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SHEEP-BREEDING EXPERIMENT  
INHERITANCE OF CHARACTERS  
IN SHEEP

[TECHNICAL]

BY S. F. RUSSELL

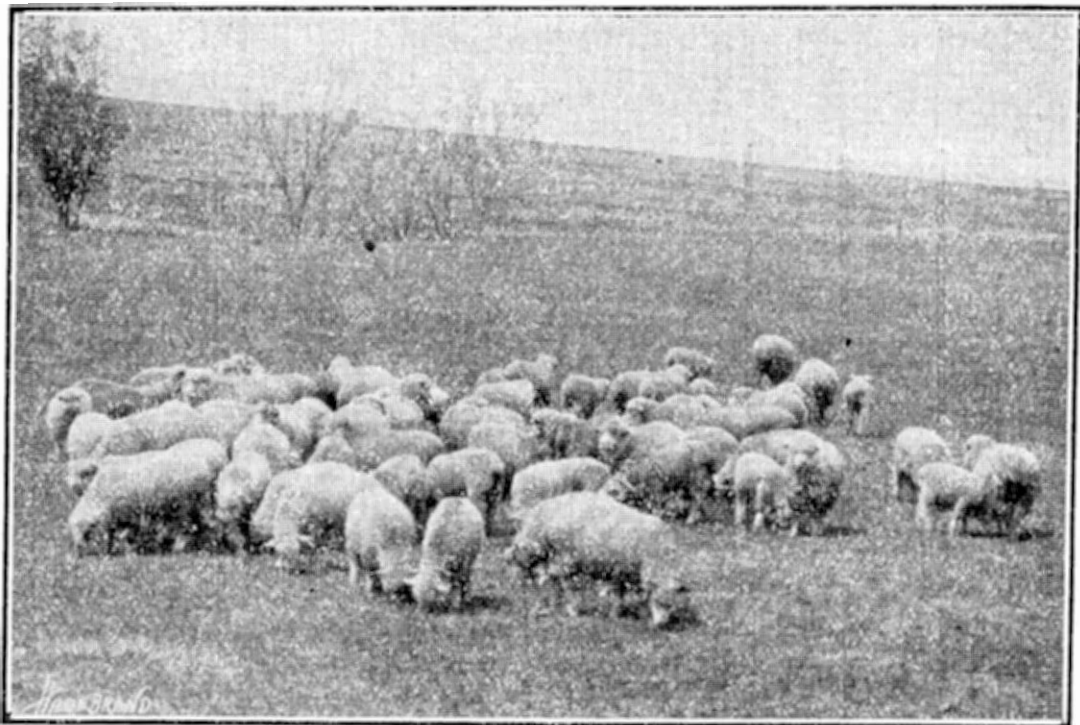


PLATE I.—A flock of Crossbred ewes and lambs taken in February, 1919. The lambs were born during October, November and December, 1918. Showing that the early breeding character of the Dorset is being grafted on the Crossbreds.

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# INHERITANCE OF CHARACTERS IN SHEEP

BY S. F. RUSSELL\*  
*Assistant Animal Husbandman*

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## INTRODUCTION AND HISTORY

This experiment was begun in 1909, its object being to produce a new breed of sheep suited to Oklahoma conditions. The work was planned and the cooperation of the Federal Department at Washington, D. C., obtained by Director J. A. Craig, then Director of the Experiment Station. To give the plan of the experiment in detail we quote here from the first two paragraphs of the memoranda submitted by Prof. Craig to the Office of Experiment Stations, Washington, D. C., in 1909:

"There are great possibilities in the breeding of winter lambs in Oklahoma and the Southwest because the state is eminently adapted to sheep, the winter conditions are favorable for winter lamb breeding, and there are large profitable markets for lambs at that time; but we do not have a breed of sheep at present that meets in a satisfactory way all requirements. I have experimented with the Dorset, the Shropshire, and the Merino at the Wisconsin Experiment Station sufficiently to know the right way to cross-breed these to produce a sheep that will be the equal of the Shropshire in mutton qualities, produce a fleece worth more than the Merino, and have that peculiarity of the Dorset of breeding at any season, without having horns and other disadvantages such as light fleeces and poor mutton form that the pure bred Dorset usually possesses.

"I made the first and second crosses of Dorset rams on Shropshire ewes, and I find the Dorset characteristic could be grafted on the progeny in that way. It would be an important line of work to get thorough statistics on the exact number of crosses that it is necessary to make. Some of the second cross had the Dorset characteristic and more of the third cross, but just what proportion has never been determined. Mendel's law could also be studied in this work."

The sheep are in charge of the Animal Husbandry Department and the experimental work was first under the supervision of Prof. W. A. Linklater, head of the department, who assumed full charge of the work in 1910-11, after the resignation of Prof. Craig. Since 1911 the work has been in charge of C. I. Bray, 1911-14, and D. A. Spencer, 1914-17. To Mr. Bray and Mr. Spencer must go most of the credit for the progress this experiment has made. A large part of the following data is compiled from their detailed tabulated study of the inheritance characters. This experiment has a two-fold value. The most valuable feature of the work from a practical point of view is, of course, the building up of a breed of sheep suitable for Oklahoma, combining the early lambing proclivities of the Dorset with the mutton form of the Shropshire, and the constitution and vigor of the Merino. From a scientific point of view the important part of the work was the possibilities it gave for studying the laws of breeding and selection; also

\*Resigned July 1, 1919.

the successive steps needed to combine the good qualities of the three breeds with as few of their faults as possible. Both features of the work needed, therefore, to be kept in mind. As many records as possible have been kept of the original flocks and of every successive cross made.

### **Foundation Flocks**

In the summer of 1909, the Experiment Station purchased 50 imported pure-bred Dorset ewes and an imported Dorset ram from the flocks of Flowers & Merson, England. Twenty-four Shropshire ewes were purchased from the flock of Thos. Buttar, Scotland, with an imported Minton ram. In the summer of 1910, a flock of twenty-five Black-Topped, Delaine-Merino ewes, and a B type Black-Topped Delaine-Merino ram were purchased in Ohio through the agency of S. M. Cleaver, Secretary of the American Delaine-Merino Association. These flocks were bred pure the first season. Crossbreeding, to a limited extent, was begun the second season.

### **The Dorset Flock**

The Dorset sheep became easily acclimated. They did not breed as freely and were not as prolific as acclimated Dorsets would have been. Something over 10% of them proved barren, and 20% or over have failed to breed before fall the first two seasons. About 50% of these that dropped lambs dropped twins. The ewes were mostly good milkers and the flock was satisfactory as a whole.

### **The Shropshire Flock**

The Shropshire flock was an imported flock, and contained some very choice sheep. The ewes were blocky, uniform and modern in type; and the Minton ram was a splendid specimen. However, from a breeding standpoint, this flock was a disappointment in the extreme the first year. The Minton ram proved infertile and no lambs were secured the first season. Thinking this might be due to other causes than natural infertility such as acclimation and the high condition of the ewes, the Minton ram was given a second chance in the fall of 1910, but as the ewes continued to come in season, another ram, bred and owned locally, quite a good individual, was purchased and put in the flock. This ram, known as Forgey's 88, proved a fair breeder. Unfortunately, some thirty days after he was bought he developed scab, which spread to some extent through the flocks, and necessitated the repeated dipping of the sheep through the winter season of 1910-11. A third Shropshire ram was bought in the summer of 1911 from Chandler Brothers, Chariton, Iowa. This ram died of blackleg about six weeks after he was delivered. Another ram was bought from Chandler Brothers and was used for some time. This non-breeding, together with evidently heavy forcing and good feeding for the first two years, seriously affected the ewes of the Shropshire flock, as far as their lamb producing qualities were concerned. Of the twenty-four imported ewes, three were killed by dogs the first season, and four died lambing the next winter, leaving a flock of seventeen. Six of these proved permanently barren.

### **The Merino Flock**

The Merino flock, purchased in 1910, was almost altogether made up of yearling ewes and all developed nicely. Only two of the ewes originally purchased died; nineteen of the remainder brought lambs the first year, 1910-11; 75% of which were singles. The Merino ewes bred quite

regularly during the early spring and summer months. An effort was made to cross-breed some of these ewes to a Dorset buck, but neither an aged buck or a yearling buck that were put with these ewes would breed them, or pay any attention to them, and finally in the early fall, a Dorset ram lamb was used. This trouble has been overcome.

### Object

The object of this experiment is really two-fold; first, to develop a type of sheep that will be particularly suited to the climatic conditions of Oklahoma by cross-breeding Shropshires, Dorsets and Merinos; and second, to study the inheritance of such characters as conformation, size, weight, growth, horns, color markings, folding of skin, fleece, time of breeding, time of lambing and prolificacy.

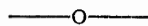


PLATE II.—Crossbred Ewes

Left M(SD) 1065

Right S(MD) 1119

Note blocky conformation and excellent fleece. 1065 was sired by a Merino ram and 1119 was sired by a Shropshire ram.



### DESCRIPTION OF TYPE

The essential characteristics of the breed of sheep that are being developed are:

1. A desirable mutton conformation.
2. Ewes to breed freely in May or June.

3. Desirable size similar to that of Shropshire.
4. A dense, fine fleece, with excellent quality and good length.
5. Prolificacy maintained to a high degree of excellence.
6. Hornless character to be established as soon as desirable; individuals without horns occur in large enough numbers to make selection on that basis possible.
7. Color, while a good trade mark for types and breeds of farm animals, is at the same time of secondary importance, and selection for color should not be at the expense of form, fleece, size, early breeding and the hornless character.
8. It seems that to have a sheep without excessive folding of the skin is of much greater importance than color of face, ears, horns, legs and hoofs.

### **Method of Breeding of Pure-Breds and Cross-Breds**

#### **Matings**

The matings from 1910 to 1918 have been as follows:

**1910.**—In 1910 the Dorset ewes were mated with Dorset, Shropshire and Merino rams, while the Shropshire ewes were all mated with the Shropshire ram and the Merino ewes were all mated with the Merino ram.

**1911.**—In 1911 the Dorset ewes with Dorset, Shropshire and Merino rams, the Shropshire ewes with Shropshire and Dorset rams, and the Merino ewes with Merino and Dorset rams.

**1912.**—In 1912 the Dorset ewes with Dorset, Shropshire and Merino rams, the Shropshire ewes with Shropshire, Dorset and Merino rams, the Merino ewes with Merino and Dorset rams, the Shropshire-Dorset cross-bred ewes with a Merino ram and the Merino-Dorset cross-bred ewes with a Shropshire ram.

**1913.**—In 1913 the Dorset ewes with Dorset, Shropshire and Merino rams, the Shropshire ewes with Shropshire ram only, the Merino ewes with Merino and Shropshire rams, the Shropshire-Dorset cross-bred ewes with the Shropshire, Dorset and Merino rams, the Dorset-Merino cross-bred ewes with a Shropshire ram.

**1914.**—In 1914 the Dorset ewes with Dorset, Shropshire and Merino rams, the Shropshire ewes with Shropshire and Merino rams, the Merino ewes with Merino and Shropshire rams, the Shropshire-Dorset cross-bred ewes with the Dorset and Merino rams and the Dorset-Merino cross-bred ewes with the Shropshire ram.

**1915.**—In 1915 the Dorset ewes with Dorset and Rambouillet rams, the Shropshire ewes with Shropshire, Dorset and Rambouillet rams, the Merino ewes with a Dorset ram, Rambouillet ewes were introduced and were all bred to a Dorset ram, the Shropshire-Dorset cross-bred ewes with a Dorset ram, the Merino-Dorset cross-bred ewes with Shropshire and Dorset rams, the Shropshire-Merino crossbred ewes with a Dorset ram, the Dorset (Shropshire-Dorset) crossbred ewes with a Dorset ram, the Shropshire (Merino-Dorset) ewes with a Dorset-Shropshire crossbred ram, the Merino (Shropshire-Dorset) ewes were also bred to a Dorset-Shropshire crossbred ram.

**1916.**—In 1916 we were mating Dorset ewes with Dorset, Rambouillet and Shropshire-Merino rams, the Shropshire ewes with Shropshire, Dorset and Rambouillet rams, the Merino ewes with Dorset and Shropshire rams, the Rambouillet ewes with the Rambouillet ram only, the Shropshire-Dorset ewes with the Shropshire, Rambouillet and Shropshire-Merino rams, the Shropshire-Merino ewes with the Shropshire, Dorset and Shropshire-Merino rams, the Dorset



(Shropshire-Dorset) ewes with Shropshire. Rambouillet and Shropshire-Merino rams, the Shropshire (Merino-Dorset) ewes with Shropshire, Rambouillet, Shropshire-Merino and Dorset (Shropshire-Merino) rams and the Merino (Shropshire-Dorset) ewes with the Dorset (Shropshire-Merino) ram.

**1917.**—During 1917 we were mating Dorset ewes with Dorset, Shropshire, Rambouillet rams, the Shropshire ewes with Shropshire and Rambouillet rams, the Merino ewes with Shropshire rams, the Rambouillet ewes with the Rambouillet ram, Shropshire-Dorset ewes with the Rambouillet ram, Shropshire-Merino ewes with the Dorset ram, Shropshire (Merino-Dorset) ewes with the Dorset (Shropshire-Merino) ram, Dorset-Merino ewes with the Shropshire ram, Dorset-Rambouillet ewes with the Shropshire ram, Dorset (Shropshire-Merino) ewes with the Dorset (Shropshire-Merino) ram, Merino (Shropshire-Dorset) ewes with the Dorset (Shropshire-Merino) ram, Dorset (Shropshire-Dorset) ewes with the Rambouillet-Shropshire ram, Dorset (Merino-Dorset) ewes with the Rambouillet Shropshire ram, Dorset-Shropshire (Merino-Dorset) ewes with the Rambouillet-Shropshire ram.

**1918.**—During 1918 we were mating Dorset ewes with Shropshire, Rambouillet-Dorset rams. Shropshire ewes with Rambouillet and Shropshire rams, the Merino ewes with Shropshire and Rambouillet rams, the Rambouillet ewes with the Rambouillet ram. Shropshire-Dorset ewes with the Rambouillet ram, Shropshire-Merino ewes with the Dorset ram, Shropshire (Merino-Dorset) ewes with Rambouillet (Shropshire-Dorset) and Dorset (Shropshire-Merino) rams, Dorset-Merino and Dorset-Rambouillet ewes with the Shropshire ram, Dorset (Shropshire-Merino) ewes with Dorset (Shropshire-Merino) and Rambouillet (Shropshire-Dorset) rams, Merino (Shropshire-Dorset) ewes with Dorset (Shropshire-Merino) and Rambouillet (Shropshire-Dorset) rams, Dorset (Shropshire-Dorset) ewes with the Rambouillet ram, Dorset (Dorset-Merino) ewes with Shropshire ram, and one ewe of the A8 cross was mated to the C8 ram.

### **Investigation of Characters**

Observations are made of each individual in regard to the characters that are used in the inheritance study. These observations are made at birth and at the ages of one week, one month, two months, three months, four months, five months, six months, nine months, twelve months, eighteen months, twenty-four months and thirty months. All the notes on these observations are recorded directly in tabulated forms which are arranged systematically, for ready reference use, in 200 page bound record books. An extensive study is made of each fleece shorn. Each shearing date is recorded as well as the weight of each fleece. From the shearing dates the period of growth is calculated. Just before shearing, observations are recorded in regard to the density and covering of each fleece. At the time of shearing, representative and uniform samples are taken of the fleeces. Three sub-samples are taken from each fleece, one from the shoulder, one from the rib and one from the thigh. With these samples of wool we are securing the following data: The length of the staple in the crimp, the length of the stretched fiber, the diameter of fiber and percentage of yolk in the fleece. All this information is used in the study of the inheritance of characters in sheep.



PLATE III.—Crossbred ram lambs 1154 and 1155, April 12, 1915 Both of these lambs are of the M(SD) cross. They are sired by the same Merino ram and their dams are sired by the same Shropshire ram. Notice the difference in general appearance, folding of skin, fleece, conformation, horns, etc. 1155 is the lamb with horns and 1154 is the lamb without horns.

Age.....	} 1154—58 days
	} 1155—52 days

TABLE I  
DESIRABLE BREEDS AND CROSS-BREEDS

(Including Proposed Matings)

**Section 1**

Shropshire  
Dorset  
Rambouillet

**Section 2**

Shropshire-Dorset  
Shropshire-Rambouillet  
Shropshire (Dorset-Rambouillet)

Dorset-Shropshire  
Dorset-Rambouillet  
Dorset (Shropshire-Rambouillet)

Rambouillet-Shropshire  
Rambouillet-Dorset  
Rambouillet (Shropshire-Dorset)



**Section 3**

Symbols—  $\left\{ \begin{array}{l} S\text{—Shropshire} \\ M\text{—Merino} \\ D\text{—Dorset} \\ R\text{—Rambouillet} \end{array} \right.$

$$\begin{aligned} (S (D-R) )-(D (S-R) ) &= S_3 D_3 R_2 = a \\ (S (D-R) )-(R (S-D) ) &= S_3 R_3 D_2 = b \end{aligned}$$

$$\begin{aligned} (D (S-R) )-(R (S-D) ) &= D_3 S_3 R_2 = a \\ (D (S-R) )-(R (S-D) ) &= D_3 R_3 S_2 = c \end{aligned}$$

**Section 4**

$$\begin{aligned} a+b &= (S (D-R)-D (S-R) )-(S (D-R)-R (S-D) ) = S_6 D_5 R_5 = a_1 \\ a+c &= (S (D-R)-D (S-R) )-(D (S-R)-R (S-D) ) = D_6 S_5 R_5 = b_1 \\ b+c &= (S (D-R)-R (S-D) )-(D (S-R)-R (S-D) ) = R_6 S_5 D_5 = c_1 \end{aligned}$$

**Section 5**

$$\begin{aligned} a_1+b_1 &= S_{11} D_{11} R_{10} = x \\ a_1+c_1 &= S_{11} R_{11} D_{10} = y \\ b_1+c_1 &= D_{11} R_{11} S_{10} = z \end{aligned}$$

**Section 6**

$$\begin{aligned} x+y &= S_{22} D_{21} R_{21} = A \\ x+z &= D_{22} R_{21} S_{21} = B \\ y+z &= R_{22} D_{21} S_{21} = C \end{aligned}$$

In Section 3, the mating of the cross breeds is proposed. It will be noticed that the cross bred rams that represent only two breeds are not to be used, if it is possible to do without them, leaving the combining of the three breeds as illustrated in section 2, for the mating of the pure bred sires and cross bred ewes of the two breed cross.

Section 3 further suggests that the Shropshire cross bred ram representing the three different breeds should be mated only with cross bred ewes that represent the three different breeds and that this mating should be by certain systems which are symbolized by z, b and c.

In Section 4, the matings that would result from combining the crosses symbolized as a, b, and c, are illustrated. A and b would result in an offspring that would have theoretically a slight predominance of Shropshire blood; expressed in definite fractions, it would be 6/16 Shropshire, 5/16 Dorset and 5/16 Rambouillet— $a_1$ . By combining a and c, there would theoretically be a slight predominance of Dorset blood. The exact theoretical fractions being expressed as 6/16 Dorset, 5/16 Shropshire and 5/16 Rambouillet, which would equal  $b_1$ , and b and c combined would result in a slight predominance of Rambouillet blood, being 6/16 Rambouillet, 5/16 Shropshire and 5/16 Dorset, which would equal  $c_1$ .

Section 5 illustrates the combining of  $a_1$ ,  $b_1$  and  $c_1$  in the same system as illustrated above.  $A_1$  plus  $b_1$  would result in an offspring that would theoretically have an equal amount of Shropshire and Dorset inheritance, with a slightly less amount of Rambouillet inheritance, which would be expressed as 11/32 Shropshire, 11/32 Dorset and 10/32 Rambouillet, and would equal x;  $a_1$  plus  $c_1$  would result in an offspring that would theoretically have an equal amount of inheritance for the Shropshire and Rambouillet and a little less for the Dorset, being 11/32 Shropshire, 11/32 Rambouillet and 10/32 Dorset, which would

equal  $y$ ;  $B_1$  plus  $C_1$  would result in an offspring that would have an equal amount of Dorset and Rambouillet inheritance, with slightly less Shropshire, being  $11/32$  Dorset,  $11/32$  Rambouillet and  $10/32$  Shropshire, which would equal  $B$ ;  $y$  plus  $z$  would result in an offspring that would have a predominance of Rambouillet inheritance, being  $22/64$  Rambouillet,  $21/64$  Dorset and  $21/64$  Shropshire, which would equal  $C$ .

When the matings have been carefully conducted to the stage represented by Section 6, the breed inheritance would theoretically be far more equal than the variation in characters that would occur in groups that were theoretically absolutely equal in breed inheritance. Individuals representing the breed combinations illustrated in Section 6 would therefore be sufficiently crossed and recrossed by the inbreeding of the crosses, as illustrated in the various sections of this table, so that in a few variations by the continuation of very careful selection for a uniform type, it would theoretically be possible to establish a breed that we have in mind.

It can be readily understood from the above discussion and arrangement of plans by the tables, that unless we hold to certain systems of combining the breeds, we will have difficulty in overcoming the variations that would be due to the unbalancing of the combinations.

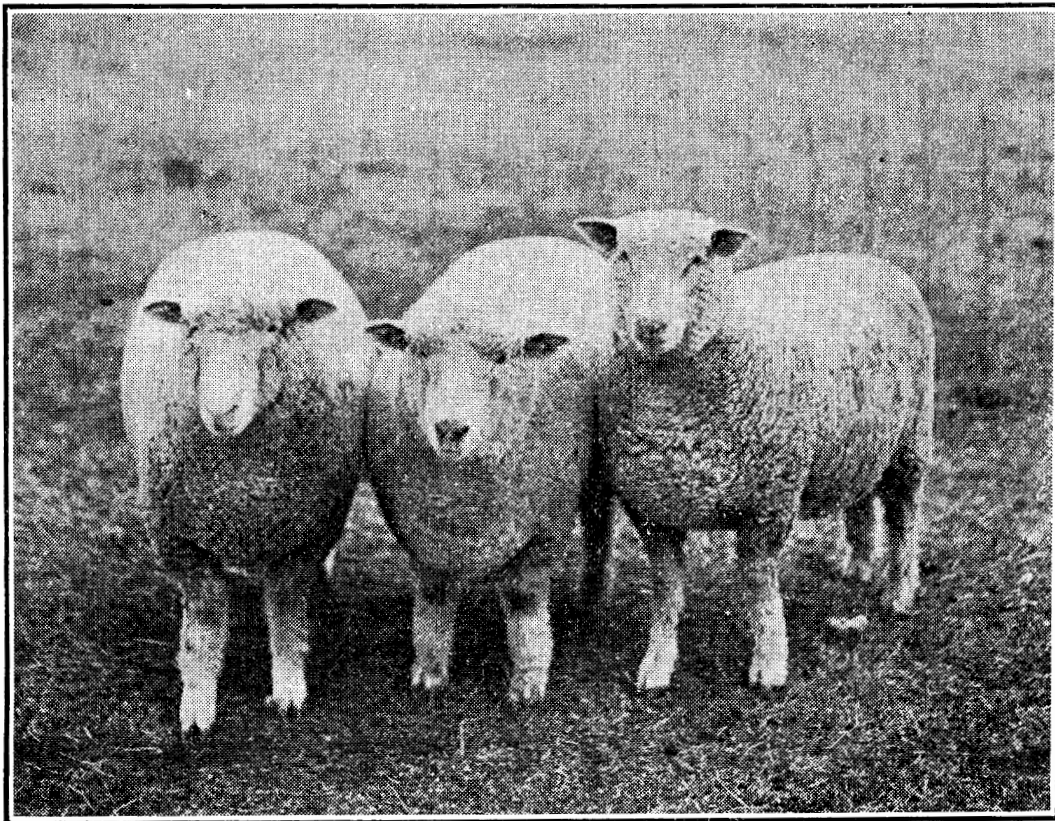


PLATE IV.—D(SD) Wethers

1227—at left  
1230—center  
1217—at right

### COMPARISONS OF BREEDS AND CROSS-BREEDS

In order to proceed intelligently in building up a new breed of sheep from the materials at hand, it is necessary to know just how these breeds and the various crosses compare with each other from various standpoints. Some of the comparisons made in the following pages may not have any very direct bearing on the work of the experiment, while others are essential to its success. In almost all cases the number of animals averaged is given, so that where only a few have been available on which to base an average, it need not be considered as definite a result as in cases where larger numbers have been used.

Two reasons may be given here which might reasonably account for the crossbreds showing up equal to or better than the pure-breds. In the first place it is a fact well known to students of animal breeding that the product of a pure-bred sire and a pure-bred dam of different breeds may for the first generation at least be superior to the parents in size and finish, whereas when a cross-bred sire is used for the second generation the progeny may not come near the standard of the pure-bred ancestry. In the second place, it may be mentioned that in slaughter tests or fattening tests the pure-breds used have not been of first quality, but have been largely culls. On the other hand, the cross-bred wethers and spring lambs sold have often been of the very best quality.

It might be in place to repeat what has been already stated elsewhere that the purpose of the experiment is to produce a sheep that will possess as much as possible of the mutton form and other mutton qualities of the Shropshire as well as its breeding powers combined with the early lambing habit of the Dorset, but with a better fleece than the Dorset usually possesses. In this case it is advisable then to study the relative size of the cross-breds produced, the weight, character and value of the fleeces produced, the habit of early lambing, and the number of lambs produced. From the fattening standpoint the rapidity with which an animal may be finished, its dressing percentage when killed and its value on the market are particularly important. In addition to this several tables are given showing the relative weights of lambs, the inheritance of horns, and the rate of growth of lambs. Table II gives the average weights of the pure-bred and cross-bred ewes in the college flocks taken. As may be understood the sheep had had very little wool on and were weighed in the morning at a time when they had been without feed all night, but had access to water. The sheep were in very fair flesh. Comparisons made with weights of sheep taken at various other times in the four years show that these averages are almost exactly the same as those that might have been obtained in winter when the sheep were in full fleece.

TABLE II

Average live weight of sheep. Breeds and cross-breds. Sheep weighed without feed.

Breed	Number Averaged	Average Weight Lbs.
Dorsets .....	34	166
Shropshires .....	14	136
Merinos .....	7	116
Merinos (March 30, 1914).....	24	116
Dorset-Shropshire .....	16	148
Dorset-Merino .....	13	143
1, 2 and 3-year old Dorsets.....	11	153
1, 2 and 3-year-old Shropshires.....	8	123
2-year-old S (MD).....	9	121.44
2-year-old D (SM).....	5	132.00
1-year-old R (SD).....	3	106.33

As will be noted, an average has been made of the younger Dorsets and Shropshires so as to afford a fair comparison with the younger cross-bred ewes raised under similar conditions and also lacking full growth. The aged Dorsets and Shropshires, which were imported, are much larger than ordinary home bred sheep, having been raised under practically ideal conditions. It is evidently unfair to the young cross-bred sheep to compare them altogether with such a large number of these large imported ewes.

### AVERAGE WEIGHT OF FLEECES

The weights of the fleeces of individual sheep has been carefully kept each year. One or two weights have been missed occasionally on account of tags becoming lost, but the averages given below are representative of the clip of four years. The price per pound is the average of the prices of 1913 and 1914. The prices for 1911 and 1912 were considerably higher, but as there were no cross-bred fleeces to sell these two years, a fair comparison could only be made by taking the prices of the last two years. As will be noted, the Dorset shears a light fleece, though the price per pound has always averaged the same as the Shropshire. The Dorset-Shropshire cross-breds appear to inherit their fleece largely from the Shropshire side, shearing even a little heavier fleece on account of their slightly larger size. The Dorset-Merino fleeces, while averaging 2 pounds heavier than the Dorset-Shropshires, have had to stand a price 2 cents lower, which makes the net value but little higher. Only one Shropshire-Merino fleece is shown, which is not enough for definite comparison. It will be seen the Merinos, while shearing a fleece of 16 pounds and more, get only a low price on account of the higher per cent of yolk or grease in the wool, consequently, though they are known as a special wool breed, the average value of the Merino fleece has proved less than that of a Shropshire or the cross-breds. There is evidently little advantage then in the special wool sheep from the standpoint of income from wool.

TABLE 3

Average weight of fleeces from pure-bred and cross-bred sheep. Value of fleeces according to average price received 1913-1914.

Breed	No. of Fleeces Averaged	Average Weight	Price Per Lb.	Average Value of Fleece
Dorset .....	181	7.2	17¼c	\$1.24
Shropshire .....	66	9.5	17¼c	1.64
Merino .....	83	16.3	10c	1.63
Dorset-Shropshire .....	30	10.0	17¼c	1.72½
Dorset-Merino .....	24	12.0	15¼c	1.83
Shropshire-Merino .....	1	15.0	15¼c	2.29

### DATA REGARDING WOOL FIBERS

Work along this line was done largely in 1911. This work, while interesting, has not a very great value except from a purely scientific standpoint and the estimates, while made as carefully as possible, could not be followed up sufficiently to be considered more than an estimate. The method of investigation is given elsewhere. The number of fibers of wool per square inch of skin compares favorably with that given by other authorities. The average breaking strength of the fibers was tried out with only a comparatively small number of fleeces and with only a relative strength that would be expected. Only a few fibers of each type of wool could be examined under the microscope to ascertain the average diameter, but the results are near enough for all

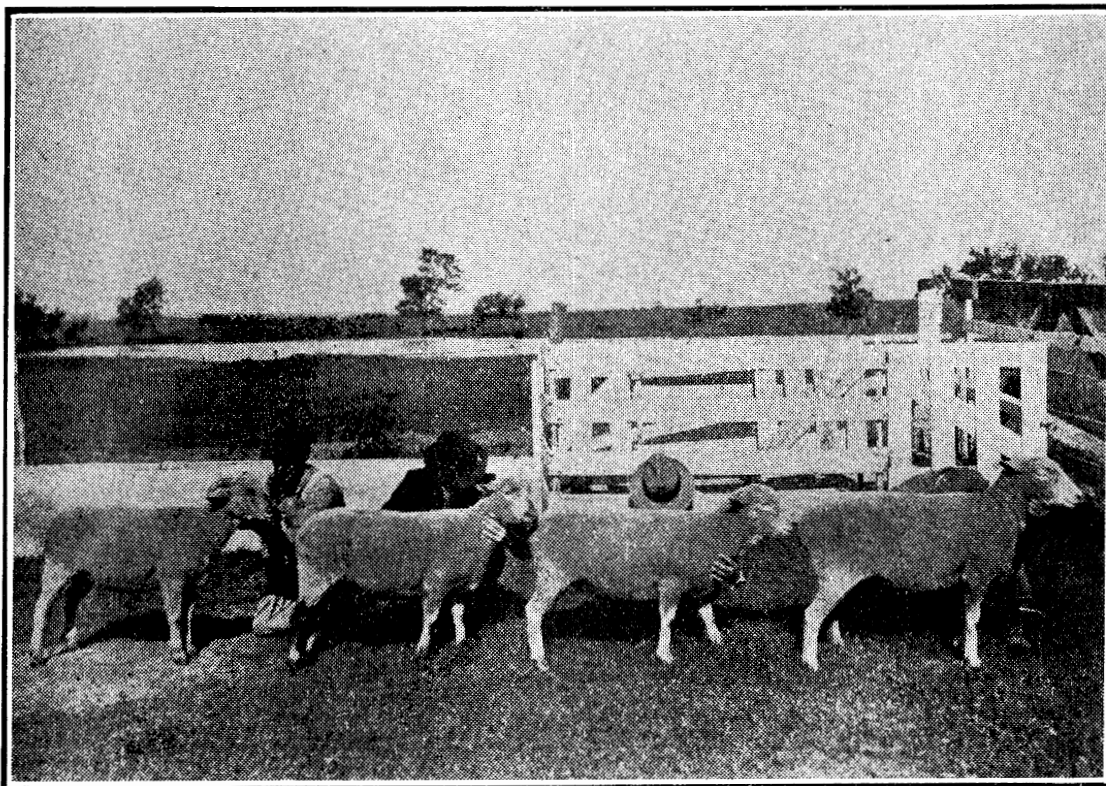


PLATE V.—The three ewes at the left are yearlings and the one at the right is two years old. Reading from left to right.

Number	Breeding	Weight	Growth of Fleecce	Weight of Fleecce
2004	A8	110 lbs.	199 days	4½ lbs.
2011	A8	115 lbs.	382 days	12 lbs.
2010	A8	118 lbs.	382 days	9½ lbs.
2001	A8	135 lbs.	353 days	6½ lbs.

All these ewes are of the same cross. Three have no horns while one (2004) has horns. Note the uniformity of type of the three hornless ewes. Here is a valuable lesson in variation. 2010 and 2011 are twins; note the variation of color markings; the folding of skin around neck of 2001 and the horns of 2004.

practical purposes. The average of the crimps or waves of wool were taken from all fleeces of wool sheared that year. It is only important when studied together with the other columns in this table showing the relation between crimp and fine quality. In judging sheep the fineness of the fleece has been determined largely by the crimp.

TABLE 4

Data regarding wool fibers. Investigational work 1911.

Breed	Fibres Per Sq. In.	Average Breaking Strength	Estimated Diameter of Fibres	Waves or Crimps in Wool Per in. of Fibre
Dorset .....	9,643	5.1 grams	1/1280 inch	18
Shropshire .....	12,365	14.7 grams		
Merino .....	33,474	14.6 grams	1/735 inch	6
Dorset yearlings .....	11,140	16.2 grams	1/750 inch	9

TABLE 5

Table showing per cent moisture, yolk and foreign matter content of wool.

Breed	Number Samples Scoured	W2 Av. Wt.			Per Cent Moisture	Per Cent Moisture Yolk and Foreign Matter
		W1 Av. Wt. of Normal Sample in Grams	of Sample After Drying in Grams	W3 Wt. of Scoured Sample in Grams		
Dorset .....	34	4.51	4.06	2.23	9.97	50.51
Shropshire .....	19	4.39	4.01	2.27	8.65	48.31
Merino .....	12	5.95	5.55	2.07	6.87	66.87
SM .....	5	5.20	4.79	2.60	7.88	50.00
SD .....	10	3.80	3.38	1.90	11.05	50.00
DM .....	10	4.22	3.75	2.00	11.15	52.84
S(MD) .....	10	8.14	7.57	3.64	7.00	55.28
M(SD) .....	7	7.97	7.26	4.25	9.16	46.67
D(SM) .....	10	4.17	3.97	2.16	4.79	48.20

#### Method of Calculation

Percentage moisture =  $W_1 - W_2 \times 100 \div W_1$ .

Percentage shrink (excluding moisture) =  $W_2 - W_3 \times 100 \div W_1$ .

Percentage shrink (including moisture) =  $W_1 - W_3 \times 100 \div W_1$ .

$W_1 - W_2$  = weight of moisture lost.

$W_2 - W_3$  = weight of yolk and foreign matter lost.

$W_1 - W_3$  = weight of total loss in moisture, yolk and foreign matter.

This work was done the past year with the wool clip of 1917. Two samples of wool were taken from the rib of each fleece. The normal samples were weighed, dried one hour and weighed again to determine the moisture content.

#### Scouring Process

Solution (Formula)	Washings	Temperature	Time	
Water (cistern) 2 liters	No. 1 Scouring Solution	55°	15 min.	
Soda Ash (Na C O <sub>3</sub> ) 25 gms.		No. 2 Water (cistern).....	50°	5 min.
Soap (ivory laundry) 15 gms.		No. 3 Water (cistern).....	40°	5 min.

Scouring samples are dried two hours and weighed to determine loss in yolk and foreign matter. All samples are kept in designation envelopes while under test and not in immediate use.

When samples are taken from the drying oven they are immediately placed in a desicator and allowed to cool 15 minutes before weighing. The results obtained compare very closely with those obtained from other authorities and show, for instance, why Merino wool necessarily brings a low price when sold in the grease.

—o—

#### WEIGHT OF LAMBS

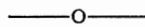
The weight of lambs at birth has been made a matter of record, although the following table does not show a very great difference in this respect between the different breeds. The weights taken below do not include the weights of all the lambs produced, but a large number of representative weights. In practically every case the average size of the lambs are determined by the size of the dams. The lambs from Shropshire ewes are a noticeable exception, as the Shropshires have almost invariably produced larger lambs than any other breed or cross-bred included here.



TABLE 6

Weight of lambs at birth.

Breed or Cross-Breed	Number of Lambs	Total Weight Lbs.	Average Per Head Lbs.
Dorset .....	95	904	9.5
Shropshire .....	38	363	9.6
Merino .....	45	371	8.2
Dorset X Shropshire (Dorset ewe).....	43	437	10.2
Dorset X Shropshire (Shropshire ewe)	4	44	11.0
Dorset X Merino (Dorset ewe).....	41	377	9.2
Dorset X Merino (Merino ewe).....	14	124	8.9
Shropshire X Merino (Shropshire ewe)	1	9	9.9
Shropshire X Merino (Merino ewe).....	15	144	9.6
Dorset-Shropshire ewe X Dorset buck	8	81	10.0
Dorset-Merino ewe X Shropshire buck	10	91	9.0



INHERITANCE OF HORNS

This table is inserted more as a matter of interest than for any practical application it might have. It had been hoped and may still be possible to breed out the horns of the Dorset and Merino in pro-

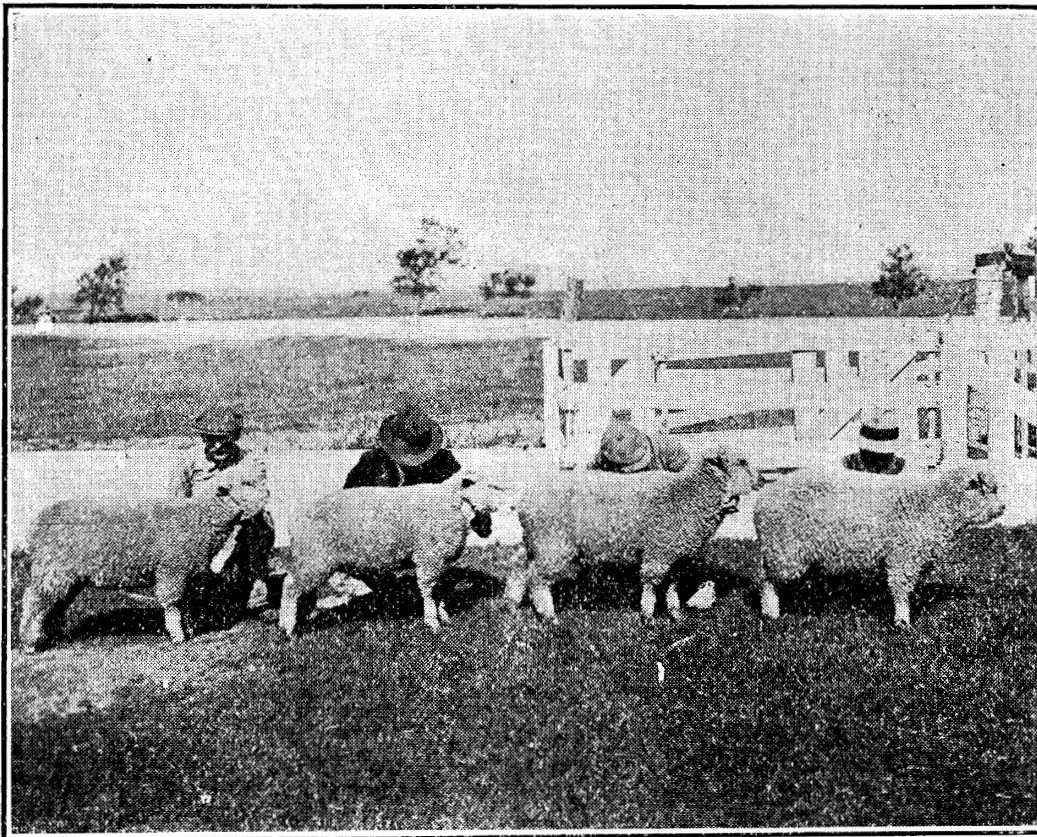


PLATE VI.—Cross-bred lambs representing the eighth cross. Reading from left to right.

- 2017—D(SM)—S(MD) wether—A8
- 2016—D(SM)—S(MD) ewe —A8
- 2018—D(SM)—S(MD) ewe —A8
- 2014—D(SM)—M(SD) ewe —C8

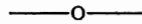
2017 and 2016 are twins and were born November 8, 1918. Wt. 4-30-19, 87 and 78 respectively. Note the blocky form, good covering of wool and horns. Both of the wether (2017) and ewe (2016).

ducing this type of sheep. The chances are very strong that the bucks at least will have horns if the ewes do not.

TABLE 7

Inheritance of horns.

Breed or Cross-Breed	Bucks	Ewes
Dorset .....	Horned	Horned
Shropshire .....	Hornless	Hornless
Merino .....	Horned	Hornless
Shropshire-Dorset .....	Small to medium horns	Hornless
Dorset-Merino .....	Horned	Horned
Shropshire-Merino .....	Horned (stubs)	Hornless
S(MD) .....	Small stubs	Hornless
D(SM) .....	Horned	Hornless
M(SD) .....	Horned	Hornless
A8 .....	Small horns	Hornless to small horns
C8 .....	Small horns	Small horns



COMPARISON OF BREEDS AND CROSS-BREEDS FOR EARLY BREEDING AND LAMBING

The Dorsets and Merinos have shown up very well for raising fall lambs. It was not expected that the Merinos would have a higher percentage of early lambs, however, than the Dorsets. The following table shows in diagram form the percentages given in table 8.

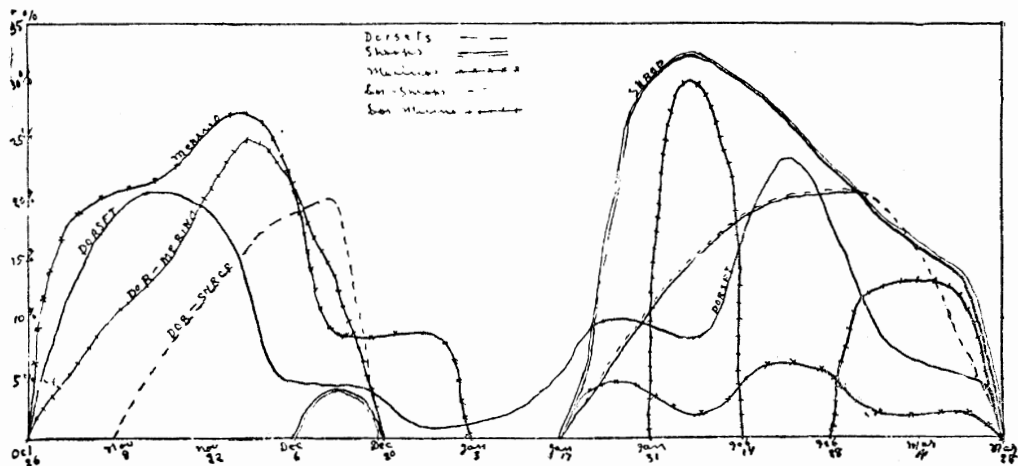
Diagram showing percentage of ewes lambing in the following given 2 week periods throughout the lambing season. Based on table below, and on basis of 100 ewes in each flock.

TABLE 8

Showing percentage of ewes lambing at various two-week periods.

Period of Two Weeks Ending	Nov. 8	Nov. 22	Dec. 6	Dec. 20	Jan. 3	Jan. 17	Jan. 31	Feb. 14	Feb. 28	Mar. 14	Mar. 28
Dorsets, 3 yrs.....	10.5	20.2	5.6	4.8	1.6	2.4	9.7	7.3	23.4	8.9	5.6
Merinos, 2 yrs.....	17.1	21.4	27.5	8.5	8.5	.....	4.30	2.1	6.4	2.1	2.1
Shrops., 2 yrs.....	.....	.....	.....	4.5	.....	.....	4.5	32.4	27.7	18.1	13.8
Shrop.-Dor., 1 yr.....	.....	10	.....	20	.....	.....	10.0	10	20	20	10
Mer.-Dor., 1 yr.....	12.5	.....	25	12.5	.....	.....	25	.....	12.5	12.5	.....
S(MD), 2-3 yrs.....	6.25	.....	.....	.....	12.5	12.5	6.25	25	.....	25	.....
D(SM), 2-3 yrs.....	25	.....	.....	.....	.....	25	50	.....	.....	.....	.....
M(SD), 2-3 yrs.....	16.6	16.6	16.6	.....	.....	.....	33.3	.....	16.6	.....	.....

This table and the accompanying diagram are made out on the percentage basis, that is, on the basis of a flock of one hundred ewes



of each breed and cross-breed. The time is divided into periods of two weeks each, beginning with a period of two weeks ending November 8 and continuing to the period ending March 28. The number of ewes dropping lambs in each period is used as the basis for the diagram and not the number of lambs produced, which has no bearing on the matter of early or late breeding. One of the most striking features of the table, or I would say the feature of this diagram most immediately noticeable is that it is divided more or less equally into two parts, there being a period during the winter when no lambs were dropped by the ewes of any breed. This lack of lambs is most particularly noticeable in the period between January 3 and January 17, but extends more or less over the three periods from December 20 to January 31. This means that the ewes do not breed during the latter part of July and the month of August. The table following this table 9 shows that the ewes do breed during this period, but evidently do not catch at this time. Ewes that take the buck during the month of June and the early part of July and fail to breed successfully almost invariably run over to September 1 before they catch.

This comparison of the breeds need not be accepted as an absolute test of the three breeds in question, but is a fair representation of what the sheep in the college flocks have done in the past few years. The records for the Merinos and Shropshires only include the years of 1912-1913 and 1913-1914, for the reason that in the years preceding, with these two breeds, early breeding was sometimes hindered on account of the bucks. Some of the Shropshire bucks failed to breed early, and in 1911 and 1912 the Dorset that was to cross-breed the Merinos refused to have anything to do with them, consequently their records are not included for these years. The diagram and table No. 8 and 9 deals with the ewes dropping lambs and does not take into account those that failed to bring lambs.

The Merinos show up remarkably well as early lamb producers, over 80% of them bringing lambs before January 3, as compared with 40% for the Dorsets. Only three Shropshires have brought lambs before Christmas, the last lamb being from the first one dropped two years before. The Dorset-Shropshires occupy a position about midway between the Shropshires and Dorsets, and the Dorset-Merinos show up slightly ahead of the Dorsets and below the Merinos. With the Dorset-Shropshires and the Dorset-Merinos, however, the figures are worked out from too small a number to make the data reliable.

18.75% of the Shropshire (Merino-Dorset) cross has lambed by January; 3.25% of the Dorset (Shropshire-Merino), and 49.8% of the Merino (Shropshire Dorset) cross.

TABLE 9

Table showing percentage of ewes breeding for the first time during various 3 week periods in the breeding season.

Period Three Weeks Ending	Dorsets 3 Yrs.	Merinos 2 Yrs.	Shrop. 3 Yrs.	Dor.-Shr. 1 Yr.	DM 2 Yrs.	S(MD) 2 Yrs.	D(SM) 2 Yrs.	M(SD) 2 Yrs.
June 21 .....	42.0	25.6	13.0	5.0	18.2	.....	40	14.29
July 11 .....	31.6	51.2	7.4	5.0	36.3	.....	20	28.58
Aug. 3 .....	12.1	9.3	16.5	10	9.1	18.18	20	.....
Aug. 25 .....	6.3	4.7	3.7	25	9.1	27.27	.....	14.29
Sept. 15 .....	4.6	7	15	30	18.2	36.36	20	28.58
Oct. 7 .....	1.7	2.4	33.2	25	.....	9.09	.....	14.29
After Oct. 7	1.7	.....	11.2	.....	9.1	9.09	.....	.....

#### Early Breeding

Table 9 gives a comparative record on the percentage basis, of the

earliest time the ewes have taken the buck regardless of whether the breeding was successful or not. It was noted in connection with the previous table 8 that while the Merinos had not bred as early as the Dorsets, as a rule, that a very high percentage of them had been bred successfully at the first service, whereas the Dorsets had come back two or three times, sometimes running over until September. As it was felt that this might be due to lack of breeding power on the part of the bucks, which it certainly was in some cases, and could not rightfully be charged to the fault of the ewes themselves, table 8 was compiled to show the relative early breeding of the different breeds. Since the length of time between periods of heat in the ewe is three weeks, the three week period was made the basis of the table, beginning with the period ending June 21 and ending with the period that closed October 28. This table shows up the Dorsets in a much more favorable light, as 42% of them have bred during the first three weeks of the breeding season in three years, and 85% before August 3. Nearly as high a percentage of Merinos have bred before August 3, or 76%. As stated before, they proved more sure breeders and did not have to be rebred. A considerable number of the Shropshires have bred in June and July, but almost invariably run over until September before being safely bred. The earliest that the Shropshires have bred safely was July 21 and July 26, and that in only two instances. Working with such small numbers, the columns showing the Dorset-Shropshire breeding and Dorset-Merino breeding are not to be entirely depended upon, but the evidence seems pretty clear that the Dorset-Shropshires do not inherit much of the early breeding proclivities of the Dorset, but run over until the fall before breeding. The Dorset-Merinos on the other hand bred somewhat earlier, though have not brought as high percentage of early lambs as the breeding table would indicate. It must be mentioned that this latter table includes the breeding of all ewes, whether they raised lambs or not.

It should not be concluded from these tables that the Merinos are necessarily more sure breeders than the Dorset or the Shropshire, though it is possible that such is the case. As has been mentioned elsewhere, the Merino flock purchased by the station was a young, healthy American bred flock, whereas the Dorset and Shropshire flocks were imported and had been in higher flesh than the Merinos and had necessarily experienced a greater change in climate and probably suffered more from the heat than did the Ohio bred Merinos.

### **Rate of Gains While Fattening**

The figures given below have possibly been made with too small a number of wethers and culls to be conclusive. As previously stated, the pure-breds used in such tests have usually been of less than average quality. The three columns to the right, however, are free from this objection, as the best pure-breds are included in the weights, although they were not marketed. The Dorset-Shropshires have shown up remarkably well in these gains, though stated elsewhere this is characteristic of cross-breds of the first cross. Only figures occurring in the same column are comparable.

TABLE 10

Rate of gain while fattening and rate of gains of lambs from birth to entering feed lot.

Breed or Cross	Fattening Sheep Pounds Gained Per Day				Growing Lambs Pounds Gained Per Day			
	1911	1912	1913	1914	Fall Market	Easter Market	Easter Market	June Market
Dorset .....	.49	....	.71	.78	.42	....	.58	.65
Shropshire .....	.46	....	....	.89	.405	....	.61	.47
Merino .....	.49	.43	....	.55	.28	....	.38	....
Dorset-Shrop. ....	.53	.59	.67	.73	.44	....	.59	....
Dorset-Merino ....	....	.45	.54	.67	....	....	.59	....
Shrop-Merino .....	....	....	....	.57	....	....	.42	....
(Dor.-Mer.) X Shr. ....	....	....	....	.77	....	....	.43	....
(Dor.-Shr.) X Dor. ....	....	....	....	....	....	....	.64	....

**Dressing Percentage**

As a rule the animal that is most valuable at the stock yards and that brings the highest price is the one that kills out the highest percentage of dressed meat in proportion to live weight. High dressing percentage is indicated by fatness or high finish, freedom from coarseness or paunchiness and by good development in those parts which are most largely used for meat. The Merino usually has a lower dress-

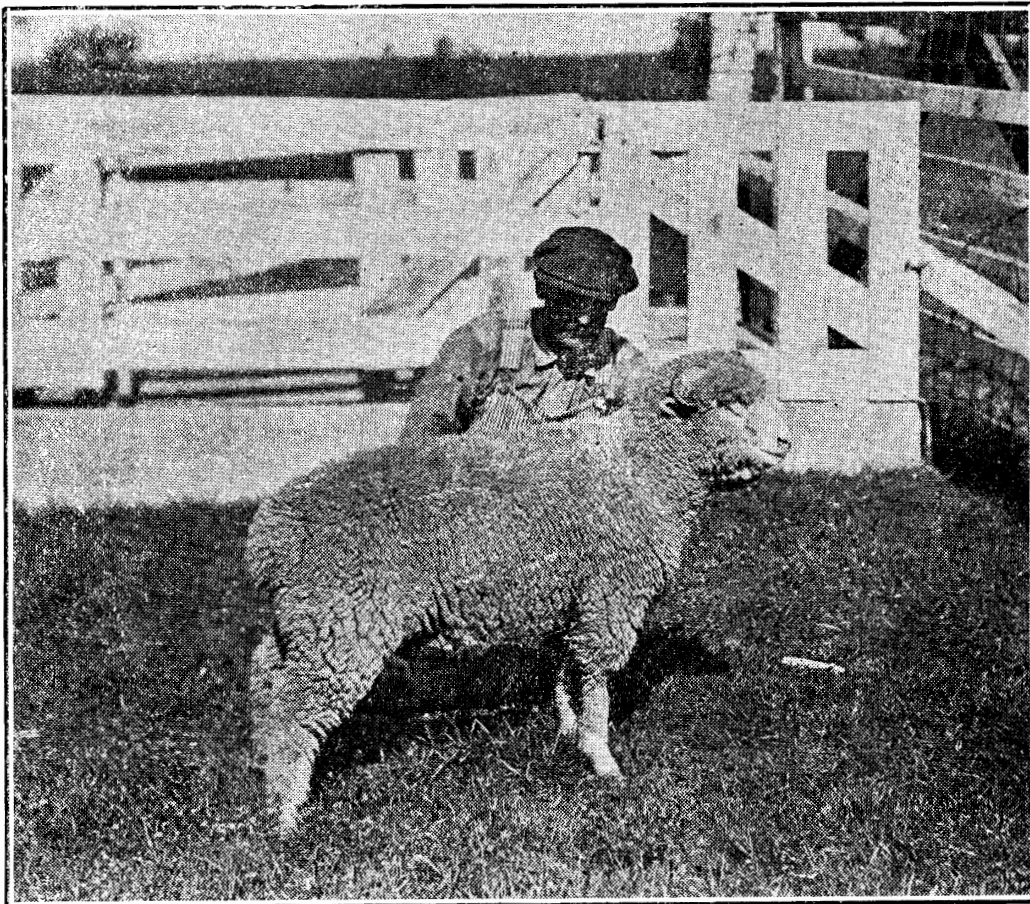


PLATE VII

Cross-bred ram lamb 2015 D(SM)—D(SM)

We have a concentration of Dorset blood in this lamb and also a predominance of Dorset character. Note covering and fineness of wool. Age six months when taken.

ing percentage on account of a thick heavy pelt and a tendency to paunchiness. These figures are taken from a relative small number of animals, as it is not often possible to get these figures. Several of the big packing companies have been very obliging about furnishing us with the necessary figures. The Shropshire-Dorset cross-breeds show up high in this particular, though in the last shipment of Christmas wethers the Dorsets proved slightly superior in this respect. The Shropshires kill out well, of course, but very few of them have been marketed this way.

Only figures appearing in the same column are comparable.

TABLE 11

Dressing percentage.

Breed or Cross	Fat Wethers and Ewes Shipped to Stock Yards		
	1912	1913	1914
	Per Cent	Per Cent	Per Cent
Dorset .....	54	....	56.8
Shropshire .....	56.6	....	....
Merino .....	46.6	....	....
Shropshire-Dorset .....	57.1	60	56.4
Dorset-Merino .....	....	56.5	54.3

TABLE 12

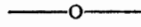
Pure-breds and cross-breeds on hand May 20, 1919.

Breeds and Crosses	Mature Sheep			Spring Lambs			Fall Lambs		
	Rams	Wethers	Ewes	Rams	Wethers	Ewes	Rams	Wethers	Ewes
Shropshire .....	2	....	8	1	1	1	....	....	....
S-D .....	1	....	3	....	1	1	....	2	....
S-D .....	....	....	4	....	....	1	....	....	1
S(DR) .....	....	....	....	....	....	1	....	....	2
S(MD) .....	1	....	6	....	....	....	....	2	2
S(D(DM)) .....	....	....	....	....	1	....	....	....	1
S(DM) .....	....	....	....	....	....	....	1	....	3
S(DS) .....	1	....	....	....	....	....	....	....	....
D .....	2	....	19	1	1	1	2	2	1
D-S .....	....	....	1	....	....	....	....	....	....
D-M .....	....	....	3	....	....	....	....	....	....
D-R .....	....	....	2	....	....	....	....	....	....
D(SM) .....	1	....	5	....	....	....	....	1	3
D(MS) .....	....	....	2	....	....	....	....	....	....
D(SD) .....	....	....	2	....	....	....	....	....	....
D(DM) .....	....	....	2	....	....	....	....	....	....
D(SM)(D(SM))..	1	....	....	....	....	....	....	1	....
M .....	....	....	3	....	....	....	....	....	....
M-D .....	....	....	2	....	....	....	....	....	....
M-S .....	....	....	....	....	....	....	....	....	....
M(SD) .....	....	....	1	....	....	....	....	....	....
R .....	3	....	4	1	....	....	2	....	2
R-D .....	....	....	2	....	1	....	....	....	....
R(SD) .....	2	....	5	....	....	2	1	1	2
((R(SD)(M(SD))	....	....	....	....	....	....	....	1	....
(R(R(SD)) .....	....	....	....	....	....	....	....	1	1
R-S .....	....	....	2	....	1	....	....	....	....
A8 .....	....	....	1	....	....	....	1	....	4
C8 .....	1	....	....	....	....	....	....	....	1
Total, 149.									

Last year the percentage of fall lambs ran very high. The per cent of fall lambs was 60 and spring lambs 40. The work became so heavy last year that it was necessary to cut down the flock of breeders to nearly half. This was done without any apparent danger to the success of the experiment. Those ewes were kept, so far as possible, that were not only fall lambs themselves, but were early breeders, and as a result of this selection we have the high percentage of fall lambs, many of which are very desirable individuals. The percentage



of fall and spring lambs can be obtained from table 1. The percentage of fall lambs was increased approximately 50% by this selection.



### RESULTS OF INVESTIGATION IN SHEEP-BREEDING

The work completed on the breeds and cross-breds will justify the following conclusions.

1. The point has been reached where we can begin breeding cross-breds of the same cross. The eighth cross has been reached. After a few years of interbreeding cross-breds, more definite conclusions can be drawn in regard to type.

2. A dominance of mutton conformation has been maintained with 50% of the inheritance of the Shropshire or Dorset.

3. The Merinos and Rambouillets have transmitted their density of fleece.

4. The absence of folded skin in the mutton breeds seem to be dominant over the presence of folds in the fine wool breeds.

5. The dark markings of the Shropshires are dominant in the F. generation.

6. The early breeding character of the Dorset is dominant and can be established by selecting those individuals that are born in the fall and have proven themselves to be early breeders. This character (early breeding) seems to follow the Mendelian ratio of 1-2-1. There is no doubt that this character can be fixed in the higher crosses.

7. The Dorset has shown up as a very good general purpose sheep, lacking somewhat in smoothness and wool production. It appears that the Dorset is the foundation on which improvement must be built in establishing a new breed.

8. The Shropshire is of course the best mutton type and shears a fleece exceeded only by some of the crosses. It is unusual for the Shropshire to drop lambs earlier than February.

9. The Merino has shown up exceedingly well as an early lamb producer, but is small, grown slowly and does not produce a desirable mutton carcass.

10. The Rambouillet was substituted in place of the Merino in 1915, and has added more size and a longer stapled fleece to the cross-breds.

11. Mathematical interpretations of the details of fleece inheritance are now under way.

12. Among the cross-breds we have several very desirable individuals. Illustrations of same can be studied from the foregoing plates.

13. In time of lambing for the pure-bred ewes, the fine wools have stood first in fall and winter lambing. Dorsets a rather close second, and Shropshires decidedly third. Of the cross-breds in the F. generation the Merino-Dorset seem to have an average lambing time midway between the Dorset and Merino; the Shropshire-Dorset midway between Shropshires and Dorsets, and the Shropshire-Merino midway

between the Shropshire and Merino. The higher crosses have not been bred on large enough numbers to give definite results.

14. Of the ewes that have lambed, the different breeds and crosses have shown the following percentage of prolificacy:

Dorset .....	148%
Shropshire .....	139%
Merinos .....	
Rambouillet .....	114%
Shrop.-Dorset .....	139%
Merino-Dorset .....	138%
Shrop.-Merino .....	109%
S (MD) .....	133%
D (SM) .....	125%
M (SD) .....	150%

15. Some of the rams of all the different crosses except those having 75% Shropshire inheritance have grown scurs or horns, although a few rams having 25%-50% Shropshire inheritance have had no horns. The horns do not occur so frequently in the females. Horns have not in a single case occurred on ewes possessing 50% inheritance of the Shropshire or 25% of the Shropshire and 50% of the Merino where the remaining 25% was Dorset blood. The hornless character of the Shropshire is doubtless dominant in the female offspring.

16. It will prove more economical to work with comparatively small numbers. Investigation to date has shown that spring lambs tend to produce spring lambs and fall lambs produce fall lambs.



