to measure growth.

Body weight is a heritable character, which is believed to be transmitted by means of multiple factors. The weaning weight of range Rambouillet lambs was studied by Hazel and Terrill (1945a) and its average heritability was estimated at 0.30. In the yearling range Rambouillet ewes, the estimate of heritability was 0.40 (Terrill and Hazel, 1943). Nelson and Venkatachalam (1949) estimated heritability of weaning weight in lambs at 0.30 ± 0.08, using a weighted average of two methods.

Certain factors such as age, sex, type of birth, and weight at birth influence growth in body weight. Ritzman (1917) studied growth of lambs in body weight during their first year of life. He found that they made about 60 per cent of their gain in weight during the first 3 months, 20 per cent during the second 3 months, 15 per cent during the third 3 months and 5 per cent during the last 3 months. Jones, *et al*. (1944)

reported that body weight increased in the Rambouillet sheep from birth up to and including the sixth year of life, and then showed a decline. Phillips (1936 and 1937) and Phillips and Dawson (1937) observed that the lambs that were heavier at birth also tended to make greater gains during their first year of life and were heavier at 3, 4, 6 and 12 months of age than the lambs that were lighter at birth. Single lambs are heavier than lambs from multiple births (twins or triplets), both at weaning age (Hazel and Terrill, 1945, and Nelson and Venkatachalam, 1949) and at yearling age (Hazel and Terrill, 1946, and Phillips and Dawson, 1937). Phillips, Stoehr and Brier (1940) found that single lambs were heavier than twin lambs, on the average, throughout the first year. Male sheep are heavier than females at weaning age (Phillips, Stoehr and Brier, 1940, Hazel and Terrill, 1945, and Nelson and Venkatachalam, 1949) and at yearling age (Hazel and Terrill, 1946, and Terrill, Sidwell and Hazel, 1948). Hazel and Terrill (1945) and Nelson and Venkatachalam (1949) found also that lambs from mature dams were heavier at weaning age than those from two-year old dams. Similar results were obtained at yearling age in ewes by Hazel and Terrill (1946) and in rams by Terrill, Sidwell and Hazel (1948). Lambs that are born earlier in the season are heavier at three months of age than late lambs, according to a study by Phillips and Dawson (1937). Differences between average weights of lambs in different years were found to be significant (Phillips, Stoehr and Brier, 1940, Blunn, 1944, and Hazel and Terrill, 1945 and 1946).

The role that nutrition plays in growth is very important. For literature concerning the effects of nutrition and management on growth, Morrison's book, "Feeds and Feeding," (1949) may be consulted.

Material and Methods

The weights, in pounds, of the F_1, the F_2 and the control lambs were obtained at two-week intervals up to six months of age, then at four-week intervals up to yearling age or later. It will be recalled that each year pure-bred Rambouillets and Delaines were selected as controls for the F_1 and F_2 generations. The age and sex distribution of the controls corresponded as nearly as possible with the experimental animals. The weights could not conveniently be obtained at exactly the same ages. For analysis, the data were corrected by linear interpolation to estimate the weights of the animals at 6, 8, 10, 12, 14, 16, 20, 24, 28, 32, 36, 40, 44, 48 and 52 weeks of age. The interpolation was performed on the assumption that the increase in weight during the interval studied was linear. The following is an example of the method used:

Actual age in days	Weight in pounds
132	55.5
146	59.5

The weight at 140 days (20 weeks) is computed as follows:

$$55.5 + (140 - 132)/(146 - 132)\ (59.5 - 55.5)$$
$$= 57.8 \text{ lbs., approximately.}$$

Weights at ages less than six weeks, including birth weights, were not available in most of the cases, and thus could not be included in the data.

Results

Body weight was studied at 6, 16, and 52 weeks of age. In order to reduce the environmental effects of sex and type of birth (single birth or multiple birth) conversion factors were used. The conversion factor for sex was obtained in the following manner:

The average 6 weeks' body weight of all the female single sheep was divided by that of all the male singles (29.54/34.23 = 0.863). Then the average 6 weeks' body weight of all the female twins was divided by that of the male twins (24.0/26.83 = 0.894). The average of the two values was obtained ([0.863 + 0.894]/2 = 0.878) and called the conversion factor for sex.

Similarly, the conversion factor for type of birth was obtained by dividing the average body weight at 6 weeks of age of all the single females by that of the twin females (29.54/24.0 = 1.229). Then the average six weeks' body weight of all the single males was divided by that of the twin males (34.23/26.83 = 1.273). The average of these two values was obtained ([1.229 + 1.273]/2 = 1.251) and called the conversion factor for type of birth.

All the weights were then brought to a single female basis. The individual weights were multiplied by the suitable conversion factors for adjustment. A single male weighing 40.5 lbs. at 6 weeks of age was converted to 40.5 x 0.878 = 35.6 lbs. A twin female weighing 27.3 lbs. would become 27.3 x 1.251 = 34.2 lbs. A twin male weighing 25.0 lbs. would become 25.0 x 1.129 = 28.2 lbs.

The same procedure was followed with body weights at 16 and 52 weeks of age. The conversion factors obtained for those ages were:

Conversion factor for sex at 16 weeks = 0.832

Conversion factor for type of birth at 16 weeks = 1.100

Conversion factor for sex at 52 weeks = 0.812

Conversion factor for type of birth at 52 weeks = 1.114

The averages and standard deviations of body weights at 6, 16 and 52 weeks, adjusted to a female single basis were calculated for each of the four groups of sheep used in the experiment, and are given in Table IX.

An ordinary analysis of variance (Snedecor, 1946, page 232) with one variable (the differences among groups) was performed and the completed analyses of variances appear in Table IX-A.

The F test revealed significance only at 16 and 52 weeks of age. A t test was performed in these two cases. At 16 weeks, it was found that the Rambouillet controls were significantly heavier than the Black Top Delaine controls. The F_1's were significantly heavier than the Black Top Delaine controls. Other differences were insignificant. At 52 weeks of age, the F_1's were significantly heavier (at one per cent level) than either one of the control groups (another evidence of heterosis in the F_1's). The F_1's were also significantly heavier (at the one per cent level) than the F_2 group. Other differences were insignificant.

Growth curves. Growth curves were constructed for the male singles, the male twins, the female singles and the female twins for each group, using the original weights at 6, 8, 10, 12, 14, 16, 20, 24, 28, 32, 36, 40,

TABLE IX

AVERAGES AND STANDARD DEVIATIONS OF BODY WEIGHTS AT 6, 16 AND 52 WEEKS OF AGE, ADJUSTED TO A FEMALE SINGLE BASIS

Group	6 Weeks			16 Weeks			52 Weeks		
	No.	Average in lbs.	Standard Deviation	No.	Average in lbs.	Standard Deviation	No.	Average in lbs.	Standard Deviation
Rambouillet controls	24	30.62	±4.90	25	57.09	±9.88	23	94.09	±21.12
Black Top Delaine controls	22	27.85	±4.58	22	49.31	±6.14	19	88.44	±23.10
F_1's	14	30.54	±4.71	15	55.43	±9.21	15	112.73	± 9.74
F_2's	38	29.97	±3.82	38	53.55	±7.74	38	88.36	±21.76

TABLE IX-A

COMPLETED ANALYSIS OF VARIANCE OF AVERAGE BODY WEIGHTS AT 6, 16 AND 52 WEEKS OF AGE

Source of Variation	6 Weeks			16 Weeks			52 Weeks		
	Degrees of Freedom	Sum of Squares	Mean Square	Degrees of Freedom	Sum of Squares	Mean Square	Degrees of Freedom	Sum of Squares	Mean Square
Total	97	1929.62		99	7275.50		94	45310.84	
Between groups	3	108.06	36.02	3	756.72	252.24*	3	7044.24	2348.08**
Within groups	94	1821.56	19.38	96	6518.78	67.90	91	38266.60	420.51

* significant at five-per cent level

** significant at one-per cent level

44, 48 and 52 weeks of age. The growth curves are shown in Figures 3, 4, 5 and 6.

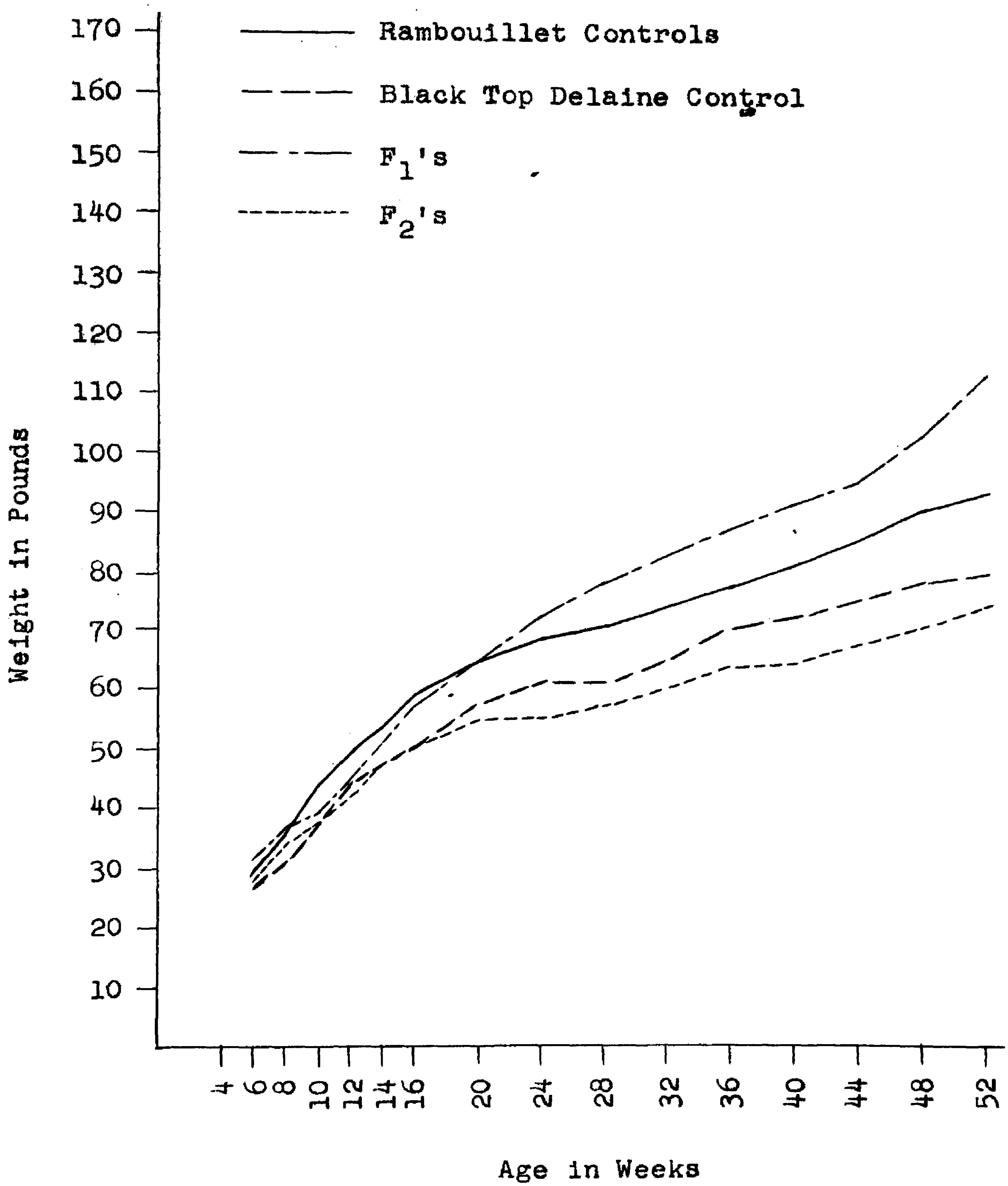

Figure 3. Growth of The Female Singles

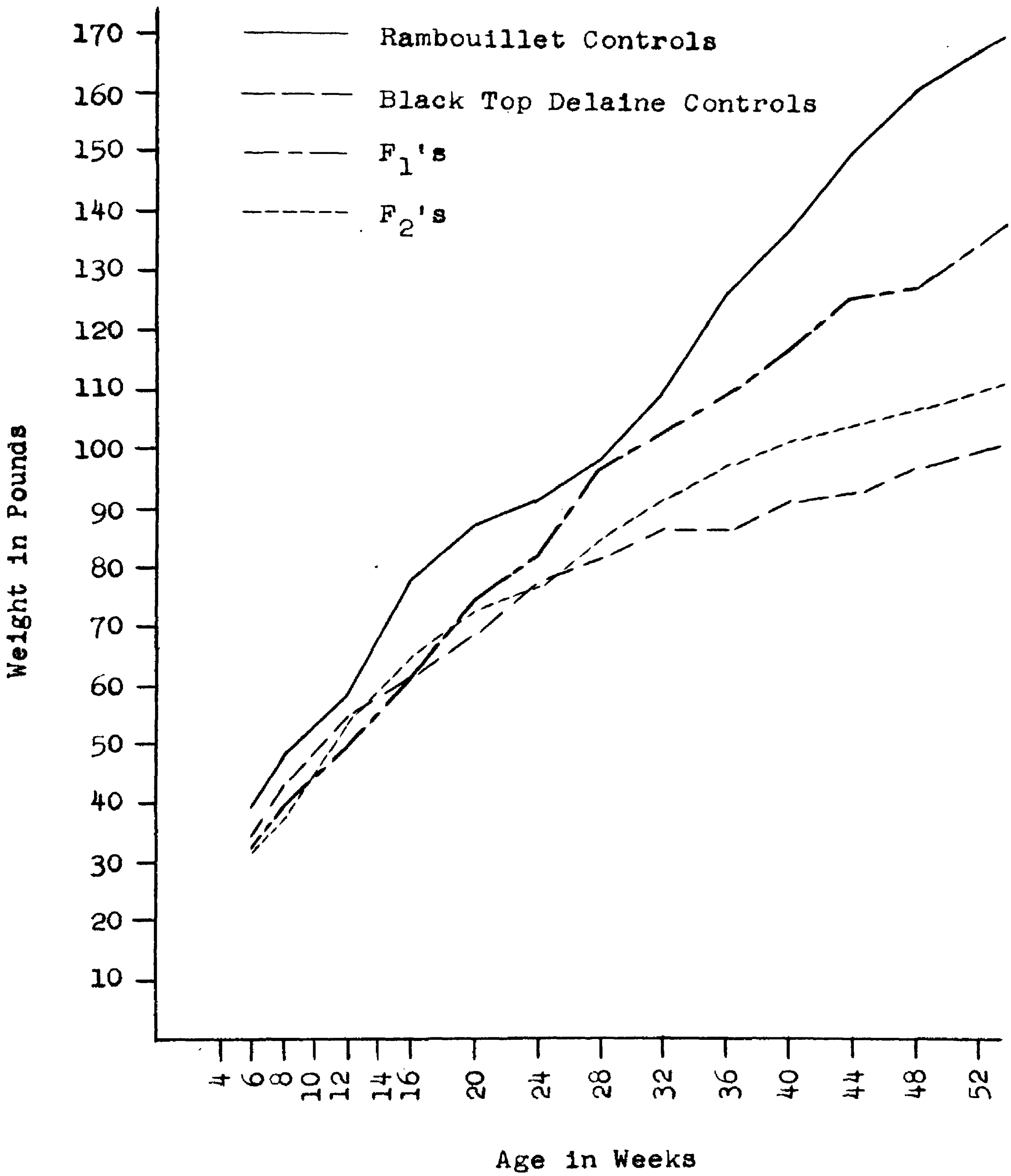

Figure 4. Growth of the Male Singles

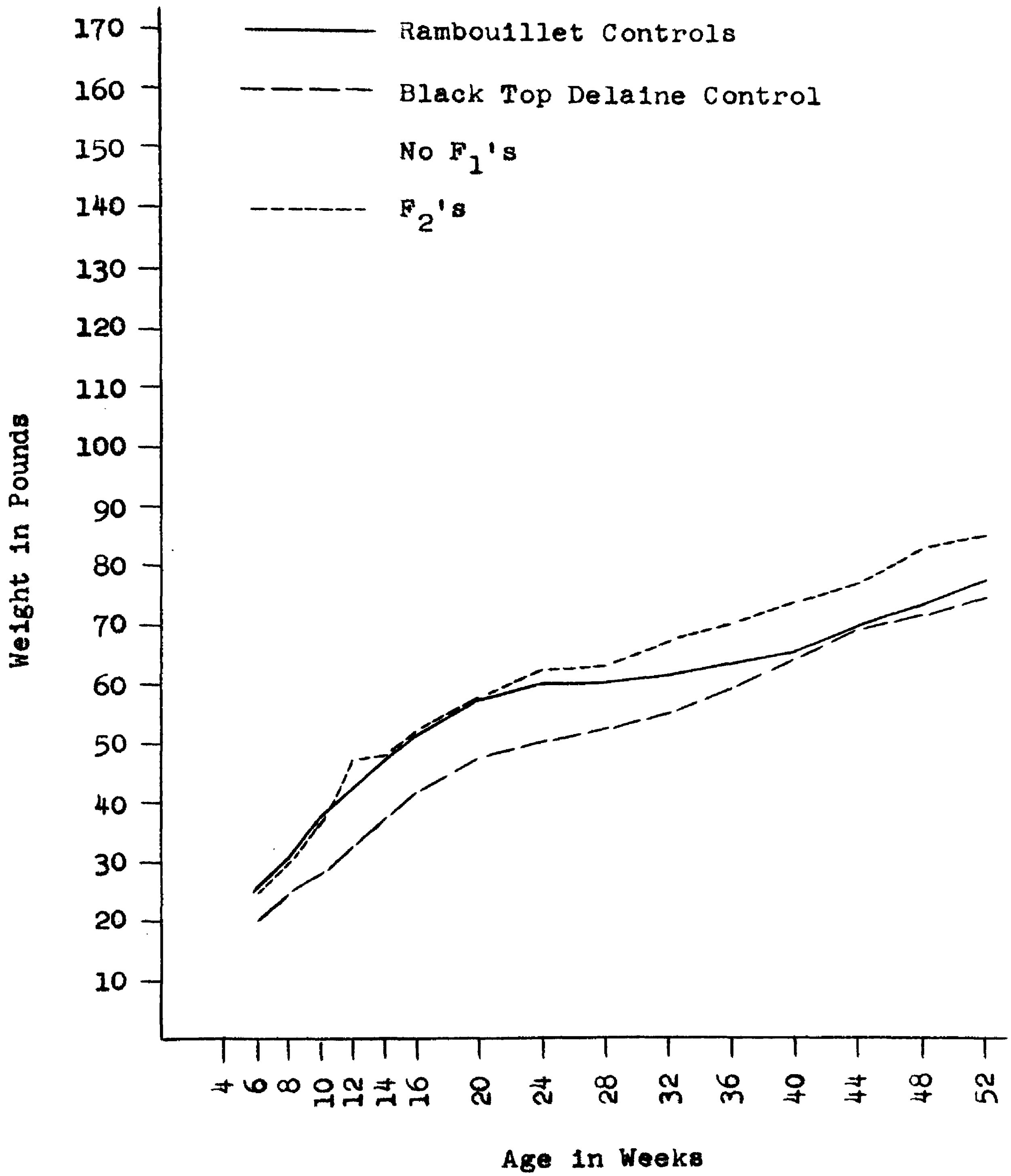

Figure 5. Growth of the Female Twins

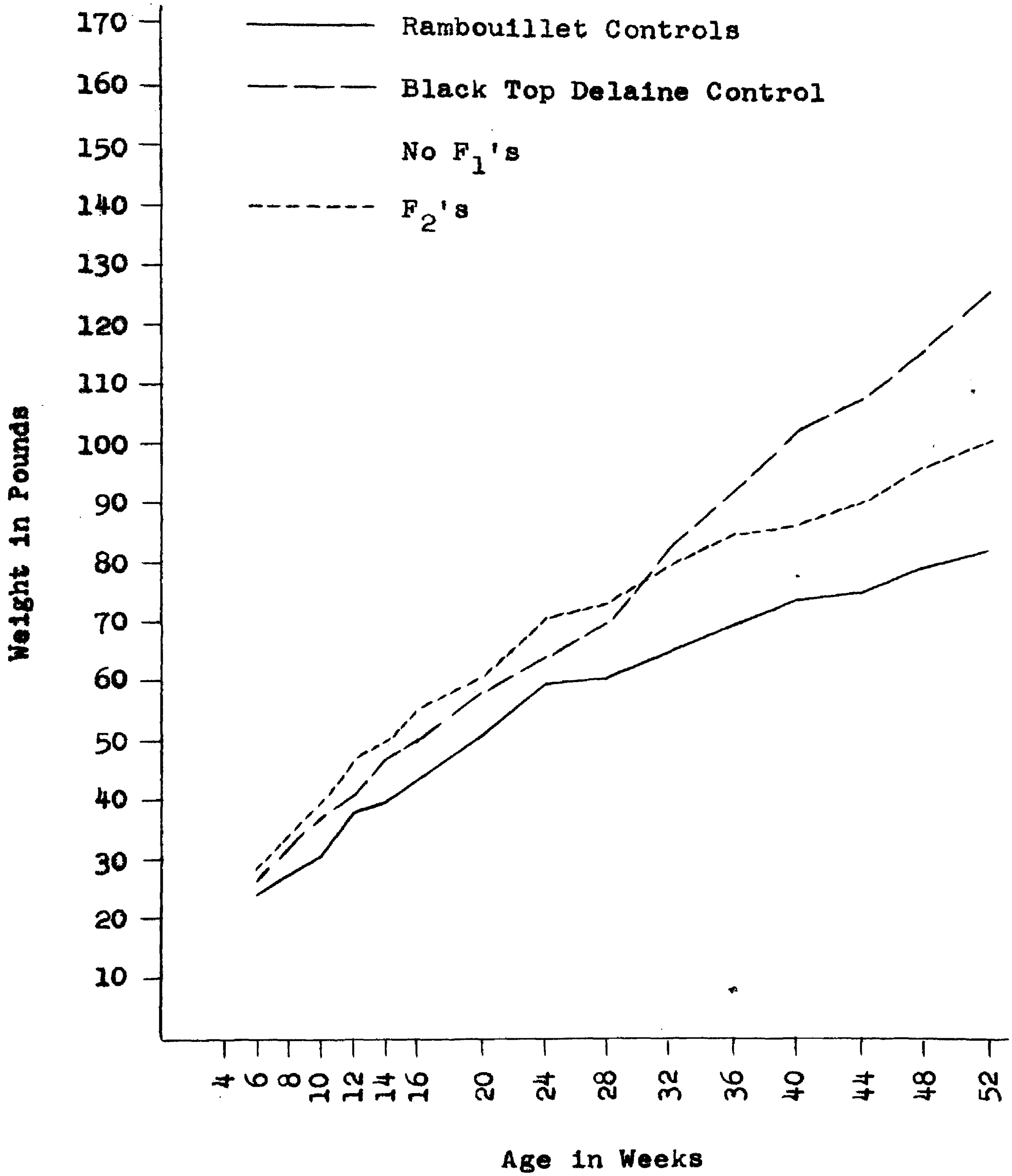

Figure 6. Growth of the Male Twins

RELATIONSHIPS AMONG THE CHARACTERS STUDIES

Correlations

The coefficients of correlation between the various characters studied were computed. The formula used was:

$$r_{xy} = \frac{SXY - [(SX)(SY)]/N}{\sqrt{SX^2 - (SX)^2/N} \cdot \sqrt{SY^2 - (SY)^2/N}}$$

where r_{xy} = the coefficient of correlation between the two characters studied.

SX = the sum of items in one character (independent).

SX^2 = the sum of the squared items of the independent character.

SY = the sum of items in the second (dependent) character.

SY^2 = the sum of the squared items of the dependent character.

SXY = the sum of the products of the two characters in each individual.

The coefficients of correlation were tested for significance by referring to a convenient table (Snedecor, 1946, page). The degrees of freedom used in each case were equal to the number of pairs studied (N) less one (i.e., the degrees of freedom = N - 1).

Table X shows the coefficients of correlation that were obtained in the Rambouillet controls, the Black Top Delaine controls, the F_1's and the F_2's. The correlations studied were: Between combined neck and body value and grease fleece weight, between combined neck and body value and body weight (at 52 weeks), between combined neck and body value and fiber diameter, between combined neck and body value and fiber length, between grease fleece weight and body weight (at 52 weeks), between grease fleece weight and fiber diameter, between grease fleece weight and fiber length, between fiber diameter and body weight, between fiber diameter and fiber length, between fiber diameter and crimp (number of crimps per two centimeters), between fiber length and body weight and between fiber length and crimp.

By reference to Table X, it is observed that, in the control groups, relatively high correlations were obtained between grease fleece weight and body weight, between fleece weight and fiber diameter, between fiber diameter and body weight and between fiber diameter and fiber length. The correlation between fiber diameter and crimp was found to be negative in the two control groups.

In the F_1 group, the coefficients of correlation differed widely, in many of the cases, from those of the

TABLE X

COEFFICIENTS OF CORRELATION BETWEEN SKIN FOLDS, WOOL CHARACTERISTICS AND BODY WEIGHT

Correlation Between:	Rambouillet Controls	Black Top Delaine Controls	Average of Control Groups	F_1's	F_2's
Neck + body value and:					
grease fleece weight	+0.2879	+0.2925	+0.2902	-0.0591	+0.3580*
body weight	+0.2283	+0.3333	+0.2808	-0.1899	+0.2176
fiber diameter	+0.3234	-0.0818	+0.1208	+0.0548	+0.3202
fiber length	+0.0823	-0.2566	-0.0272	-0.7528**	-0.3116
Grease fleece weight and:					
body weight	+0.9532**	+0.7480**	+0.8506	+0.6639**	+0.8078**
fiber diameter	+0.9581**	+0.6138*	+0.7860	+0.0639	+0.4760**
fiber length	+0.3863	+0.1657	+0.2760	+0.2148	+0.0500
Fiber diameter and:					
body weight	+0.9009**	+0.3888	+0.6448	+0.3189	+0.5757**
fiber length	+0.3332	+0.5957*	+0.4644	-0.2927	-0.1503
crimp	-0.2764	-0.5777*	-0.4270	+0.0599	-0.5338**
Fiber length and:					
body weight	+0.4621	+0.0498	+0.2520	+0.1122	+0.0021
crimp	+0.2986	-0.3224	-0.0119	-0.0225	+0.0927
Number of pairs studied	10	12		14	32

* significant at five per cent level.
** significant at one per cent level.

control groups. On the other hand, in the F_2 group, the coefficients of correlation approached the average of the two parental (control) groups.

Descriptive Statements

General statements[1] of the F_1 and F_2 hybrids were recorded for each individual and are given in the Appendix. These statements further clarify the relations between some of the characters (body, wool and wrinkles) of individuals in the F_1 and F_2 groups.

---

[1] The statements were given by Professor G. A. Brown.

DISCUSSION OF THE RESULTS

Skin Folds

By examining the difference between the two breeds, it is found that the Rambouillet sheep have a higher average neck fold value than the Black Top Delaine, while the latter breed has a higher average body value and combined neck and body value.

The presence of more skin folds in the F_1 hybrids than in either one of the parental breeds is clearly indicated by a higher average neck value, body value and combined neck and body value. Studies by Jones, et al. (1944) have proved that the less wrinkly type is both more profitable and desirable in fine wool sheep than the wrinkly type. Thus, the increase of folds in the F_1's, being undesirable, is justifiably called negative heterosis. Since skin folds are controlled by multiple factors, in which the dominant genes are those for smooth body (Jones et al., 1946), it is evident that the dominance hypothesis of heterosis cannot be applied. The gene interaction hypothesis (Rasmusson, 1933) seems to offer a plausible explanation. It is imagined, for the sake of simplicity, that two pairs of genes, A, a, B and b, control skin folds, A and B being the dominant genes for smooth body, and a and b are their recessive alleles for the presence of skin folds. If each of the dominant genes (A and B) has, by itself, an effect equal to 1, the effect of both genes (A + B) combined would have an effect less than 2, *i.e.*, the effect of the dominant genes A and B is not additive. If it is supposed that one of the parental breeds contained individuals of the genotypes AAbb, Aabb, and aabb in the ratio of 1 : 2 : 1 respectively, each individual would contain an average of one dominant gene A, having an effect equal to 1. If the other parental breed contained individuals of the genotypes aaBB, aaBb and aabb in the ratio 1 : 2 : 1 respectively, each individual would contain an average of one dominant gene B, having an effect equal to 1. The hybrids resulting from a random mating between these two breeds would contain individuals of the genotypes AaBb, Aabb, aaBb and aabb in equal proportions. The average of the dominant genes in the hybrids would be [(A+B)+A+B+0]/4, which causes an average effect on wrinkling equal to [(less than 2) + 1 + 1 + 0]/4 = (less than 4)/4 = less than 1. In other words the average effect of the genes for smooth body in the F_1's is less than that in either one of the parental breeds. This leads to the increase in skin folds in the F_1 hybrids over the parental breeds.

It was also noticed that in the F_1's, the standard deviations were lower than those of the parental breeds.

This could very well be attributed to the fact that most of the F_1's (10 out of 15) were born during one year, while the controls representing the parental breeds were born over a period of five years. The environment was therefore more uniform for the F_1's, leading to less variation.

In the F_2's, it is observed that the average neck value, body value and combined neck and body value were intermediate between the parental breeds but resembled more the breed with the higher average. This could be caused by segregation and recombination in the F_2's.

Wool Characteristics

Fiber Length:

The Black Top Delaines, as expected, were found to possess longer wool fibers than the Rambouillets, and the difference was significant. The average fiber length of the F_1's was slightly less than that of the Rambouillet controls. However the difference was not significant. Since fiber length is believed to be, at least partially dominant, (Ritzman and Davenport, 1926), the decrease of fiber length in the F_1 hybrids can be explained on the basis of gene interaction.

In the F_2's, the average fiber length was intermediate between the parental breeds, an evidence of segregation.

Fiber Diameter and Crimp:

Another instance of negative heterosis in the F_1 hybrids is the increased average fiber diameter over either one of the parental breeds (coarser fibers are less desirable and hence the term negative heterosis). Since coarser fibers are dominant (Ritzman and Davenport, 1926), either the dominance hypothesis or the gene interaction hypothesis of heterosis can explain the observed phenomenon. Also, the average number of crimps per two centimeters in the F_1's was less than in either of the parental breeds.

The F_2's had slightly coarser and less crimpy wool than the parental breeds.

The standard deviations of fiber diameters in the F_1's in both shoulder and hip samples, were less than either parental breed. This is attributable to the fact that most of the F_1's were born during one year, while the controls were born over a period of five years.

Grease Fleece Weight:

The much heavier unscoured fleece weights in the F_1's than those of the parental breeds suggest hybrid vigor or positive heterosis, since heavier fleeces are more desirable. Dominance or gene interaction can provide an explanation for the observed hybrid vigor.

In the F_2's, the average of the unscoured fleece weights was intermediate between the two parental breeds, but approached the breed with the higher average. The greater uniformity in the F_1's, as indicated by a less standard deviation than either parental breed, is probably caused by the uniformity of their environment as compared to the controls that were born intermittently over a period of five years.

Shoulder versus Hip Samples:

It was observed that samples from the shoulder region of the four groups (the two control groups, the F_1's and the F_2's), had more fiber length, less fiber diameter and more crimp than samples taken from the hip region. This is in agreement with earlier findings by Hultz and Paschal (1930), Ensminger (1942 and 1942a) and Pohle and Schott (1942 and 1943).

Growth

By studying the average corrected body weights at 6 and 16 weeks of age, it was observed that the F_1 averages approached those of the heavier Rambouillet controls. At 52 weeks of age, the F_1's were significantly heavier than either one of the parental breeds. This was another evidence of positive heterosis in the F_1 hybrids which could be explained by the dominance hypothesis or the gene interaction hypothesis of heterosis. The study of the growth curves also revealed faster gains in the F_1 females after weaning up to yearling age. The slower growth rate in the F_1 single males as compared to the Rambouillet males must have been caused by experimental error (due to smaller number of males than females in those two groups).

The delay of the F_1's in exhibiting heterosis until a later age could be explained by the fact that before weaning, the weights of the F_1's depended on the milking abilities of their mothers. After weaning, the growth of the F_1 individuals became independent of the mother's milking abilities and the heterosis could exhibit itself.

The F_1's were highly uniform in body weights at 52 weeks of age, as compared to the parental breeds and the F_2's. The probable cause is that all the F_1's were born within a period of two years, while the other groups were born over longer periods. Another reason could possibly be a greater genotypic similarity among the F_1's.

Relationships Among the Characters Studied

The presence of positive correlations between skin folds (combined neck and body values) and grease fleece weight, body weight and fiber diameter, and a negative correlation between skin folds and fiber length in the two control groups agrees with earlier findings by Jones _et al_. (1944). Also, the presence of positive correlations between fleece weight and fiber diameter and between fleece weight and fiber length are supported by earlier studies by Spencer (1925), Spencer, Hardy and Brandon (1928), Lambert, Hardy and Schott (1938), Pohle and Keller (1943), Jones _et al_. (1944) and Slen (1949). The positive correlations between body weight and skin folds, grease fleece weight, fiber diameter and fiber length are supported by similar results obtained by Jones _et al_. (1944).

In the F_1 group, the coefficients of correlation varied widely, in most of the cases, from those of the parental breeds. The fact that the F_1's constituted a peculiar group, differing from the parental breeds in most of the characters, explains the discrepancies in their correlation coefficients.

The correlations in the F_2 group approached the average correlations of the parental breeds in most of the cases. This seems to follow the pattern exhibited by the F_2's throughout the experiment.

CONCLUSIONS

It is not a simple matter to derive positive conclusions from the experiment as a whole, in view of its many limitations (these will be discussed in the next section). None of the hybrid individuals combined the better mutton qualities of the Rambouillet with the longer wool of the Black Top Delaine. The F_1 hybrids were growthy and had heavier fleeces but had inferior wool qualities to either parental breed and were too wrinkly. The F_2's were intermediate in most of the cases and none of them was found to be a superior individual in all the characters examined. These results point to the possible use of the cross to raise F_1 hybrids up to yearling age, thus benefiting from the hybrid vigor in their body weights and fleece weights. From a breed or herd improvement standpoint, however, the cross is not recommended until further experimentation shows its value.

POSTSCRIPT

All farm animals, including sheep, constitute a highly complicated experimental material, as far as genetics research is concerned. The following are some of the difficulties encountered by the experimental geneticist, once he endeavors to work with farm animals:

1. Fairly large numbers of animals are required for significant results from genetics research. Large numbers are not easily obtained in the case of farm animals for the following reasons:
   (a) The long gestation period of farm animals and the long time they require until they reach the age of useful reproductive activity.
   (b) A relatively small number of offspring is produced by a single female farm animal (except the sow) during her lifetime. An average ewe, for example, can produce her first lamb when she is about two years old. Even if she continues producing every year, the ewe will not be able to produce more than 12-15 lambs during her lifetime. Compared with laboratory animals, this reproductive rate is extremely low.
   (c) Multiple birth is not a very frequent occurrence in farm animals (except swine), thus denying the

experimenter of a valuable source of information about full brothers and sisters raised together (full sibs).

2. In sheep, identical twins, which offer a most important source of genetic information, are very rare (Venkatachalam, 1949).
3. The so-called "economic characters," such as wool characters, skin folds and growth in sheep, are apparently controlled by a large number of genes, and are further complicated by various forms of gene interaction.
4. Environmental factors exert unmistakable effects on the more important quantitative (or economic) characters. Farm animals are subjected to various weather and other environmental conditions (especially when on pasture) which are impossible to keep constant from year to year, or from one generation to the next.
5. Although inbreeding has been practiced in many of the purebred sheep, it has not been practiced long enough to produce sufficiently homozygous stocks.
6. To obtain homozygosity, intensive inbreeding has to be practiced for a long period of time. This is complicated, however, by the decrease of vigor observed under such conditions.

7. Considerable financial assistance is needed for conducting experiments that deal with farm animals, for such experiments extend over long periods of time. Such financial assistance is not available in most cases, especially if the experiment is purely academic and the results have no immediate economic advantages.

In the present experiment with fine-wool sheep, none of the difficulties mentioned above was successfully overcome. The shortcomings of the experiment will be immediately conceived if it is recalled that:

1. The number of animals used in the experiment was too small.
2. The parents were from a heterogeneous stock as far as age and breeding were concerned.
3. Very little information about the parents was available.
4. Five F_1 males were castrated and sold as weanlings before any of their data could be obtained.
5. Selection was practiced within the F_1 males for producing F_2's.
6. None of the controls that were used to represent the parental breeds and compare them with their F_1 and F_2 hybrids were born during the same year as the F_1's.

It was practically impossible to plan and execute a scientifically satisfactory experiment in sheep breeding with the existing limitations in space, labor and funds.

SUMMARY

Two Rambouillet rams were crossed with 19 Black Top Delaine ewes in order to improve the Rambouillet breed and develop individuals combining the length of fiber and heavy fleece of the Black Top Delaine with the mutton qualities of the Rambouillet. Fifteen F_1's and 37 F_2's were raised. Their skin folds and wool characteristics at yearling age and their growth during the first year of life were studied and compared to those of 16 Rambouillet and 18 Black Top Delaine controls at the same age. The following results were obtained:

1. The F_1's had significantly more extensive skin folds, heavier unscoured fleeces and heavier body weights than either one of the parental breeds at yearling age.
2. The average fiber length in the F_1's was similar to that of the Rambouillet control group, while their average fiber diameter was more and their average number of crimps per two centimeters was less than in either of the parental breeds.
3. The F_2's occupied an intermediate position between the parental breeds in most of the characters studied.

4. Wool samples taken from the shoulder region of all the animals studied had, on the average, longer fibers, smaller fiber diameters and more crimps per two centimeters than those taken from the hip region of the same animals.
5. In the control groups and the F_2's, high positive correlations existed between grease fleece weight and body weight, between grease fleece weight and fiber diameter and between fiber diameter and body weight. There was a negative correlation between fiber diameter and crimp. The F_1's, constituting an unusual group, differed widely, in most of the correlations studied, from the other three groups.
6. Under the limitations of the experiment, positive conclusions regarding the cross could not be given. However, it seemed from the results obtained, that the use of the cross should not be recommended for breed improvement until further experimentation shows its value.

APPENDIX

Statements[1] about some F_1 and F_2 individuals are cited on the following pages. The individuals are identifiable by sex, number and year of birth. Further identification can be obtained by referring to Figures 1 and 2.

---

[1] All the statements were given by Professor G. A. Brown except those for F_1 males No. 3105 and No. 3110, and parts of those for F_1 males No. 3102 and No. 3107 which were given by Mr. V. Freeman.

F_1 SHEEP

Female No. 3101 of 1930

Body. Wide, deep bodied, short legged, blocky, straight top and bottom lines. Well placed on legs, legs far apart.

Wool. Three-inch length of staple. Good free-flowing oil. Good surface of fleece. Bright, lustrous fleece. Considerable kemp on neck wrinkles. Quality of fleece of low Delaine order because of coarseness on neck and britch.

Head. Wool extending half-way from eyes to end of nose. Open under eyes. No wool over eyes.

Wrinkles. Heavy apron. Three neck folds. Heavy dewlap. Considerable number of pin wrinkles.

Male No. 3102 of 1930

Low, weak back; narrow chest; crooked hind legs; short fleece; wrinkled body; fair width of body; blocky head; dense fleece; second choice among the F_1 males.

Body. Medium sized. Fairly deep of body but pinched in heart girth. Low in the back and not as deep as desirable in the fore flank. Back low in the dorsal region, very sharp on the shoulder. Knees and hocks close together, slightly sickle-hocked. Fair to medium width of body.

Wool. Excellent covering on legs and belly. Extremely dense, very uniform in density. Moderate length of staple, 2½ inches. Heavy, thick sluggish oil. Fine crimp but lacking in luster. Heavy, gummy surface on fleece. Rather fine fibers over the body of the fleece, but the fleece was coarse in the wrinkles with a large amount of kemp.

Head. Slightly narrow between the eyes, trifle long on the nose. Wide-spreading horns. Fair covering of the head with wool within two inches of the nostril. Wide-spreading horns. Good covering on the ears, extending to their end.

Wrinkles. Rather heavy apron. Three wrinkles going entirely around the neck. Heavy dewlap. Several side wrinkles on the body. Tail rosette. Longitudinal wrinkles on the hip, and thigh wrinkles. Many pin wrinkles.

Rather undesirable type because of heavy, shrinking fleece, short staple, narrow chest, and too many wrinkles.

Female No. 3103 of 1930

Body. Very low set (short-legged), deep bodied ewe, with straight top and bottom lines, well placed legs, with straight knees and hocks. Heavy boned.

Wool. About 3-1/4 inches long, lustrous, with free-flowing oil. Good wool covering on legs and belly. High Delaine quality of wool with moderate density. Wool light surfaced.

Head. Moderately covered with wool extending down half-way between eyes and nostrils.

Wrinkles. Rather heavy apron. Two lower neck folds (i.e., do not extend over top of neck). Very light dewlap.

Probably the best of the older F_1 ewes.

Male No. 3105 of 1930

Narrow body; crooked hind legs; wrinkled body; short fleece; dense fleece; oily fleece; deep chest; third choice among the F_1 males.

Male No. 3107 of 1930

Little weak in the back; slightly narrow; fleece lacks density; large size; fleece long; head medium to long; smooth bodied; first choice among the F_1 males.

Body. Medium sized, good depth of body, fairly straight top and bottom line. A little high at the shoulder. Well placed on the legs. Both knees and hocks are straight (not sickle-hocked or knock-kneed). Fair to medium width of body.

Wool. Excellent covering on legs and belly. Approximately three inches; clear, white oil. Very short, fine, even crimp with bright, lustrous fiber and free-flowing oil. Very fine fibers. A light shrinking fleece. Easily of Delaine standard from all standpoints. Practically no surface oil.

Head. Excellent wool covering on head and ears; wool two inches from opening of nostril. Head broad. Good length of wool on head. Spreading horns.

Wrinkles. Moderate apron. One neck wrinkle and a light dewlap. Wrinkles do not extend over top of neck.

A very desirable ram.

Male No. 3110 of 1930

To be eliminated; too slim of body; wrinkled body; high narrow back; droopy rump; light leg; narrow throughout; short, blocky head; crooked hind legs; lacks flesh; very wrinkly; no good.

Female No. 3114 of 1930

Body. Low-set, rather blocky, moderate width of body, little narrow at shoulders, and between the front legs.

Wool. A heavy dense fleece, close and compact on the surface, with free-flowing white oil. About three inches long. Wool of a low Delaine quality.

Head. Rather wide head, completely covered with wool, ears well covered, and the wool extends to within $1\frac{1}{2}$ inches of the nostril.

Wrinkles. Heavy apron. Three neck folds extending all around the neck. Very heavy dewlap. Two light folds in the fore flank. Some folds on the thighs. Some kemp on the folds.

A very desirable ewe.

Female No. 3115 of 1930

Body. Deep bodied, short legged, straight top line, little narrow at shoulder, shallow chested. Short, steep rump.

Wool. Excellent wool covering, but staple is short, 2-1/4 inches long. Very oily fleece with heavy black surface. A bright, lustrous, fine fleece, but too short for Delaine quality.

Head. Short, broad head. Excellent wool covering on head extending down to two inches of nostrils.

Wrinkles. Heavy apron. Three neck folds extending clear around the neck. Several body folds. Folds at the base of the tail and on thighs.

An undesirable ewe from the standpoints of length of fleece and conformation.

Female No. 3116 of 1930

Body. Medium sized, low set. Straight top and bottom lines. Body a little narrow, particularly through the shoulders. Legs a little close together.

Wool. Excellent covering of wool. Good length of staple (3 inches). Free flowing white oil and rather heavy surface. Good density. Lustrous. Considerable kemp showing on neck wrinkles and thighs.

Head. Short and broad, almost typically Rambouillet, with wool extending down to within two inches of nostrils and extending well out on the ears.

Wrinkles. Heavy apron; three neck folds completely circling the neck; several side wrinkles on the body; wrinkles about the tail, head and on thighs.

Female No. 3117 of 1930

Body. Low-set, deep bodied, good breadth of body throughout. Well placed legs.

Wool. Excellent wool covering. Moderate length of staple about three inches long. Free flowing, white oil, very lustrous fleece. Quality of wool, of the lower Delaine order.

Head. Well shaped head, with the covering extending 2/3 of the distance from the eyes to the end of the nose.

Wrinkles. Moderate apron. Two neck folds that surround the neck. One light fold in the fore flank.

A very desirable ewe.

Female No. 135 of 1932

Body. Large, rugged, vigorous. Excellent body conformation. Straight top and bottom lines. Well placed legs.

Wool. Excellent covering. Good length of staple - 3-1/4 inches. Clear, white, free flowing oil. Good surface of fleece. Very lustrous fleece. Extremely fine. Fair density. Good Delaine quality of wool.

Head. Excellent head covering, wool extending 2/3 of the distance from the eyes to the tip of the nose.

Wrinkles. Practically no apron. Very light neck fold. Very little dewlap.

An excellent ewe.

Female No. 136 of 1932

Same characteristics as for ewe 137 of 1932, except (1) that 136 has more head covering with wool extending down to half-way between eyes and nostrils, and (2) 136 is not quite as wide in the chest as 137.

An exceptionally good ewe.

Female No. 137 of 1932

Body. Low, thick-set, square bodied. Of excellent body conformation. Smooth shoulder, full chested, good width of back. Well placed on the legs, which are wide apart.

Wool. Excellent covering of wool over legs and belly. Good density. Clear, white, free flowing oil. Good surface of wool. Lustrous, with short, fine crimp. Three inches long. Fine grade of Delaine staple.

Head. Practically no wool covering below eyes. Very little wool on ears.

Wrinkles. Light apron. One medium-sized neck fold. Very small dewlap.

A very desirable ewe.

F_2 SHEEP

Male No. 132 of 1932

Body. Large, vigorous, heavy boned. Excellent depth of body. Short legged. Straight under line. Slightly low back of shoulders along the top line. Well placed legs, a little crooked at the hocks.

Wool. 3-3/4 inches long. Free flowing oil. A light surface for the fleece (moderate amount of oil) about right for the surface. Fleece very dense. Wool bright and lustrous. Belly and legs well covered. A Delaine fleece.

Head. Head rather long. Face rather long and narrow. Wide spreading horns. Open faced, practically no wool below the eyes. Ears well covered with wool.

Wrinkles. Heavy apron. One wrinkle extends around the neck. Heavy dewlap. No body folds. Slight wrinkle at the tail head.

Save for breeding with F_2 ewes.

Female No. 139 of 1933

Body. Medium sized for her age. Short legged. Somewhat narrow of body. A little low back of the shoulder.

Wool. Medium length of fleece, about 2-1/2 inches. Density fair. Wool too short for Delaine quality.

Head. Wool covering extends about one inch below eyes.

Wrinkles. Rather heavy apron. Two complete neck folds. Heavy dewlap. Several side wrinkles on body. Wrinkles on thighs and about the tail.

Save for breeding.

Male No. 140 of 1933

Body. Medium to small size. Straight top and bottom lines. Rather narrow body. Somewhat fine boned. Short neck.

Wool. Good length of staple. Light oil. No surface of fleece. Wool lacking a little in density fleece lustrous. Wool would rate as low Delaine. Excellent covering of legs and belly.

Head. A very short, broad head completely covered with wool over nose and ears. Good spread of horns. Typical Rambouillet head.

Wrinkles. Heavy apron, one neck fold, heavy dewlap.

Male No. 141 of 1933

Body. Rather large. Large boned. A little high at the shoulder. Stands a little close on his legs. Good width of body. Slightly crooked hocks. Heart girth a little small.

Wool. About three inches long. Very light oil. Practically no surface of fleece. Free flowing oil. Lustrous fibers. Somewhat lacking in density. Excellent wool covering on legs and belly. Low grade of Delaine.

Head. Slightly long and narrow. Horns a little closely spiralled. Excellent wool covering of head and ears.

Wrinkles. Light apron. One light neck fold. Light dewlap. No body on tail folds.

A fair ram.

Female No. 145 of 1933

Body. Medium sized. Good depth of body. Medium to fine boned.

Wool. Three inch staple. Medium density. Very fine wool. Bright, lustrous, with a very fine, even crimp. White, free-flowing oil. Wool has a light surface.

Head. No wool on head below the eyes.

Wrinkles. Practically no apron. Only a trace of neck folds.

A very desirable ewe. Save for breeding.

Male No. 146 of 1933

Body. Rather small, narrow body. Legs close together. Fairly straight top and bottom lines. Slightly long of neck.

Wool. Good wool covering on legs and belly; very little wool below eyes. Fair length of staple, about 2-3/4 inches. Clear, white, free-flowing oil with lustrous staple which was medium in density. Light surface of fleece. High grade Delaine quality of wool.

Head. Rather pointed nose. Horns rather closely spiralled.

Wrinkles. Light apron. Light neck fold and dewlap. No body folds.

Not a good combination of characters.

Male No. 119 of 1934

Body. Large, growthy lamb. Slack in heart girth (flat-ribbed and narrow-backed at the shoulder). Rather sloping at the rump.

Wool. Well covered head (too much covering; a Rambouillet covering). A very dense, heavy, oily fleece, lacking a bit in quality of fleece.

Wrinkles. Very heavy apron. Three neck folds. Wrinkled in the flanks; also at the tail.

Discard him because he is too wrinkled an animal.

Male No. 120 of 1934

Body. A trifle narrow in the body. A little sloping in the rump. Fair growth.

Wool. Lacks character in the fleece.

Head. Short, broad, Rambouillet head covered to within 1½ inches of the end of the nose.

Wrinkles. Heavy apron. Two neck folds. Wrinkles at the tail head.

Keep for possible breeding.

Female No. 121 of 1934

Body. Rather large and growthy with a wide, deep body.

Wool. Fleece with good density, good length, and a very desirable Delaine quality.

Head. Open face. Wool 1/2 inch below the eyes.

Wrinkles. Body is smooth.

Keep for a breeder.

Male No. 122 of 1934

Body. Low set and compact; fair width of body.

Wool. Excellent length of fleece; good covering; fair quality; fleece a bit lacking in density and oil.

Head. Very short, broad, well covered head with wool to within two inches of the end of the nose.

Wrinkles. One slight fold on the neck; otherwise the body is smooth.

Keep for possible breeding.

Female No. 123 of 1934

Body. Rather flat-ribbed and narrow-chested. A little sloping on the rump. Small in size.

Wool. Very desirable fleece; excellent density; good quality, but a little heavy shrinkage. Fleece a little bit like that of Merino.

Head. Rambouillet head covering to within one inch of the end of the nose.

Wrinkles. Rather, heavy apron and lower neck folds. Wrinkles in flanks.

Should be discarded.

Female No. 124 of 1934

Body. Rather small in size. Lacking in width or spread of body. Very crooked on hind legs. Short in both middle and quarters.

Wool. Rather open fleece but with excellent length and quality.

Head. Very complete head covering like Rambouillet.

Wrinkles. Smooth body.

Keep for a breeder.

Male No. 126 of 1934

Body. A rather growthy lamb. Rather narrow body.

Wool. Short, dry fleece, lacking character.

Head. Short, broad head; well covered to within two inches of the end of the nose.

Wrinkles. Very heavy apron. Three complete neck folds. A fold at the tail head. He is too heavily wrinkled.

Discard him.

Male No. 139 of 1935

Very small; undersized; narrow and shallow chest; drooping rump; thin pointed head and slender neck. Very inferior animal.

Discard.

Female No. 140 of 1935

Looks unhealthy; very thin; fair boned; straight back, extremely thin and emaciated.

Male No. 141 of 1935

Rather large and rugged; heavy boned; growthy; discarding because he is light in the chest and very drooping in the rump. He is a fairly good ram.

Discard.

Female No. 142 of 1935

Medium growth; back is straight; medium boned; a good head with wool down to just below the eyes; very thin in flesh.

Male No. 143 of 1935

A large, rugged, heavy-boned ram; deep chest; reasonably straight top (back); a little narrow in the forehead, rather crooked at the hocks; a fairly good animal. It had been sheared before this description was made.

Keep this animal.

Male No. 149 of 1935

Medium sized; straight back; head fairly wide; body extremely narrow; flat-ribbed; drooping rump. A medium good animal.

Discard.

Male No. 150 of 1935

Small; fine-boned; undersized; slim-necked. A poor animal.

Discard.

Female No. 127 of 1936

Fairly, growthy. Moderately smooth bodied. Good width of body for a fine wool. Good back. Very good head. A little steep on the rump.

Female No. 129 of 1936

Rather small. Narrow head and face. Rather shallow chested. A little short in her quarters. A little long in the neck.

Male No. 131 of 1936

Good sized; growthy. Good width of body, wide chest floor, fairly square quarters. A little sharp at the withers. Good depth of body. "A pretty decent sheep."

Male No. 132 of 1936

Large, growthy animal. Good depth of body. Lacks width, being sharp at the shoulders. A little flat of rib. Long and narrow head.

Male No. 133 of 1936

Rather small. Somewhat narrow chested. A little flat-ribbed. Lacks width of body throughout. A typical Merino. Short, broad head; head well covered with wool, and ears well covered with wool. Heavily folded on the neck. Heavy apron and two heavy neck folds.

Female No. 134 of 1936

A large growthy ewe. Good depth of body. Lacking somewhat in width of body. A little crooked in the hocks. A bit long in the neck.

Male No. 10 of 1937

Smooth bodied. Heavily folded neck. Head covering extends two inches below the eyes. The fleece is very fine, and does not have too much oil.

Female No. 11 of 1937

A rather small ewe, lacking in body width. Wool comes only down to the eyes. The fleece is only of the Delaine density. Moderately heavily folded on the neck.

Male No. 12 of 1937

Would pass for a Black Top Delaine. A rather growthy, smooth-bodied ram, free of wrinkles. Wool covering extends to about an inch below the eyes. Has a typical Black Top fleece.

Male No. 13 of 1937

Smooth bodied; there are a few light folds on the neck. The head covering and character are very similar to the Rambouillet. Rather narrow bodied. Fleece is rather dry and lacking in density.

Male No. 14 of 1937

Of B Merino type. Heavily folded neck and a good many body wrinkles. Rather small, fine boned, and narrower bodied than the Rambouillet or Delaine. A throwback to the American Merino type. Has a very short, fine fleece. Completely covered on the head with fleece.

Female No. 15 of 1937

A rather small ewe; not growthy. Somewhat fine boned. Short and compact. Heavily folded on the neck. A very fine fleece of somewhat greater density than the Delaine.

Male No. 16 of 1937

A rather growthy, very smooth-bodied ram. Has a Delaine-type head. Lacks width of body. Has very open, dry fleece, lacking in character.

Female No. 17 of 1937

A rather large, strong-bodied ewe. Has folds on the neck. Very complete head covering. Fleece is of good length, is extra fine, and of fair density. The fleece is intermediate between a Rambouillet and Delaine in density. Lacking a little in body width.

Female No. 18 of 1937

A very large, smooth-bodied ewe, free of wrinkles. Fleece extremely fine. Density of fleece like the Delaine. Has extreme head and leg covering, like the Rambouillet.

Female No. 19 of 1937

A rather low, thick ewe. Head and leg covering of the Rambouillet. Extremely fine, very dense fleece of Rambouillet density. A good many pin wrinkles which are large on the body.

BIBLIOGRAPHY

Barker, S. G. and King, A. T.
1926 A Comparison of Diameters of Wool Fibers with the Micro-balance and the Projecting Microscope with Applications to the Determination of Density and Medulla (kemp) Composition. Journal of the Textile Institute, 17:68-74.

Blunn, C. T.
1944 The Influence of Seasonal Differences on the Growth of Navajo Lambs. Journal of Animal Science, 3:41-49.

Burns, R. H.
1924 Some Phases of Wool Inheritance in F_1 Generation. The American Society of Animal Production, Proceedings, 24:92.

Burns, R. H.
1935 The Growth of Skin Area in Sheep. The American Society of Animal Production, Proceedings, 35: 146-151.

Burns, R. H. and Koehler, W. B.
1925 The Micrometer Caliper as an Instrument for Measuring the Diameter of Wool Fibers. Wyoming Agricultural Experiment Station Bulletin. 141.

Carter, H. B.
1941 The Influence of Plane of Nutrition on the Growth of Skin in the Merino. The Australian Institute of Agricultural Science Journal, 3:101-102.

Darlow, A. E.
1930 Factors That Affect the Quality of Wool. The American Society of Animal Production, Proceedings, 30:195.

Dickson, W. F. and Lush, J. L.
1933 Inbreeding and the Genetic History of the Rambouillet Sheep in America. Journal of Heredity, 24:19-33.

Ensminger, M. E.
1942 Studies of Important External Physical Characteristics of Wool. Journal of Animal Science, 1: 58.

Ensminger, M. E.
1942a Fiber Diameter Studies of Different Body Areas. *Journal of Animal Science*, *1*:355-356.

Grandstaff, J. O.
1940 A Rapid Method for Projecting and Measuring Cross Sections of Wool Fibers. U. S. D. A. Circular. 590.

Hardy, J. I.
1935 A Practical Laboratory Method for Projecting and Measuring Cross Sections of Fibers. U. S. D. A. Circular. 378.

Hardy, J. I.
1935a Cross Sectional Variability of Wool Fibers. The American Society of Animal Production, *Proceedings*, *35*:144-146.

Hardy, J. I. and Wolf, H. W.
1939 Two Rapid Methods for Estimating Fineness and Cross-sectional Variability of Wool. U. S. D. A. Circular. 543.

Hazel, L. N. and Terrill, C. E.
1945 Effects of Some Environmental Factors on Weanling Traits of Range Rambouillet Lambs. *Journal of Animal Science*, *4*:331-341.

Hazel, L. N. and Terrill, C. E.
1945a Heritability of Weaning Weight and Staple Length in Range Rambouillet Lambs. *Journal of Animal Science*, *4*:347-358.

Hazel, L. N. and Terrill, C. E.
1946 Effects of Some Environmental Factors on Fleece and Body Characteristics of Range Rambouillet Yearling Ewes. *Journal of Animal Science*, *5*: 382-388.

Hultz, F. S.
1927 Wool Studies with Rambouillet Sheep. Wyoming Agricultural Experiment Station Bulletin. 154.

Hultz, F. S. and Paschal, L. J.
1930 Wool Studies with Rambouillet Sheep, No. II. Wyoming Agricultural Experiment Station Bulletin. 174.

Jones, J. M., Warwick, B. L., Dameron, W. H., Davis, S. P., McPhee, H. C. and Spencer, D. A.
1936 A Study of the Inheritance of Skin Folds on Rambouillet Sheep. Texas Agricultural Experiment Station, Forty-ninth Annual Report, page 38.

——— 1937 Inheritance of Skin Folds in Rambouillet Sheep. Texas Agricultural Experiment Station, Fiftieth Annual Report, page 42.

——— 1938 A study of the Inheritance of Skin Folds on Rambouillet Sheep. Texas Agricultural Experiment Station, Fifty-first Annual Report, page 35.

——— 1939 A Study of the Inheritance of Skin Folds on Rambouillet Sheep. Texas Agricultural Experiment Station, Fifty-second Annual Report, page 41.

——— 1940 A Study of the Inheritance of Skin Folds on Rambouillet Sheep. Texas Agricultural Experiment Station, Fifty-third Annual Report, page 39.

Jones, J. M., Dameron, W. H., Davis, S. P., Warwick, B. L. and Patterson, R. E.
1944 Influence of Age, Type and Fertility in Rambouillet Ewes on Fineness of Fiber, Fleece Weight, Staple Length and Body Weight. Texas Agricultural Experiment Station Bulletin. 657.

Jones, J. M., Warwick, B. L., Phillips, R. W., Spencer, D. A., Godbey, C. B., Patterson, R. E. and Dameron, W. H.
1946 Inheritance of Skin Folds in Sheep. Journal of Animal Science, 5:154-169.

Lambert, W. V., Hardy, J. I. and Schott, R. G.
1938 A Preliminary Study of the Relation between the Fleece Characteristics of Weanling and Yearling Range Sheep. The American Society of Animal Production, Proceedings, 38:298-303.

Lush, J. L.
1922 The Influence of Age and Individuality upon the Yield of Wool. The American Society of Animal Production, Proceedings, 22:105-109.

Madsen, M. A., Esplin, A. C. and Phillips, R. W.
1943 Skin Folds in Sheep. Utah Agricultural Experiment Station Bulletin. 307.

McNicholas, H. J. and Curtis, H. J.
1931 Measurement of Fiber Diameters by the Diffraction Method. U. S. National Bureau of Standards, Journal of Research, 6:717-734.

Morrison, F. B.
1949 Feeds and Feeding. Twenty-first edition. The Morrison Publishing Company, Ithaca, N. Y. 1207 pp.

Nelson, R. H. and Venkatachalam, G.
1949 Estimates of the Heritability of Birth Weight and Weaning Weight of Lambs. Journal of Animal Science, 8:607-608.

Phillips, R. W.
1936 The Relation of Birth Weight to Growth Rate in Lambs. Massachusetts Agricultural Experiment Station Bulletin. 327.

Phillips, R. W.
1937 The Relation of Birth Weight to Vitality and Growth Rate in Lambs. Massachusetts Agricultural Experiment Station Bulletin. 339.

Phillips, R. W. and Dawson, W. M.
1937 The Relation of Type and Time of Birth and Birth Weight of Lambs to Their Survival, Growth and Suitability for Breeding. The American Society of Animal Production, Proceedings, 37:296-306.

Phillips, R. W., Stoehr, J. A. and Brier, G. W.
1940 Growth in Corriedale and Rambouillet Sheep under Range Conditions. The American Society of Animal Production, Proceedings, 40:173-181.

Phillips, R. W., Schott, R. G., Hardy, J. A. and Wolf, H. W.
1940 Comparison of the Accuracy of Two Methods of Estimating Fineness of Wool. Journal of Agricultural Research, 60:343-350.

Pohle, E. M.
1940 The Application of a Rapid Comparator Method for Determining Fineness and Variability in Wool. The American Society of Animal Production, Proceedings, 40:161-168.

Pohle, E. M. and Keller, H. R.
1943 Staple Length in Relation to Wool Production. Journal of Animal Science, 2:33-41.

Pohle, E. M. and Schott, R. G.
1942 Fineness of Fiber in Eight Sampling Areas on Yearling Rambouillet Ewes. Journal of Animal Science, 1:356.

Pohle, E. M. and Schott, R. G.
1943 Wool Fineness in Eight Sampling Regions on Yearling Rambouillet Ewes. Journal of Animal Science, 2:197-208.

Pohle, E. M., Keller, H. R. and Hazel, L. N.
1945 Monthly Changes in Fineness, Variability and Medullation in Hairy Lambs. Journal of Animal Science, 4:37-46.

Rasmussen, K.
1942 The Inheritance of Fleece Weights in Range Sheep. Scientific Agriculture, 23:104-116.

Rasmusson, J.
1933 A Contribution to the Theory of Quantitative Character Inheritance. Hereditas, 18:245-261.

Ritzman, E. G.
1917 Nature and Rate of Growth in Lambs during the First Year. Journal of Agricultural Research, 11:607-624.

Ritzman, E. G.
1923 Inheritance of Size and Conformation in Sheep. New Hampshire Agricultural Experiment Station Technical Bulletin. 25.

Ritzman, E. G. and Davenport, C. B.
1926 Some Wool Characters and Their Inheritance. New Hampshire Agricultural Experiment Station Technical Bulletin. 31.

Slen, S. B.
1949 The Relationship of Clean Fleece Weight to Fibre Thickness. Scientific Agriculture, 29:595-598.

Snedecor, G. W.
1946 Statistical Methods. The Iowa State College Press, Ames, Iowa. 485 pp.

Spencer, D. A.
1925 Factors Which Influence Fleece Weights of Rambouillet Sheep. The American Society of Animal Production, Proceedings, 25:97-101.

Spencer, D. A., Hardy, J. I. and Brandon, M. J.
1928 Factors That Influence Wool Production with Range Rambouillet Sheep. U. S. D. A. Technical Bulletin. 85.

Terrill, C. E. and Hazel, L. N.
1943 Heritability of Yearling Fleece and Body Traits of Range Rambouillet Ewes. Journal of Animal Science, 2:358-359.

Terrill, C. E. and Hazel, L. N.
1946 Heritability of Face Covering and Neck Folds in Range Rambouillet Lambs as Evaluated by Scoring. Journal of Animal Science, 5:170-179.

Terrill, C. E., Sidwell, G. M. and Hazel, L. N.
1948 Effects of Some Environmental Factors on Traits of Yearling and Mature Rambouillet Rams. Journal of Animal Science, 7:311-319.

Tomhave, W. H. and McDonald, C. W.
1920 Cross Breeding Delaine Merino Ewes with Pure Bred Mutton Rams. Pennsylvania Agricultural Experiment Station Bulletin. 163.

Vaughan, H. W.
1948 Breeds of Live Stock in America. Long's College Book Company, Columbus, Ohio. 780 pp.

Venkatachalam, G.
1949 Estimates of Heritability of Birth Weight and Weaning Weights of Lambs. Michigan State College Ph.D. Thesis. 68 pages.

Wilson, J. F.
1930 The Relation of the Plane of Nutrition to the Breaking Stress, Limit of Elongation, Rate of Growth and Diameter of the Wool Fiber. The American Society of Animal Production, Proceedings, 30:203-207.