329-1023-11,000-L180

TEXAS AGRICULTURAL EXPERIMENT STATION

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS
W. B. BIZZELL, President

BULLETIN NO. 311 SEPTEMBER, 1923

DIVISION OF ANIMAL INDUSTRY

The Influence of Individuality, Age, and Season Upon the Weights of Fleeces Produced by Range Sheep

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†As of October 1, 1923.
*In cooperation with School of Veterinary Medicine, A. and M. College of Texas.
**In cooperation with United States Department of Agriculture.
‡On leave.

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SUMMARY

1. There is a great deal of opportunity for increasing the average weight of fleece produced by range sheep in Texas.

2. The weight of the fleece produced by a sheep is controlled by three kinds of influences: (a) permanent individual differences between the sheep (called 'individuality" in this Bulletin), (b) environmental influences which affect some sheep but not others (such as sickness, suckling a lamb, etc.), and (c) environmental forces which affect all the sheep alike (such as age, drouth, etc.).

3. In a flock consisting of 337 grade Rambouillet ewes, 132 grade Rambouillet wethers, 23 registered Rambouillet ewes, and 12 registered Corriedale ewes, kept at Substation No. 14 in Sutton and Edwards Counties, from the summer of 1917 until the summer of 1923, the differences in the weights of fleeces produced at any one shearing by sheep of the same age and sex were found to be very largely permanent differences, that is to say, due to individuality. The average coefficient of correlation between different fleeces sheared by the same sheep was +.607.

4. Individuality was found to be the cause of the following percentages of the differences in the weights of the fleeces produced by different groups of sheep:

33.5 per cent. for the grade Rambouillet ewes.
38.6 per cent. for the grade Rambouillet wethers.
53.7 per cent. for the registered Rambouillet ewes.
69.2 per cent. for the registered Corriedale ewes.

5. If all sheep which produced less than the average amount of wool the first time they were sheared had been culled out at the time of that shearing the future average fleece weight of that flock would have been raised about two-thirds of a pound per sheep. 16.2 per cent. of the flock would have been culled when they should have been kept, and 15.2 per cent. would have been kept when they should have been culled as shown by fleece weights at a later shearing. However, most of those which would not have been culled correctly, produced less than a pound either more or less than the average and therefore it would not have made much difference whether they were culled or not.

6. Individuality varies in importance in different groups of sheep, being slightly more important with wethers than with ewes, and being much more important in flocks of mixed breeding than in flocks of uniform breeding where the rams have been bought for years with a definite ideal in mind and from only one or two breeders. Culling will be more immediately helpful on a mixed flock than on a very uniform one.

7. No one age is more accurate than another for culling sheep according to their fleece weights except that sheep which have been born in a year of drouth can be more accurately culled at two years of age than as yearlings. In the interest of economy sheep should be culled as young as possible. Therefore it is recommended that culling be done

at the yearling shearing except following a drouth, when it should be postponed a year.

8. One season is as good as another for culling except as noted above for young sheep after a drouth. Fall shearings are about as reliable as twelve-month shearings for culling on the basis of fleece weight.

9. Consecutive shearings are slightly more alike than shearings farther apart, but even shearings four and five years apart show a high degree of correlation.

10. When culling ewes two years old or older, one should be careful to observe whether they are dry or are suckling lambs; otherwise, it is possible that culling on the basis of fleece weights might cause more barren ewes to be retained in the flock.

11. Culling will increase the average weight of fleece for the flock of sheep which is culled and it will also increase the wool-producing qualities of the next generation in so far as the individual differences in the sheep culled are hereditary. There are reasons for thinking that very much of this individuality is inherited.

12. The whole matter of individuality may be summed up in the words: "Once a good sheep—always a good sheep; once a poor sheep—always a poor sheep." There are a few exceptions, of course, but this is much truer than has been generally believed heretofore by the average flockmaster.

13. The wool production of a sheep at one shearing is about as accurate an indication of its future production as one year's milk and fat record is of the future production of a dairy cow, and is as accurate an indication as the first year's egg-production is of a hen's future egg-production.

14. Ewes produce the heaviest fleece at two years of age. Later fleeces are somewhat lighter than the two-year-old, but still heavier than the yearling until old age begins to exert an influence.

15. Wethers produce very much heavier fleeces as two-year-olds than as yearlings but their three-year-old fleeces may be still heavier than their two-year-old ones.

16. Wethers produced heavier fleeces than ewes at every age axcept the yearling in this test.

17. Eight-year-old ewes in the Experiment-Station flock have not yet shown a very decided decrease in wool production due to their age.

18. Abnormal seasons can influence wool production enough to obscure the effects of age.

19. Practical methods of culling according to fleece weight are discussed.

20. Length of staple is an indicator of weight of fleece (within a breed at least) but is only fairly accurate. The longer fleeces tend to be the heaviest.

Bulletin No. 311. September, 1923

THE INFLUENCE OF INDIVIDUALITY, AGE, AND SEASON UPON THE WEIGHTS OF FLEECES PRODUCED BY RANGE SHEEP

BY

JAY L. LUSH
J. M. JONES

PART I

INTRODUCTION.

Immediately after the establishment of the Ranch Experiment Station near Sonora in southwest Texas, with suitable arrangements for special range investigations with sheep and goats as well as cattle, the Texas Station was able to acquire a sufficient number of range-bred Rambouillet ewes to begin a study of several important factors which were thought to have an important bearing on wool and mohair inheritance and production.

Accordingly in 1917 a comprehensive study of wool- and mohair-production problems was begun by the junior author in his special capacity as Animal Husbandman in Charge of Breeding Investigations, assisted by E. M. Peters, Superintendent of the Ranch Station. This was the first opportunity that the Texas Station had to systematically accumulate this needed information.

In 1921 the senior author, a trained Animal Geneticist, was employed on the Station Staff, since which time he has assembled and summarized the shearing data so far available at the Ranch Experiment Station. This Bulletin, which represents the accumulation of six years' shearing records on one phase of wool-production, the effect of age and environment upon the weights of fleeces produced by range sheep, is the first complete bulletin based entirely upon investigations conducted on the Ranch Station, although experiments and observations made there have been used in the preparation of Texas Experiment Station Bulletin No. 297 and Circulars Nos. 27 and 28.

The importance of Texas as a sheep-raising state is shown by the fact that since 1920 Texas has had a larger number of sheep within its borders than any other state.* However, it is not a matter of pride to learn from the same source that there are a large number of states where the average weight of wool produced by each sheep is greater than in Texas. According to the estimates of the United States Department of Agriculture, supplemented by those of the National Association of Woolen Manufacturers, during the last ten years the number of states

*Yearbooks of the U. S. Department of Agriculture.

where the average weight of fleece has been as large or larger than in Texas has been as follows:

Year	Number of states which excelled or equalled Texas
1913	28
1914	30
1915	33
1916	32
1917	21
1918	23
1919	20
1920	21
1921	7
1922	17

Of course, these figures are only estimates and there are certain to be some inaccuracies among them, but they are based upon more facts than any other agency has at its command and are the most reliable estimate which we have and clearly point to the fact that the sheepmen of Texas are not getting as many pounds of wool from each sheep as are the sheepmen of many other states, particularly those of the northern Rocky Mountain and northern Pacific states. According to these

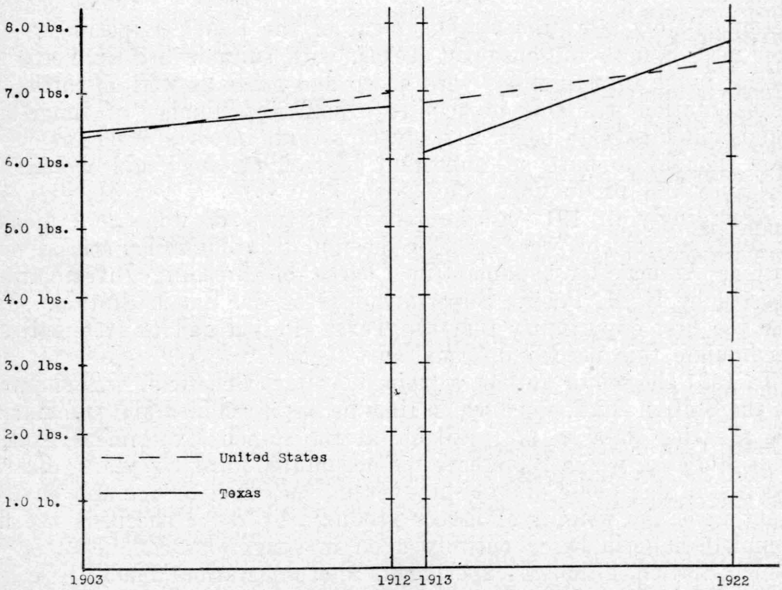

Figure 1. The trend of the average weight of fleece produced in Texas and in the United States during the two ten-year periods from 1903 to 1922, inclusive.

same figures the average weight of fleece in Texas has increased during the course of the last ten years, but there is nothing to indicate that it has increased as fast as was possible.

Figure 1 shows the general trend of the average weight of fleece produced in Texas and also in the entire United States during the last two ten-year periods for which the figures are given in the Yearbooks of the United States Department of Agriculture. The important fact which this figure shows graphically is that the increase in fleece weight which took place at about the same rate during both periods for the United

States as a whole, went on more slowly in Texas in the first period and then grew very rapidly in the second period. The low average fleece weights estimated for Texas in 1914 and 1915 and the high weight estimated for 1921 emphasize the trend for the last ten years in Texas unduly, but even when that is taken into consideration, it is certain that the average fleece weight in Texas has been increasing faster in the last ten years than in the preceding ten years. This improvement coincides with, and is undoubtedly due to the use of improved sires of good breeding, which first began to be a wide-spread general practice among Texas wool-growers from six to twelve years ago. There is still much room for improvement in this respect.

Undoubtedly there are many influences which have an effect upon the weight of the fleece just as it comes from the sheep's back. For the purpose of this study they are divided into two classes: first, those influences which are temporary and may affect a certain sheep this year but not next year, and second, those whose effects are permanent and last throughout the lifetime of the sheep. As examples of the first class there are such things as prolonged rainy weather, which may wash an unusual amount of yolk and foreign matter out of the wool; prolonged dry windy weather which may result in an excess of dirt and sand in the wool; high temperature preceding shearing, which may increase the amount of sweat or yolk in the wool, abundance or scarcity of food, temporary sickness, pregnancy, suckling a lamb, and in fact any condition which can produce a temporary effect upon the growth of wool and not leave a permanent effect upon the individual sheep.

As examples of the second class there are the forces of heredity which are fixed for any one sheep at the moment it is conceived and cannot be changed throughout the rest of its life, and also certain environmental forces which affect the embryo before it is born or the young lamb before it has reached its maturity. The manner in which these environmental forces act is better known for some than for others. Thus it is fairly easy to see how prolonged drouth or the loss of its mother while it was still very young might keep a lamb from attaining its full growth until after it had lost the ability to grow, and thus would cause it to be permanently stunted and too small to produce as heavy a fleece as its hereditary possibilities would have enabled it to produce if it had received the proper nourishment as a lamb. However, the action of some environmental forces is not so clear. For example, color in most animals is very little influenced by feeding or other easily understandable environmental forces and yet it has been shown that variations in the amount of black and white in guinea-pigs is very largely determined by irregularities in embryonic development and other vaguely understood environmental influences.* There is every reason to suppose that the wool-producing ability of a sheep likewise may be partly fixed before it is born by environmental forces, whose action is but dimly understood, and which cannot be effectively controlled until they are better understood.

In the studies reported in this Bulletin it has not been possible to separate clearly from each other the effects of heredity and the permanent effects which environmental forces had produced upon the sheep

*Wright, Sewall, 1920, Proceedings of the National Academy of Sciences, Vol. 6, No. 6, pp. 320-332.

before it was sheared for the first time. These two effects have been grouped together under the term "individuality" and in this Bulletin individuality is defined as the permanent characteristics of a sheep with respect to the amount of wool it can produce, which are almost completely fixed by the time it is first sheared.

Individuality accounts partly for the weight of the fleece,—just how much will be shown later—and temporary environmental forces account for the rest. These environmental forces which affect all of the sheep are grouped together in this Bulletin under the term "season." Season includes such things as the variation from year to year in the amount and kind of grazing, variations in rainfall and temperature in so far as they affect the weight of fleece directly, variations in the date of shearing, etc. To determine accurately the influence of season on the weight of fleece will require much larger numbers of sheep and a study extended over much longer periods than are required to determine the influence of individuality. This Bulletin does not contain a complete statement of the effect of season. It is necessary, however, to refer to the effect of season in discussing the effects of individuality and age and therefore it was thought best to include a statement of the effects of season so far as our data show them at present.

It is known that the age of the sheep has an influence upon the weight of its fleece and therefore the data bearing upon the influence of age are presented, although here, too, many more sheep and more years of study are necessary to find the complete truth.

There are many factors which might cause the wool-production to be increased or decreased temporarily without leaving a permanent effect upon the sheep and which might affect some sheep and not others. Examples of such things are that sheep might be sick during part of the time the fleece is growing, some ewes might be pregnant while others are barren, and a ewe might be pregnant one year and barren the next, a ewe might suckle a lamb one year and be dry the next either through having lost her lamb or not having produced one, etc. These factors have not been studied separately, but taken all together they are discussed in the part dealing with individuality because they and individuality together are responsible for the differences in the weight of wool produced by different sheep of the same age and sex and in the same year.

MATERIAL.

The material on which this study was made consists of the individual weights of all fleeces shorn at Substation No. 14 during the period beginning with the spring of 1918 and ending with the spring of 1923. All sheep were shorn every spring and in addition approximately half of the sheep were shorn in the fall of the years 1920, 1921, and 1922, in connection with a study, which is still being carried on, of the effects of shearing twice each year as compared with those of shearing only once a year. The three fall shearings were made at almost the same time each year, the extreme variations in the date of finishing shearing being October 16 in 1920 and October 23 in 1922. There was a little more variation in the dates of the spring shearings, for which the extreme final dates were April 21 in 1923 and May 19 in 1922. These variations do not affect the evidence on the importance of individuality, but do need to be taken into consideration when the evidence on the influence of age and season is being examined.

The sheep consisted of 12 registered Corriedale ewes, 23 registered Rambouillet ewes, and 95 grade Rambouillet ewes and their descendants, making a total of 504 sheep which were sheared at least twice at the Station. The twelve Corriedales consisted of eight which were purchased and had been born in 1919, and four ewe lambs produced from them in 1921. The twenty-three registered Rambouillet ewes consisted of three, which were born at the Station in 1919, and twenty which were purchased from various sources and were of mixed ages, one of them having been born as early as 1914 and some as late as 1918. The ninety-five grade Rambouillet ewes were of Robert Massie's breeding and were purchased in the summer of 1917, and were larger and of better mutton type and also were better producers of wool than the average flock of that region although they were possibly not the best grade ewes to be found there. They varied from a heavy-shearing B-type to a light-shearing C-type. They were out of a flock which had been established for a good many years and where careful attention has been paid to selecting the rams which were used, and therefore they were fairly uniform in their breeding. About sixty per cent. of them were born in 1915, about thirty per cent. in 1914, and about ten per cent. in 1916; but no exact record was kept for each ewe. The breeding policy for the grade flock was to keep all ewes for breeding purposes, and to sell the wethers at convenient times. Some of the wethers were kept until they were three years old, but most were sold at an earlier age. The sheep were kept under range conditions typical of Southwestern Texas. They received no feed other than natural grazing except during the latter part of the winters following drouths when it was necessary to feed them a small amount of cottonseed cake to keep them healthy and to keep the ewes in good condition for lambing. The registered ewes received slightly more feed before lambing than the grades, but during most of the year they also depended upon the grazing for all of their feed and during all of the year they depended upon grazing for at least part of their feed. They were loose-grazed in so-called "wolf-proof" pastures, no herding being done except for a few weeks during lambing.

PART II

THE EFFECT OF INDIVIDUALITY.

Individuality as used in this Bulletin has been defined as the permanent differences between sheep in their ability to produce a heavy or a light fleece. No one will deny that there are differences in the weights of the fleeces obtained under the same conditions from sheep of the same age and sex and even of similar breeding, but probably not many sheepmen realize how great those differences are. Moreover, the mere fact that these differences exist at one shearing tells us of itself nothing about whether the same differences will exist at the next shearing. That is the fact which is to be determined, namely, whether sheep that shear a heavy fleece at one shearing will be likely to shear a heavy fleece at the next shearing and, if so, what the reasons for it are. If it is so, it will be possible to raise the average weight of the fleeces produced in the future by culling out the poor producers in the present. If it is not so, culling on the basis of fleece weights will do no good and we shall have to look elsewhere for methods of increasing the wool production of a flock. That culling on this basis is a success has been recognized in a practical way by the sheepmen of Australia, New Zealand, and South Africa and is beginning to be recognized by the range sheepmen of this country.

Only one previous scientific study has been made of this question, so far as the authors of this Bulletin are aware. That one is reported in Bulletin No. 127 of the Wyoming Agricultural Experiment Station and, besides the fact that the sheep were raised under different climatic conditions and in a different region and were of somewhat different breeding, it differs from the studies in this Bulletin in two particulars. First, the Wyoming studies were made on the clean or scoured weight, while these studies were made on the grease weight of the fleece just as it was taken from the sheep's back. Second, the Wyoming studies were made on one flock of wethers selected for their uniformity, and kept under feedlot conditions three of the four years, and numbering only twenty-nine head. These studies are based on eight distinct groups of ewes and four distinct groups of wethers, kept under range conditions the entire time. Many of the groups contained smaller numbers than in the Wyoming studies but many of them contained more, the largest number in any one group being eighty-three head.

In view of these differences it is somewhat surprising and highly gratifying to find that the results of this study are completely in agreement with those of the Wyoming study and support the conclusions reached in that bulletin. Moreover, the fact that the two studies are in agreement as far as they go gives us added confidence in the conclusions reached in this Bulletin in regard to a number of points not covered by the Wyoming study.

A preliminary study which is as yet unpublished has been made by the Bureau of Animal Industry of the United States Department of Agriculture and agrees in principle with the results to be given in this Bulletin although the Bureau investigators found that individuality was considerably less important than was found in this study.

Fleece Weights, Spring of 1920

Fleece Weight, Spring of 1919.	6.00	.25	.50	.75	7.00	.25	.50	.75	8.00	.25	.50	.75	9.00	.25	.50	.75	10.00	.25	.50	.75	11.00	.25	.50	.75	12.00	.25	.50	Total
6.25	1																											1
.50																												0
.75									1																			1
7.00		1																										1
.25			1							1																		2
.50									1	1							1											3
.75								1			1		1															3
8.00		1			1								1															3
.25									1		1		2															4
.50									1	1	2		4	2	1					1								12
.75									2						1		1											4
9.00										1	2		2		1	1												7
.25					1	1					2		2	2	1	2							1					12
.50							1			1	1			2			2		1								1	9
.75					1										1	1			2									5
10.00														1		1	2		1									5
.25																	1				3							4
.50																		1	1									2
.75																	1								1			2
11.00																			1									1
.25																	1											1
.50																												0
.75																												0
12.00																							1					1
Total	1	2	1	0	3	1	1	1	6	5	9	0	12	7	5	5	9	1	6	1	3	0	2	0	1	0	1	83

1919:
Average = 9.04 lbs.
Standard Deviation = 1.032 lbs.
Coefficient of Variation = 11.51 %

1920: Average = 9.13 lbs.
Standard Deviation = 1.282 lbs.
Coefficient of Variation = 14.04 %

Coefficient of Correlation = +.655 ± .042

Figure 2. Grade Rambouillet Ewes, Nos. 1–100, most of them born in 1915. Correlation between the weights of the fleeces shorn in the Spring of 1919 and the Spring of 1920.

Fleece Weights, Spring of 1923.

Fleece Weight, Spring of 1918	5.00	.25	.50	.75	6.00	.25	.50	.75	7.00	.25	.50	.75	8.00	.25	.50	.75	9.00	.25	.50	.75	10.00	.25	.50	Totals
6.25			1																					1
.50	2		2																					4
.75																								0
7.00							1																	1
.25					1																			1
.50	1		1	1	1			1	1						1									7
.75			1					1		1														3
8.00		1	1	1	1	1	1			1			1											8
.25						1		1	1			1												4
.50		1					1		1			1												4
.75				1			1																	2
9.00									1	1	2	1	1			1								7
.25									1									1						2
.50												1												1
.75								1		1					1			1						4
10.00			1										1											2
.25													1											1
.50																							1	1
.75														1										1
Totals	3	2	7	3	3	2	4	4	5	4	2	4	4	1	2	1	0	2	0	0	0	0	1	54

1918:
Average = 8.38 lbs.
Standard Deviation= 1.070 lb
Coefficient of Variation = 12.78 %

1923: Average = 6.85 lbs.
Standard Deviation = 1.226 lbs.
Coefficient of Variation = 17.91 %

Coefficient of Correlation = +.657 ± .052

Figure 3. Grade Rambouillet Ewes, Nos. 1–100, most of them born in 1915. Correlation between the weights of the fleeces shorn in the Spring of 1918 and in the Spring of 1923.

Fleece Weights. Spring of 1920.

Fleece Weight, Spring of 1921	11.00	.25	.50	.75	12.00	.25	.50	.75	13.00	.25	.50	.75	14.00	.25	.50	.75	15.00	.25	.50	.75	16.00	.25	.50	.75	17.00	.25	.50	.75	18.00	.25	.50	.75	19.00	.25	.50	.75	20.00	Totals
9.00	1																																					1
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.25																																						0
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.75																																						0
14.00																																						0
.25																																						0
.50																																						0
.75																																						0
15.00																																						0
.25																																						0
.50																																						0
.75																																					1	1
	2	0	0	0	0	0	0	0	1	0	1	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	9

1921:
Average = 11.47 lbs.
Standard Deviation = 1.795 lbs.
Coefficient of Variation = 15.67 %

1920 :
Average = 14.21 lbs.
Standard Deviation = 2.575 lbs.
Coefficient of Variation = 18.12 %

Coefficient of Correlation = + .985 ± .007

Figure 4. Registered Rambouillet Ewes, (including only those which were three years old or older in 1920). Correlation between the weights of the fleeces shorn in the Spring of 1920 and in the Spring of 1921.

Fleece Weight, Long Spring of 1923

Fleece Weight, Spring of 1919	5.75	6.00	.25	.50	.75	7.00	.25	.50	.75	8.00	.25	.50	.75	9.00	.25	Totals
8.25													1			1
.50																0
.75	1							1			1			1	1	5
9.00							1									1
.25				1					1							2
.50									1		2					3
.75											1					1
10.00										1						1
Totals	1	0	0	1	0	0	1	1	2	1	4	0	1	1	1	14

1919 :
Average = 9.13 lbs.
Standard Deviation = .470 lbs
Coefficient of Variation = 5.15 %

1923 :
Average= 7.89 lbs.
Standard Deviation = .905 lbs
Coefficient of Variation = 11.47 %

Coefficient of Correlation = -.074 ± .179

Figure 5. Grade Rambouillet Ewes, Nos. 111–192, born in 1918. Correlation between the weights of the fleeces shorn in the Spring of 1919 and in the long Spring of 1923.

The method of study was to take all the sheep of the same age and sex which were sheared at two different times and rank them in the order of the weight of the fleece which they produced at the first shearing and then see how nearly they would come to ranking in the same order according to the weights of their fleeces at the second shearing. The method of doing this is known to mathematicians as the method of correlation and the number which expresses the result is known as the "coefficient of correlation". The coefficient of correlation is an abstract number which can never be less than minus one or more than plus one. If the two rankings should be exactly the same, the coefficient of correlation would be plus one and we would say that the correlation was perfect. Of course in actual data that never happens because there are too many temporary causes of variation. If the two rankings had no relation to each other the coefficient of correlation would be zero, and we would say that there was no correlation and would know that the sheep which sheared a heavy fleece one time was just as likely as not to shear a light fleece the next time. If the second ranking were exactly opposite to the first the coefficient of correlation would be minus one and we would say that there was perfect negative correlation and we would know that the sheep which sheared a heavy fleece one time was certain to shear a light fleece the next time.

As already stated, correlations in actual practice are never perfect and their importance is judged by their size. For most practical purposes a correlation is of very little importance if its coefficient is less than .30 and is of very great importance if its coefficient is greater than .60. The importance of the correlation increases with the square of its coefficient and therefore the higher coefficients show correlations ever so much more important than the lower ones.

There were 161 different comparisons concerned in this study and of course it is impossible to show within the limits of this Bulletin every one of those correlation tables. However, four correlation tables are shown as samples in Figures 2 to 5. These four correlation tables were selected for the following reasons: Figure 2 shows the table including the largest number of individuals and is a representative table; Figure 3 shows the table which includes the two shearings farthest apart in time and is also a fairly representative table; Figure 4 shows the table which gives the highest of all correlations and is therefore an extreme case and is not truly representative and is based on too small a number of sheep to be regarded as truly important; Figure 5 shows the table which gave the lowest correlation and is also an extreme case and is not truly representative. This last correlation is the only one which came out negative and since it is less than half its "probable error" (see page 18), its being negative is without significance.

Figures 2 and 3 will be used for illustrations in further explaining what correlation tables show. Turning to Figure 2, one will see that the ewe which sheared the lightest fleece in 1919 (6.25 lbs.) also sheared the lightest fleece in 1920 (6. lbs.). However, the ewe which sheared the second lightest fleece in 1919 (6.75 lbs.) did better the next year and there were ten sheep which sheared less and five others which sheared just as much (8.00 lbs.). The ewe which sheared the third lightest fleece in 1919 was tied with one other for second lightest in 1920. Of the two ewes which were tied for fourth lightest fleece in

1919, one was fourth and the other tied four others for seventeenth lightest fleece in 1920. Turning to the other corner of the table, one will see that the ewe which sheared the most in 1919 (12.00 lbs.) was tied with one other for third place in 1920, while the ewe which was second in 1919 was beaten by fifteen ewes and equalled by eight others in 1920. The ewe which was third highest in 1919 was beaten by eight ewes and tied by five others in 1920. Of the two ewes which were tied for fourth heaviest fleece in 1919, one stood second and the other was beaten by fifteen and equalled by eight others in 1920. Thus it will be seen that while the two rankings are not identical there is a strong resemblance between them.

It might be argued in the case of the ewes which sheared light fleeces in both years that perhaps they were slightly crippled, or suffering from some slight but chronic sickness which extended over at least part of both years. Of course, all noticeably crippled or sick or shedding ewes were excluded from these records, but in the hurry and confusion of the shearing pen it is likely that some of the slightly affected ones escaped notice and were recorded as all right. This, then, is a possible explanation of some of the consistently poor producers in Figure 2, but it is not easy to see how it could explain the consistently good producers in the same table.

Moreover, this argument will not apply at all to Figure 3. The poorest producer in 1918 was tied with six others for sixth poorest in 1923. Of the four which were tied for second lightest fleeces in 1918, two were tied with one other ewe for lightest fleece in 1923 and the other two were tied with five others for sixth lightest fleece in 1923. Turning to the other corner of the table we find much the same condition. The ewe which sheared the heaviest fleece in 1918 sheared the seventh heaviest in 1923. The ewe which stood second in 1918 was first in 1923. The ewe which stood third in 1918 was tied with three others for eighth heaviest fleece in 1923. The remarkable thing about it is that these shearings were five years apart. The average weight of the fleece decreased 1.53 lbs. (on account of age, early shearing in 1923, and light shrinkage in 1923, all to be discussed later) and yet the ewes came about as near to keeping their same ranking as they did in the two consecutive shearings of 1919 and 1920 shown in Figure 2. It will be shown later that on the average the consecutive correlations are slightly higher than the non-consecutive ones and therefore that temporary environmental forces which overlap two consecutive wool-growing periods do have an influence, although a slight one, upon the size of the correlation.

It will be noticed in Figure 3 that there are quite a number of ewes represented in the lower left-hand corner of the table although there are almost none in the upper right-hand corner. This means that many of the ewes which did fairly well in 1918 did poorly in 1923, but that almost none of the ewes which did poorly in 1918 did well in 1923. Undoubtedly the explanation for this is that many of the ewes were beginning to show the effects of their age in 1923. It is known that some of them were already showing broken mouths in 1923. The majority of them were eight years old at the last shearing and some of them were nine, which is rather old for range sheep.

Before we leave these illustrations it would be well to explain in as practical a way as possible the meaning and importance of correlation with respect to what would happen if the sheep were to be culled on the basis of their fleece weights at the earlier of the two shearings. It has already been stated that the importance of a coefficient of correlation varies according to the square of the coefficient.* Thus in Figure 2 the coefficient of correlation is +.655, which squared equals .429. This means that in this particular case 42.9 per cent. of *the differences* between individual ewes were the same for both years. If the correlation had been perfect (i. e., +1.000) 100 per cent. of the differences would have been the same for both years and culling on the basis of fleece weights would be without mistakes. If there were no correlation at all and the poorest producing half of the flock were to be culled on the basis of their first shearing record it is likely that just as many would be culled which would be good producers the next year as would be poor producers at the next shearing. In other words culling where no correlation existed would result in about 50 per cent. right selections and 50 per cent. wrong selections, just as a matter of chance. Now the fact of the matter is that there is a correlation, although not a perfect one, and that 42.9 per cent. of the differences are constant. Now if the ewes which sheared less than the average were to be culled, we would be right in somewhat more than 42.9 per cent. of the cases on account of the correlation and in half of the remaining cases just as a matter of chance. Thus theoretically we would be right in slightly more than 71.5 per cent. of the cases ($42.9 + \frac{1}{2} \times 57.1$) and wrong in less than 28.5 per cent. of the cases. Turning to the actual facts in Figure 2 we find that 41 ewes produced less than the average in 1919 and only nine of those produced more than the average in 1920. Of the 42 ewes which produced more than the average in 1919 only 10 produced less than the average in 1920. Thus there would be only 19 mistakes among the 83 head or only 22.9 per cent. mistakes.

Turning to Figure 3, we find that the square of the coefficient of correlation is .432 and we expect to be right in more than 71.6 per cent. of the cases and wrong in less than 28.4 per cent. As a matter of fact we find that of the 29 ewes which produced less wool than the average in 1918 only 7 produced more than the average in 1923, and of the 25 which produced more than the average in 1918 only 6 produced less than the average in 1923. Thus there would have been 13 mistakes among the 53 ewes, or the culling would have been right in 75.9 per cent. of the cases and wrong in 24.1 per cent.

Moreover the mistakes which would have been made would have been small ones. Thus in Figure 2 only one of the nine which would have been culled out mistakenly, afterward beat the average by as much as one pound and only four of the ten which would have been kept mistakenly, afterward produced as much as a pound less than the average. In Figure 3 only two of the seven which would have been culled out mistakenly, afterward beat the average by as much as one pound and only three of the six which would have been kept mistakenly, afterward produced as much as a pound less than the average.

Thus it will be seen that the mistakes made in culling on the basis of fleece weights will be almost entirely among sheep of average merit

*Wright, Sewall, 1921. Journal of Agricultural Research 20: 557–585. "Correlation and Causation."

and that almost all the extremely heavy-shearing sheep will be retained and almost all of those producing light fleeces will be culled out.

In the case of Figure 2, if the ewes which produced fleeces lighter than the average in 1919 had been culled out, the average weight of fleece produced by the flock in 1920 would have been increased from 9.13 lbs. to 9.73 lbs. In the case of Figure 3 culling in 1918 would have raised the average production of the flock in 1923 from 6.85 lbs. to 7.54 lbs. Moreover, this culling would not have to be done more than once in the lifetime of each group of sheep but the increased average production resulting from selling the poor-producers would be obtained every year as long as the sheep were kept. Of course, it is advisable to cull all old sheep as fast as they become broken-mouthed.

The average of all the 161 correlations is +.607 and the square of that is .368. Therefore we would expect to be correct in more than 68.4 per cent. (36.8 + ½ of 63.2) of the cases if we divided the sheep into a poor and a good flock equal in size on the basis of one shearing record and expected each of them to fall into the same two groups at later shearings. If such a division had been made at the time each group was first sheared, there would have been 1493 comparisons of two fleeces from the same sheep. In 512 cases the sheep was in the poorest half both times, in 241 cases the sheep was in the poorest half of the first shearing and in the best half of the second shearing, in 228 cases the sheep was in the best half at the first shearing and in the poorest half at the later shearing, and in 512 cases the sheep was in the best half both times. We would have been correct in 68.6 per cent. of the cases and, as was pointed out above, in very few of the mistaken cases would the mistake have been more than a pound and therefore it would not matter much whether those sheep were culled out or kept. Moreover, half of the mistakes would have been in keeping poor producers and most of these mistakes could be culled out at the next shearing if culling was continued. Altogether it is impossible to escape the conclusion that culling on the basis of fleece weights, would be highly efficient in finding and removing the sheep which consistently produced light fleeces, and in thereby increasing the general average yield of wool in any particular flock.

It is of course impossible to discuss each correlation table separately but in order to show the variation among these correlations and study the possible causes of these variations, a list of the entire 161 coefficients of correlation and their "probable errors",* together with the number of sheep included in each is given in Table 1.

*"Probable error" is a term used by mathematicians to show how likely it is that the same results will be obtained if the experiment is repeated under the same conditions. For example the coefficient of correlation for Figure 2 is +.655±.042. This means that if another 83 ewes of this same age and breeding had had their fleeces weighed during the same two years the coefficient or correlation might not be exactly the same but it would probably not be more than +.655+.042=.697, nor less than +.655—.042=.613. If a coefficient is less than its probable error it might very easily be the result of chance, if it is three times its probable error the odds are about 22 to 1 that it was not an accident, while if it is five times its probable error the odds are more than 1350 to 1 that it is not the result of chance nor an accident. Thus in the example used, five times the probable error is .210 and .655+.210 equals +.865 while .655—.210 equals +.445. Therefore, the odds are more than 1350 to 1 that if the fleece weights had been taken on 83 other similar ewes the same years, the resulting coefficient of correlation would not be less than +.445 or more than +.865 and it would be most likely to be somewhere between +.600 and +.700. Probable error is therefore merely a means of measuring within what limits the facts found in this experiment would repeat themselves if the experiment were repeated.

Table 1.

A List of All Correlations Between Different Fleece Weights.

		Number of sheep included	Coefficient of correlation
Grade Rambouillet Ewes, Number 1–100, born mostly in 1915 but some in 1914 and very few in 1916.			
Long Spring of 1918	with Long Spring of 1919	82	+.714±.036
	with Long Spring of 1920	80	+.482±.058
	with Fall of 1920	37	+.636±.066
	with Short Spring of 1921	36	+.658±.064
	with Long Spring of 1921	35	+.546±.080
	with Fall of 1921	36	+.431±.092
	with Short Spring of 1922	33	+.401±.099
	with Long Spring of 1922	30	+.720±.059
	with Long Spring of 1923	54	+.657±.052
Long Spring of 1919	with Long Spring of 1920	83	+.655±.042
	with Fall of 1920	37	+.688±.058
	with Short Spring of 1921	35	+.772±.046
	with Long Spring of 1921	39	+.569±.073
	with Fall of 1921	40	+.566±.072
	with Short Spring of 1922	36	+.614±.070
	with Long Spring of 1922	29	+.579±.083
	with Long Spring of 1923	57	+.705±.045
Long Spring of 1920	with Fall of 1920	41	+.703±.053
	with Short Spring of 1921	40	+.625±.065
	with Long Spring of 1921	40	+.546±.087
	with Fall of 1921	41	+.532±.076
	with Short Spring of 1922	37	+.400±.093
	with Long Spring of 1922	34	+.621±.071
	with Long Spring of 1923	61	+.611±.054
Fall of 1920	with Short Spring of 1921	39	+.753±.047
	with Long Spring of 1922	33	+.647±.068
	with Long Spring of 1923	32	+.581±.079
Short Spring of 1921	with Long Spring of 1922	34	+.692±.060
	with Long Spring of 1923	30	+.576±.082
Long Spring of 1922	with Long Spring of 1923	29	+.779±.049
Long Spring of 1921	with Fall of 1921	38	+.535±.078
	with Short Spring of 1922	34	+.520±.084
	with Long Spring of 1923	30	+.638±.073
Fall of 1921	with Short Spring of 1922	37	+.485±.085
	with Long Spring of 1923	32	+.679±.064
Short Spring of 1922	with Long Spring of 1923	31	+.728±.057
Average for all 36 correlations of ewes 1–100			+.612±.011
Grade Rambouillet Ewes Nos. 111 to 192, all born in 1918.			
Long Spring of 1919	with Long Spring of 1920	39	+.416±.089
	with Fall of 1920	20	+.600±.097
	with Short Spring of 1921	21	+.483±.113
	with Long Spring of 1921	16	+.255±.158
	with Fall of 1921	15	+.165±.169
	with Short Spring of 1922	14	+.044±.180
	with Long Spring of 1922	20	+.758±.064
	with Fall of 1922	16	+.693±.088
	with Short Spring of 1923	16	+.382±.144
	with Long Spring of 1923	14	—.074±.179
Long Spring of 1920	with Fall of 1920	20	+.793±.056
	with Short Spring of 1921	21	+.597±.095
	with Long Spring of 1921	16	+.490±.128
	with Fall of 1921	15	+.542±.123
	with Short Spring of 1922	14	+.617±.112
	with Long Spring of 1922	20	+.717±.073
	with Fall of 1922	16	+.642±.099
	with Short Spring of 1923	16	+.561±.116
	with Long Spring of 1923	14	+.715±.088
Fall of 1920	with Short Spring of 1921	20	+.573±.101
	with Long Spring of 1922	19	+.738±.055
	with Fall of 1922	15	+.617±.108
	with Short Spring of 1923	15	+.473±.135

Table 1.—Continued.

A List of All Correlations Between Different Fleece Weights.

		Number of Sheep included	Coefficient of correlation
Grade Rambouillet Ewes Nos. 111 to 192, all born in 1918—Continued.			
Short Spring of 1921	with Long Spring of 1922	19	+.776 ±.062
	with Fall of 1922	15	+.568 ±.118
	with Short Spring of 1923	15	+.600 ±.112
Long Spring of 1922	with Fall of 1922	16	+.682 ±.090
	with Short Spring of 1923	16	+.563 ±.115
Fall of 1922	with Short Spring of 1923	16	+.577 ±.113
Long Spring of 1921	with Fall of 1921	14	+.614 ±.112
	with Short Spring of 1922	13	+.808 ±.065
	with Long Spring of 1923	13	+.264 ±.174
Fall of 1921	with Short Spring of 1922	14	+.330 ±.161
	with Long Spring of 1923	12	+.649 ±.113
Short Spring of 1922	with Long Spring of 1923	12	+.505 ±.145
Average for all 35 correlations of ewes 111 to 192			+.535 ±.023
Grade Rambouillet Ewes Nos. 197 to 297, all born in 1919.			
Long Spring of 1920	with Fall of 1920	29	+.771 ±.051
	with Short Spring of 1921	28	+.710 ±.062
	with Long Spring of 1921	28	+.717 ±.062
	with Fall of 1921	27	+.660 ±.073
	with Short Spring of 1922	27	+.459 ±.102
	with Long Spring of 1922	28	+.751 ±.056
	with Fall of 1922	26	+.391 ±.112
	with Short Spring of 1923	26	+.428 ±.108
	with Long Spring of 1923	27	+.618 ±.080
Fall of 1920	with Short Spring of 1921	29	+.677 ±.068
	with Long Spring of 1922	28	+.820 ±.042
	with Fall of 1922	26	+.409 ±.110
	with Short Spring of 1923	26	+.642 ±.078
Short Spring of 1921	with Long Spring of 1922	28	+.735 ±.059
	with Fall of 1922	26	+.463 ±.104
	with Short Spring of 1923	26	+.542 ±.093
Long Spring of 1922	with Fall of 1922	27	+.487 ±.099
	with Short Spring of 1923	27	+.728 ±.061
Fall of 1922	with Short Spring of 1923	27	+.450 ±.104
Long Spring of 1921	with Fall of 1921	26	+.786 ±.052
	with Short Spring of 1922	26	+.632 ±.079
	with Long Spring of 1923	24	+.752 ±.060
Fall of 1921	with Short Spring of 1922	27	+.534 ±.093
	with Long Spring of 1923	25	+.687 ±.071
Short Spring of 1922	with Long Spring of 1923	25	+.632 ±.081
Average for all 25 correlations of ewes 197 to 297			+.619 ±.017
Grade Rambouillet Ewes Nos. 298 to 418, all born in 1920.			
Long Spring of 1921	with Fall of 1921	30	+.491 ±.094
	with Short Spring of 1922	30	+.226 ±.117
	with Long Spring of 1922	33	+.808 ±.041
	with Fall of 1922	31	+.485 ±.093
	with Short Spring of 1923	31	+.710 ±.060
	with Long Spring of 1923	29	+.418 ±.103
Fall of 1921	with Short Spring of 1922	33	+.505 ±.087
	with Long Spring of 1923	30	+.568 ±.083
Short Spring of 1922	with Long Spring of 1923	30	+.626 ±.075
Long Spring of 1922	with Fall of 1922	31	+.755 ±.052
	with Short Spring of 1923	31	+.818 ±.040
Fall of 1922	with Short Spring of 1923	31	+.653 ±.070
Average for all 12 correlations of ewes 298–418			+.589 ±.033

Table 1.—Continued.

A List of All Correlations Between Different Fleece Weights.

	Number of Sheep included	Coefficient of correlation
Grade Rambouillet Ewes, Nos. 420 to 590, all born in 1921.		
Fall of 1921 with Short Spring of 1922	37	+.622±.068
with Long Spring of 1923	36	+.460±.089
Short Spring of 1922 with Long Spring of 1923	36	+.646±.066
Long Spring of 1922 with Fall of 1922	40	+.385±.091
with Short Spring of 1923	39	+.173±.105
Fall of 1922 with Short Spring of 1923	42	+.386±.089
Average of 6 correlations of ewes 420 to 590		+.445±.044
Grade Rambouillet Wethers, born in 1918.		
Long Spring of 1919 with Long Spring of 1920	31	+.570±.082
with Fall of 1921	15	+.275±.161
with Short Spring of 1921	15	+.300±.158
with Long Spring of 1921	13	+.754±.081
Long Spring of 1920 with Fall of 1920	15	+.840±.051
with Short Spring of 1921	15	+.740±.079
with Long Spring of 1921	15	+.915±.028
Fall of 1920 with Short Spring of 1921	15	+.804±.062
Grade Rambouillet Wethers, born in 1919.		
Long Spring of 1920 with Fall of 1920	13	+.695±.097
with Short Spring of 1921	13	+.356±.163
with Long Spring of 1921	13	+.739±.085
Fall of 1920 with Short Spring of 1921	13	+.779±.074
Grade Rambouillet Wethers, born in 1920.		
Long Spring of 1921 with Fall of 1921	10	+.787±.081
with Short Spring of 1922	9	+.897±.044
with Long Spring of 1922	12	+.555±.134
with Fall of 1922	10	+.411±.177
with Short Spring of 1923	10	+.768±.088
with Long Spring of 1923	8	+.568±.162
Fall of 1921 with Short Spring of 1922	10	+.865±.054
with Long Spring of 1923	8	+.795±.088
Short Spring of 1922 with Long Spring of 1923	8	+.660±.135
Long Spring of 1922 with Fall of 1922	10	+.726±.101
with Short Spring of 1923	10	+.643±.125
Fall of 1922 with Short Spring of 1923	10	+.477±.165
Grade Rambouillet Wethers, born in 1921.		
Fall of 1921 with Short Spring of 1922	25	+.498±.102
with Long Spring of 1923	23	+.462±.111
Short Spring of 1922 with Long Spring of 1923	23	+.603±.091
Long Spring of 1922 with Fall of 1922	23	+.550±.098
with Short Spring of 1923	22	+.161±.139
Fall of 1922 with Short Spring of 1923	22	+.430±.112
Average of all 30 correlations involving wethers		+.621±.024

Table 1.—Continued.

A List of All Correlations Between Different Lleece Weights.

	Number of Sheep included	Coefficient of correlation
Registered Rambouillet Ewes (using only fleeces shorn when the ewes were two years old or older). All shearings were long since these ewes were not used in the twice-a-year shearing project.		
1919 with 1920	10	+.724±.101
1921	9	+.718±.109
1922	9	+.534±.161
1923	8	+.319±.219
1920 with 1921	9	+.985±.007
1922	9	+.891±.046
1923	8	+.792±.089
1921 with 1922	15	+.840±.051
1923	13	+.746±.083
1922 with 1923	19	+.782±.060
Average of the 10 correlations involving registered Rambouillet ewes	....	+.733±.038
Registered Corriedale Ewes (using only fleeces shorn when the ewes were two years old or older). All shearings were long, since these ewes were not used in the twice-a-year shearing project.		
1920 with 1921	7	+.800±.092
1922	8	+.644±.140
1923	7	+.764±.106
1921 with 1922	7	+.849±.071
1923	7	+.948±.026
1922 with 1923	7	+.856±.068
Registered Corriedale Ewes, born in 1921.		
1922 with 1923	4	+.962±.025
Average of 7 correlations involving registered Corriedale ewes	....	+.832±.026

SUMMARY.

	No. of different sheep involved	Average of the coefficients of correlation
Correlations involving grade Rambouillet ewes, 114 tables	337	+.579±.010
Correlations involving grade Rambouillet wethers, 30 tables	132	+.621±.024
Correlations involving registered Rambouillet ewes, 10 tables	23	+.733±.038
Correlations involving registered Corriedale ewes, 7 tables	12	+.832±.026
All correlations, 161 tables	504	+.607±.009

(The term "Short Spring," as herein used signifies a shearing following a fall shearing. Such shearings represent approximately six and one-half months growth of wool instead of the twelve months growth meant by "Long Spring.")

It will be seen from glancing at Table 1 that there is a great variation in the amount of correlation. It is therefore necessary to examine these figures more carefully to determine whether this variation is accidental, or whether certain groups of sheep, certain ages or certain seasons are characterized by higher correlations than others. Among all the correlations only one is negative, and it and two other small positive correlations are the only ones which are less than their probable errors. Thirteen correlations are larger than their probable errors but less than three times as large and therefore we cannot be sure that they are not accidental. Thirty correlations are more than three times but less than five times their probable errors and we can be reasonably certain that they surely indicate a positive correlation which would be found if the experiment were repeated. Finally, one hundred and fifteen correlations are more than five times their probable errors and compel us to believe beyond any reasonable doubt that the weight of fleece produced by a sheep is to a large extent a constant character throughout that sheep's life.

INDIVIDUALITY IN DIFFERENT GROUPS.

In the search for the causes of the wide variations shown in the correlations one of the most obvious facts is that there is a difference between different groups of sheep. Thus the correlations are remarkably high both in the case of the registered Corriedale ewes and in the case of the registered Rambouillet ewes. There are two reasons for this: First, the registered ewes were all at least two years old when the first shearing used in this test was made and therefore no yearling correlations enter into their averages. The yearling correlations are somewhat lower than the other, as will be shown later. Second, and probably most important, there is probably more hereditary variation among these particular registered sheep than among these grades. The reason for thinking that this is the explanation of the high correlation shown by the Corriedales is that they represent a breed of recent origin which as a whole has not had enough generations of selective breeding to make it as uniform hereditarily as the older breeds. However, in view of the small number of Corriedales used in this study it is not safe to draw any general conclusions from it in regard to this breed as a whole. The reason for thinking it of the registered Rambouillets is that they were purchased from different flocks and therefore represent different bloodlines. Also they were selected with the idea of securing representatives of both the B and C types of Rambouillets.

Among the different groups of grades the ewes born in 1921 show significantly lower correlations than the others and the ewes born in 1918 show correlations (especially those involving their first fleeces) which are significantly lower than most of the others. The only thing which these two groups of ewes have in common that the other three groups do not, is that they were born in years of severe drouth and were somewhat stunted, those born in 1921 being decidedly stunted. The data on the wethers also show that the correlations involving those born in 1921 are very much below the average for the others, and show very low correlations for those born in 1918 where their first fleece is involved, although their correlations involving later fleeces are very high. This almost perfect agreement between the wethers and ewes born in 1918, and between the wethers and ewes born in 1921, and between the 1921 and 1918 sheep, when only the correlations involving the first fleeces of the latter are considered, lead us clearly to the conclusion that the first shearing of lambs which have been born, suckled, and weaned in a period of severe drouth is not nearly as reliable an index of their wool-producing ability as are the later shearings. Since the drouth cannot have helped to make the poor-producers better, it must have worked by preventing the better-producers from developing at an early age to the limits of their individual abilities. In other words the drouths of 1918 and 1921 and resultant poor grazing have tended to hold all the lambs down to a dead level of mediocre production. The drouths did not succeed completely in doing this but they did hurt the good producers proportionately more than the poor producers, as is shown by the correlations which are still positive but are lower than for similar lambs born and reared in years of good grazing. Whether the stunted lambs remain permanently stunted or recover completely during their second and third years is not shown by these figures but they do show that the good individuals recover most or all of their natural advantage over the poor individuals because correlations involving only shearings later than the first are very much higher than those involving the first shearings. The practical consequence of this is that lambs reared during a drouth should not be culled on the basis of their first-fleece weights or at least should not be culled as severely as lambs reared under conditions of abundant grazing.

There is no exact way of correcting for the drouthy conditions under which these 1918 and 1921 lambs were reared but when the effects of these conditions are taken into consideration there seem to be no significant differences in the importance of individuality among any of the groups of grades unless it be that individuality is a little more important among the wethers than among the ewes.

INDIVIDUALITY AT DIFFERENT AGES.

It is very important to know whether permanent differences are more easily or surely distinguished at one age than at another, because if that is true all culling can be practiced on sheep as they reach that age with more accurate results than if done earlier or later. To find out whether there is any such influence of age, Table 2 was prepared. In it the correlations are sorted out according to the age of the sheep involved and those pertaining to sheep of the same age are all averaged together. This means that each correlation table is counted in two different places because, of course, it refers to the same sheep at two different ages. However, since each one is counted twice and only twice, none of the correlations are unduly emphasized by this method. The registered ewes were not included in this table because their correlations were higher and they were not sheared in the fall. Therefore, it would not be fair to compare a spring shearing in which their correlations were involved with a fall shearing in which they were not involved.

Table 2.

The Influence of Age Upon the Amount of Correlation.

Sheep Included	Age in Years							
	½	1	1½	2	2½	3	3½	4
All grades	.511 ±.022	.515 ±.022	.621 ±.026	.622 ±.017	.626 ±.021	.615 ±.015	.450 ±.028	.617 ±.019
Ewes 1–100						.583		.651
Ewes 111–192		.372		.609	.632	.548	.460	.594
Ewes 197–297		.612	.664	.668	.667	.642	.440	.609
Ewes 298–418		.523	.521	.623	.631	.632		
Ewes 420–590	.541	.457	.386	.457				
Wethers	.480	.558	.700	.644	.589	.657		

Table 2.—Continued.

The Influence of Age Upon the Amount of Correlation.

Sheep Included	Age in Years							
	4½	5	5½	6	6½	7	7½	8
All grades	.630 ±.010	.520 ±.026	.668 ±.015	.619 ±.016	.538 ±.021	.599 ±.023		.662 ±.014
Ewes 1–100		.575	.668	.619	.538	.599		.662
Ewes 111–192	.630	.474						

It appears from Table 2 that four and possibly five of the fifteen ages given show significantly lower correlations than the others. Those are the six-months shearings, the yearling shearings, the shearing at three and one-half years, the shearing at five years, and possibly the shearing at six and one-half years, which is significantly lower than the highest of the other ages but not significantly lower than some of the other ages showing high correlations.

The low correlations shown by six-months and by yearling fleeces are due to two reasons. First and most important are the drouths of 1918 and 1921, which affected ewes 111 to 192 and 420 to 590 and the wethers born the same years. All of the six-months lamb shearings were made in the fall of 1921 but the yearling shearings also included the shearings of ewes 197 to 297, and 298 to 418, and wethers of the same ages which did not suffer the drouths. If due allowance is made for the effects of the drouths it does not seem that the correlations for these two ages would be significantly lower than for other ages. There is a reason, however, why we might expect the first shearing to be a less reliable indicator of the wool-producing ability of a sheep than other shearings. That is the fact that the lambs are not all the same age and therefore a good producer dropped late in the season might not show up as well at the first shearing as the poor producer born early in the season, simply because the late-dropped lamb has not had as many days in which to grow its fleece. The fact that the first shearings show up almost as well as the later ones when due allowance is made for the effects of drouthy years is very encouraging for the practice of culling on the basis of fleece weights because any system of culling which is to be very effective should be carried out when the animals are as young as practical. In the Experiment-Station flock there was not much difference in the ages of the earliest and latest born lambs each year. Our recommendation therefore would be to cull at the yearling shearing except when following periods of extreme drouth, in which case heavy culling should be postponed until the year-and-a-half or two-year-old shearing. We do not know of any satisfactory reason why the correlation at the three-and-one-half-, five-, and six-and-one-half-year ages should have been so low. Until we have many more records covering many other sheep in other years we must decide tentatively that no definite age after one year old is better than any other as an indicator of the wool-producing ability of a sheep. The fall shearings are almost or quite as reliable as the spring shearings. However, to the man not using the scales, differences in the weight of the twelve-month fleece would be much more evident than in the short fleeces.

THE EFFECT OF SEASON UPON INDIVIDUALITY.

It is theoretically possible that drouth or other unusual seasonal influence might affect the good-producers more than the poor-producers or vice versa and therefore that culling might be more successful if practiced in good than in poor years. To determine whether this is so the correlations were classified by years and the result is shown in Table 3. Here, also, each correlation is counted in two different seasons since each correlation concerns two different shearings. The correlations for the registered ewes are shown but are not included among the averages because they are not represented among the fall and short spring shearings.

Table 3.

The Influence of the Season on the Size of the Correlation.

Sheep Involved	Long Spring of 1918	Long Spring of 1919	Long Spring of 1920	Fall of 1920	Short Spring of 1921	Long Spring of 1921
All grades	.583 ± .026	.499 ± .033	.618 ± .015	.660 ± .020	.626 ± .019	.607 ± .022
Ewes 1–100	.583	.651	.575	.668	.679	.559
Ewes 111—192	....	.372	.609	.632	.600	.486
Ewes 197–297	....	....	.612	.664	.625	.722
Ewes 298–418	....	....	....	....	....	.523
Ewes 420–590	....	....	....	....	....	....
Wethers	....	.475	.694	.679	.596	.714
Registered Rambouillet ewes	....	.574	.848	....	....	.822
Registered Corriedale ewes	....	....	.736	....	....	.866

Table 3—Continued.

The Influence of the Season on the Size of the Correlation.

Sheep Involved	Fall of 1921	Short Spring of 1922	Long Spring of 1922	Fall of 1922	Short Spring of 1923	Long Spring of 1923
All grades	.570 ± .020	.554 ± .025	.643 ± .022	.535 ± .017	.532 ± .025	.590 ± .022
Ewes 1–100	.538	.525	.673	....	....	.662
Ewes 111–192	.460	.461	.706	.630	.526	.412
Ewes 197–297	.667	.564	.704	.440	.558	.672
Ewes 298–418	.521	.452	.794	.631	.727	.537
Ewes 420–590	.541	.634	.279	.386	.280	.553
Wethers	.681	.705	.527	.515	.496	.618
Registered Rambouillet ewes	....	....	.762	....	....	.660
Registered Corriedale ewes	....	....	.828	....	....	.883

It is certain from the evidence of this table that season has very little influence upon the size of the correlation and possibly it has none at all except on the young lambs in time of drouth. There is some indication that the correlation is highest when wool production is highest. Thus the correlations are high for the mature sheep in 1919 and for nearly all the sheep in 1920 and for the spring shearing of 1921, which followed years of abundant grazing. However, the correlations are also high for all except the young sheep in the long spring shearing of 1922, which followed a year of drouth and in which the weight of fleece was less than normal.

Hence, this study points to the conclusion that the amount of correlations is almost or quite independent of seasonal influences, being possibly a little higher in years when the average weight of fleece is high. In other words, there is a possibility that unfavorable conditions may hurt the good-producing sheep proportionately a little more than they do the poor-producing ones, but in general their fleece weights decrease proportionately in bad years and increase proportionately in good years.

So far as seasonal conditions are concerned one year is as good as another for culling except, as already stated, in the case of immature sheep reared under conditions of drouth.

THE PERMANENCE OF INDIVIDUALITY.

Individuality was defined as the permanent characteristics of one sheep, which were different from those of other sheep of the same age, sex, and treatment. However, it might be argued that it is quite possible that some of these differences in wool-producing ability might last over the period of two or three shearings but not last through all the life of a sheep. Thus some sheep might gradually get worse while others improved as wool-producers or a minor ailment might last over at least part of two wool-growing periods, although no sheep were included in these studies which were noticed to be sick or crippled.

To answer this important question the correlations were divided according to whether the shearings concerned in each were consecutive shearings or whether there were one or more shearings in between the two shearings concerned in the correlation table. The results are given in Table 4.

Table 4. The Effect of the Length of Time Between Shearings Upon the Size of the Correlation.

Sheep involved	Consecutive shearings	Shearings separated by one other shearing	Shearings separated by two other shearings	Shearings separated by three other shearings	Shearings separated by four other shearings	Shearings separated by five other shearings
All	.661 ±.013	.598 ±.018	.571 ±.020	.535 ±.033	.491 ±.066	.520 ±.066
Grade ewes 1–100	.659	.591	.595	.579	.609	.657
Grade ewes 111–192	.576	.591	.495	.526	.393	.382
Grade ewes 197–297	.643	.671	.483	.550	.428	....
Grade ewes 298–418	.640	.524	.564	....	....	....
Grade ewes 420–590	.510	.317	....	....	....	....
Wethers	.676	.549	.545	....	....	....
Registered Rambouillet ewes	.833	.785	.663	.319	....	....
Registered Corriedale ewes	.867	.796	.764	....	....	....
Number of correlation tables included	64	46	28	14	7	2

The average correlations are given by groups to show that the general trend of the average for all groups is not unduly influenced by any one group. It will be seen that the only significant difference is that between the consecutive shearings and the others. Even this difference is so small that its significance might be doubted were it not for the fact that this same difference is found in all the groups of sheep and in every comparison except between consecutive shearings and shearings separated by one other shearing in the case of grade ewes, Nos. 111 to 192 and Nos. 197 to 297.

These figures compel the conclusion that only a very small part of the correlation between the weights of fleeces of the same sheep in different years is caused by the common ailments, pregnancy, the suckling of a lamb, or other temporary conditions affecting some of the individuals and lasting through at least part of two consecutive wool-growing periods.

Using the average figures found for all the sheep included in this study, we find that the differences in the weights of the fleeces shorn at one shearing will be permanent* to the following extent in subsequent shearings:

The next shearing	43.7 per cent.
The second shearing	35.8 per cent.
The third shearing	32.6 per cent.
The fourth shearing	28.6 per cent.
The fifth shearing	24.1 per cent.
The sixth shearing	27.0 per cent.

The differences between the last five figures are so small and the number of correlations on which they are based is so small that it is uncertain whether the differences between them are really significant, but it is reasonably certain that the first figure is significantly higher than the others and will probably be found to be higher in future studies made on similar sheep. The registered ewes are not represented at all in the correlations involving shearings separated by four and five other shearings and are only represented by one correlation involving two shearings separated by three other shearings. The absence of the high correlations of the registered sheep from the last three figures given above undoubtedly is one reason why they are lower than the second and third figures and is further evidence that the differences between the last five figures are all probably insignificant.

THE EFFECT OF BARRENNESS.

The objection has been raised that the high correlation found in this study may be due to the fact that some ewes are permanently barren and therefore produce heavy fleeces while others raise a lamb every year and therefore produce lighter fleeces. This objection is not well founded because the records show that there was little or no permanent barrenness and very little temporary barrenness among the ewes of the Experment-Station flock. The effect of pregnancy and of suckling a lamb upon the weight of fleece, has never, so far as the authors are aware,

*The square of the coefficient of correlation gives the degree of "determination."

been determined exactly. However, it probably does have some influence and, if that influence is very great, culling a band of breeding ewes two years old or older on the basis of fleece weights would cause an unusually large proportion of barren ewes to be retained if no attention were paid to this point. It is believed that the proportion of permanently barren ewes in Texas range flocks is so small that it is of very little practical importance.

That these high correlations are not due to this cause, however, is shown by the fact that the wethers show a slightly higher correlation than the grade ewes. In fact, ewes which have a lamb some years and are barren other years undoubtedly do more to lower the correlation than the permanently barren ewes and the consistent breeders do to raise it. If these studies were confined to the permanently barren ewes or to the consistent breeders, the importance of the individuality would appear to be even greater than it does with the present figures.

Practically, this whole matter of barrenness would have no bearing on culling practiced before the sheep were two years old, but when ewes two years old or older are being culled dry ewes should be required to produce a heavier fleece than ewes with lambs at foot. Probably barrenness would not make as much difference with the two-year-old ewes as with older ones because two-year-old ewes with lambs would differ from dry ewes of the same age only in the matter of having been pregnant the preceding fall and winter and having suckled a lamb for a very few weeks before shearing, whereas with older ewes there would also be a difference in that the barren ones had not suckled a lamb all through the preceding season.

INDIVIDUALITY AND HEREDITY.

Thus far it has been shown clearly in this Bulletin that there are differences in the weights of the fleeces produced by similar sheep of the same age and sex in the same season and that these differences are, to a large extent, permanent throughout the life of a sheep. On account of this fact culling on the basis of fleece weights has been recommended as a means of increasing the average weight of fleece produced by a flock. There is no doubt that it will accomplish that purpose.

The question still remains, however, as to whether and to what extent these individual differences are inherited. As was stated in the introduction, individuality is the combined result of the forces of heredity and environmental forces which produce permanent effects. We have no convincing evidence which will prove to us that the effects of environmental forces are ever inherited. Hence, we must depend entirely upon selecting the results of hereditary forces if we are to produce better and better sheep with each succeeding generation. Therefore, it becomes highly important that we know how much of individuality in this matter of fleece weights is due to heredity and how much due to environment. If it is all due to environment, culling will be successful in raising the average fleece weight of the sheep on which it is practiced but will not increase the average fleece weight of the next generation. If part of it is due to heredity, culling will increase the average fleece weight of the next generation of lambs also.

We do not have conclusive proof to present here of just how important heredity is in the individual differences in the Experiment-Station flock but we do have several indications which make us think that it is very important and enough is known about heredity to indicate the conditions under which it may be more important or less important in privately-owned flocks than in the Experiment Station flock.

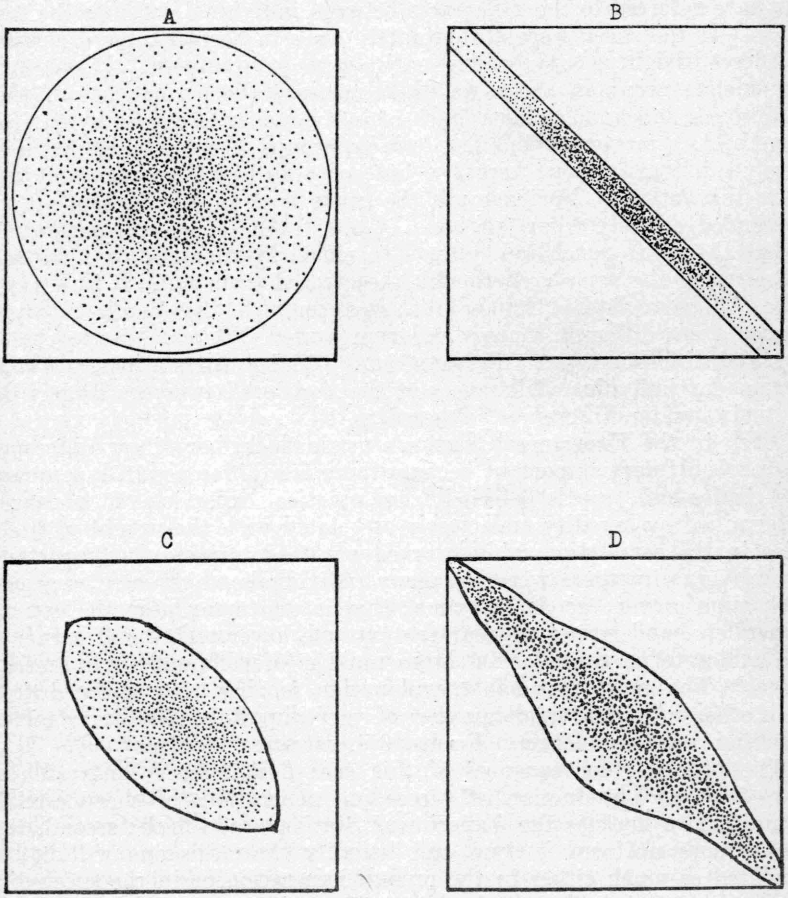

Figure 6. Theoretical and actual forms in which data may be grouped in correlation tables. (Solid lines limit the main area in which the data are distributed.)
A. Theoretical grouping when there is no correlation.
B. Theoretical grouping when there is perfect positive correlation.
C. Theoretical grouping when there is a strong positive, but not perfect, correlation due to a large number of common causes acting independently of each other.
D. A diagram of the type of grouping actually found in many of the correlation tables discussed in this Bulletin. Presumably caused by a few, very important hereditary factors possessed by some but not all of the sheep in each group.

Of course, at bottom, all wool-production depends upon heredity. More properly speaking, a sheep inherits the ability to produce a certain amount of wool. Whether it actually does produce the full amount, almost that much, or much less, will depend upon environmental influences. Some characters, such as color and the presence of horns, cannot be influenced very much by environment. Others, such as body size and the amount of fat carried can be very strongly influenced by environment. Probably wool-production occupies an intermediate position, being very largely determined by heredity but subject to a very little permanent modification and considerable temporary modification by environment.

It should be kept clearly in mind that the facts and discussions so far have referred to the *differences* between individual sheep in the same flock. If the sheep were all absolutely *alike* in heredity, the differences in fleece weight would be due entirely to environment. If we could get such a group of sheep we could measure the permanence of their differences and find out how much of individuality is caused by environment. As a matter of fact there are no groups of sheep which are absolutely uniform in their heredity, but some flocks are more nearly uniform than others. For example, the grade flock in this experiment was descended entirely from one band of ewes even for several generations before they were purchased by the Experiment Station and care was used in selecting the rams even though they varied from light B to heavy C types. The registered Rambouillet ewes, on the other hand, were purchased from different sources and represented different lines of breeding and different types. Presumably the higher correlations and more permanent individual differences of the registered ewes are largely due to their greater differences in heredity.

Even in the Experiment Station's grade flock, hereditary differences are probably very important because there is a difference in type among the grades and type is believed from practical experience to be largely determined by heredity and closely associated with the weight of fleece. Also in the correlation tables worked out to determine the importance of individuality there were too many individuals which were very poor each time or very good each time; that is, too many near the extreme upper left-hand corner or near the extreme lower right-hand corner of the tables to be caused by a large number of different environmental forces. The most reasonable explanation is that they differed from each other in a very small number of very important hereditary factors affecting wool-production. Figure 6 illustrates this point.

The practical consequences of this are: first, that culling will improve the wool-production of succeeding generations of sheep even in as uniform a flock as the Experiment Station grade flock; second, that flocks more uniform in type and heredity than this one will not be benefited as much either in the present generation or in the succeeding generations; third, that flocks less uniform in type and breeding than this one will be benefited more by culling, both in the increased production of the present generation and in the increased production of succeeding generations. Therefore the hereditary benefits to be derived from culling are going to depend entirely, and the present benefits will depend somewhat on the amount of hereditary variation in wool-production in the flock which is to be culled.

CULLING FOR WOOL AS COMPARED WITH CULLING FOR BUTTERFAT AND EGG PRODUCTION.

Culling dairy cows on the basis of their record for one year or even on the basis of their record for seven-day or thirty-day periods has been advocated for many years and has fully justified itself when put in practice. Hence it is interesting to compare the reliability of culling dairy cattle on the basis of their milk production with the reliability of culling sheep on the basis of their wool production. The correlation between different advanced registry records for 365 days made by the same cows has been found† to be +.692 for the Guernsey breed and +.667 for the Holstein breed, and +.535 for records made by a single large Jersey herd extending over a period of more than twenty years. When these correlations are compared with the +.579 obtained for all the grade Rambouillet ewes in this study it will be seen that the weight of the fleece of a sheep at a single shearing is practically as reliable an index for culling that sheep as is an entire year's milk record for culling a dairy cow. Probably it is even more reliable because advanced registry records are selected data,—i. e., cows have had to produce at least as much as the minimum entrance requirements two different times in order to be included in that study. Moreover, nearly every cow was under the care of the same owner during both tests but different owners gave widely different care, whereas this flock of grade Rambouillet ewes was under the same care all the time. The comparison with the large Jersey herd is fairer for both these reasons but even it has an advantage over the sheep records in that some ewes would occasionally lose their lambs and therefore would not be giving milk during part of the time they were growing wool. The records of the cows are of course not complicated by an irregularity of this kind except the number of days they were carrying a calf. Therefore, it is no exaggeration to say that culling for wool-production can be fully as successful as culling for milk-production has been.

Culling hens on the basis of their trapnest records and on the basis of certain body characteristics has also been recommended very widely. The first-year and second-year egg-production records of white leghorn hens have been found* to show a correlation of between +.539 and +.554. The body characters which show the largest correlation with egg-production are the color of shanks and beak (in the light colored breeds)**. Color of shanks has shown a correlation of +.622, the lighter color indicating the larger egg-production, and color of beak has shown a correlation of +.603. Other characters have shown smaller correlations. Hence it will be seen that the fleece weight at one shearing is as reliable an index for future wool-production as the egg-production for one year is for future egg-production or as any external body character is for egg-production.

†Gowen, John W. and Marie S., 1922. Annual Report of the Maine Agricultural Experiment Station, page 33.

*Harris, J. Arthur and Lewis, H. R., 1922. Genetics, Vol. 7, pages 274–318.

**Sherwood, R. M., 1922. Texas Agricultural Experiment Station, Bulletin 295. Correlation between External Body Characters and Annual Egg-Production in White Leghorn Fowls.

PART III

THE INFLUENCE OF AGE AND SEASON ON THE WEIGHT OF FLEECE.

It was possible to study individuality without taking either the effects of age or season into consideration, merely by using in any one correlation table only sheep of the same age and sex which were sheared the same two seasons. It is not, however, possible to study the effects of age and season separately. This is obviously true because if shearing records of the same sheep at different ages are used they will also be influenced by differences in season while if we compare sheep of different ages the same year their individual wool-producing abilities may be different. It is possible, however, to study the combined influence of age and season, and if the study is carried on with enough sheep over a great many years, accurate knowledge can be secured of the exact effect of age and seasonal changes. The facts reported in this Bulletin are not sufficient to answer all the questions about the effect of age and season on fleece weight, but they tell something about it and, as such, are worth presenting.

It is a matter of common knowledge among wool-growers that the average weight of fleece changes with age and is different in different years, but, so far as the authors know, there has been published only one study of the amount of these changes*. In that study the conclusion was drawn that the lightest fleece was the yearling fleece and the heaviest was that shorn at three years of age. However, it was observed that in some crosses the second fleece was the heaviest, and it could only be said of one age that its fleece was surely either smaller or larger than the others. That was the yearling fleece which was significantly smaller than the others in almost every comparison. The sheep used in the Arizona study were Hampshire, Shropshire, Tunis, native and various crosses between them.

It does not necessarily follow that the Rambouillet will behave in the same way with respect to age as the four kinds of sheep named above. Moreover, the grade Rambouillets in this study were bred under different conditions and the records were taken in different years from those in the Arizona study. It will be found that these results disagree with the Arizona results chiefly in that the three-year-old shearing is not the heaviest, except in the case of the wethers, and that later mature shearings can be even lighter than the yearling shearings in very unfavorable years.

The combined influence of age and season upon the weight of fleece produced by the different groups of grade Rambouillets in the Experiment Station flock is shown in Tables 5 and 6 and Figures 7 and 8.

*Arizona Agricultural Experiment Station, Twenty-seventh Annual Report, 1916, pp. 281–283.

Table 5.

The Influence of Age and Season on the Weight of Twelve-month Fleeces.
(Expressed in Percentage of the Yearling Fleece Weight.)

Kind of Sheep	1918	1919	1920	1921	1922	1923
Ewes 1–100	*100.0	109.3	111.7	101.9	92.3	81.7
Ewes 111–192		100.0	116.8	104.9	101.4	86.4
Ewes 197–297			100.0	117.8	100.6	86.1
Ewes 298–418				100.0	99.9	86.2
Ewes 420–590					100.0	**94.5
Wethers born in 1918		100.0	127.2	141.4		
Wethers born in 1919			100.0	134.0		
Wethers born in 1920				100.0	132.2	116.6
Wethers born in 1921					100.0	**127.5

*Most of these ewes were three years old at this shearing. They were not purchased until the summer of 1917, when most of them were two years old but some of them were three and a very few were only one. Therefore, 100% represents about a three-year-old fleece in this case instead of a yearling fleece as in all other cases.

**Comparison between different individuals, since yearling and two-year-old twelve-months fleeces were not taken from the same individuals. These sheep were divided in the fall of 1921 into two equal groups for alternate once-a-year and twice-a-year shearings. The division was made by running them through a cutting chute and taking alternate individuals for the two lots. Therefore, the division was probably as nearly equal as it was possible to make it

Table 6.

The Influence of Age and Season on the Weight of Short Fleeces.
(Expressed in Percentage of the Yearling Fleece Weights.)

Kind of Sheep	Fall, 1920	Spring, 1921	Fall, 1921	Spring, 1922	Fall, 1922	Spring, 1923
Ewes 1–100, born mostly in 1915	55.1	58.9	45.4	60.3		
Ewes 111–192, born in 1918	55.0	64.9	47.4	58.2	40.2	49.1
Ewes 197–297, born in 1919	60.7	65.4	49.1	61.4	42.7	48.7
Ewes 298–418, born in 1920			52.4	57.2	44.1	50.2
Ewes 420–590, born in 1921					48.3	59.3
Wethers born in 1918	67.8	84.2				
Wethers born in 1919	68.5	82.6				
Wethers born in 1920			64.1	79.1	59.5	75.2
Wethers born in 1921					58.6	80.1

(Fleeces of ewes 1–100 expressed in percentage of the three-year-old fleeces, since the yearling fleece weights were not available.)

Table No. 6 shows that the fleece weights were rather light in the fall of 1921 and spring of 1922 and very light in the fall of 1922 and spring of 1923. This agrees very well with Table No. 5. Table No. 6 also shows that the spring fleeces were distinctly heavier than the fall fleeces. The fall of 1920 and fall of 1921 clips include about five and one-half months' wool in each, the fall of 1922 includes about five months', the spring of 1921 includes six and one-half months', the spring of 1922 includes seven months', and the spring of 1923 includes only six months' growth of wool. A comparison of Tables 5 and 6 will show that the combined weight of the two short clips is slightly greater than that of the single long clip, usually between five and ten per cent. greater. This twice-a-year shearing experiment is not yet completed, however, and there are many other things besides the weight of the wool to be considered. These other things will be discussed in detail in the bulletin which will be published when the experiment is completed. Therefore no further comment will be made on this subject at this time except to say that the results so far are not very favorable to the practice of shearing twice a year.

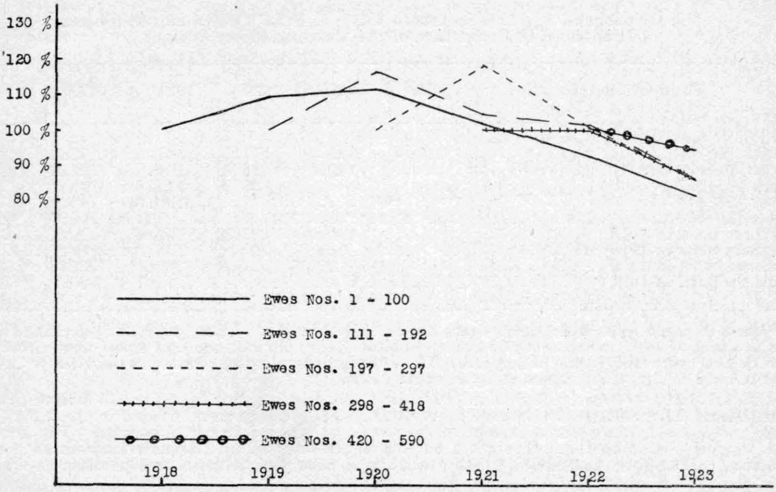

Figure 7. The Influence of Age and Season on the Weight of Twelve-month Fleeces Produced by Grade Rambouillet Ewes.
The weight of the first fleece is taken as one hundred per cent and later fleeces are compared directly with the first one. The first one is the yearling fleece in every case except with ewes Nos. 1–100, most of which were three years old in 1918. The figure shows graphically that the two-year-old fleece tends to be the heaviest but that the influence of season is greater than that of age. (The data are taken from Table No. 5.)

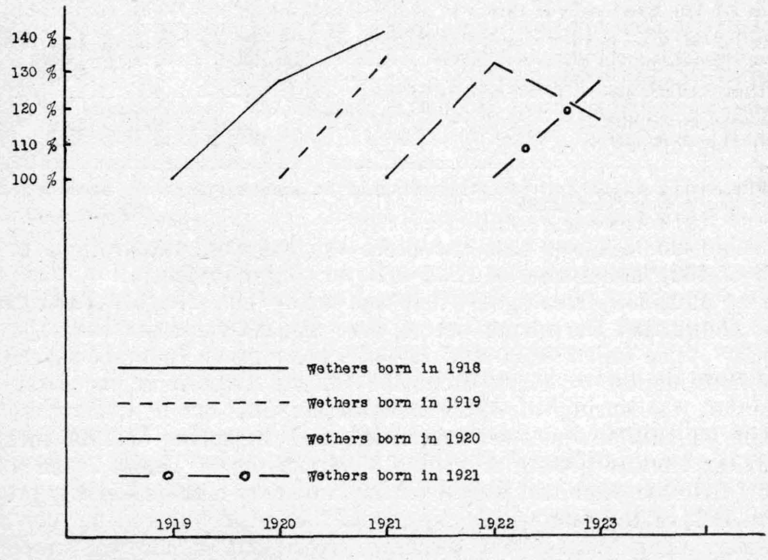

Figure 8. The Influence of Age and Season on the Weight of Twelve-month Fleeces Produced by Grade Rambouillet Wethers.
The weight of the first fleece is taken as one hundred per cent and later fleeces are compared directly with the first one. The first one is the yearling fleece in every case. The figure shows graphically that the two-year-old fleece is very much heavier than the yearling fleece. Probably in most normal years the older fleeces are still heavier than the two-year-old fleece. Seasonal influences do not affect the wool-production of the wethers as much as they do that of the ewes.

In order to eliminate the differences in individuality the average weight of the first fleeces shorn was taken as one hundred per cent. and later fleece weights were compared with this first weight. This first fleece weight was the yearling weight in every case except for grade ewes 1-100, for which the yearling fleece weight was not known, since the most of them were three years old when they were first sheared as Experiment Station property.

The comparison is between the same individuals in every case. Thus, with ewes 111-192 there were 39 head which were sheared both in the spring of 1919 and the spring of 1920 and the comparison between those years is based on the average fleece weights of the entire 39 head. In the spring of 1921, however, only 16 of the 39 head produced full year's fleeces (most of the others having been sheared in the fall of 1920 as part of the experiment on shearing twice-a-year, and a few having died) and therefore the average fleece weight of these 16 sheep in the spring of 1921 is compared directly with the average fleece weight of the same 16 sheep in 1919 instead of with the average of the entire 39 in 1919. In this way differences due to individuality are eliminated and it makes no difference whether the sheep which died during the period covered by these records were the best or the poorest. There is an exception to this in the case of the lambs born in 1921, for half of them were sheared as fall lambs and hence they have never yet all produced a full year's fleece at the same time. If these lambs were fairly divided the first fall, the comparison is all right; but if one group happened to get better individuals than the other, the comparison is not so reliable. Since the division was as fair as was possible in the judgment of the men dividing them and there were 22 to 25 wethers in each group and 35 to 40 ewes in each group, it is probable that the differences between the two groups were very slight and that the comparison of their 1922 and 1923 records is as reliable as the other comparisons.

There were slight differences in the date of shearing in different years with the following result:

The 1918 fleece represents about eleven months' wool.
1919 fleece represents about twelve months' wool.
1920 fleece represents about eleven and one-half months' wool.
1921 fleece represents about twelve months' wool.
1922 fleece represents about twelve and one-half months' wool.
1923 fleece represents about eleven months' wool.

Therefore the figures for 1918 and 1923 are a little lower and those for 1922 are a little higher than they should be.

The only other very marked difference between seasons was in the amount of rainfall and the resultant scarcity or abundance of grazing. The rainfall for the twelve months preceding each shearing (May 1 to April 30) is as follows:

1919 shearing	24.43 inches
1920 shearing	28.65 inches
1921 shearing	28.73 inches
1922 shearing	18.71 inches
1923 shearing	29.21 inches

The rainfall records were not taken preceding the 1918 shearing at the Experiment Station itself but it is known that that season was very dry and was preceded by a very dry one, and the records for the corresponding period at San Angelo, one hundred miles farther north where the rainfall is usually a little less than at the Experiment Station, show 8.16 inches of rainfall for those twelve months. Of course, the distribution of the rainfall is fully as important as its amount and when that is considered it is evident that there was a short drouth in the summer months of 1918, and that the severe 1921 drouth began about the middle of June and lasted until the following March, there being only one month between these two dates when there was as much as one inch of rainfall. In summary, then, the shearings of 1918 and 1922 followed periods of severe drouth and scanty grazing, but the other shearings probably were not affected. (The 1919 shearing may have been somewhat affected). The pastures were decidedly understocked with sheep the first four years.

Turning to Table No. 5 one will see that the variation in the amount of wool produced from year to year is not large. The average weight of fleece was small in 1922 and quite small in 1923. For the two groups of older ewes it was also small in 1921. Even when it is remembered that the 1922 shearing represents twelve and one-half months' growth of wool whereas the 1923 shearing represents only eleven months' growth, there still seems to be a need for further explanation of the low average weight of the fleeces in 1923. We know that they were unusually light in their shrinkage and can offer tentatively only the explanation that the unusually numerous and heavy rains in the three months preceding shearing may have washed out much more of the dirt and grease than usual and that the early shearing before hot weather began would have caused much less yolk to be present than if the sheep had been sheared a month later. However, it may be that a small part of this decreased production in 1923 is merely an after effect of the drouth of 1921 as a result of which the sheep started into the season of 1922 under-nourished and in poor condition. We need more data on the subject of how long it takes a sheep to recover from the under-nourishment experienced during a severe drouth, and we need much more data on the variations in shrinkage percentages of wool grown under different conditions and clipped at different seasons. Such data on shrinkage are being collected at present by the wool-scouring laboratory of the Experiment Station not only for the Experiment-Station flocks but also for the flocks of many cooperating wool-growers of the state.

On account of the fact that the fleece weights were abnormally low in 1922 and 1923 it is not possible from this study to establish exactly the effect of age upon fleece weight. However, it seems clear that the two-year-old fleece is decidedly heavier than the yearling fleece and that with the ewes the two-year-old-fleece is heavier than the subsequent ones. With the wethers it is probable that the three-year-old fleeces may be even heavier than the two-year-old fleeces, as they were in one of the cases shown in Table 5. This difference in the effect of age on ewes and wethers is probably due to two things: first, the aged wethers are larger than the aged ewes and, second, the ewes drop their first lambs at two years of age and their fleeces shorn at that time show only the effects of pregnancy while later fleeces show the effects both of pregnancy and of having suckled a lamb through the preceding season.

These data do not show how old a ewe must be before her wool production decreases on account of old age. Ewes 1-100 were mostly eight years old in 1923 and many of them were showing outward signs of age; yet their average fleece weight decreased that year and the preceding year only a little more than the fleece weights of the other groups of ewes.

Admitting that the data are not complete enough to prove beyond all reasonable doubt the conclusions given below, nevertheless we think it wise to draw from these data and from practical experience the following tentative conclusions with respect to the effect of age on fleece weight:

1. The fleeces of two-year-old ewes are heavier than those of yearling ewes; usually ten to twenty per cent. heavier in normal years.
2. The two-year-old is the heaviest fleece produced by breeding ewes. Later fleeces are somewhat lighter than those produced by two-year-old ewes but are heavier than the yearling fleece.
3. Two-year-old wether fleeces are very much heavier than yearling wether fleeces, usually twenty to forty per cent. heavier.
4. Aged wethers produce fleeces still heavier than two-year-old wethers.
5. Wethers produce heavier fleeces than ewes at every age except the yearling.
6. The influence of very drouthy seasons is greater upon the fleeces of the ewes than upon those of the wethers and is great enough to cover up all the influences of age upon the fleeces of the ewes.
7. Fleece weights of ewes do not decrease very much on account of old age before they reach the age of at least seven or eight years.

PART IV

PRACTICAL WAYS OF CULLING THE FLOCK FOR INCREASED WOOL PRODUCTION.

As a means of attaining a higher degree of perfection in the breeding of sheep in Texas, wool-growers are urged to adopt a systematic method of culling or removing all animals that do not come up to the average standard of the flock. For example, all off-type sheep including those possessing weak constitutions, as well as those possessing light frowzy fleeces should be removed from the flock in order to provide accommodations for more productive and profitable ones.

Culling has been practiced among the leading pastoralists of some of the more progressive sheep countries for many years and it is no doubt true that the leading position in the production of some of the choicest fleeces in the world, which is today held by the Australians, has been due to the rigid method of culling and classing their flocks, although, of course, the general use of sires of superior breeding has had its wholesome effect.

The information presented in this Bulletin serves as a further illustration that there is likely to be a wide amount of variation in the amount of wool produced by the various individuals of the average flocks of this state. Furthermore, it shows that the general tendency under similar conditions and management is for a sheep that shears a heavy fleece one season to produce a heavy fleece at subsequent shearings. Likewise under similar conditions a sheep which shears a light fleece at one shearing will be very likely to produce a light fleece at all future shearings.

However, it is clearly recognized that this study deals only with weight of fleece and that this is only one of the factors which determine how much profit can be obtained from keeping each sheep for a year. Culling on the basis of fleece weights alone would therefore be a very imperfect method of flock improvement. The scales tell nothing but weight and the man who would cull and breed according to weight of fleece alone would be pursuing just as foolish a course as the dairyman who culls and breeds his cows solely on the basis of the amount of milk they produce without regard to its quality and without taking into consideration the body characteristics of the cows. Such a practice would be better than making no effort at all to improve the flock and it would be fairly certain to increase the *quantity* of wool produced, but it would also be very likely to lead frequently to the keeping of sheep weak in constitution and undesirable in mutton conformation, or producers of wool too coarse or too straight, or containing kemp or "beard" hair, or some other undesirable *kind* of wool. All these things should be considered in culling.

Australian wool growers who are not qualified to class their own flocks employ sheep classing experts who are recognized as being thoroughly efficient and must be familiar with the various kinds of wool produced by the flocks on which they work and also with the class of wool in greatest demand. Sheep classing requires not only that the classers have a knowledge of wool but also that they be fairly good judges of sheep.

Since we are not so fortunate as to have expert sheep classers available for such a service in Texas at the present time it is necessary to approach the culling problem from another angle. It has been one of the aims and purposes of the Texas Station through the medium of the Wool Grading and Scouring Plant to grade and scour representative samples of wool for the wool growers of the state with a view of placing in their hands some valuable information with reference to the quality and condition of samples scoured. The majority of Texas wool growers are fairly competent to distinguish between a good mutton sheep of desirable type possessing a strong constitution and one which is lacking in constitution and development. Therefore, with his knowledge of the fact that it would be utterly futile for him to attempt to produce the highest class of wool on a sheep that does not have a strong constitution, it will be possible for the grower, with the aid of information upon the subject of wool, to make some material progress in the direction of flock improvement.

The amateur wool grower should first of all establish his ideal and constantly strive toward that goal. If he is not competent to distinguish between the best fleeces carried by certain members of the flock and those produced by some of the mediocre animals he should seek the advice of someone who is qualified to select his best sheep, both from the standpoint of type, and wool-production. This will enable him to establish a definite type toward which he can well afford to work in the improvement of his flock.

Sheep of the fine-wool breeds having the following faults should be culled from the flock:

1. All sheep that are undersized or possess weak constitutions.
2. Sheep that are off type, that is, those possessing long legs out of proportion to their size, weak backs, over-shot or under-shot jaws, etc.
3. Sheep producing light frowzy wool lacking in density.
4. Sheep producing wool with too much variation in the size of fibers.
5. Fine-wool sheep producing patches of black wool on any part of the body.
6. All those producing kempy hairs. Such hairs are likely to be found about the face, forelegs, and thighs. Kemp is a separate and distinct fiber from the so-called "beard" hair which is frequently found on the folds or breech. This "beard" hair, as it is sometimes designated, is also very objectionable.

Constitution and type should be given the first consideration by the breeders who are attempting to raise the standards of their flocks. In the selection of the sires and dams or in the culling of the off-type individuals from the flocks, breeders should bear in mind that there is a certain standard of excellence which should be maintained for the ewes as well as for the rams.

A ram should show masculinity while the ewe should display a fair degree of refinement without any tendency toward weakness. The ram should be masculine, commanding, and active. The head should be well set on, being neither too large nor too small, but proportionate to the size of the body. The forehead should be slightly arched and broad between the eyes; eyes should be bright and prominent with determined expression. The face should be of moderate length with a full slightly rounded nose, covered with fine silky hair; muzzle well developed, nostrils open, wide and thick; neck of medium size, well rounded and muscular, tapering gradually from the head to the shoulders. The chest should be broad and roomy with a well developed heartgirth; withers broad or rounded, top-line straight without any deficiency immediately back of the withers; back strong, ribs well sprung, hips well developed and not too prominent. The rump should be moderately long, broad, and not too drooping; tail well set on. Hind quarters should be well rounded and muscular to hock; legs of medium length, straight, wide apart, and well set under body. The hoofs of the fine-wool breeds should be of a clear amber or honey color and free from any black streaks.

The foregoing description could in a general way be applied to representative breeding ewes. However, breeders recognize that members of the ewe flock should be more highly developed in the hind quarters than are the rams which have more strongly developed fronts.

It is impossible in the limited space allotted in this Bulletin to enter into a lengthy discussion of the desirable and undesirable characteristics of wool, therefore the authors have deemed it advisable to reproduce the Wool Score Card which was prepared several years ago by Professors Bray and Hill of the Colorado Agricultural College and the University of Wyoming, respectively. Although this card has not been officially adopted by animal husbandmen it has been carefully prepared and should prove valuable to not only practical sheepmen but to animal husbandry workers and students as well.

THE BRAY AND HILL WOOL SCORE CARD.

QUALITY OR FINENESS—Fine fiber, breed or grade considered. Not a mixture of fine and coarse fibers. Not a wide difference between shoulder and breech. Fine areas large, coarser ones small 20

LENGTH—Should be clearly of combing length for the grade, i. e., fine, $2\frac{1}{2}''$; $\frac{1}{2}$ blood, $3''$; $\frac{3}{8}$ blood, $3\frac{1}{2}''$; $\frac{1}{4}$ blood, $4''$. Lengths more than $\frac{1}{2}$ inch greater of no additional value except in wool coarser than $\frac{1}{4}$ blood. Fibers that lie together, all the same length. Little variation over main parts of the fleece. A minimum of short wool.................... 15

SOUNDNESS—Strong throughout, no weak spots. Fibers of uniform thickness from base to tip except for tapering of yearling fleeces 15

PURITY—No hair, kemp, or black or dark brown fibers. Cut heavily for: beard-hairs on wrinkles of fine wooled sheep, dark fibers mixed through the fleece of downs, and coarse hair on the breech of crossbreds.................... 12

CHARACTER—

(a) Fiber, evenly crimped throughout, crimp close and distinct, fibers parallel except for sufficient binders to hold the fleece together. Tips free from wastiness. No frowzy wool 6

(b) Soft and springy to touch, elastic under pressure....... 2

COLOR—White, bright. Main fleece free from stains. Minimum of stained areas around breech and on belly............... 4

CONDITION—

(a) Yolk, moderate in quantity, light color evenly distributed	3
(b) Free as possible from natural adhering sand and dust, and from heavy tags and sweat locks.	3
(c) Free from burrs, chaff, seeds or other foreign matter, not mouldy or mothy, free from excessive paint, not tied with sisal or rough jute twine or with excessive amounts of twine. Not cotted.	20
Total.	100

With the assistance of this card the experienced wool-grower who has a practical knowledge of judging sheep will be able, with a little practice, to distinguish between those individuals producing wool of high quality and character and those that produce open frowzy fleeces. It will be an easy matter to identify these individuals producing wool with a wide variation in the degree of fineness from shoulder to breech, as a result of a careful examination of the fleece. Kemp and beard hair if present on certain individuals can be easily detected.

According to American wool manufacturers one of the outstanding criticisms of Texas fine wool is that it is sent to market in rather uneven lengths. Therefore, it will serve as a reminder to Texas wool-growers that the length of the wool fiber should be given greater consideration in order that a larger amount of fine combing wool, which should be at least 2½ inches in length, might be made available for the manufacturer by the Texas growers. Wool-growers are engaged in the sheep business as an enterprise and are anxious to make maximum profits. They should therefore strive to produce wool that will meet with the requirements of the leading manufacturers of the country. Upon length of staple depends the strength of the yarn to be spun, there being much less waste in the spinning of a long than of a short fiber.

Moreover, long-stapled fleeces tend to be heavier than short-stapled ones, at least as between fleeces of the same degree of fineness. (This is shown by a correlation of +.56 on 69 Rambouillet fleeces at the Wyoming Station; an average correlation of +.35 on 259 grade Rambouillets in nine groups in unpublished studies by the Texas Station; certain experiments of the United States Bureau of Animal Industry reported by Marshall which show the same thing but are not figured in terms of correlation. These are correlations of length and weight taken on the same fleece, and the length of one fleece and the weight of subsequent fleeces probably would not show as high a correlation as this). Therefore, it seems that the breeder who selects for length of fibers is also selecting to some extent for weight of fleece, but this point needs further study. Fineness of fiber is necessary in order that the spinners may be enabled to spin the yarn to the requisite number of counts. Fineness to a certain degree is an indicator of breeding but there is a posibility of such a condition as over-fineness of fiber.

Luster is one of the striking features of crossbred and braid wools. Whiteness is an indicator of good breeding. A yolk of a light orange color is not objectionable; however, different colors of yolk on the same sheep are not desirable. Members of the flock which carry fleeces with an overabundance of thick gummy and clotted yolk of a dark color should be discriminated against since it is difficult to remove such stains from wool during the scouring process.

All flock-masters have observed that there is a considerable variation in the amount of crimp in the wool fibers of the different types of fleeces represented. Some members of the flock produce wool in which the crimp is almost imperceptible, while others produce wool having a distinct crimp which almost forms a half circle either way. Such crimp represents the typical merino fiber. They give greater elasticity to the fiber and improve the general felting properties.

At shearing time if the wool grower is desirous of culling the light shearers and off-type individuals from his flock he can proceed more efficiently if he establishes the practice of separating the sheep by ages into several groups. For instance, if he should decide to cull his yearling flock he will find the culling operation to be much easier if he will first separate his yearlings from the remainder of the flock before he proceeds with the culling operation. He should first decide on the percentage of ewes to be culled; then he should select several typical representatives of the best as well as several of the most undesirable members of the flock in order that he may establish a more effective culling basis upon which to proceed more readily and accurately.

If the grower feels qualified to rely on his judging ability exclusively in the culling of the flock he can proceed to examine each individual carefully just before shearing time. He should place a mark or brand on the face of each sheep that he plans to cull, while those that are to be retained can go unmarked. The paint mark placed on the culls if located on the face or ear will probably not remain visible more than a few days; therefore, after the ewes have been sheared they should either be separated from the main flock or given a body paint brand in order that their identity may be known as long as they are retained in the flock.

If the grower does not feel competent to rely on his judgment exclusively he can secure a small amount of additional help at shearing time and weigh the individual fleeces. This will give him accurate information with reference to the amount of wool produced; however, as was mentioned above, growers are advised against the establishment of the custom or practice of culling based *exclusively* on shearing weights. For example, it is possible that a sheep possessing a very weak constitution might produce an extra heavy or attractive fleece, and since it is the aim of every progressive breeder to eliminate off-type, under-sized animals from the flock, he should adhere to this practice even though an occasional off-type flock member here and there should produce a heavy fleece. Furthermore, the scales do not reveal such deficiencies or objections as the presence of an undue amount of kemp and the so-called "beard" hairs so frequently found on certain sheep. It is therefore obvious that if the wool-grower hopes to make a fair degree of progress in the direction of flock improvement he must learn some of the rudiments of wool judging and classing since he cannot hope to attain the highest possible degree of perfection in his flock without first being able to distinguish between superior and inferior fleeces.

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