Influence of the plane of nutrition on wool growth
by Francis L Niven

A THESIS Submitted to the Graduate Committee in partial fulfillment of the requirements for the Degree of Master of Science in Agriculture
Montana State University

Abstract:
Because the sheep Industry forms one of the most important sources of Montana's income and because sheepmen throughout Montana and other western range areas are vitally interested in the optimum level of winter feeding required for the economical production of wool, it is important that information relating to the effect of the plane of nutrition on the rate of wool growth be made available.

This study reports the effect of the plane of nutrition on the growth of wool during the winter feeding period. A total of about 1200 ewes were fed on a high and a low plane of nutrition during three successive winters. Individual records on wool growth were kept on about 150 ewes included in the above groups. In another phase detailed records were kept on 15 ewes fed individually on three planes of nutrition for one winter feeding period.

For the convenience of the reader this thesis is divided into three parts: Part I briefly reviews some of the more outstanding literature pertaining to the relationship between the growth of wool and nutrition.

Part II - "A" outlines and reports results of the extensive phase of the experiment at the Fort Ellis Range Sheep Experiment Station.

"B" outlines and reports results of the "wool-tie" phase at Fort Ellis.

Part III outlines and reports results of the individual feeding trial conducted at Montana State College under the personal supervision of the author.

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Walsh Research Fellow in Agriculture, 1933-1934.

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INTRODUCTION

Because the sheep industry forms one of the most important sources of Montana's income and because sheepmen throughout Montana and other western range areas are vitally interested in the optimum level of winter feeding required for the economical production of wool, it is important that information relating to the effect of the plane of nutrition on the rate of wool growth be made available.

This study reports the effect of the plane of nutrition on the growth of wool during the winter feeding period. A total of about 1200 ewes were fed on a high and a low plane of nutrition during three successive winters. Individual records on wool growth were kept on about 150 ewes included in the above groups. In another phase detailed records were kept on 15 ewes fed individually on three planes of nutrition for one winter feeding period.

For the convenience of the reader this thesis is divided into three parts:

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Part II - "A" outlines and reports results of the extensive phase of the experiment at the Fort Ellis Range Sheep Experiment Station.

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PART I

REVIEW OF LITERATURE

In addition to the feed required by animals for growth and maintenance, sheep require energy for wool production.

Because wool contains a large amount of protein it has generally been considered that sheep should be fed feeds that contain a relatively high percent of protein. The high protein content of wool has led many investigators, especially those interested in animal nutrition, to analyze wool in an effort to determine the relationship between wool production and feed requirements.

Chemical Analysis of Wool

Wool is composed chiefly of keratin, which is a protein substance and consists of the following amino acids:

Glycin	0.6%	Glutamic Acid	12.9%
Alanine	4.4%	Cystine	13.1%
Valine	2.8%	Tyrosine	4.8%
Leucine	11.5%	Tryptophane	1.8%
Serine	2.9%	Arginine	10.2%
Proline	4.4%	Histidine	6.9%
Aspartic Acid	2.3%	Hysine	2.6%

(S. G. Barker 1)

The mineral ash left after burning yields:

Potassium Oxide (K_2O)	31.1%
Sodium Oxide ($Na\ O_2$)	8.2%
Calcium Oxide ($Ca\ O$)	16.9%
Alumina (Al_3O_3) and Ferric Oxide (Fe_2O_3)	12.3%
Silica (SiO)	5.8%
Sulphur Trioxide (SO_3)	20.5%
Carbon Dioxide (CO_2)	4.2%
Phosphorus Pentoxide (P_2O_5)	Trace
Chlorine (Cl)	Trace
	100

(Hultz and Hill 13)

<u>Influence of Age and Management</u>

Spencer, Hardy, and Brandon (21) found the age of sheep to be the most important factor influencing length of staple; fleeces becoming shorter as ages advanced.

In an experiment using five Corriedale ewes, Hardy and Tennyson (10) studied the effect of the rate of wool growth on the fineness and length of fibers. They found that the rate of growth and fineness varied throughout the year, both growth and diameter being greatest in summer and fall and least during midwinter. The greatest growth in length seemed to be correlated with the largest diameter of fibers and vice-versa. During the period of the most rapid wool growth the sheep were in a very good, thrifty condition. The period of least wool growth occured in ewes, usually during lambing and for about forty-five days previous to lambing. The authors state indications are that the character of the fleece is probably very largely within the control of the flock owner because the experiment appears to show that there was a rather close relationship between the thriftiness of a sheep and the quality and quantity of wool produced.

In discussing the detrimental effects on wool caused by undesirable methods of managing sheep, Wilson (27) brings out the following points. Sheep that are poorly nourished or are old are likely to produce fleeces that are weak. Overfeeding as well as underfeeding and fever may cause breaks in the wool. Sheep poorly nourished during the winter often produce breaks when turned out on rich green feed in the spring. Strength of wool has a large part in determining the kind of material it will be made into, therefore, care should be taken to avoid systems of management which will produce weak fibers.

Rate of Growth of Wool

Studies on the rate of growth of wool have terminated in conflicting results. Early investigators, such as Rhode (1857), Stohmann (1873), Heyne (1916), and Gartner (1924) hold that wool grows twice as rapidly during the first six months after shearing as in the next six months. Later investigators, however, like Nordmeyer (1927), Hardy and Tennyson (1930), Hackedorn and Sotola (1929), and more recently Burns (1931), report a comparatively uniform growth throughout the year.

Duerden (7) reports the results of an experiment, with one Merino wether, which lasted for two and one-half years. During this time samples of wool were taken approximately every month but the wether was not shorn. The rate of growth, month by month, was found to be nearly equal throughout this period. The greatest variation occured in late summer and the early winter. The results suggest that under ordinary conditions the average growth in length of the Merino fleece is the same from year to year and that wool grows at approximately the same rate during the second six months after shearing as it did during the first six months.

Rate of Feeding

Joseph (14) reported an experiment in which he stated--"that in sheep of fine wool breeding the organs which are concerned with the secretion of the wool fibers are not easily subject to such influence as changes in level of feeding---". He further observed that feed had very little,if any, influence on the secretion of wool fibers and that their growth took place in a uniform manner in so far as size, strength, and elasticity of the fibers were concerned.

The length of the fiber was modified almost imperceptibly under average conditions and the slight difference was purely secondary to that caused by age. In other words, "the quality of the wool fiber is affected not at all, and the quantity of the wool fiber may be modified only slightly."

In a later experiment reported by Joseph (15) ewes on a heavy ration produced slightly more wool and lambs than those on a light ration but the difference only covered about one-third of the extra cost of feed. "The preliminary results of these trials, therefore, indicate that increased production on more liberal feed is not sufficient to cover additional cost."

In an experiment conducted in California; Wilson (25) tried to determine the effect of different amounts of feed on wool growth. The results of this experiment conflict directly with those obtained by Joseph (14 and 15); Waggener (23) and Mitchell, Kammlade and Hamilton (17).

Three Romney Marsh wethers were used in Wilson's experiment. For six months the wethers were fed a liberal fattening ration, followed by a maintenance ration for a second period of six months. The sheep were sheared at the end of each period with the following results.

"The fleeces grown on the fattening ration, when compared with the fleeces grown later by the same animals on a submaintenance ration were:

A - "About 343% heavier in average grease weight.

B - "About 319% heavier in scoured weight.

C - "Softer and fuller in texture.

D - "Superior in crimp.

E - "172% longer staple.

F - "About 206% stronger as indicated by the mean breaking stress on the basil portions of the fibers.

G - "Coarser, as indicated by the mean diameter, especially at the base of the fiber, which portion most accurately represents the physiological effect of the rations."

According to Wilson, the experiment indicates that wool growers can and should give supplemental feeds during those times when the sheep would otherwise lose weight rapidly and when the increase in fleece weight, length, strength, and character will pay for the trouble and expense of some supplements. This experiment, however, cannot be taken as conclusive since data from only three sheep are included.

In studying the energy value of alfalfa hay for the maintenance of sheep; Mitchell, Kammlade, and Hamilton (18) found that sheep compare quite favorably with steers in their ability to utilize the metabolizable energy of alfalfa hay.

Approximately 2.3 pounds of hay per day for each 100 pounds live weight was required to maintain ten to fourteen months old western lambs at a constant weight for 133 days.

In a similar experiment 2.44 pounds of alfalfa meal per day for each 100 pounds live weight was fed by Waggener (23) to maintain the weight of Shropshire lambs. In this experiment he found that the maintenance plane of nutrition as compared with the high plane retarded growth of body, and did not produce as much total grease wool. The length and diameter of fibers from the maintenance group were reduced slightly and these fibers were not quite as strong as those from the high plane. On the other hand, the maintenance group gave an increase over the full fed group in the per-cent of clean wool produced, and also a slight increase in the number of crimp per inch.

In the book "Feeds and Feeding" Henry and Morrison (11) note that experiments by Wolff and Henneberg showed that when sheep are fed in-sufficient feed to maintain their weight, the yield of raw wool is considerably diminished. Henry and Morrison state, "a balanced ration is essential to obtain more growth of wool."

Similar results were reported by Weber (24) in 1932. He states, "wool fibers of the full fed group were uniformly stronger than those fed a submaintenance ration," and goes on to say, "It appears justifiable, therefore, to conclude that wool growth is materially retarded when sheep are subjected to a low plane of nutrition".

Protein in Feed

In studying the effect of nitrogenous matter on the growth of wool, Roberts and Wing (19) found that wool growth was directly proportional to the nitrogenous matter contained in the ration of fattening lambs. The findings of Goessman (9) though less conclusive, agrees with Robert's and Wing's results, Craig (5) found that lambs fed grain from birth averaged 2.2 pounds more grease wool than those fed grain from weaning time through fattening or those fed grain through the fattening period only. The difference, however, was largely due to the greater amount of yolk which the wool contained. A slight difference favoring the lambs fed grain from birth was found in the length of the staple.

In studying the effect of "carbonaceous" as contrasted with "nitrogenous" rations for Merino ewes, Cook and Jones (4) found that rations of this type produced no measurable difference in diameter of fibers. They pointed out, however, that the wool fibers of a few of the sheep that "did not do well" were "shrunken in diameter".

A similar experiment conducted by Craig (6) has been interpreted from a different viewpoint. Shropshire wethers were used to study the relative effect of "carbonaceous" and "nitrogenous" rations. The wethers fed the "nitrogenous" ration sheared 2.4 pounds more unwashed wool than the wethers fed the "carbonaceous" ration. The additional weight of unwashed wool was credited "in a limited degree, to the amount of yolk in the fleeces of the lots".

Using Rambouillet wethers in three lots of ten head each, Hill (12) studied the effect on wool production of feeding rations having wide, medium, and narrow nutritive ratios, for a period of one year. The daily rations for the lots consisted of (1) 36 pounds native hay; (2) 30 pounds native hay and three pounds of oil cake; and (3) 20 pounds of native hay and eight pounds of oil cake, respectively. The tendency was for the narrow ration to give greater wool production than either the wide or the medium rations. There was no decided difference in the strength of the wool grown by the different groups.

In still another experiment based on the nitrogen content of the ration, Frasier and Roberts (8) report results from two groups of sheep, one of which was fed an excessive amount of protein and the other group a ration which lacked in protein. They found no significant difference between the two groups with respect to any of the wool characteristics measured and the mean increase in body weight during the experiment was the same for both groups.

Results of a somewhat similar nature were obtained by Mitchell, Kammlade, and Hamilton (17) when they found that sheep on a submaintenance ration and a continuous negative nitrogen balance produced nearly as much protein in the form of wool as did sheep on a high plane of nutrition.

These sheep lost weight at a steady rate of .05 to .10 pounds per day, and stored daily an average of 4.37 grams of protein and 45.3 calories of gross energy in their wool.

Meat By-Product Supplements

An experiment conducted at "Meteor Downs", central Queensland, by Marston (16) to determine the response in wool growth by Merino sheep when natural pasture was supplemented with blood meal was reported in 1932. During the first year the group receiving the supplement made a greater growth and at shearing time weighed approximately 10% more than the control group. The group receiving the supplement sheared, on the average, 110.9 ounces of wool, while the control group averaged 80.9 ounces. In the supplemented group most of the fleeces represented well grown 64's, while in the control group many poorly grown and tender 70's were found.

The pasture conditions during the second year were more uniform, and the control group reached about the same body weight as the supplemented group had reached at the previous shearing. The average fleece weight of the supplemented group during the year was 130.3 ounces and the control group 95.6 ounces. The quality of the clip as a whole was practically the same as at the previous shearing.

Mention is also made in this report to an experiment in which "A study of the effect of supplementary feeding sheep on poor pastures at Molo in South Africa, showed that the addition of two ounces per head, per day of a protein rich supplement consisting of 40% fish meal, 10% meat meal, and 50% sim-sim cake, resulted in an increase of about 30% in the weight of wool fleece grown, and a general improvement in wool quality."

The author's name is not given for this quotation.

Mineral Supplements

According to Barker (1) wool keratin contains about 13.1 percent cystine which in turn contains all of the sulphur found in wool.

An interesting experiment to measure the effect of sulphur on wool growth was carried on in South Africa by Steyn (22) in which four groups of sheep were fed the following amounts of sulphur for twelve months:

Group A--5 grams sulphur - once weekly.

Group B--5 grams sulphur - three times weekly.

Group C--5 grams sulphur - six times weekly.

Group D--Control group receiving no sulphur.

Group A clipped 10.25 pounds of wool; Group B, 12.9 pounds; Group C, 12.25 pounds; and Group D, 9.3 pounds. Steyn concluded that sulphur can be administered to Merino sheep at the rate of five grams, once, three, or six times weekly, over prolonged periods with striking beneficial results. Furthermore, that these amounts of sulphur given over a period of one year had no detrimental effect on the wool and did not increase the cystine content.

The influence of phosphorus on wool growth was observed in South Africa by Becker (2). Sheep, from phosphorus deficient areas were used in the experiment. Group I grazed on ordinary pasture with access to common salt lick; Group II in addition to the pasture, received a lick consisting of 75% bone meal (22% P_2O_5) and 25% ordinary salt.

The fleece weights were as follows:

Groups	10 Months Wool	12 Months Wool
I Controls	2.456 Kgm.	3.554 Kgm.
II Bone Meal Lick	2.456 "	3.616 "

While the difference appears to be too small to be significant, the results show that phosphorus had a slight tendency to increase the amount of grease wool produced. It was also observed that finer wool was produced by sheep run in phosphorus deficient areas in the South Western districts of Cape Province. The author points out, however, that phosphorus deficiency results in a state of malnutrition which leads to the production of wool fibers of smaller cross-sectional area.

Summary

The available literature which pertains to the effect of the plane of nutrition on wool growth is rather inconsistent and is not conclusive. Some experiments have shown very definitely that feeding on a high level increases wool production to a marked extent, while others have indicated only a slight increase in the amount of wool produced. Several experiments have contained some phase or factor such as un-uniform or small groups of sheep, some have lacked equipment for carrying on this type of work so that it is doubtful that the reported results in several instances, can be definitely attributed to the effect of the plane of nutrition on wool growth.

Technique of Sampling and Measuring Wool

There is very little information to be obtained which explains accurate and rapid methods of sampling and measuring wool fibers. Hardy and Tennyson (10) explain a method by which they obtained samples of wool every 28 days by removing all fibers from an area about one-half inch square, located about three inches to the rear of the point of the shoulder and midway between back and belly. The wool was removed from this area by use of a pair of sharp scissors that cut very close to the skin. On the same dates that fiber clippings were taken, two small locks of wool were tied with dental floss close to the skin and near the place from which the fibers had been removed, one on each side of the same sheep.

The length of wool clippings were measured with a binocular miscroscope magnifying 7.5 diameters. To do this a few of the fibers were placed on a thin piece of glass beneath which was a sheet of cross-section paper the same size as the piece of glass. A microscope slide was then placed across the fibers even with one of the lines on the cross-section paper. The fibers were then pulled out from under the slide by means of a pair of tweezers. When the end of the fiber was just free of the slide the motion of the tweezers was stopped and the length read to the nearest millimeter on the cross section paper. Five fibers were measured from the left and five from the right side of each sheep.

It seems that this method, at best, would only given an approximation of the crimped length of the fibers, and that individual differences in the amount of crimp in the wool of the sheep in the experiment would increase the amount of error. Hardy and Tennyson do not tell how the lengths of the tied locks were determined.

More recently Burns (3) has been using an improved method of removing the clippings of wool. To do this he uses an ordinary pair of electric hair clippers fitted with triple naught plates, allowing the clippers to cut very close to the skin and thereby obtaining a clipping that is free from second cuts, which is not always the case where scissors are used. The use of the clippers necessitates the removal of wool from a triangle, the sides of which are about three inches long.

A method for measuring the short clippings of wool which is more accurate than that reported by Hardy and Tennyson (10) and which resembles in some ways the method used by the author for measuring the fibers in this experiment, is reported by Wilson (26). During Wilson's experiment, clippings were taken every 28 days from the right and left shoulders of each sheep by using a pair of small curved scissors. Fifty fibers from each of the small samples so taken were cleaned, dyed, mounted, projected on a screen with a magnification of 20 diameters and measured for length with a map-measuring device. Since the magnification was 20 diameters, the actual error involved in the measuring was thus reduced to 1/20 of the apparent error.

PART II

STUDIES ON THE EFFECT OF THE PLANE OF NUTRITION ON THE GROWTH OF WOOL AT THE MONTANA AGRICULTURAL EXPERIMENT STATION

The work here reported was taken from unpublished data on winter feeding trials conducted at the Fort Ellis Range Sheep Experiment Station by the Department of Animal Husbandry. The first phase of the experiment includes the results of feeding two groups of approximately 200 ewes each on a high and a low plane of nutrition during three successive winters. The second phase includes individual wool growth records on about 25 ewes in each of the above groups.

A. Extensive Phase

Housing and Feeding Equipment

During the winter trials at the Fort Ellis Range Sheep Experiment Station each lot of ewes had access to a shed, open to the south, which furnished shelter for the ewes during the winter. Directly to the south of the shed a long lot provided room for the sheep to be fed, watered, and exercised.

Selection of Ewes

The ewes for this experiment were selected from the band of grade Rambouillet range ewes kept at Fort Ellis. Each fall the ewes for the trial were selected according to their age and weight.

Length of Feeding Trials

During the first two trials (1931-1932, and 1932-1933) the experiment started about December 15 and continued 112 days. The third winter a shortage of hay made it necessary that the ewes be carried on the range later into the fall than usual so that it was not possible to start the experiment before January 3, 1934, or to contimue the experiment longer than 84 days because of the approach of the lambing season.

Feed and Amount Fed

Alfalfa hay grading about U. S. No. 2 formed the basic portion of the ration for the two lots of ewes during the three trials. At the outset it was estimated that about three pounds of the alfalfa hay per head daily should maintain the weight of the ewes in Lot I and produce an increase in weight approximately equal to that of the foetuses, foetal membranes, and fluids, at the close of the trial. The first winter each ewe in Lot I received 3.02 pounds of alfalfa hay daily (Table I). The second winter the amount fed was 2.89 pounds. The third winter the ewes received 3.06 pounds of alfalfa hay per head daily.

Each ewe in Lot II was liberally fed and received in addition to the daily ration of 4.02 pounds of alfalfa hay, a supplement of one-third pound of oats during the first two winters. The third winter, however, the oats were eliminated from the ration and the ewes full fed 4.53 pounds of alfalfa per head daily.

Salt was provided in troughs at all times so that the ewes in both lots could consume salt at will.

Body Weights

As explained under "Feed and Amount Fed," it was intended that the ewes in Lot I gain only enough weight to equal the weight of the developing foetuses, foetal membranes, and fluids at the close of the trial. The first winter the ewes in Lot I made an average gain of 7.65 pounds (Table II) as compared with a gain of 27.26 pounds for Lot II which was liberally fed. The second trial Lot I gained an average of only 3.57 pounds while Lot II gained 26.76 pounds. The third trial Lot I gained 9.34 pounds and Lot II gained 22.29 pounds, although the trial lasted for only three months. The difference in average gains between lots each winter were 19.61, 23.19, and 12.95 pounds, respectively.

The small average gain made by Lot I during the second winter may have been partially due to the long period of very cold weather about the middle of the trial. The large average gains made by both Lots I and II during the third winter may be partially due to the exceptionally mild winter weather throughout the trial.

Fleece Weights

The first year the ewes were shorn by hand, but for the last two years they were shorn with machines.

The first year the ewes in Lot I produced fleeces averaging 8.49 pounds as compared with 9.09 pounds for Lot II (Table I). The difference was .60 pounds. The second year Lot I produced an average of 9.62 pounds of wool and Lot II 10.77 pounds, a difference of 1.15 pounds. The third year Lot I produced fleeces which averaged 9.95 pounds while those of Lot II averaged 10.56 pounds. The difference between the lots was .61 pounds.

TABLE I

BODY WEIGHTS, WINTER RATIONS, AND FLEECE WEIGHTS
(Extensive Phase)

	Lot I Maintenance			Lot II Liberally Fed		
Year	1931-32	1932-33	1933-34	1931-32	1932-33	1933-34
No. of ewes in experiment	194	184	230	192	189	230
No. of days on experiment	112	112	84	112	112	84
Ave. initial weight, lbs.	130.53	129.21	129.01	131.7	131.75	129.41
Ave. final weight, lbs.	138.18	132.78	138.34	158.96	158.51	138.34
Ave. gain per ewe, lbs.	7.65	3.57	9.34	27.26	26.76	22.29
Daily ration per ewe						
Alfalfa, lbs.	3.02	2.89	3.06	4.02	4.02	4.53
Oats, lbs.	----	----	----	.33	.33	----*
Daily ration per 100 lbs. live wt.						
Alfalfa, lbs.	2.18	2.04	2.09	2.70	2.64	2.95
Oats, lbs.	----	----	----	.219	.217	----*
No. of fleeces	192	173	225	187	180	228
Ave. wool produced per ewe, lbs.	8.49	9.62	9.95	9.09	10.77	10.56

*Oats were not included in the ration during this period.

B. Wool-Tie Phase

Within each lot of ewes on the extensive phase was a group of 25 ewes on which individual wool-tie data were collected every 28 days throughout the winter trials. These ewes were managed, housed and fed with the ewes on the extensive phase (page 20).

Selection of Ewes

Fifty-two two-year-old ewes were selected for the wool-tie phase of the study on a basis of their fleece weight at the previous shearing. The fleece weights of these ewes fell within a range of one pound and represented about the average fleece weight of all the two-year-old ewes in the band. After selection, the ewes were divided into two uniform lots according to weight. The ewes in the first lot were placed with the ewes in Lot I already described under the extensive phase (page 20). The ewes in the second lot were placed with Lot II of the extensive phase.

These ewes were assigned permanently to the wool-tie phase and no additions were made to the two groups after the experiment started. Each year the ewes were reversed in the lots so that they could be fed on both the planes of nutrition.

Body Weights

Table V gives a summary of the weights of Lots I and II for the three winter trials studied. During the three trials Lot I made average gains of 12.92, 7.19, and 11.38 pounds per head respectively, while Lot II made corresponding gains of 32.62, 30.62, and 23.30 pounds per head. These gains are all somewhat higher than the average gains made by the 200 ewes in each lot of the extensive phase, which may have been due to the younger age of the wool-tie ewes.

Fleece Weights

Weights in the Grease: The first year the wool-tie ewes in Lot I produced fleeces averaging 9.54 pounds as compared with 10.03 pounds for Lot II. The difference was .49 pound. The second year the two lots produced fleeces averaging 10.48 and 11.88 pounds respectively. The difference was 1.40 pounds per ewe. The third year the two lots produced 11.20 and 11.23 pounds respectively. Here the difference was only .03 pound per ewe.

Scoured Weights: The first two years immediately after shearing the fleeces from the wool-tie ewes were shipped to the Texas Agricultural Experiment Station, at College Station, Texas, where they were graded and scoured individually. From this it was possible to obtain a more accurate comparison of the differences in the actual amount of wool produced by the two lots of ewes. Table II gives a summary of the results of grading and scouring. Because of the relatively small numbers of ewes within each lot, the two years' results have been combined. The results for the third year are not available.

TABLE II

SUMMARY OF GREASE WOOL AND SCOURED WOOL WEIGHTS
FOR WOOL-TIE EWES*

Lot Plane of nutrition	Lot I Maintenance Total	 Average	Lot II Liberally Fed Total	 Average	Differences between average of Lot I and Lot II
No. of ewes	51		49		
Grease weight, lbs.	512.3	10.05	537.7	10.97	.92
Scoured weight, lbs.	232.0	4.55	23.62	4.82	.27
Ave. shrinkage %		54.70		55.51	.81
Ave. yield %		45.30		44.49	.81

*Includes data for 1931-32 and 1932-33 only.

Table II shows that while Lot II produced an average of .92 pounds more grease wool than did Lot I, the scoured wool amounted to only .27 pounds more. The difference of .81% higher yield of scoured wool by Lot I indicates that while Lot II produced more grease wool than Lot I, the additional weight was largely due to an increased amount of yolk; and only about one-third of the increase was due to a difference in the actual amount of clean wool produced.

<u>Tied Locks and Clippings</u>

Every fall at the start of the trial, two small locks of wool, slightly less in diameter than a lead pencil, were tied with dental floss as close to the skin as possible on each ewe. These locks were located about three inches back of the point of the shoulders and half way between the withers and floor of the chest. Every 28 days a new tie was made on the locks so that when the locks were removed at the close of the trial each spring, the amount of wool grown during the 28 day-periods could be measured.

On the same dates that the ties were made, the wool was clipped from a small area near the tied lock with the use of a pair of sharp, curved scissors.

Measurements of Tied Locks and Clippings

The tied locks obtained from the ewes the first two winter trials were measured by mounting the locks between two microscope slides, fastening the ends of the slides together with small clamps and then measuring the wool grown during each period of 28 days with a binocular-microscope, equipped with a micrometer eye piece. These measurements were made to the nearest thousandth of a centimeter.

The third winter trial the locks were mounted in exactly the same manner but were measured with a comparator or traveling microscope. With this instrument it was possible to make a direct reading to the nearest thousandth of a centimeter without calibrating.

As a check on the accuracy of these two instruments, wool-ties from six ewes on each of the planes of nutrition were measured with both machines and the results compared. Table III gives a summary of the results.

TABLE III

COMPARISON OF MEASUREMENTS MADE WITH THE USE OF A BINOCULAR MICROSCOPE AND WITH A COMPARATOR

	Lot I*		Lot II*		
	Total Length	Average Length	Total Length	Average Length	Differences between Averages of Two Lots
Binocular Microscope	52.571 cms.	.578 cms.	53.969 cms.	.593 cms.	.015 cms.
Comparator	51.990	.571	53.330	.586	.015
Differences	.581	.007	.639	.007	.000

*Figures represent average measurements of tied locks from six ewes in Lot I and six ewes in Lot II.

This indicates that from a relative standpoint the binocular microscope and the comparator gave equally good results. It cannot be said which method is the more accurate, since locks measured with the binocular microscope averaged .007 of a centimeter longer in the case of both Lots I and II.

Table IV gives a summary of the results of the wool-tie data for the three winter trials.

TABLE IV

COMPARISON OF LENGTHS OF TIED LOCKS GROWN
BY LOTS I AND II

Year	1931-1932	1932-1933	1933-1934*
	Ave. Length	Ave. Length	Ave. Length
Lot I	.534 cms.	.574 cms.	.543 cms.
Lot II	.561 cms.	.598 cms.	.558 cms.
Difference	.027 cms.	.024 cms.	.015 cms.

*Figures for 1933-1934 are based only on three month's data.

It is unfortunate that the 1933-1934 measurements did not include data from a four months' winter trial, so that it could be compared directly with the other two trials. However, in all cases the small differences in the length of tied locks produced are evident.

The clippings taken from the wool-tie ewes were not measured. When the study of the data was first started, neither the method or the equipment were available for measuring the clippings, so that a great deal of time was spent endeavoring to find a satisfactory method for measuring the fiber lengths. After suitable equipment (page 42) had been obtained and a method for measuring the individual fibers developed, the time remaining for such work was too short to permit measuring the necessary number of fibers.

TABLE V

BODY WEIGHTS, WINTER RATIONS, AND FLEECE WEIGHTS
(Wool-Tie Phase)

	Lot I Maintenance			Lot II Liberally Fed		
Year	1931-32	1932-33	1933-34**	1931-32	1932-33	1933-34**
No. of ewes in experiment	26	27	24	26	26	23
No. of days in experiment	112	112	84	112	112	84
Ave. initial weight, lbs.	132	138	141	133	137	136
Average final weight, lbs.	145	145	152	165	167	165
Ave. gain per ewe, lbs.	12.92	7.19	11.38	32.62	30.62	23.30
Daily ration per ewe						
Alfalfa, lbs.	3.02	2.89	3.06	4.02	4.02	4.53
Oats, lbs.	----	----	----	.33	.33	----***
Number of fleeces	25	26	22	24	25	23
Ave. grease wool per ewe, lbs.	9.59	10.48	11.20	10.03	11.88	11.23
Ave. scoured wool per ewe, lbs.	4.42	4.67	-----*	4.55	5.08	-----*
Ave. shrinkage %	54.00	55.38	-----*	54.69	56.31	-----*
Ave. yield %	46.00	44.62	-----*	45.31	43.69	-----*
Ave. length of wool-ties, cms.	.534	.574	.543	.561	.598	.558

*Data not available.
**Includes only three periods of 28 days each.
***Oats were not fed.

PART III

INDIVIDUAL FEEDING TRIAL

The work reported in this phase is based on the individual feeding trial conducted at Montana State College by the author. Fifteen ewes were fed individually for a period of 112 days. Five ewes were fed all the chopped alfalfa hay they would clean up, five were fed so as to maintain their initial weight, and the remaining five were fed to lose weight.

Housing and Feeding Equipment

All the ewes in the individual feeding trial were fed, watered, and housed in the same lot and shed.

The lot was located to the West of the shed in which the ewes were housed. Other sheds provided partial shelter on the North and South, but the West was unprotected. Most of the time the lot was well drained and dry, but during exceptionally wet weather it became muddy. A small stream in the West end of the lot furnished running water at all times.

The shed in which the ewes were fed was a one story frame building with a cinder floor. The ewes were placed in ordinary lambing jugs twice daily at feeding time. Along the East side ten jugs were arranged with a three-foot feed alley between them and the wall. Along the West side the remaining eight jugs were placed against the wall. As an aid to the shepherd in penning the ewes, each jug was numbered corresponding to the number branded on the back of the ewe using the jug.

At first ordinary twelve quart pails were used as feed containers. These were fastened one in a corner of each jug, but were soon discarded because the sheep were inclined to turn around in the jugs while eating thus dropping feed onto the floor.

The pails were removed and stanchion-like openings fixed in the fronts of the jugs along the East side of the shed. In front of each jug, about 16 inches from the floor, was fastened a box for feed, 20 inches long, 12 inches wide and 18 inches deep. The stanchions prevented the ewes from turning around in the jugs while eating although they were free to back out and then turn around if they wanted to. The boxes were small enough for the ewes to reach all the feed and were deep enough to prevent any spilling over the edges.

On the West side the arrangement was somewhat different. Part of the sides of the jugs were removed and a long trough fastened inside along the front about 20 inches from the floor. Partitions to prevent mixing the feed of the various ewes were placed between the jugs and the front of the jugs boarded up solid to prevent any feed from being wasted. This trough, which was 12 inches wide, so reduced the size of the jug that it was almost necessary that the ewes stand in one position the entire time they were in the jugs. The ewes were allowed to remain in the jugs until they had finished eating or had cleaned up all of their feed, usually about an hour each morning and evening.

Selection of Ewes

It was recognized at the start of the experiment that such factors as breeding, age, body type, body weight, freedom from wrinkles, fleece weight, character and density of fleece, fineness and length of staple, face covering, and other individual differences were factors which should be considered in selecting the ewes.

The individual record of each ewe was carefully studied before the animals themselves were selected. All the yearlings in the Fort Ellis band had previously been scored on the points mentioned above. Of the 430 head of yearling ewes, the 29 head which most nearly represented the average of all the yearlings in the band were chosen from their records. Of these 29 the 18 most uniform in appearance were selected. To further eliminate individual differences which did not present themselves to the eye at the time of selection, to allow time for breeding, and to let the ewes become accustomed to their new quarters, the eighteen ewes were placed on a 28-day preliminary feeding period, of which detailed individual records were kept. From this it was possible to eliminate the three ewes that ate the least feed, made the smallest daily gain, were smallest at the end of the period, and which resembled the rest of the group the least. Table VI gives the individual scores of the 15 ewes after the final selection and allotment had been made. The scores range from 1 to 4, with a score of 1 being the preferred rating.

The remaining 15 head, which were as nearly similar and equal to each other as it was possible to obtain, were divided into three groups of five head each on the basis of body weight and the average amount of hay consumed during the preliminary feeding period.

Length of Feeding Trial

The ewes were fed on a 28-day preliminary feeding period before

TABLE VI

INITIAL SCORES OF EWES ON INDIVIDUAL
FEEDING TRIAL

Lot I - High Plane

Ear Tag Number	Paint Number	Body Type	Body Wrink.	Body Cond.	Fleece Spinning Count	Fleece Charac.	Fleece Density	Fleece Face Covering
138	2	2	1	2	60	3	2	2
322	6	2	2	1	62	2	1	4
462	9	1	2	2	70	1	1	1
618	13	2	2	3	64	1	2	3
754	16	1	1	1	64	2	3	2
Lot II - Maintenance Plane								
193	3	2	2	1	70	1	1	4
480	10	2	2	3	64	2	2	2
520	11	2	2	3	64	2	2	4
718	15	1	1	1	64	1	2	2
930	17	2	1	2	70	1	1	3
Lot III - Submaintenance Plane								
212	4	2	3	3	64	3	2	3
414	8	2	2	2	64	2	1	3
599	12	1	3	3	60	2	1	4
690	14	2	3	2	64	2	2	3
932	18	2	2	2	70	2	1	3

the actual trial began. The feeding trial lasted for 112 days, or four 28-day periods.

Feed and Amount Fed

Ground alfalfa hay was the only feed in the ration. To obtain hay that was uniform in quality, the alfalfa used was all taken from one stack. Two members of the Agronomy Department inspected the hay and estimated its grade to be low U. S. No. 2 alfalfa. These men estimated that the hay did not contain over 30% leaves, 35% green color, or more than 7% foreign material. The foreign material consisted mostly of dark brown dandelion leaves, which was one of the reasons for the hay grading so low in color.

To make the hay uniform and to eliminate waste, the hay was passed through a hammer mill. It was not possible to use a dust collector and as a result the hay was very dusty.

The daily ration for each ewe was weighed out in a paper sack. Four sacks of feed were weighed each Tuesday and three each Friday. After weighing, the sacks were placed on a shelf over the jug corresponding to the ewe for which the feed was intended. Approximately one-half of a sack was fed to a ewe each evening and the remainder fed the following morning.

Since the ewes were being bred, flushing was desirable, and in order to determine which ewes ate the least feed and made the smallest gains, they were given all the chopped alfalfa hay they would eat during the 28-day preliminary feeding period. After the preliminary period the ewes in Lot I received all the chopped hay they would eat. It was planned that the ewes in Lot II maintain their initial weight without an allowance for the developing foetus, hence they were started out on 2.3 pounds of hay daily per hundred pounds live weight. This figure was reported by Mitchell, Kammlade, and Hamilton (17) to have maintained the weight of western lambs over a period of 133 days. However, it was found that this amount allowed the ewes to gain in weight so that it became necessary to vary the amount fed from time to time depending on the weekly weights of the ewes. Lot III was started on a submaintenance ration by allowing them 1.8 pounds of hay per 100 pounds live weight daily. This amount was later decreased to 1.5 pounds and from that time on varied according to the weekly weights of the ewes.

The ewes in Lots I, II and III consumed an average of 4.09, 2.64, and 1.88 pounds respectively of chopped alfalfa hay per head daily. On a basis of 100 pounds live weight these values are 2.95 pounds for Lot I, 2.07 pounds for Lot II, and 1.88 pounds for Lot III (Table XII).

Feed not eaten by a ewe was weighed back once each week and the amount deducted from the total fed. Most of this "weigh-back" was taken from the feed boxes of the ewes in Lot I, but occasionally some of the ewes in Lot II failed to eat all their hay.

Samples of the chopped hay were taken at intervals of approximately one month and submitted to a chemical analysis by the Chemistry Department of the Experiment Station. Samples of the hay left in the feed boxes by the ewes were also analyzed to determine the difference between the "weigh-back" and the chopped hay. Table VII gives the results of the analysis of the chopped hay and of the "weigh-back" removed from the feed boxes. The differences between the two are so small that little emphasis can be placed on the analysis since there were only four samples of the chopped hay and three of the "weigh-back" analyzed.

TABLE VII

ANALYSIS OF ALFALFA HAY USED IN THE INDIVIDUAL FEEDING TRIAL

	Chopped Alfalfa Hay (percent)	Weigh-back (percent)
Samples	4	3
Ash	8.88	9.70
Moisture	6.88	8.68
Ether Extract	1.99	1.58
Crude Fiber	32.87	36.68
N-Free Extract	37.91	32.17
Crude Protein	11.48	11.20
P_2O_5	.48	.47
Ca 0	2.24	1.96

During the preliminary feeding period and for the first two weeks of the experiment, the ewes received salt ad libitum, but it became evident that some of the ewes on the low plane of nutrition were eating an exceptionally large amount of salt. It was thought that these ewes might develop salt poisoning, so from the third to seventh weeks, inclusive, the ewes received 10 grams of salt per head three times weekly, a total of 30 grams per week. During this five-week period the sheep in all lots developed a craving which caused them to eat wood. (Plate 2). The only way this could be accounted for was the possibility that the ewes were not getting enough salt, so the amount of salt fed was increased to 45 grams per head each week and from that time on there was a marked decrease in wood chewing, although some of the ewes continued to eat wood occasionally.

Health of Ewes

With the exception of ewe number 138F in Lot I, no sickness was noticed throughout the trial. During the fourteenth week of the experiment this ewe did not eat well and walked as though her hind legs were stiff. A member of the Veterinary Science Department diagnosed the stiffness as a slight case of foundering. The amount of feed was reduced for about a week and the disorder corrected itself without treatment.

Body Weights

The initial weight of each ewe was determined from an average of three weights taken on successive days at the start of the experiment. Each Tuesday afternoon at one o'clock, throughout the trial, the ewes were weighed and this weight used as a basis for determining the amount of hay each ewe in Lots II and III received during the following week. In closing the trial the ewes were again weighed on three successive days and the averages taken as the final weight (Table XII).

The ewes in Lot I were full fed and made an average gain of 27.1 pounds per head (Table XII). The ewes in Lot II, were fed so as to maintain their weight, but made an average gain of 5.2 pounds. However, this gain was not enough to offset the weight of the foetus, foetal membranes and fluids at the end of the trial. Lot III, which was fed on a submaintenance plane of nutrition, lost an average of 6.5 pounds per head. This loss would be more than doubled if the weight of the foetus, foetal membranes, and fluids were added.

Lambing Record

Only single lambs were produced. The lambs dropped by the ewes in Lots II and III were slightly heavier (Table VIII) and stronger than those produced by Lot I. The ewes in Lots II and III also appeared to have more milk than did the ewes in Lot I, although they did not carry as much condition. Evidently the low planes of nutrition did not effect the lamb and milk production.

TABLE VIII

LAMBING RECORDS OF EWES ON
INDIVIDUAL FEEDING TRIAL

Ear Tag No. of Ewe		Cond. of Ewe at Lambing	Milking Qual. of Ewe	Sex of Lamb	Birth Wt. of Lamb lbs.	Strength of Lamb
138F		1	2	R	10.4	2
322F		1	2	E	9.6	2
462F		1	2	E	11.3	1
618F		1	2	E	7.7	3
754F		1	3	R	10.3	2
	Average	1	2.2		9.86	2.0
193F		2	1	R	11.6	1
480F		2	1	R	10.7	1
520F		2	1	R	10.1	2
718F		1	3	E	9.5	2
930F		2	1	E	11.2	1
	Average	1.8	1.4		10.62	1.4
212F		2	2	R	9.7	2
414F		2	1	R	12.0	1
599F		2	2	E	9.5	2
690F		3	1	E	9.5	2
932F		3	1	R	9.0	2
	Average	2.4	1.4		9.94	1.8

Fleece Weights

The ewes in Lot I of the individual feeding trial produced fleeces which averaged 10.02 pounds, those in Lot II, 10.42 pounds, and those in Lot III, 9.75 pounds (Table XII).

Measurement of Tied Locks

The tied locks and clippings were handled in the same manner as has already been described for the wool-tie ewes at Fort Ellis (page 26).

Tied Locks: The tied locks for the individual feeding trial were measured with a comparator, the same as has already been described for the wool-tie ewes at Fort Ellis (page 27). During the four months over which this study continued, the average wool growth for each 28-day period for Lot I was .615 centimeter, for Lot II, .575 centimeter, and for Lot III, .510 centimeter. Lot I produced an average of .014 and .082 centimeter, respectively, longer wool than did Lots II and III each month.

To determine whether or not these differences were significant, the individual measurements for the four months were submitted to an "analysis of variance" (Table IX) as explained by Snedecor (20) and with his assistance through personal correspondence.

Snedecor explains "analysis of variance as "---a technique for segregating from comparable groups of data the variation traceable to specified sources. It furnishes an estimate of experimental error freed of that part of the variability whose origin is known. In conjunction with the associated test of significance, it affords a basis of judgment as to whether or not several groups are samples from a single homogeneous population. Through the use of degrees of freedom it is equally well adapted to the treatment of large or small samples."

TABLE IX

ANALYSIS OF VARIANCE OF TIED LOCK MEASUREMENTS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	119	1.225	
Within sub-classes	96	0.946	0.010
Level of nutrition	2	0.153	0.076
Month	3	0.064	0.021
Level-month interactions	6	0.025	0.004
Remainder	12	0.037	0.003

The mean square "within sub-classes" is the proper estimate of error. It measures the variation from animal to animal in the 24 "level-month-side-sub-classes". The only significant main effect is the level of nutrition, the mean square of which is 7.6 times as large as the experimental error. The monthly variation is large but cannot be termed significant.

Clippings: In first attempting to measure the short wool clipping, less than one centimeter in length, it was found that none of the ordinary measuring devices available were adapted to this work. As a result, several weeks were spent in an effort to discover a way in which these short fibers of wool could be measured rapidly and accurately. The first method tried was described by Hardy and Tennyson (10) (page 18) but was not as accurate as seemed desirable, so modifications were made in which oil or balsam was placed between the microscope slides, in the hope that they would supply enough tension on the fibers to make it possible to draw the fibers out straight. While part of the crimp was removed, it was impossible to remove all of the crimp, hence the actual length could not be determined accurately.

The next attempt was to mount the fibers on a microscope slide using a rapid drying liquid for a medium, in the hope that it would be possible to stretch each fiber perfectly straight and have the medium hold it in this position. Here again it was not possible to remove all the crimp; and further, the media used--including two kinds of shellac, glue, collodion, and Du Point household liquid cement--caused the wool fibers to become transparent to a degree which made it almost impossible to see them when placed under the comparator.

The use of an ordinary lantern slide projector offered a possible means for projecting fibers on a screen, but it was not possible to obtain the desired degree of magnification, nor was it possible to direct the projected images onto a flat surface without the use of a very large mirror. Since a large mirror and a room in which this equipment could be set up were not available this plan had to be discontinued, but led to the development of the method by which the fibers were measured.

This method involved the use of a micro-projector of simple construction, which was purchased by the Animal Husbandry Department especially for this purpose, and a map measuring device. Part of the technique followed was similar to that described by Wilson (26) (page 19) although the two methods were worked out independently. Wilson's report was not known to the author until after the fibers for this experiment had been measured.

The wool clippings were cleaned in carbontetrachloride and dried between blotters. Each clipping of wool was divided into five pieces approximately equal in size. It was estimated that 25 fibers from each side of a ewe would give a fair estimate of the length of wool grown each month, but 30 fibers were mounted. Three fibers were drawn from each portion of the clipping with a pair of tweezers and mounted between microscope slides and the ends of the slides fastened together with gummed stickers. It was necessary to mount two slides from each clipping. Before the second slide was mounted, each part of the clipping was turned over and the remaining 15 fibers drawn out. This doubled the number of places from which the fibers were selected and gave a more accurate estimate of the average fiber lengths.

At first the fibers were mounted dry, but because of the static electricity in wool, the short fibers had a tendency to bunch together and therefore, made measuring more difficult. To offset this, a small amount of water was placed on the slide before the fibers were mounted, but it was found that water would not form a uniform layer on the slide, especially if the slide were a little greasy. Mixing a little water with an equal amount of alcohol overcame this difficulty and a uniform, thin layer of the liquid formed over the slide, which completely eliminated bunching caused by static electricity.

The micro-projector was placed above a work bench in such a way that it was possible to project the image, by use of a small surface mirror, at right angles onto the top of the bench. It was much easier to measure the length of the fibers accurately with the image of the wool fibers projected upon a horizontal surface than it would have been to run the map-measuring device along a perpendicular surface.

The lens, which was furnished with the machine had a magnification of approximately 50 diameters at about four feet. It was found, however, that this lens was imperfectly ground and had an error of about five percent at this distance. To correct this error, the original lens was removed and a Leitz 24 mm., Micro-summar lens substituted in its place. At four feet four inches the magnification was 51.625 diameters and it was impossible to detect any error. With this magnification, the ease of measuring the fibers was facilitated and any error incurred due to measuring was reduced to 1/51.625 of the apparent amount.

The projected image of each fiber was measured by running the map-measuring device along the image and then reading the projected length to the nearest centimeter. These measurements were recorded and later changed to the actual lengths by using a table of projected length values and their corresponding actual value.

The average length of clippings produced by Lot I were .847 centimeter, for Lot II .761 centimeter, and for Lot III .703 centimeter (Table X). Lot I produced an average of .086 and .144 centimeter, respectively, more wool than did Lots II and III.

TABLE X

CLIPPINGS BY MONTHS FOR EWES ON THE INDIVIDUAL FEEDING TRIAL*

(Average of 25 Fibers)

Lot No.	No. of Ewe	First 28 Days	Second 28 Days	Third 28 Days	Fourth 28 Days	Average
		cms.	cms.	cms.	cms.	cms.
I	138F	.9100	.9193	.7338	.7380	.8253
	322F	.8608	.7525	.6756	.7167	.7541
	462F	.8821	.7388	.8289	.7477	.7994
	618F	.8825	.87594	.9230	.8430	.8811
	754F	.9189	1.03826	.9681	.9863	.9779
	Average	.8909	.8649	.8259	.8063	.8470
II	193F	.6969	.7508	.7353	.6636	.7117
	480F	.8600	.8608	.7721	.8267	.8299
	520F	.7826	.6842	.6350	.6663	.6921
	718F	.7756	.8519	.8217	.7771	.8065
	930F	.8031	.7496	.7655	.7469	.7663
	Average	.7837	.7801	.7459	.7362	.7613
III	212F	.7392	.8577	.6056	.6629	.7159
	414F	.8159	.7287	.6791	.6907	.7286
	599F	.6664	.6396	.5684	.5753	.6125
	690F	.7450	.7678	.7659	.7372	.7540
	932F	.8019	.7508	.5761	.6791	.7020
	Average	.7537	.7489	.6386	.6691	.7026

*All figures are averages from right and left sides.

To determine whether or not there was a relationship between the plane of nutrition and the length of wool grown by the ewes, three correlations were made. In the first case, initial weight was correlated with the average length of clippings for each ewe and the resulting $r = .0470 \pm .1738$ indicated that the initial weight had very little if any influence on wool growth. In the second case the total gain per ewe was correlated with the average length of clippings (Figure 1) and $r = .7558 \pm .0747$ indicating that the gain (indirectly the plane of nutrition) did influence the length of the wool grown. In the third case average weight per ewe for the trial, which really includes the total gain, was correlated with the average length of clippings and the value $r = .6776 \pm .0942$ obtained.

Table X shows a gradual decrease in the amount of wool produced month by month as the experiment progressed. This seems to indicate that some factor other than the plane of nutrition may have caused the gradual decrease, and it may be that as the time for lambing approached there was a tendency for more of the feed taken in by the ewes to be used for developing the foetus at the expense of wool growth.

Since the purpose for taking both the wool-ties and clippings was to use one as a check against the other, Table XI gives a comparison in percentages of the two methods of sampling.

TABLE XI

COMPARISON OF AVERAGE LENGTH OF MEASUREMENTS
OF TIED LOCKS AND CLIPPINGS FROM
INDIVIDUAL FEEDING TRIAL

Lot	First 28 Days	Second 28 Days	Third 28 Days	Fourth 28 Days	Average
I					
Clippings, cms.	.891	.865	.826	.806	.847
Wool ties, cms.	.618	.640	.595	.615	.617
% wool ties are of clippings	69.3	74.00	72.04	72.27	72.85
II					
Clippings, cms.	.784	.780	.746	.736	.761
Wool ties, cms.	.648	.610	.578	.575	.603
% wool ties are of clippings	82.69	78.20	77.49	78.10	79.21
III					
Clippings, cms.	.754	.749	.639	.669	.703
Wool ties, cms.	.545	.585	.500	.510	.535
% wool ties are of clippings	72.31	78.12	78.30	76.22	76.15

Table XI shows that the two methods do not give as similar results as are desirable in an experiment where a high degree of accuracy is necessary. A knowledge of the manner in which the samples were taken and measured leads one to believe that the clipping method is the more accurate of the two for determining the rate of wool growth.

The description of Plates III to XI give the individual records of all the ewes on the individual feeding trial.

TABLE XII

BODY WEIGHTS, WINTER RATION, FLEECE WEIGHTS AND WOOL MEASUREMENTS FOR EWES

(Individual Feeding Trial)

Number	Weights, lbs. Initial	Final	Total gain lbs.	Ave. feed consumed daily lbs.	Fleece weight lbs.	Ave. length of clippings cms.	Ave. length of tied locks cms.
				Lot I			
138F	122.3	149.0	26.7	4.15	9.1	.825	.550
322F	126.0	152.0	26.0	4.29	12.4	.751	.547
462F	128.6	154.0	25.4	4.11	9.1	.799	.600
618F	117.6	143.0	25.4	3.84	10.5	.881	.700
754F	128.3	160.3	32.0	4.06	9.0	.778	.688
Average	124.6	151.6	27.1	4.09	10.02	.847	.617
				Lot II			
193F	126.6	133.0	6.4	2.69	10.7	.712	.528
480F	121.0	129.0	8.0	2.56	9.8	.830	.650
520F	122.0	127.0	5.0	2.51	10.3	.692	.541
718F	124.3	126.7	2.4	2.72	11.1	.807	.716
930F	129.6	133.7	4.1	2.72	10.2	.766	.579
Average	124.7	129.8	5.2	2.64	10.42	.761	.603
				Lot III			
212F	124.0	115.3	-8.7	1.89	8.8	.716	.559
414F	119.6	121.0	1.4	1.74	8.7	.729	.494
599F	129.0	118.0	-11.0	2.02	11.7	.612	.472
690F	128.6	122.7	-5.9	1.90	10.2	.754	.606
932F	123.6	115.3	-8.3	1.85	9.3	.702	.544
Average	125.0	118.4	-6.5	1.88	9.75	.703	.535

SUMMARY

Experimental Methods

1. The results reported in this thesis are based on studies of grade Rambouillet ewes selected from the band at the Fort Ellis Range Sheep Experiment Station.
2. This study consists of three phases, namely: (A) Extensive phase; approximately 400 ewes on two planes of nutrition were studied during each of the three winter feeding trials;

   (B) Wool-tie phase; detailed records were kept on approximately 50 ewes included with the above ewes; and

   (C) Individual feeding trial; detailed records of 15 ewes individually fed on three planes of nutrition during one winter feeding period.
3. (A) The ewes on the extensive phase were divided into two lots each winter on a basis of age and weight; without reference to treatment during the previous winter feeding period.

   (B) The ewes on the wool-tie phase were selected permanently for this experiment when two-year-olds, on a basis of body weight and wool production. They were rotated between Lots I and II from year to year.

   (C) The yearling ewes on the individual feeding trial represented an average of the yearling ewes in the Fort Ellis band during the fall of 1933.
4. (A) The extensive and wool-tie phases of the experiment lasted for 112 days during the first two winter feeding trials, but only 84 days during the third trial.

(B) The ewes in the individual feeding trial were carried on a 28-day preliminary feeding period before being placed on the experiment which lasted for 112 days.

5. (A) The ewes on the extensive and wool-tie phases of the experiment received a good quality U. S. No. 2 alfalfa hay during each of the three winter feeding trials.

(B) The ewes on the individual feeding trial received low quality U. S. No. 2 alfalfa hay which was chopped with a hammer mill.

Results

6. (A) Lot I of the extensive and wool-tie phases received 3.02, 2.89, and 3.06 pounds respectively of alfalfa hay per head daily for each of the three winter feeding trials. Lot II during the first two trials received 4.02 pounds of alfalfa hay and .33 pounds of oats per head daily. In the third trial no oats were fed, but the hay was increased to a full feed, or 4.53 pounds per head daily.

(B) The ewes in Lot I of the individual feeding trial consumed 4.09 pounds; those in Lot II received 2.64 pounds, and those in Lot III received 1.88 pounds of chopped alfalfa hay per head daily. On a basis of amount of hay fed daily per hundred pounds live weight, these values were: 2.95, 2.07, and 1.54 pounds respectively.

7. (A) The first and third winter feeding trials, the ewes in Lot I of the extensive phase made respective gains of 7.65, and 9.34 pounds per head, which was approximately equal to the weight of the developing foetus, foetal membranes and fluids at the end of the experiment. The second trial, however, the gain was only 3.57 pounds per head, which actually

represents a loss from initial body weight.

(B) For the three winter feeding trials the ewes in Lot I of the wool-tie phase made gains of 12.9, 7.2, and 11.4 pounds respectively, which were approximately equal to the weights of the developing foetuses, foetal membranes and fluids at the time the trials were ended. The ewes in Lot II made corresponding average gains of 32.62, 30.62, and 23.30 pounds per head.

(C) The ewes in Lot I of the individual feeding trial made average gains of 27.1 pounds per head, those in Lot II gains of 5.2 pounds per head, while those in Lot III lost 6.5 pounds per head, which would be doubled if the weight of foetal membranes and fluids at the time the experiment ended were added to the loss in body weight.

8. (A) Lot II of the extensive phase produced .60, 1.15, and .61 pounds respectively more grease wool than did Lot I for each of the three years.

(B) Lot II of the wool-tie phase produced .45, 1.40, and .03 pounds more grease wool than did Lot I for each of the three years.

(C) Lot II of the individual feeding trial produced .40 and .67 pound more grease wool respectively than did Lots I and III.

9. The fleeces from the ewes on the wool-tie phase were scoured by the Texas Agricultural Experiment Station. Lot II produced .12 and .40 pound respectively more scoured wool than did Lot I for the two years.

10. (A) No wool-ties or clippings were taken from the ewes on the extensive phase.

(B) Wool-ties and clippings were taken from the ewes on the wool-tie phase, but the clippings were not measured.

(C) The wool-ties and clippings which were taken from the ewes on the individual feeding trial were both measured.

11. (A) The ewes in Lot II of the wool-tie phase produced an average of .027, .024, and .015 centimeter respectively longer tied locks than did the ewes in Lot I.

    (B) The ewes in Lot I of the individual feeding trial produced .014 and .082 centimeter respectively longer tied locks than did Lots II and III.

12. The average difference in length of clippings between Lots I and II on the individual feeding trial was .086 centimeter, the difference between Lots I and III was .144 centimeter.

13. Except for one ewe in Lot I, none of the ewes on the individual feeding trial exhibited any signs of sickness during the winter feeding trial.

14. The ewes in Lot I of the individual feeding trial carried more condition than did Lots II and III at lambing time but the Lot I ewes did not have quite as much milk as the other ewes, nor were their lambs quite as large and strong.

CONCLUSIONS

From a practical standpoint the maintenance and submaintenance planes of nutrition with the feeds as used in this experiment did not decrease the rate of wool growth during the four months' winter feeding period to any appreciable extent. About two-thirds of the small difference in wool production between ewes liberally fed and ewes fed to maintain their weight was due to a higher percent of shrinkage in the wool and only one-third due to the clean wool produced.

The results of this experiment indicate that it is unprofitable to feed pregnant range ewes, that are in good condition at the start of the winter feeding period, more than enough feed to maintain their initial weight, and that wool prices, as well as the cost of feed, should be considered when deciding how much feed should be fed.

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DESCRIPTION OF PLATES

Plate I

Figure 1

Correlation of average length of clippings in centimeters with total gain per ewe in pounds, the value of $r = .7558 \pm .0747$

Plate II

Figure 2

A lock of wool, tied with dental floss, showing growth during four periods of 28 days each.

Figure 3

Illustrating the extent to which the ewes ate wood.

Plate III

	Figure 4	Figure 5
Number	138F	322F
Lot	I	II
Initial weight, lbs.	122.3	126.0
Final weight, lbs.	149.0	152.0
Total gain, lbs.	26.7	26.0
Ave. feed consumed daily, lbs.	4.15	4.29
Ave. length of tied locks, cm.	.550	.547
Ave. length of clippings, cm.	.825	.751
Weight of fleece, lbs.	9.1	12.4
Condition at lambing	1	1
Milking quality	2	2
Birth weight of lamb, lbs.	10.4	9.6
Strength of lamb	2	2

Plate IV

	Figure 6	Figure 7
Number	462F	618F
Lot	I	I
Initial weight, lbs.	128.6	117.6
Final weight, lbs.	154.0	143.0
Total gain, lbs.	25.4	25.4
Ave. feed consumed daily, lbs.	4.11	3.84
Ave. length of tied locks, cm.	.600	.700
Ave. length of clippings, cm.	.799	.881
Weight of fleece, lbs.	9.1	10.5
Condition at lambing	1	1
Milking quality	2	2
Birth weight of lamb, lbs.	11.3	7.7
Strength of lamb	1	3

Plate V

	Figure 8
Number	754F
Lot	I
Initial weight, lbs.	128.3
Final weight, lbs.	160.3
Total gain, lbs.	32.0
Ave. feed consumed daily, lbs.	4.06
Ave. length of tied locks, cm.	.688
Ave. length of clippings, cm.	.978
Weight of fleece, lbs.	9.0
Condition at lambing	1
Milking quality	3
Birth weight of lamb, lbs.	10.3
Strength of lamb	2

Plate VI

	Figure 9	Figure 10
Number	193F	480F
Lot	II	II
Initial weight, lbs.	126.6	121.0
Final weight, lbs.	133.0	129.0
Total gain, lbs.	6.4	8.0
Ave. feed consumed daily, lbs.	2.69	2.56
Ave. length of tied locks, cm.	.528	.650
Ave. length of clippings, cm.	.712	.830
Weight of fleece, lbs.	10.7	9.8
Condition at lambing	2	2
Milking quality	1	1
Birth weight of lamb, lbs.	11.6	10.7
Strength of lamb	1	1

Plate VII

	Figure 11	Figure 12
Number	520F	718F
Lot	II	II
Initial weight, lbs.	122.0	124.3
Final weight, lbs.	127.0	126.7
Total gain, lbs.	5.0	2.4
Ave. feed consumed daily, lbs.	2.51	2.72
Ave. length of tied locks, cm.	.541	.716
Ave. length of clippings, cm.	.692	.806
Weight of fleece, lbs.	10.3	11.1
Condition at lambing	2	1
Milking quality	1	3
Birth weight of lamb, lbs.	10.1	9.5
Strength of lamb	2	2

Plate VIII

	Figure 13
Number	930F
Lot	II
Initial weight, lbs.	129.6
Final weight, lbs.	133.7
Total gain, lbs.	4.1
Ave. feed consumed daily, lbs.	2.72
Ave. length of tied locks, cm.	.579
Ave. length of clippings, cm.	.766
Weight of fleece, lbs.	10.2
Condition at lambing	2
Milking quality	1
Birth weight of lamb, lbs.	11.2
Strength of lamb	1

Plate IX

	Figure 14	Figure 15
Number	212F	414F
Lot	III	III
Initial weight, lbs.	124.0	119.6
Final weight, lbs.	115.3	121.0
Total gain, lbs.	-8.7	1.4
Ave. feed consumed daily, lbs.	1.89	1.74
Ave. length of tied locks, cm.	.559	.494
Ave. length of clippings, cm.	.716	.729
Weight of fleece, lbs.	8.8	8.7
Condition at lambing	2	2
Milking quality	2	1
Birth weight of lamb, lbs.	9.7	12.0
Strength of lamb	2	1

Plate X

	Figure 16	Figure 17
Number	599F	690F
Lot	III	III
Initial weight, lbs.	129.0	128.6
Final weight, lbs.	118.0	122.7
Total gain, lbs.	-11.0	-5.9
Ave. feed consumed daily, lbs.	2.02	1.90
Ave. length of tied locks, cm.	.472	.606
Ave. length of clippings, cm.	.612	.754
Weight of fleece, lbs.	11.7	10.2
Condition at lambing	2	3
Milking Quality	2	2
Birth weight of lamb, lbs.	9.5	9.5
Strength of lamb	2	2

Plate XI

	Figure 18
Number	932F
Lot	III
Initial weight, lbs.	123.6
Final weight, lbs.	115.3
Total gain, lbs.	-8.3
Ave. feed consumed daily, lbs.	1.85
Ave. length of tied locks, cm.	.544
Ave. length of clippings, cm.	.702
Weight of fleece, lbs.	9.3
Condition at lambing	3
Milking quality	1
Birth weight of lamb, lbs.	9.0
Strength of lamb	2

Plate I

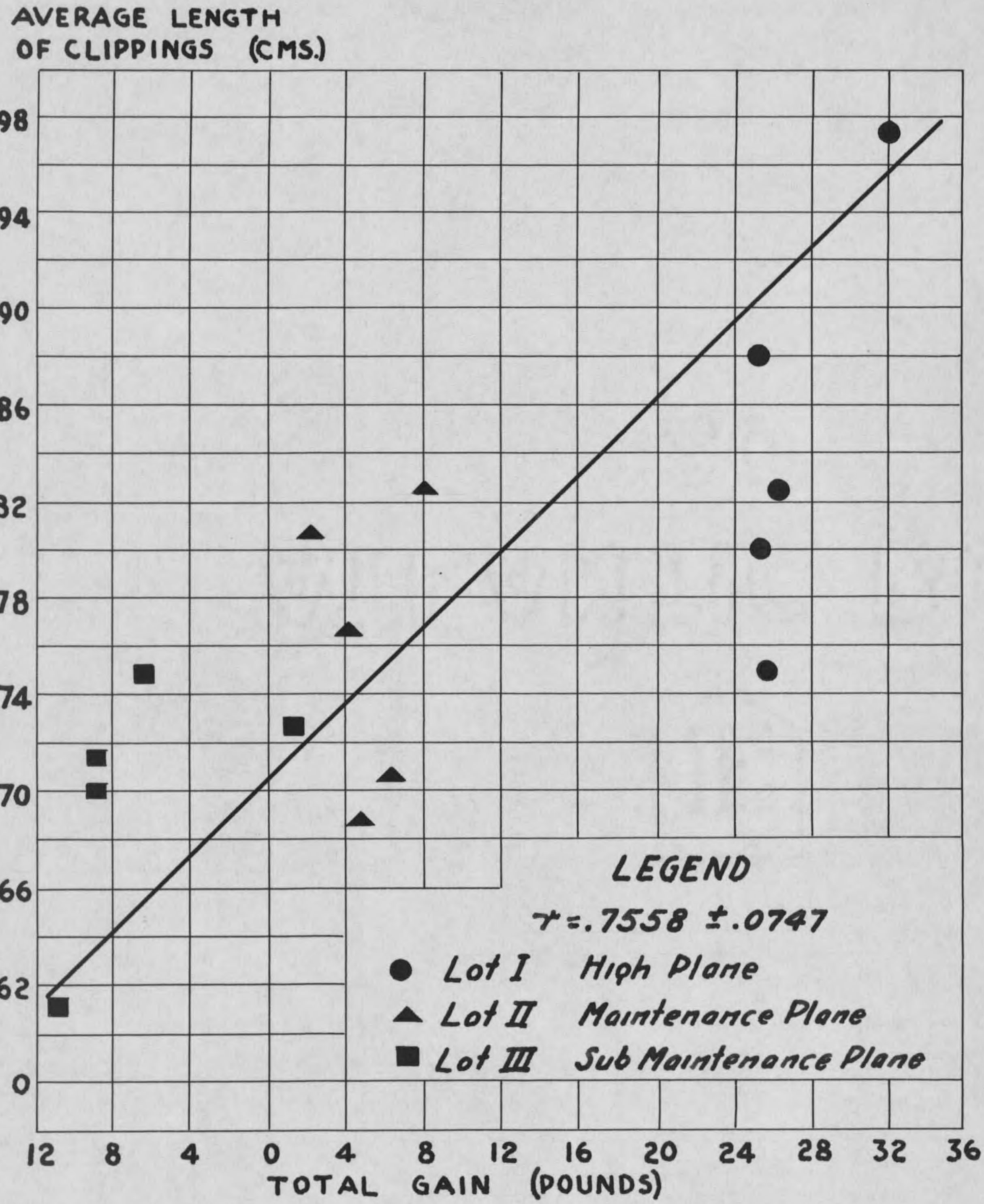

Figure 1

Plate II

Fig. 2

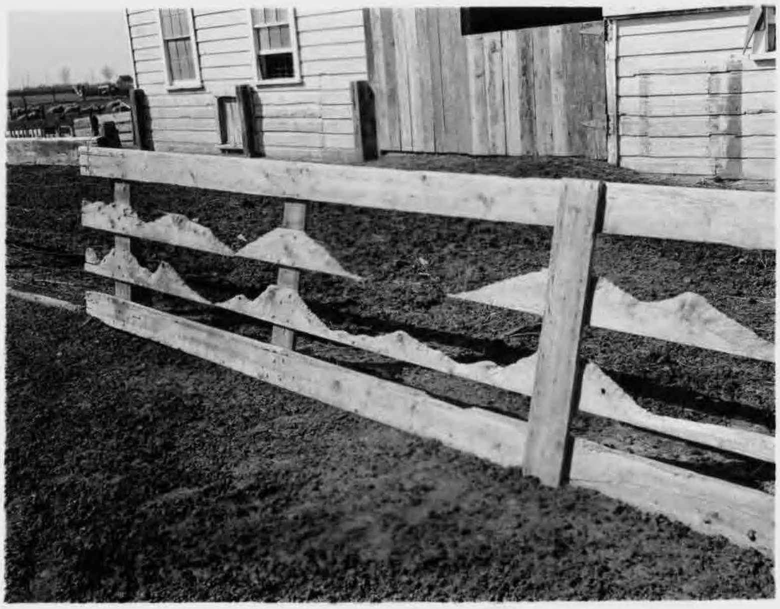

Fig. 3

Plate III

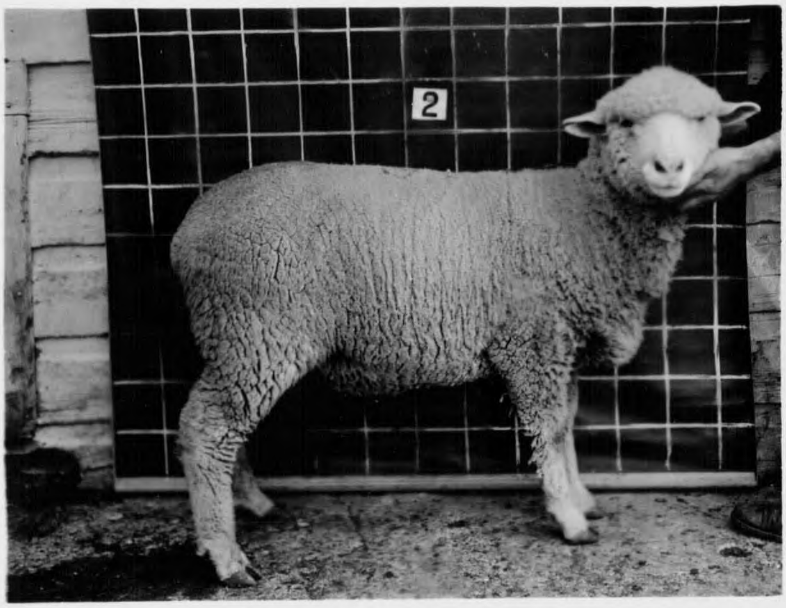

Fig. 4

Fig. 5

Plate IV

Fig. 6

Fig. 7

Plate V

Fig. 8

Plate VI

Fig. 9

Fig. 10

Plate VII

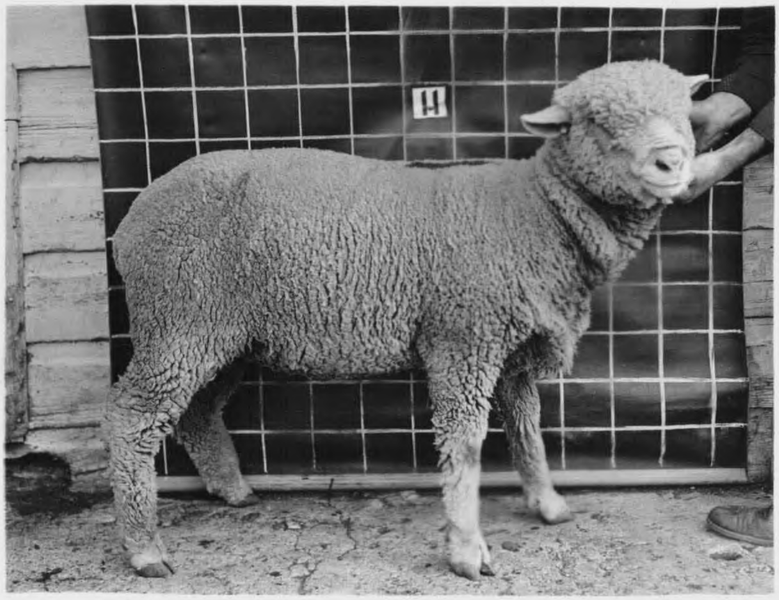

Fig 11

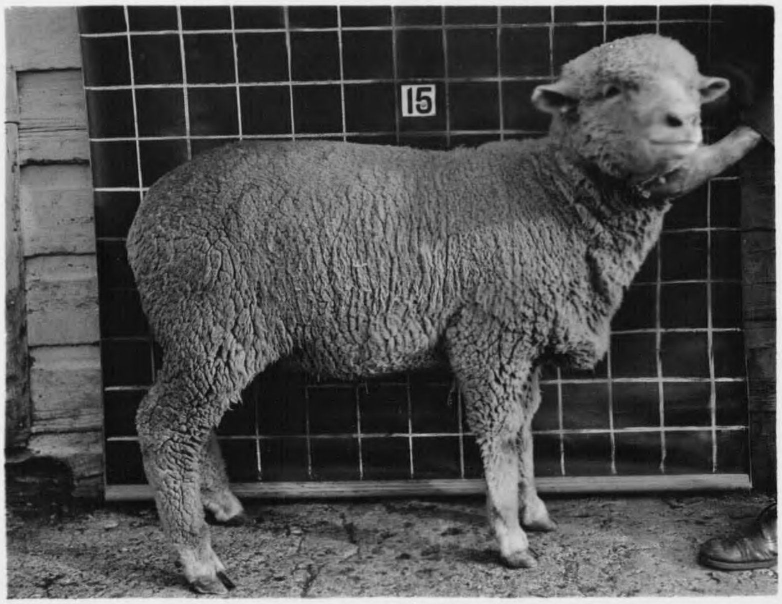

Fig. 12

Plate VIII

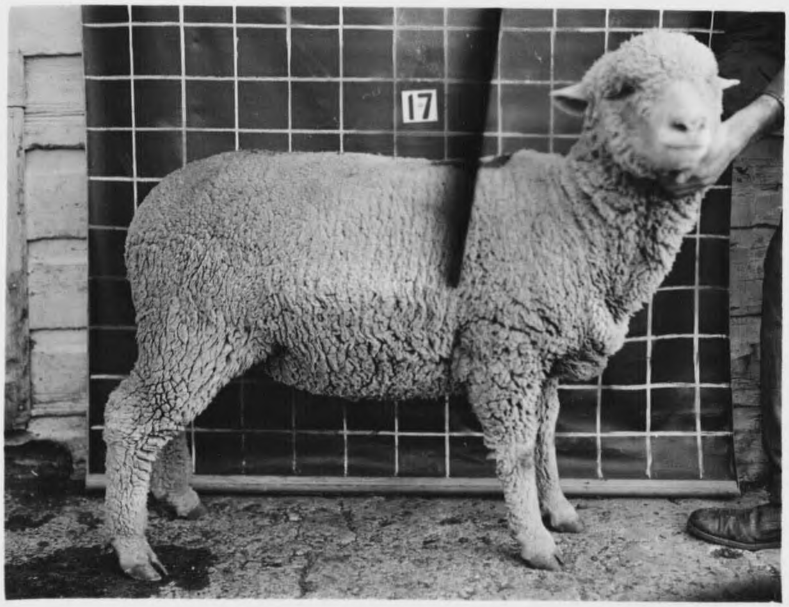

Fig. 13

Plate IX

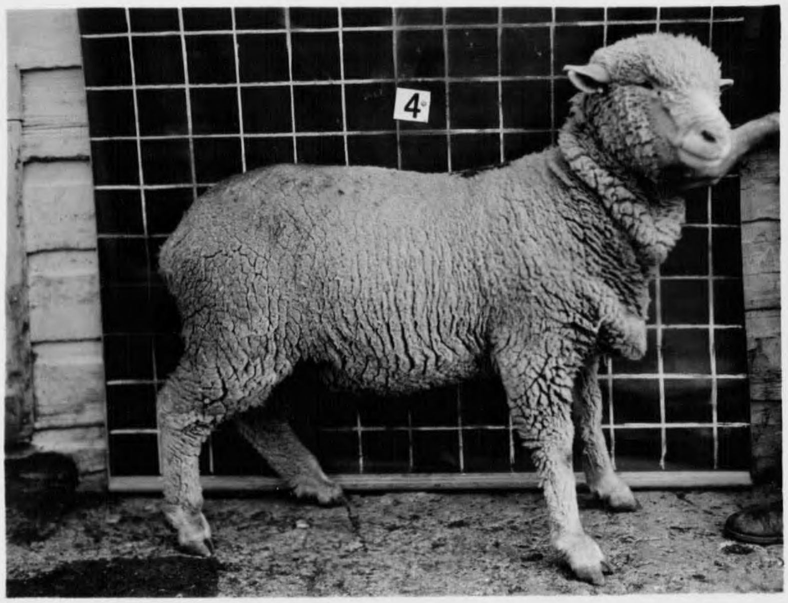

Fig. 14

Fig. 15

Plate X

Fig. 16

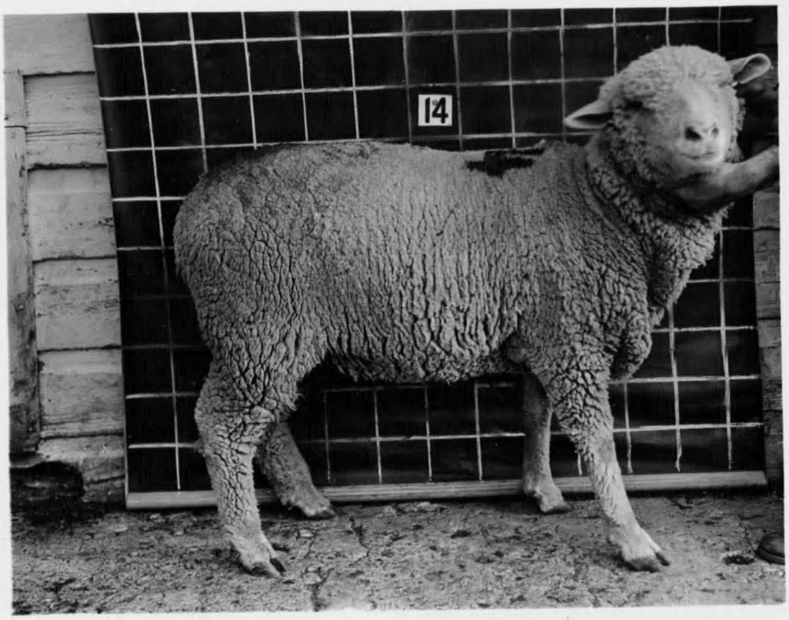

Fig. 17

Plate XI

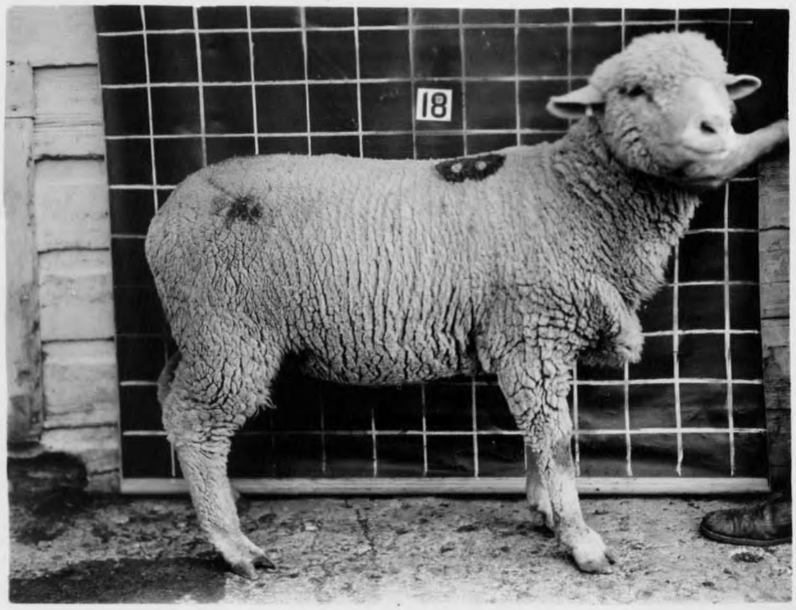

Fig. 18