A THESIS

ANIMAL BREEDING

THE INHERITANCE OF CHARACTERS IN SHEEP

BY

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HISTORY.

There has been very little systematic effort toward improvement of any class of livestock by using a system of cross breeding.

Most of our present breeds of sheep, according to Charles Plumb*, originated from unsystematic cross breeding. This cross breeding however was not the crossing of distinct breeds, but rather a mingling of a general type with a more firmly established type or breed. The improvement that has been brought about is due mainly to selection rather than crossing. This latter statement is proven by the fact that most of the improvement has occurred in later years.

The most recent attempts at establishing a type or breed by cross breeding have been carried on in New Zealand, Australia, and the Government Sheep Farm at Boise, Idaho.

The first mentioned cross-breeding in New Zealand and Australia was not by systematic experimental trials, but was brought about by an increased demand for mutton. The early history of the sheep in these two countries shows that the main object in keeping sheep was for the wool produced. When land became higher in price and cold storage shipping was developed the sheep men naturally gave some consideration to mutton production. In attempting to produce mutton they were loathe to sacrifice the fine wool sheep because they were admirably suited to the range conditions. The result was the development of a system of crossing these fine wooled sheep on the Lincoln

*Types and Breeds of Farm Animals, Charles Plumb. P 655.

and Cotswold, long wool breeds.

The result of this crossing is a breed called the Corridale. This has not been established as a breed with definite characteristics but is recognized as a breed by Mr. Plumb*.

The conditions on the range in the northwestern part of the United States were similar to those of New Zealand and Australia. The need of a breed for our range country that would be a dual purpose breed was early recognized by the U. S. Department of Agriculture and a systematic effort to establish such a breed was started.

The system used by the Department of Agriculture was much the same as that mentioned as used in New Zealand. However, a systematic method of selection was followed.

There has been no detailed peport of this trial published; but this work has progressed far enough that the U. S. Department of Agriculture is encouraging the use of the name "Columbian" to designate this cross-breed.

The New Hampshire Experiment Station has studied the inheritance of fecundity and the results of this study are reported in the New Hampshire Technical bulletin No. 14 by E. Z. Ritzman.

The original part of this experiment was started in 1909 by Professor John A. Craig, then Dean of the School of Agriculture and Director of Experiment Station at Oklahoma A & M College. **"To give the plan of the experiment in detail we quote here from the first two paragraphs of the memoranda submitted by Professor Craig to the office of Experiment Stations, Washington, D. C. in 1909".

*Types and Breeds of Farm Animals."
**Oklahoma station bulletin 126.

* "There are great possibilities in breeding 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 this 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 the 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 characteristics 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 characteristics 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 have been in charge of the Animal Husbandry Department and the work has been under the supervision of the following men: Professor J. A. Craig, 1909; Professor W. A. Link-later, 1910-1911; Professor C. I. Bray, 1911-1914; Professor

*Oklahoma Station bulletin 126.

D. A. Spencer 1914-1917; Professor F. S. Russell, 1918; Professor W. T. Magee a few months following Mr. Russell, and myself, A. E. Darlow, for the years 1919-1922.

The foundation flocks consisted of fifty purebred Dorset ewes and one imported ram; twenty-four purebred Shropshire imported ewes, and one ram; twenty-five pure bred Merino ewes and one ram.

* "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."

The type as described in Station bulletin 126 is about as follows:

1. A desirable mutton conformation.
2. Ewes to breed freely in May or June.
3. Desirable size similar to that of Shropshire.
4. A fine dense fleece with excellent quality and good length.

* Oklahoma Station Bulletin 126.

5. Prolificacy maintained to a high degree of excellence.

6. Hornless character to be established as soon as desirable.

7. Dark color of face and legs.

8. Sheep not to have excessive folds.

The cross-breeding started in 1910 and all three breeds were combined as soon as possible. The method of procedure for the various characters precede the discussion of said characters in the body of this thesis. All the characters mentioned in this introduction were observed and the observation carefully recorded. Observations were made at birth and at the ages of one week, one month, six months, nine months, twelve months, eighteen months, twenty-four months and thirty months.

Explanation of wool data will be found on pages 33, 37 & 38 of this thesis.

TABLE SHOWING SYSTEM OF MATING AND METHOD OF DESIGNATING THE BREEDS AND CROSS-BREDS.

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 —
(S - Shropshire
(M - Merino
(D - Dorset.
(R - Rambouillet.

(S (D-R))-(D (S-R)) = S3 D3 R2 = a
(S (D-R))-(R (S-D)) = S3 R3 D2 = b

(D (S-R))-(R (S-D)) = D3 S3 R2 = a
(D (S-R))-(R (S-D)) = D3 R3 S2 = c

Section 4

a + b = (S (D-R)-D (S-R)) -- (S (D-R)- R (S-D)) = S6 D5 R5 = a_1
a + c = (S (D-R)-D (S-R)) -- (D (S-R)- R (S-D)) = D6 S5 R5 = b_1
b + c = (S (D-R)-R (S-D)) -- (D (S-R)- R (S-D)) = R6 S5 D5 = c_1

Section 5

$a_1 + b_1 = S_{11} D_{11} R_{10} = x$

$a_1 + c_1 = S_{11} R_{11} D_{10} = y$

$b_1 + c_1 = D_{11} R_{11} S_{10} = z$

Section 6

$x + y = S_{22} D_{21} R_{21} = A$

$x + z = D_{22} R_{21} S_{21} = B$

$y + z = R_{22} D_{21} S_{21} = C$

The following are the conclusions arrived at by Mr. Russell from his work and a study of all previous records; and published in Station bulletin 126, July 1919.

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 Mendalian 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.

INTRODUCTION

In beginning the work on this experiment I started at the point reached by Mr. Russell and reported in Oklahoma Station bulletin No. 126, published in 1919.

It was necessary in planning this work that I follow rather closely the proposed system of mating found on page 9 of Oklahoma Experiment Station bulletin No. 126 and recopied in the general introduction to this thesis. This necessity is evident when the objects of this particular phase of the work are considered. Part of my work was to determine whether conclusions reached in 1919 were justified in light of more recent data and part was to get definite results regarding those points which were still undetermined from the previous work done.

The system of designating the breeds and cross-breds in my work was the same as that shown on pages 5 and 6 of this thesis.

The study of the fineness, scouring compactness and covering of fleece followed that described on page 5 of the Introduction of this thesis with the exception that in 1921 we used the Bradford count system to designate fineness.

The Bradford count system is a system that was developed in the Bradford mills of England and is based on the weaving quality of the wool. The count given a particular fleece is the number of hanks,(560 yds) of yarn that one pound of combed fleece will weave.

The samples showing the fineness of fleece for the various counts were furnished by Mr. D. A. Spencer, of the U. S. Department of Agriculture. The results are obtained by a system of comparison. They are not as accurate as those obtained by microscopic measurements but are much more practical.

The terms used to designate fineness, compactness and covering of wool were changed to numbers. The system of estimating these various items was not changed but numbers were substituted in order to arrive at a definite comparison.

Object one of my work is a continuation of the work preceding and the conclusions regarding this point were reached after three years' work following the plan outlined by my predecessors. Objects 2 to 6 were to check conclusions reached by other investigators and to get some new information regarding fleece inheritance.

As was stated in the general introduction, the Rambouillet was substituted for the Merino in 1915. All the Merinos were not disposed of at this time and I will discuss the purebred Merino in this present work. There were also a number of the cross-bred Merino sheep present when the Merino was dropped and there will be a large number of these Merino crosses in the following discussion.

OBJECTS

I

To continue the study started regarding the cross-breeding of sheep, in the effort to develop a new breed suited to Oklahoma climatic conditions; such study to be carried on to a definite conclusion.

II

To ascertain whether the dark markings of Shropshire or white markings of Dorset and Rambouillet are dominant.

III.

To determine whether the polled character of Shropshire is dominant over horns of Dorsets in F_1 generation.*

IV.

To study the inheritance of weight, fineness, compactness, scouring and covering of fleece of the Rambouillet, a fine wooled breed, when crossed with Dorset and Shropshire, medium wool breeds.

V.

To determine the dominance of smooth or wrinkled skin and to study the relationship between folds and fineness of fleece.

*First Cross

Table showing presence and location of folds also presence or absence of horns.

ed	Folds: No. of sheep	Number with folds on: Neck	Tail	Body	Thigh	Loose	Smooth	Horns: Present	Absent
D-M) M-D)	14	--	--	--	---	7	7	14	0
M-S) or S-M)	3	3	3	3	3	--	---	1	2
M-S) or S-M)	2	2	--	--	--	--	--	0	2
or D-M	42	24	6	6	8	10	8	42	0
S-D) or D-S)	2	--	--	--	--	--	2	2	0
	12	5	2	2	2	2	5	8	4
	12	5	2	2	2	2	7	8	4
	12	2	1	1	1	1	10	8	4
S-M) or M-S)	17	2	2	2	2	6	9	10	7
or S-D	43	--	--	--	--	--	43	7	36
S) or S-M	24	15	5	5	5	--	2	2	22
D) or D(DS)	25	--	--	--	--	--	25	22	3
D) or M(D-S)	24	12	7	7	7	10	2	20	5
D-M))-(d(M-S)	1	--	--	--	--	--	1	0	1
SD))-(M(SD))	1	--	--	--	--	1	--	1	0
D) or S(DM)	44	14	4	4	4	9	21	24	20
(MD)	3	1	--	--	--	2	0	3	0
(SM)	1	--	--	--	--	1	--	---	1
) ((SM))	1	--	---	--	--	1	--	1	--
SD) (MS))	2	2	1	1	1	--	--	2	--
M (SD))	1	--	--	--	--	1	--	1	--
(MD))	3	--	--	-	--	2	1	3	--
(SD))	4	2	--	--	--	3	1	4	--
(SD))	1	--	--	--	--	--	1	--	1
D (DM))	1	--	--	--	--	--	1	1	--

Table No. I shows the inheritance of the folds or wrinkles of the fine wooled breeds and also of the character of horns. Any sheep showing folds to any marked extent does to a certain degree lack the compact mutton conformation because of the predominance of the fine wool characters. According to the preceding table and observation of the flock, it is difficult to obtain the desired fineness of fleece without at the same time getting the undesirable feature of folds.

It will be noticed in the D-M or M-D cross of 42 animals only 8 were smooth, 24 had folds at neck, 10 showed looseness and 8 were wrinkled all over the body. The M-S or S-M cross showed but two smooth sheep out of 24, 15 had folds at neck and 5 were wrinkled all over.

The M (SD) cross had 2 smooth animals out of 24. 12 had folds at neck and 7 had folds all over.

S (M-D) 44 animals showed 21 animals smooth and 14 had folds at neck.

The C cross had 5 smooth out of 12 animals, B had 7 and A had 10 out of 12 animals.

The A cross had less of the fine wool blood than either of the other crosses while C had the most concentration of this blood.

The horned character will be hard to overcome and breed out because as a rule this character is dominant except when crossed with the Shropshire. The Dorsets have horns in both sex and the Merino in the ram.

Page 16.

There were 43 sheep of the D-S or S-D cross and 36were without horns. Seven had horns. The hornless character of the Shropshire is dominant over the horns of the Dorset. The S (SD) or S (DS) had animals and both have horns. This is a small number but there is a greater concentration of Shropshire blood than in the former cross.

The D (D(SD)) cross showed showed that out of three animals all three had horns. Seventeen of the D(SM) cross show 10 with horns and 7 without. Of 25 M (SD) or M (DS) 20 had horns and 5 did not. The latter is significant because it is a higher percentagethan in the D (SM) cross.

Of the A, B and C cross each had eight animals with horns and four without. The concentration of Dorset blood is different in each one of these crosses, but the horns are the same in each.

It can be seen from the foregoing table that the horned character appears recessive at times at least.* When the Dorset blood is present to any considerable concentration the horns are present in at least a percentage of the offspring.

*Evolution, Variation and Heredity, R. H. Locke.

Table showing the percentage of ewes of the various breeds and cross breeds lambing within any given 3 week period.

Breed	No.	Week Ending: Jan.30	Feb. 21	Mar. 14	Apr. 7	May 1	Sept. 21	Oct. 14	Nov. 7	Dec. 1	No. of fall	No. of Spring	Percent of fall
Dorset	91	5.5	11	20	23.39	6.6	1.1	1.1	12	16.5	35	70	30.7*
Merino	16	6.25	--	6.25	25	6.25	--	--	25	31.25	9	7	56.25
Shropshire	33	------	9.1	27.3	37	24.2	--	--	3	-----	1	32	33
Rambouillet	22	13.63	--	9.1	13.63	9.1	--	9.1	36.36	9.1	12	10	54.5
S-D	51	7.84	13.72	7.84	21.51	9.8	--	--	7.84	31.57	20	31	39.2
D-S	11	---	9.1	27.27	36.36	9.1	--	9.1	---	9.1	8	24	25
D (DS) D (SD)	8	25	25	--	25	12.5	--	--	--	12.5	5	15	25
DM or MD	39	5	5	10	15	5	--	12.5	25	20	23	16	60
SM or MS	27	7.4	3.7	11.1	11.1	3.7	--	--	22.2	40.7	17	10	63
D(SM)orD(MS)	14	14.4	7.2	7.2	14.4	--	--	14.4	21.6	21.6	8	6	57.6
D-S(S(MD))	2	--	--	50	--	50	--	--	--	----	----	2	00
S (MD)	25	20	20	4	24	4	--	--	20	8	8	11	33
M (D-S) M (S-D)	9	33.3	--	11.1	--	---	---	--	44.4	11.1	5	4	55.5
D (D(SD))	1	--	--	--	100	---	---	---	----	----	----	1	00
D (D-M) or D (M-D)	5		20	20	20	---	---	---	40	----	2	3	40
A	7	28.6	14.3	28.6	--	14.3	14.3	---	---	----	1	6	14.3
R (SD)	1	---	100	---	---	----	---	--	---	----	---	1	00

It will be remembered that the object for having the Dorsets in this experiment is on account of their early breeding qualities.

The preceding chart shows that the percentage of fall lambs in the Dorset breed was 30.7, and the Merino 56.25.

The S-D cross had 39.2% fall lambs. The D (DS) had 25% fall. The S-D cross had a higher percentage of fall lambs than the Dorset pure breds. The D (DS) had a smaller percentage than either the Dorset or S-D. Thirty nine lambs were born from M-D or D-M cross and 60% of them were fall lambs. This is inline with what might be expected but 27 S-M or M-S had a percentage of 63 for fall lambs. The Shropshire is a late breeding sheep, therefore this result is hardly what would be expected.

The poor showing of the Dorset may be attributed in part to the lack of proper feeding, that is green feed or flushing during the early breeding season. It will also be seen later that the Dorset breeds early but the percentage of lambs is small in this breed as compared to the others.

The early breeding of the Dorsets at this station have not come up to expectations or as high as some of the others. This early breeding of the Dorsets is more of an individual matter than a breed characteristic. As is shown elsewhere, a very high percentage of the ewes that are born in the fall will produce fall lambs.

III Table showing the percentage of ewes of the various breeds and cross breeds taking the ram for the first time in any given three week period.

Breed	No. of ewes	Week Ending: May 31	Jun21	Ju.14	Aug7	Aug31	Sep21	Oct14	Nov7	Nov31
Dorset	99	7	25.2	15.1	10.08	6.1	8.1	8.1	13	7
Rambouillet	26	34.6	11.6	---	15.8	11.6	3.87	11.6	11.6	11.6
Shropshire	34	---	3	9	---	6	3	30	45	6
Merino	24	20.8	20.8	16.6	4.17	12.5	8.3	4.17	4.17	8.3
S (D-M) S (M-D)	36	5.5	16.6	8.3	13.9	13.9	23.2			
A	8	---	37.5	12.5	---	25	---	---	25	---
D (SD) or D (DS)	14	14.3	7.1	---	---	7.1	14.3	14.3	35.5	7.1
M (SD) M (DS)	9	---	44.4	11.1	---	11.1	22.2	11.1	--	---
S-M or M-S	25	28	24	20	12	8	---	4	4	---
D-S or S-D	39		15.4	2.56	15.4	17.92	7.68	20.48	12.8	7.68
D (D (SD))	2	---	---	---	---	50	---	---	50	---
D-S (S(M-D)	2	---	---	---	---	50	50	---	--	---
DM or MD	41	19.5	26.8	7.32	9.76	12.20	7.32	4.08	7.32	4.8
D (SM)	13	23	46	---	---	---	7.75	7.75	--	15.5

The above table as stated is to show the percentage of the various breeds and cross-breds that bred for the first time in any given season. This has nothing to do with lambing as many of the services noted above failed to impregnate the ewe. It will be noticed in studying this table in connection with the one on lambing that the figures do not necessarily correspond. There were about 57% of the Dorsets recorded here that took the ram early enough to produce fall lambs while only 30.7%* of them actually produced fall lambs. This is in line with what has been published concerning this before. The Dorsets

* Productive Sheep Husbandry -- Coffee, p. 64.

show a large percentage of ewes breeding early but a low percentage of them producing fall lambs. This can be explained only by the fact that the ewes do not get with lamb on the first service and oftentimes not until the third or fourth.

In this discussion we have divided the time of breeding for fall and spring lambs at the period ending August 7. All matings before this are in time for fall lambs, all after are for spring lambs. According to this division there were about 60% of the Rambouillet ewes taking the ram during the early months or for fall lambs. Referring to Table II it will be seen that 54% produced fall lambs, a good deal better showing than the Dorset.

Sixty-two percent of the Merino ewes bred before August 7th. Of these 56.2% brought fall lambs. This is about the same results as shown by the Rambouillet, and is a very good percentage of lambs as compared to ewes bred.

Of the cross breds, the S-M or M-S cross showed 74% of the ewes breeding before August 7. This is a larger percentage than the purebred Merino. The Shropshire is notably a late breeding sheep, therefore we would naturally expect the S-M cross to show a smaller percent of early breeding ewes. This high percentage includes 25 ewes and is unexplainable. This same cross shows 65% of fall lambs as shown in Table No. II.

The D-M or M-D combinations of two early breeding breeds show an early breeding record of 64% or slightly more than either of the purebreds but not as high as the S-M or M-S cross.

Both the D-S and S-D cross showed 56.4% of the ewes breeding before August 7th. This is about what would be expected as it is somewhat less than the purebred Dorsets. The percentage of fall lambs in this cross is something around 32, slightly more than the purebred Dorset.

The A cross showed 50% breeding before, and 50% breeding after August 7th, but only 14.3% of them produced fall lambs.

According to table No. 2 and analysis of same, it is difficult to draw any definite conclusions regarding the inheritance of early breeding among the Dorsets, Merino or Rambouillet.

We are comparatively safe according to the preceding table in concluding that this character of early breeding does not follow Mendel's law of variation*, also that there is nothing definite about its inheritance at all.

The S-M cross had a higher percentage than any of the other crosses or pure-breds.

The A cross which is nearest the proposed goal in this cross-breeding showed only 50% of ewes breeding early and 14.3% produced fall lambs.

From this we may conclude that if the early and late breeding is transmitted at all, the chances of securing early breeders by this system is next to impossible.

*Variation, Heredity and Evolution by R. H. Locke, Chapter VII.

IV Table showing the prolificacy of breeds and cross-breeds used in this test.

Breed	No. of: ewes	No. of: lambs	No. of ewes: bringing twins	% of lambs: twins	Trip-lets	% of prolificacy
D-M or M-D	30	50	17	74	1	166 2/3
S-M or M-S	27	28	1	3.57	0	103
D-S or S-D	15	23	8	70	0	153.3
Merino	17	21	3	35.3	0	123.5
D(S-D) or D(DS)	9	13	2	30.6	1	166 2/3
M(S-D) M(D-S)	9	10	1	20	0	111
S(MD) or S(DM)	26	31	5	32.26	0	120
A	8	9	1	22.2	0	112.5
Dorset	75	107	29	57.15	1	142.7
Shropshire	32	39	7	36	0	122
Rambouillet	22	26	4	30.8	0	118
D(DM) or D(MD)	6	9	3	66 2/3	0	150
R (SD)	1	1	0	0	0	100
D (SM) or D(MS)	12	16	4	50	0	133.3
DS (S (MD))	2	2	0	0	0	100
D (D (SD))	1	1	0	0	0	100

Table No. IV is inserted as a matter of interest mainly, because there is no mention of a study of the inheritance of this particular character in the experiment proper. It is interesting however, to study inheritance of prolificacy in connection with early breeding and also from the standpoint of transmission of said character.

The number of Dorset ewes recorded in this table is 75. These 75 ewes produced 107 lambs or a prolificacy of 142.7%. This includes a large number of ewes and is carried over a number of years. Considering the length of time covered this is a very good percentage.

The Merino show a prolificacy of 123.5% for 17 ewes.

The D-M or M-D cross show a percentage of 166 2/3 for 30 ewes. This is larger than either of the purebred. This is very desirable of course, but we cannot say this character is following a certain line of inheritance laws. Whether this increase is directly traceable to this cross or just happened is not known.

The D(D-M) or D(M-D) shows 150% prolificacy of 122% including all Shropshires ever used in this experiment.

The S-M or M-S shows only 103% with 27 ewes. If this would follow the same law or course as the D-M or M-D cross we might expect a larger percentage than either of the purebreds. At least we would expect as much as either of the purebreds. This low figure cannot be attributed to the Shropshire because in crossing

Shropshire with Dorsets we got a prolificacy of 153.3%.

We cannot make a general statement that the cross-breds are more prolific than the purebreds. This is not true of M-S or S-M cross nor the S(MD) or S(DM). This cross had a percentage of 120 while the M(SD) or M(DS) showed only 111%.

The A cross which is the farthest we have gone in our proposed matings with ewes old enough to breed, showed a percentage of 112.5. This was on 8 ewes only and might increase if the number was larger. At present however, it is a little discouraging.

From the figures recorded we are unable to see where this character follows the Mendelian ratio and we are unable to figure out any ratio that certain crosses will follow.

The variation is large and no direct connection can be found between this variation and the method of crossing.

V. Table showing average weight of lambs at birth.

	No.	Net	Average
Shropshire	39	345.5	8.86
Rambouillet	26	252	9.7
Dorset	110	921	8.37
S(MD) S(DM)	31	281	9.06
SM or MS	28	258.25	9.22
A S	9	75	8.32
DS or SD	23	196.50	8.54
D (SD) or D (DS)	13	114	8.77
M (SD) or M (DS)	10	76.25	7.625
D (SM) or D (MS)	16	117	7.31
DS (S (MD))	2	18.25	9.125
C S	7	65	9.3
D(D (SD))	1	9.25	9.25
D (DM) or D (MD)	9	73	8.1
D (D (SD))	1	10	10
(SM) (DM)	1	9	9
R (SD)	1	12.50	12.50
DM	50	375.75	7.51
Merino	18	182.75	10.15

It will be noted in the preceding table that the R (SD) cross breed is the largest when born. This is however, on such a small number averaged that it is not at all conclusive.

The Merino purebred gives a surprising result when we see that the average weight at birth is 10.15 pounds.

The average weight of 39 Shropshire lambs was 8.86 while 25 (S-M) or M-S showed an average weight of 9.22 pounds at birth. This seems to show that the Merino raises the average weight of the Shropshire at birth when crossed with them.

The average weight of 110 Dorsets was 8.37 pounds, a very good average for such a large number of lambs. 50 lambs of the D-M cross averaged 7.51 pounds at birth, which is considerably less than either of the original pure breds.

The D-S or S-D cross had an average for 23 lambs of 8.54# which is a moderate size for lambs and mid-way between weights of Shropshire and Dorset. When the three breeds were combined the size seemed to decrease with the exception of the S(MD). 31 animals of this cross had an average weight of 9.06. The M(SD) 10 animals averaged 7.625. 16 D (SM) averaged 7.31. In this case the Shropshire on top seemed to add size that was not present in the other crosses.

In comparing the A, B and C crosses we find 9 of the A cross averaged 8.32, 7 of the C cross averaged 9.3 and 8 of the B cross averaged 8.625.

The size of the ewe will to a certain extent determine the size of the lambs at birth. However, the weights of the various combination of breeds is hardly what we might expect. The size of lambs at birth will not necessarily determine the size of the mature sheep.

Table No. VI in this discussion will take up the weights of the different crosses at six months of age.

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VI Table comparing the weights of the various breeds and cross breds at six months of age, all animals included.

Breed	No. of Animals averaged	Weight
M (SD) or M (DS)	25	85.4
D (SD) or D (DS)	25	81.
S M or M S	24	78.9
D S or S D	42	80.9
A	12	78.0
D (SM) D(MS)	17	84.8
B	12	54.4
C	12	60
S (SD) or S (DS)	2	105
M D or D M	42	85
M (MS M (SM)	3	75.3
S MD) or S (DM)	47	88.4
D (DM) D (MD)	14	72 6 at 3 mo.
Shropshire	11	94.3
Dorset	38	97.8
Merino	3	73.7
Rambouillet	10	88.5
S (MS) or S (SM)	2	78.9

The weights given in table No. 6 are more in accordance with the mature size than the weights at birth.

Of the purebreds the Dorsets were the largest. 38 Dorsets had an average weight of 97.8 pounds. 11 Shropshire averaged 94.3 pounds. All of the breeds and cross breds, excepting the A, B, and C crosses were about the relative size that would be expected. The A cross averaged 78 for 12 animals, the B cross averaged 54.4 for 12 animals, and the C cross averaged 60 for 12 animals. This is not at all satisfactory when we remember that these last crosses are nearing our goal of proposed matings.

It will be noticed in table No. 6 that the first cross is not a larger sheep than the purebreds.

There is an idea prevalent in some sections at least, that the first cross in any kind of livestock, providing the breeds are of the same type, will result in a feeder superior to either of its parents. This does not hold true in all crosses according to table No. 6. The S-D or D-S was smaller than either of the purebreds at 6 months of age. This should not be taken as absolute proof as there were a comparatively small number of animals included but it is representative of the results obtained at this Station.

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VII

Table showing inheritance of color of face.

Breed	No. ewes	No. with face black	Brown	White	Mottled	Gray	Gray Brown	White Brown	White
M(SD) or M (DS)	25	--	--	10	7	8	--	--	--
D(SD) or D(DS)	25	4	10	--	2	9	--	--	--
S-M or M-S	24	--	1	1	9	1	10	2	--
D(DM) or D(MD)	14	--	1	13	--	-	--	--	--
A	12	--	2	1	1	1	--	7	--
C	12	-	-	6	2	--	--	3	--
S (SD)orS (DS)	2	--	--	--	--	--	2	--	--
M-D or D-M	42	--	--	42	--	--	--	--	--
D-S or S-D	43	--	16	--	11	2	10	4	--
D(SM) or D(MS)	17	--	--	7	--	7	--	3	--
S(MD) or S(DM)	48	2	14	2	2	18	8	2	--
S M (MD)	3	--	--	--	--	--	--	1	2
(S-M) (S-M)	3	--	--	--	--	--	3	--	--
D(SM) (SM)	1	--	--	--	--	--	1	--	--
M(SD) (MS)	2	--	2	--	--	--	--	--	--
DS (M(SD))	1	--	--	--	--	--	--	1	--
S (D(DM))	4	1	--	1	1	1	--	--	--
D (D (SD))	3	--	--	1	1	--	--	1	--
DS (S(MD))	2	--	--	--	--	--	--	2	--
MS (D(SD))	1	--	--	1	--	--	--	--	--

VIII

Color of Legs.

Breed	No. of ewes	Leg : Black	Brown	White	Mottled	Gray	Gray Brown	White Br. Brown	Br. Bl.
S (D(DM))	4	1	2	--	--	--	1	--	--
D (D(SD))	3	--	--	1	1	--	--	1	--
DS (S(MD))	2	--	--	1	1	--	--	--	--
MS (D(SD))	1	--	--	1	--	--	--	--	--
S (S (MD))	3	2	--	--	1	--	--	--	--
M (D (SD))	4	--	--	2	--	--	--	2	--
S (D (SD))	1	--	1	--	--	--	--	--	--
MS (D(DM))	1	--	1	--	--	--	--	--	--
SM (MD)	3	--	--	1	--	--	--	2	--
S-M S-M	1	--	--	--	--	--	--	--	1
D(SM) (SM)	1	--	1	--	--	--	--	--	--
M (SD) (MS)	2	--	1	--	--	--	--	1	--
DS (M(SD))	1	--	--	1	--	--	--	--	--
S (MD)or S(DM)	48	2	21	2	1	8	12	2	--
D (SM)or D (MS)	17	--	4	3	--	7	2	--	1
D-S or S-D	43	2	20	--	--	14	4	--	3
MD or DM	42	--	--	42	--	--	--	--	--
S (SD)or S(DS)	2	--	--	--	--	--	2	--	--
C 8	12	1	--	6	--	2	1	2	--
B8	12	--	3	5	--	--	1	3	--
A 8	12	--	2	1	1	1	--	7	--
D (SM)orD (MD)	14	--	1	13	--	--	--	--	--
MS or SM	24	12	7	--	--	--	1	--	4
D (SM) orD(DS)	25	4	1	20	--	--	--	--	--
M (SD)or M(DS)	25	--	6	--	--	10	9	--	--

The color markings of sheep is not of the material value that some of the other characters studied in this test are, however, a dark faced sheep meets a stronger demand on the market than white faced sheep. It is desirable to have black faces on our crosses but this is not as important as form, horns, etc., therefore it has not received the attention of the other characters. It was deemed more important to produce mutton type and develop the black face later.

The S-D or D-S cross followed what has been said of this cross before. The Shropshire is a dark brown at the extremities and the Dorset is white. None of the F_1 generation had a white face. 16 were brown and eleven mottled. The D (SD) or D(DS) showed about the same color as the F_1 generation with a slightly larger percentage of grays. The S(SD) or S(DS) had only two animals and had gray brown faces.

The A cross showed one white face and the others were all a combination of black and white. The C crossbreds were half white and one fourth white brown. All of these advanced crosses were well removed from the desirable dark color.

The color of legs is also given in table #8 and will correspond fairly closely to the color of face.

The color of face and legs showed no dominance of any color but rather a distinct blending of the dark and white color.

The data taken on wool each year was practically complete. This is necessary because the inheritance can be studied from the standpoint of weight of fleece, fineness of fiber, amount of yolk, etc. There were a few fleeces missed occasionally because of lost ear tags and marks of identification, but with these few exceptions every year at shearing time the fleece from each sheep was weighed and the weight carefully recorded. At shearing time the density of the entire fleece was also estimated and recorded. The terms used in this estimation are: Excellent, good, medium fair and open.

When we tried to get an average of the density of the breeds and cross-breds it was impossible because of the terms used. Accordingly we changed this system and are now using numbers instead of words. Number 1 is used instead of excellent, 2 for good, 3 medium, 4 fair and 5 for open. By this system we can easily get an average of the numbers and will thus have the relative density of the fleece within any given breed or crossbred.

In addition to this we recorded the covering of fleece on the face, ears, fore leg, hing legs and belly. The terms used here were complete, good, fair, scant and bare. Here again we substituted the numbers, 1, 2, 3, 4, and 5 for the words.

In table No. IX we have the length of the growing period, the average weight and computed weight for 365 days. This is necessary because we must get all the fleece on a common footing before we can compare them.

The column "average density" is directly comparable because this is an average of the estimated density at shearing time.

The rest of the table is divided into average face, ears, legs and belly. The last column is the average of all these. This gives us an average of the covering of the entire body. This column does not include average density as that is complete within itself.

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IX. Table showing weight covering and density of fleece.

1. Excellent 1. Complete
2. Good 2. Good
3. Medium 3. Fair
4. Fair 4. Scant
5. Open 5. Bare.

Breed	No. of animals	Ave. Wt.	Ave. grow th	wt. 365 days	Ave density	Ave. face	Ears	fore legs	rear legs	Belly	Ave.
S(MD)orS(DM)	30	5.94	226.5	9.56	2.53	2.77	4.4	3.07	2.37	1.23	2.77
D(DM)orD(MD)	14	1.15	101	5.5	2.37	3.36	4.18	3.00	2.09	2.00	2.92
M(MS M(SM)	2	4.25	212½	7.3	3	3	3	3	3	1	2.6
S(MS) S(SM)	2	5.25	208.5	8.8	2.5	1	3.5	3	2	1	2.1
SM(S(MD))	1	3	153	7.16	3	2	4	2		1	2
MD or DM	21	5.6	214	9.53	2.331	3.3	4.5	3.43	2.2	1.9	3.1
S(SD)orS(DS)	1	3	99	11.2	2	3	4	4	2	2	3
C 8	2	4	203	7.32	3	2.5	4	2.5	3	1	2.6
B 8	1	4	173	8.2	4	3	3	4	3	1	3
D(SM) D(MS)	17	4	172	9.42	216	2.4	4	2.62	1.5	1	2.825
A 8	8	6.68	2.73	8.91	2.75	3.1	4	3.4	2.3	1	2.75
D-S or S-D	32	6.42	276	8.47	2.9	2.9	4.28	3.62	2.56	1.94	3
M-S or SM	24	8.3	242	12.52	2.16	1.85	4.36	2.43	1.5	1.143	2.256
D(SD) D(DS)	25	2.35	132	8.6	3	3.25	4.3	4.17	2.17	2	3.17
M(SD) M (DS)	25	6.5	261	9.1	2.4	2.26	3.86	2.66	1.73	1.13	2.33
Dorset	63	5.11	281.1	6.613	3.33	4.4	4.5	4.4	3.52	2.8	3.72
Rambouillet	15	21.78	431.3	18.5	1.47	1.47	2.47	1.7	1.13	1	1.55
Merino	11	16.05	340	17.23	1.36	2.	4.1	2.1	1.36	1.45	2.2
Shropshire	37	8.05	323.2	9.08	2.9	2.0	3.92	3.08	2.21	1.54	2.31

Table No. IX shows the relative weight, density and covering of wool for the breeds and cross breds used in this test.

It will be noticed that of the pure breds the Dorset is the lowest in every respect. The Dorset is known and often criticized for its poor wool covering. The computed weight for 365 days was 6.613 pounds. This was a little below what could be expected in the Dorset as a rule. I should be remembered that all the wool considered in this table was of the first shearing only.

The Rambouillet and Merino are both wool breeds and are very similar in fleece covering. The Rambouillet averaged 18.5 pounds and the Merino 17.23 for 365 days growth. The heavier weight of the Rambouillet fleece is due primarily to the size of the sheep rather than density of fleece.

The average on covering was 1.554 for the Rambouillet and 2.2 for the Merino. This is hardly what would be expected as the Merino is very well covered as a rule. The density of the fleece however, was greater in the Merino, being 1.36 while it was only 1.47 in the Rambouillet.

The Shropshire is a medium wool breed, having fair density but is very completely covered. It will be seen in the table that the average weight for the Shropshire was 9.08 for a period of 365 days, - only a fair average for Shropshire. The density is shown as 2.9 or just fair while the average of the covering is 2.31, just a little less than the Merino.

The S-M or M-S cross had 24 sheep cutting the first fleece with an average computed weight for 365 days of 12.52#. This is a

decided increase in weight of fleece over the purebred Shropshire. The average density of this cross was 2.16. Almost an average of the Shropshire and Merino density. The average covering is 2.256. The Merino is 2.2 and Shropshire is 2.31. It will be seen that in every repsect the S-M or M-S crossbred is middle way between the purebreds in fleece covering.

The D-S or S-D crossbreds have an average fleece weight of 8.47 pounds for 365 days. This is a material increase over the average of the pure bred Dorset. The density of this cross was 2.9, the same as that of the purebred Shropshire.

The D-M or M-D cross averaged 9.53 pounds for 365 days, an increase of 3 pounds over the purebred Dorsets. The averaged ensity was 2.33. This is nearer the density of the Merino than of the Dorset. The average fleece covering was 3.1 or half way between the purebreds.

The M(M-S) or M(S-M) had an average weight of 7.3 pounds for 365 days with an average density of 3 and a covering of 2.6. This was not as good as the fleece shwon by the S-M or M-S cross. There were 25 sheep representing the D(SD) or D(DS) cross and showing an average weight for 365 days of 8.6, a little increase over the D-S or S-D cross. The S(SD) or S(DS) showed 11.2 pounds for 365 days with a density of 2 and fleece covering of 3. This is a greater weight and density than the purebred Shropshire.

The C cross had an average fleece weight of 7.32 pounds for 365 days, an average density of 3 and an average covering of 2.6. The B cross averaged 8.2 pounds fleece weight for 365 days, showed an average density of 4 and an average fleece covering of 3. The A cross has an average weight of 8.91 pounds for 365 days, an average density of 2.75 and a fleece covering of 2.75.

The lack of weight of fleece in these various crosses can be attributed in part to the lack of size of the sheep. It will be noticed that the C cross has a density of 3 or less than the Shropshire and the B cross has a density of only 4. The A cross had a density and fleece covering of 2.75, or a very little in advance of the Shropshire.

The density and fleece covering appeared to be dominant over lack of covering and open fleece in the first cross. This can be seen by studying the S-M, D-S and D-M crosses in table No.IX. After the first cross the density was not as certain but appeared in some crosses at least to break into a 3-1 ratio. 3 sheep showed density and 1 showed a loose fleece. On the whole the latter crosses are not as satisfactory as we might expect from results obtained in the first cross. There has been no improvement in our A, B and C crosses as to weight, density or covering. In the B and C crosses especially there is a deterioration in this respect as compared to the purebred Shropshire.

The density of fleece on our crossbreds as mentioned in the object of this experiment are far from realization at present.

At shearing time in addition to taking the samples to be used in measuring the fineness, amount of crimp and stretch there ~~is~~ was a sample taken from the rib. This ~~is~~ was divided into two equal parts and placed in small envelopes bearing the ear tag number of the sheep shearing date and labeled sample A and sample B. The samples ~~are~~ were used in determing the moisture content and amount of yolk and foreign material in the fleece.

Method of Calculation.

Percentage moisture = $W\,1 - W^2 \times 100 - W$

Percentage shrink (Excluding moisture) = $W^2 - W^3 \times 100 - W$

Percentage shrink (including moisture $W^1 - W^3 \times 100 - W$

$W^1 - W^2$ = 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.

Method of Procedure.

A convenient sized sample of wool is taken and carefully weighed to the third decimal on chemical balances and placed in an electric vacum oven for at least two hours and often times longer. It is then removed, reweighed and placed in a desicator for future use.

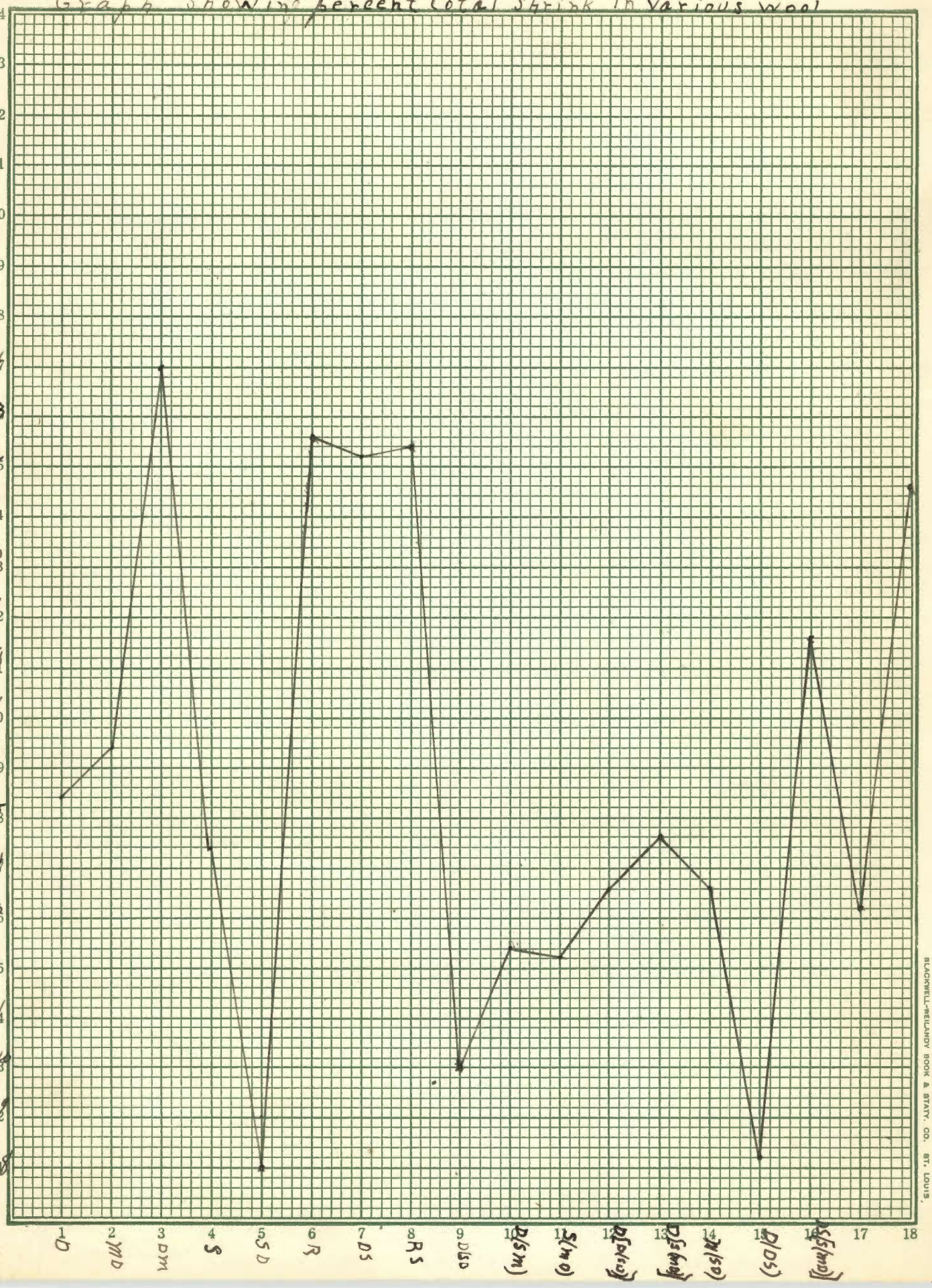
The weight of the normal sample of wool is that referred to as W^1 and the weight after the first heating or drying as W 2. The difference bewteen these two weights is the moisture content.

Formula	Scouring Method.		
Solution formula.	Washings	Temperature	Time.
Cistern Water 2 liters.	No.1. Scouring solution	55°	15 min.
Soda ash (NA_2CO_3) 25 gms.	No.2. Water (Cistern)	50°	5
Soap (Ivory laundry) 15 gms.	No.3. Water (Cistern)	40°	5

The samples used in determining moisture content are securely fastened on an endless cloth belt and are so marked that the fleece number is kept straight. This endless belt is then slowly moved through the above mentioned solutions for the stated time. There is some little wool lost in this process but not enough to unbalance the results, especially considering that the error is almost equal in every sample.

When the scouring is finished the samples are removed and placed in the oven until completely dry which will take several hours and are then taken out, placed in a desicator and allowed to cool. When they have become cool they are weighed. This weighing is that referred to as W3. From these weights it is possible to calculate all we need to know concerning the scouring qualities of the fleece.

Graph Showing percent total Shrink in various wool



Graph Showing the percentage moisture in Wool.

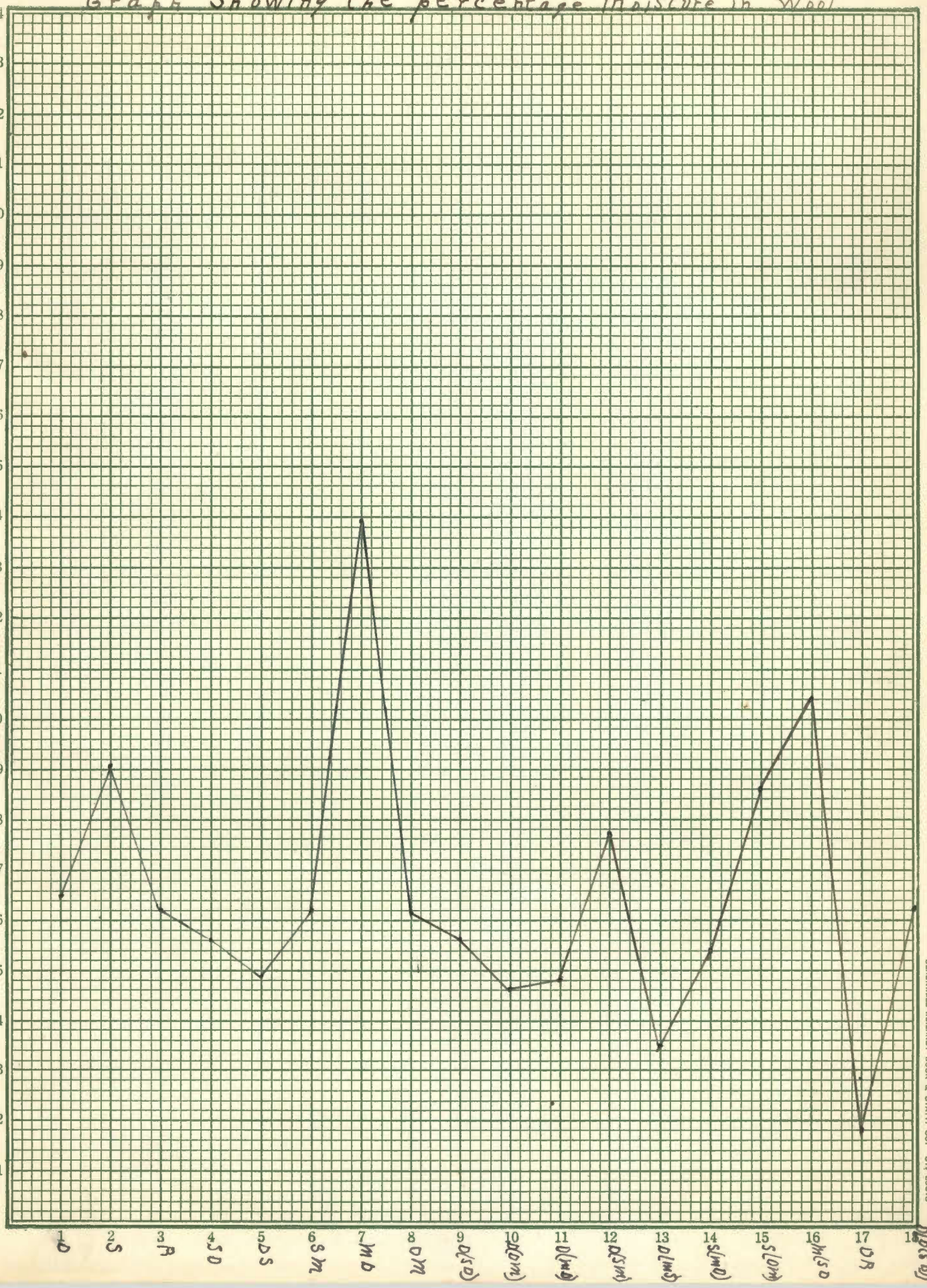


Table showing the average scouring percentage of wool from the various breeds and cross breds.

Breed	No.of fleece avg.	W 1	W 2	W 3	W1-W2	W2-W3	W1-W3	% moist	%yolk &dirt	%total shrink
D	68	3.762	3.511	2.053	.251	1.458	1.709	6.67	38.757	45.427
S	22	4.099	3.725	2.193	.374	1.532	1.906	9.148	37.372	46.520
R	10	5.489	5.487	2.681	.362	2.806	3.168	6.206	47.97	53.996
SD	35	4.603	4.344	2.547	.259	1.797	2.056	5.627	39.04	44.667
DS	7	4.219	4.013	2.617	.206	1.396	1.602	4.859	33.09	37.949
SM	17	4.491	4.211	2.135	.280	2.076	2.356	6.457	46.226	52.683
M-S	3	5.507	5.141	2.627	.366	2.512	2.880	6.646	45.651	52.297
M-D	21	4.800	4.172	2.321	.628	1.851	2.509	13.833	38.562	52.395
D-M	15	4.554	4.276	2.726	.278	1.550	1.828	6.104	34.036	40.140
D (SD)	29	4.123	3.892	2.360	.231	1.532	1.763	5.602	37.16	42.762
D (DM)	6	3.187	3.039	1.834	.148	1.205	1.353	4.644	37.810	42.454
D (MD)	12	4.216	4.013	2.388	.203	1.625	1.828	4.815	38.544	43.359
D (SM)	4	2.773	2.56	1.542	.213	1.018	1.231	7.681	36.711	44.392
D (MS)	2	3.457	3.336	1.955	.121	1.381	1.502	3.500	39.948	43.448
S (MD)	18	5.980	5.663	3.688	.317	1.975	2.292	5.3	33.028	38.328
S (DM)	2	5.504	5.032	2.830	.472	2.202	2.674	8.575	40.01	48.585
M (SD)	4	8.778	7.888	4.990	.890	2.898	3.788	10139	33.014	43.133
D R	2	4.532	4.439	3.183	.093	2.256	2.349	1.83	49.74	51.57
D(D(SD))	5	3.938	3.688	2.317	.250	1.371	1.621	6.348	34.789	41.137
DS(S(MD))	4	3.421	3.32	1.904	.101	1.416	1.517	3.000	41.388	44.388

It is a well known fact that the finer the texture of wool the more yolk there is present and as a rule more foreign matter because dust in particular clings to the wool grease.

The scouring percentage or percentage of shrink in this table may not compare favorably with that given for the various breeds. It is practically impossible where such a small sample of wool is scoured to get the definite results we might expect when thousands of fleeces are scoured. The loss of a very small particle of wool would in this case effect the results materially. The loss of any wool in the scouring was prevented as nearly as possible and theoretically at least the possible error is the same in all the samples. Therefore, even though the percentage for the breeds may not be just what it should be the same process was used on them all and we can draw a direct comparison between the various breeds and crossbreds which will be fairly accurate. This is our main purpose as we wish to determine the inheritance of the various characters.

There will be several later tables giving the actual fineness and stretch of the wool but table No. X will give an idea of the fineness.

This work was not all kept up to date and some of the samples were old before they were scoured. This would give different results from those when the wool was freshly clipped. Here again all the breeds represented had the same treatment and the relationship between them would be the same.

The amount of yolk present in a fleece will to a certain extent depend on the care and feeding of the sheep and the amount of dirt and foreign material varies a great deal, depending to a large extent on the way the sheep are fed.

When the variability of foreign material is considered, it will readily be seen that the scouring percentage may vary from what is expected and this variance is not due to inheritance of fine wool but rather due to the carelessness of the feeder.

The percentage of moisture was also taken up and compared. This factor is not of as much importance as the yolk and foreign matter and will vary somewhat in this test due to the length of time the fleece has been kept before the scouring was done.

In referring to table No. X we note that the comparison between the two first breeds is hardly what would be expected.

The Shropshire produced a wool that was a good deal more dense and carried more yolk than that of the Dorset. The Dorset is notably a loose dry fleeced sheep. The Shropshire in this table had an average shrink of 46.520 percent on twenty-two trials. The Dorset on sixty-eight trials averaged 45.427.

According to what has been said of the fineness of wool and its scouring qualities we might expect the Shropshire fleece to show more shrink than that of the Dorset. This might be explained by the fact that although the Dorset fleece is low in yolk content, it is extremely high in dirt and foreign material because of this looseness and dryness of fleece. It does not exclude dirt as it would if it were denser and carried more yolk.

The purebred Rambouillets showed a shrink in scouring of 54.996 percent on ten trials. This was about what might be expected considering that the Rambouillet is a fine wool sheep.

The S-D cross had 35 individuals and showed a shrinkage of 44.667 percent. This was less than either of the purebreds but was close enough, varying only one percent, that there was nothing of a marked degree showing the tendency of this character of fine compact fleece. The D-S cross having seven trials showed something that was a good deal more interesting, a shrinkage of 37.949. This was less than either of the purebreds. In the F_1 generation the ram has a little more influence on wool than the ewe.

The S-M and M-S crosses both had a shrinkage of around 52 percent as did also the MD cross. The D-M cross however,

showed a shrink of only 40.14 percent. This again appears as though the Dorset ram had considerable influence even when crossed with Merino ewes.

The D(SD) cross had a shrinkage of 42.762 percent. The D(DM) cross had a shrink of 42.454. It here appeared that the Merino when not present in more than 25 percent had very little influence on the scouring qualities of the wool. The D(MD) had a little the advantage, scouring 44 percent loss. The D(SM) cross and the D(MS) cross shrunk a little more than when there was a double cross of the Dorset.

The S(DM) cross loses 48.484 percent in scouring and the M(SD) cross loses only 43.13 percent. We might ordinarily expect about the same amount of shrink in this cross as was found in the S-M or M-D crosses. This however, was not true.

The D(D(SD)) cross carrying a very large percentage of Dorset blood (87.5%) had a shrink about the same as that of the Dorset - 41.37. The DS(S(MD)) had a shrink of 44.338 percent.

It will be noted that when the fine wooled breeds were used in this crossing the F_1 generation showed that the fine wooled blood had a marked influence on the scouring qualities of the wool. There were such a variety of characters studied in this test that we could not follow the breeding for fine wool to the exclusion of all other characters. However, from the results obtained so far the fixing of this character would be fairly easy of accomplishment. The tendency to the fine wool characteristics was very noticeable when there was as much as one-third of the blood coming from the fine wool.

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Table showing the average fineness of fleece for the various breeds and crossbreds according to Bradford Count System for 1921

Breed	No.of Fleece	Ave.Count	Breed	No.of Fleece	Ave.Count
D	27	43	C	6	53
R	8	63	B	1	46
S	7	47.3	A2	2	53
SD	4	47	2	2	44
S-M	1	54			
S (MD)	3	49			
S (DM)	2	47			
D (SM)	3	48			
D (MS)	2	48			
M (SD)	1	52			
D R	1	58			
R (SM)	1	66			
R (SD)	3	56			
S (D (DM))	1	50			
R (D (SD))	1	48			
S (D (DM))	1	52			
R (DS)	1	44			
A	3	48			
B	4	50			

Mr. D. A. Spencer of the Sheep Division, Bureau of Animal Industry, Department of Agriculture, Washington, D. C. consented to select some samples of wool showing the Bradford count as used for designating the fineness of wool on the English market. The Bradford count is a system of figures designating the number of hanks (560 yards) a pound of combed wool will spin when spun to capacity. The larger numbers designate the finest wools.

This was not substituted entirely for our measurement work but gave us an easy means of determining the comparative fineness of the fleece obtained from sheep used in this experiment.

A sample of the fleece was obtained at shearing time and closely compared to our samples showing the count, and the count was thus determined.

This work was not carried on before this year, therefore, the results given in the accompanying table are for the 1921 fleece only.

It will be noticed that the Dorset had the coarsest wool, grading only 43 which was rather low on the whole for Dorsets. The Shropshire graded 47.3. This again was a little below what we had a right to expect from the Shropshire. The Rambouillet, a fine wool sheep, graded 63.

The S-D cross, the first cross made in this test, had a fleece average of 47 for 1921. This was a good deal more like the Shropshire than it was like the Dorset. The S-M cross graded 54. The D-R cross showed a grade of 58. The D(SM) and D(MS) both averaged a little better than the purebred Shropshire.

The S(DM) averaged 47 and S(MD) 49, being practically the same grade as when the Dorset was the top cross. The R (SD) graded 56, a considerable improvement over Dorset and Shropshire purebreds.

The A cross graded 48, the B 50 and the C 52.

From Table No. XI and discussion our prediction that the sire has more influence than the dam in the F generation as far as wool is concerned seems to be disproved. Rather from the preceding we would be more justified in saying that the fine wool of the Rambouillet and Merino is dominant over the coarser wools of the Shropshire and Dorset. Here again we can say what was said following the table on scouring percentage; namely, the character of finer wool could be fixed with a fair degree of ease because where as much as one-third of the blood comes from a fine wooled breed the tendency is strongly in favor of fine wool. The A, B and C crosses showed an improvement over the Dorset and Shropshire in this respect and for the first time in all of the characters so far discussed. The actual measurement of the fibers will serve as a check on this and will followin this bulletin.

Photograph taken by the author, 1921.

No. 1317 representing the R (SM) cross. The 3/4 fine wool blood gives all the characteristics common to the Rambouillet.

Photograph taken by Author, 1921.

Ewe No. 2037 R(SD)S(MD) - B. This ewe shows a complete covering of rather loose open wool, short horns, gray face, mottled legs and poor mutton form.

A very undesirable type from any standpoint and representing one of our most advanced crosses.

Photograph by author, 1921.

A purebred Shropshire ewe, 738, and twin lambs by a Rambouillet ram. Lambs one month old when photograph was taken.

Photograph taken by author, 1921.

Ram No. 2015 representing the C cross shows Dorset characteristics but is very much undersized (weight 135 pounds). Three fleeces averaged 7.7#. This ram differs widely from our proposed type but is very near the limit of our proposed matings.

Photograph taken by author, 1921.

Ram No. 1273 A R(SD) showing the Rambouillet characteristics to a marked degree. This ram was used extensively in our cross-breeding.

Photograph by author, 1921.

Ewe No. 2001 A and twin lambs by ram No. 2015 C representing the B cross. Wether has well developed horns; ewe is smooth; color white. This photograph shows our most advanced crosses. They all have undesirable white faces, fair mutton form and horns on the male. This is far from our ideal type.

Graph Showing percent of stretch in Wool

Table showing Length and Streton of Fiber XII.

Breed	No. of Sheep	Crimp	Shoulder Stretched	Actual Streton	Rib C	Rib S	Rib S	Thigh C	Thigh S	Thigh S	Final C	Final S	Final S	%S.
Dorset	73	2.506	3.822	1.316	2.520	4.000	1.480	2.520	3.972	1.452	2.515	3.931	1.416	56.34
M-D	18	2.722	4.060	1.338	2.555	4.611	2.056	3.055	4.055	1.000	2.777	4.242	1.466	52.76
D-M	15	2.133	2.933	.800	2.400	3.800	1.400	2.000	3.133	1.133	2.177	3.288	1.111	51.03
S	21	2.714	4.430	1.716	2.762	5.000	2.238	2.476	4.381	1.905	2.651	4.603	1.952	73.64
S-D	30	2.733	3.933	1.200	2.866	4.666	1.800	2.800	3.266	.400	2.799	3.955	1.156	41.30
R	15	2.333	4.066	1.733	2.466	4.400	1.934	2.466	4.000	1.534	2.422	4.155	1.733	71.55
D-S	4	2.875	4.750	1.875	3.250	5.250	2.000	2.625	4.250	1.625	2.916	4.750	1.834	62.89
R-S	1	1 5/8	3 1/8	1 1/2	1 3/4	2 5/8	7/8	1 3/4	2 1/2	3/4	1 3/4	2 7/8	1 1/8	69.32
D(SD)	27	1.852	2.703	.841	1.814	2.900	1.086	1.777	2.777	1.000	1.814	2.793	.942	51.99
D(SM)	3	2.125	3.41	1.285	2.	3 1/8	1 1/8	2.200	3.225	1.025	2.125	3.416	1.291	60.75
S(MD)	15	2.333	3.535	1.202	2.4	4.00	1.600	2.066	3.533	1.467	2.299	3.689	1.39	60.46
D(D(SD))	3	1.5	2.166	.666	1.604	2.166	.562	1.5	2.125	.625	1.336	2.152	.816	61.07
Ds(s(MD))	2	1.6	2.425	.825	1.75	2.825	1.075	1.750	2.562	8.12	2.750	2.612	.862	31.52
M(SD)	6	2.45	3.33	.88	2.33	3.33	1.00	2.3	3.417	1.117	2.36	3.359	.999	42.33
D(MD) D(DM)	10	.912	1.39	.478	1.185	1.622	.437	1.174	1.812	.638	1.09	1.608	.718	65.87
Ds(S(MD))	2	1.625	2.625	1.	1.78	2.875	1.095	1.75	2.66	.81	1.718	2.653	.935	54.88

Table No. XII was arrived at in the following manner:

At shearing time a sample of wool was taken from the shoulder, one from the rib, and one from the thigh. Three sample fibers were taken from each of the three main samples. These were each measured in crimp then stretched and measured again. The average length of shoulder fiber in crimp and stretched was determined and also the average for rib and thigh samples. The columns in Table No. XII, as crimp on shoulder, etc. are the averages thus found.

This data was taken on every individual fleece and the numbers in the table given here are averages of all the individuals in that particular breed or cross.

The first column under "Breed" is given the designation of breed or cross. The second column is the number of sheep of fleeces measured.

The actual stretch of shoulder, rib, and thigh samples are given but the percent of stretch is given for the fleece as a whole or the average of the three samples before given.

It should be remembered that the table contains the first fleece and in many instances, especially in the Dorset and cross breds, the fleece was taken from a fall lamb thereby cutting down the average length. For this same reason the first column in each case, "crimp", is of very little value. The item, actual stretch, given under each of the three main divisions is of value only when compared to the length in crimp.

It is the last column or percent of stretch in which we are primarily interested but even here we have some unexpected things occurring probably due again to the fact that lamb wool was measured and averaged with that of mature sheep.

This table will be of more value when studied in connection with the one immediately following. Table No. XIII gives actual measurements of the fineness of the wool fiber.

This table brings out the fact that the fleece on the thigh was almost invariably longer than that on the shoulder and often longer than the rib sample.

For convenience we will discuss the data to be found under the main heading "Final" as this is an average of all that going before.

The first thing to be noticed is that the pure bred Dorset fleece was shorter in crimp than the cross-bred fleece M-D. This is unexpected as the Merino has a very short staple as compared to the medium wool breeds. This was probably due to the fact that many of the fleeces averaged with the Dorset are those coming from lambs. The cross D-M was shorter than the pure Dorsets and was more what might be expected in that respect than the M-D cross, but the percent of stretch of both these crosses is less than the stretch of the pure Dorset.

The measurements of Shropshire showed some greater length in crimp than did the Dorset. Due in part perhaps that there were very few sheep clipped under one year of age. The percent of stretch was very high in the Shropshire, averaging 73.64%. This was higher than the Rambouillet a fine wool breed.

The cross-breds S-D had a stretch of only 41.30%, a good deal less than either of the pure breds. There were 30 animals

or fleeces averaged in this cross and the results should be fairly accurate. The cross breds D-S showed a stretch of 62.89 more what we might expect but there were only four (4) animals averaged in this result so it would be hardly as reliable as the first one mentioned.

The stretch of fiber to a certain extent corresponds closely to the amount or number of crimp. Table No. XIII would indicate that this particular character was not strongly transmitted by the fine wooled breeds. We might even say from the results shown in this table that stretch does not behave at all in the manner of unit character. The only explanation we could possibly offer if this is a definite transmissable character is that some crosses offer an especially favorable combination while other crosses are directly opposite. This explanation is necessary when we see that some crosses fall far below the lowest of the parents and again some cross shows much more stretch than the best of the parents. We might expect that the S-D cross is a very poor combination in this respect while the D-S is much more desirable.

DIFFICULTIES MET IN ATTEMPTS TO ESTABLISH A HYBRED BREED OF SHEEP

In theory the foregoing experiment is excellent indeed. It would be very desirable to possess a sheep with the mutton conformation of the Shropshire, the early breeding characteristics of the Dorset and the fine wool of the Rambouillet.

In attempting to produce this type of sheep however some of the accepted laws of animal breeding have been overlooked or disregarded.

It is more or less generally agreed that the fixing of one character at a time will occupy one's time and necessitate very close attention and selection.

In the outline of this experiment we are told that the object is the production of a sheep carrying the fineness of wool of the Rambouillet, but having a smooth skin and mutton conformation like that of the Shropshire. It is a well known fact that the number of folds of the Merino and Rambouillet are in direct proportion to the fineness of wool. The smooth skinned Rambouillets show a tendency to coarser wool. The Rambouillets showing the most folds also produce the finest wool. If, as appears likely, a wrinkled skin and fineness of fleece are linked characters, we are trying the impossible when we attempt to produce a smooth sheep with fineness of fleece common only to wrinkled sheep.

We have shown that the fineness of wool appears to be a blending character but at the same time and to the same degree wrinkles and smoothness of skin blend. The only hope then would be to devise some means by which we could separate these two characters. So far this has not been possible.

We will often hear that the first cross resulting from two purebred parents will, in the case of meat animals, produce an animal of better feeding qualities than either of the pure bred originals. This has been demonstrated at some of the leading shows where cross-bred steers take the Grand championship. The same of wethers and barrows. This idea of cross breeding will hold only when animals of like characteristics are crossed. When animals of like types are crossed we will sometimes produce an animal more desirable than either of the parents, but we have no reason for believing that by crossing an animal of good type on one of inferior type that we can produce an animal more desirable than the best parent. We will probably improve greatly on the less desirable type but not attain the perfection found in the most desirable animal.

It is probably this belief that is responsible for the attempt to produce an animal with Shropshire characteristics by crossing the Shropshire on some other breed. This might have been successful if the opposing breed had been different. The Dorset does not show the desirable development of the Shropshire, but is a fairly good type. If the Dorset had been the only breed used we still might have had some hopes of success, but when the Rambouillet was added to this cross it is absolutely impossible. We have no reason for believing the mutton conformation of the Shropshire will retain all its desirable features when crossed with the less desirable Dorset and the positively inferior Rambouillet. All laws of animal breeding and the experience of practical breeders would show us we cannot hope to attain this object.

As stated in the original outline of this experiment, one of the objects was to produce a breed of sheep that would produce fall lambs. This was hoped to be accomplished by the addition of the Dorset, an early breeding sheep.

As we have shown in some previous tables all Dorsets do not breed early and still fewer produce fall lambs. The table regarding this early breeding feature shows that about 30% of the Dorset lambs produced in this experiment have been fall lambs. The other 70% being spring lambs. It was obviously impossible to produce a new breed of sheep all of which could produce fall lambs by crossing one breed with a record of 30% fall lamb production on a breed producing all spring lambs. The actual results obtained from this crossing were not at all desirable but were better than we would naturally expect.

This trouble might have been overcome, in part, if the Dorsets had been more carefully selected. This characteristic, fall lamb production, is not common to all Dorsets but to certain individuals. The encouraging thing about it is that it appears to be directly transmissable from parent to offspring and could perhaps be established in the cross bred by using only Dorsets that produce fall lambs. When the cross-bred results from the union of a Shropshire and an early producing Dorset the character seems dominant over late breeding.

In introducing the Dorset breed for fall lamb production, we also introduced horns and white face of the Dorset. The polled character of the Shropshire is dominant over horns of the Dorset in the F_1 generation. This, according to Mendel's law, would on successive crossing, result in a cross bred

sheep homozygos for the character of hornlessness. We can only assume that horns of Dorset are a truly recessive character in the present test because the work was not carried on in this manner. That is, the cross breds were not recrossed with each other but were crossed with the Rambouillet. The Rambouillet have horns in the male and the female is hornless. The introduction of this breed would, of course, prevent any definite percentage of hornless sheep appearing and would prevent a close study of the behavior of this particular character from a genetic point of view.

The cross breds were invariably hornless when they carried as much as 50% of Shropshire blood. We cannot retain this predominance of Shropshire blood without sacrificing some of the other objects in view and we would necessarily have to rely on chance and rigid selection. We might in this way obtain a hornless breed without a preponderance of Shropshire blood. It can readily be seen that 50% of Shropshire blood would limit the amount of Dorset and Rambouillet blood in the cross-bred and would sacrifice both the character of fine wool and early breeding or attempt to fix one and disregard the other entirely which of course could not be done under the present system of crossing.

We met the same difficulties with the dark color of face that we did with hornlessness, as both of these were represented by the Shropshire. We had the added difficulty however that the Rambouillet and Dorset both have white faces. We would have to depend more strictly on selection and chance because of the blending of color markings of sheep.

The color markings of sheep, as has already been stated is of secondary importance and could easily be omitted until the desired type is well fixed and this character be fixed by selection.

In attempting to produce a type of sheep with the mutton conformation of the Shropshire, the fine wool of the Rambouillet and the peculiarity of breeding at an early season of the Dorset, we apparently lost sight of some very important things.

We apparently assumed that we could obtain the desired character but lost sight of the fact that some of the undesirable characters were no less unit characters and were just as strongly transmitted and sometimes even more strongly than the particular character we wished to fix. We assumed that the early breeding of the Dorset would be dominant in the various crosses but that the white face and horns common to this breed would disappear.

We tried to fix the fineness of wool common to a Rambouillet on a cross-bred without the undesirable folds also common to this breed. As has been suggested, these last two characters seem to be linked. In this case we were attempting the impossible. If these characters are not linked, the folds would in all probability be as strongly transmitted as fineness of fleece. This seems to be the case, as fine wool accompanies folds and vice versa.

We were attempting to retain all desirable features of the Shropshire plus some of the desirable characters of other breeds. We were in fact attempting to graft early breeding and fine wool on the present day type of Shropshire, an impossibility.

Our proposed system of mating would, in the course of several years, reach the point where the amount of blood from the different breeds would be almost equal. The crossing and re-crossing would theoritically have reached the point where all desired characters were equally represented and could be fixed there by selection.

If the three main characters in question could be taken as separate units and placed together in this proportion, we might have the product sought for. We must consider, however, that in our dealings with animal life we will meet many characters other than those in question. We would also have to contend with many characters and influences which we could figure on before hand and could cope with when they were met in the problem.

When we had passed the first or second cross where more than one character was considered, we had numerous possible combinations of the various characters and naturally this would result in offspring of numerous types. The more crosses and the more characters considered, the more possible combinations. This is exactly the point we have reached in our present system of crossing. The offspring from identical crosses are very different in appearance, due to a difference in the combination of all the possible combinations, present in the particular individual under question.

We are sometimes told that continuous cross-breeding will result in reversion. We have also met this obstacle. We have produced everything from black lambs, on up to desirable colors common to the breeds used in crossing.

The sheep without horns were wrinkled. The fine wooled sheep were wrinkled. The desirable mutton form had horns, a white face and were late breeders. We have produced them all, but not the desired combination.

As we have said before this object might be realized where unlimited sheep could be used for the purpose of selection. We can imagine a state of affairs where there is a possibility of having the characters all present in one individual. This would be the advantage of numbers.

We could study genetics in connection with this were we considering only one character. As it is, we cannot follow this beyond the first generation.

We have reached the place where every individual sheep is a type unto himself. We cannot know what to expect from any given cross.

We are prepared to say that with our present crosses and equipment to work with the production of such a sheep as is mentioned in the introduction and referred to numerous times since, is IMPOSSIBLE.

SUMMARY

I. Polled character of Shropshire is dominant over horns of Dorset.

II. Color markings of sheep tend to blend. A black and white face produce a mottled face in the cross bred.

III. Fineness of wool is slightly dominant over coarse wool but these characters blend.

IV. Weight of fleece is a blending character in first cross.

V. Mutton and wool conformation tend to blend, with mutton slightly predominating in the first cross.

VI. Smooth skin and folds blend with a slight tendency to folds in first cross.

VII. Character of early breeding is not common to all Dorsets but is an individual matter.

VIII. It is impossible to obtain all the desirable features of a Rambouillet wool without some of their disadvantages as to mutton.

IX. A dark face in this system cannot be obtained without Shropshire blood predominating.

X. It is impossible to establish a type breeding true without large numbers from which to select.

XI. Fleece covering is dominant over bareness.

XII. Horns appear more often on rams than on ewes.

XIII. Early breeding of Dorset appears dominant when the Dorset selected is of an early producing strain.

XIV. The fineness of wool desired will undoubtedly be accompanied by looseness of skin and folds.

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