THE EVALUATION OF SOME FLEECE AND BODY CHARACTERS FOR SELECTION OF EWE REPLACEMENTS BY VISUAL APPRAISAL AND A SELECTION INDEX

by

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I. THE PROBLEM

Statement of the Problem

The purpose of this study was to compare a visual appraisal system with a selection index system for selection of ewe replacements when both systems were used to evaluate some fleece and body characters.

Importance of the Study

Selection of replacement ewes is important and is a problem that confronts all sheep growers, whether they are large commercial growers with 40,000 head of sheep, one or two band operators with 2,000 to 4,000 head of sheep, farm flock operators with less than 600 head of sheep, or purebred breeders with 200 to 300 head of sheep.

It is a widespread practice for sheep growers to save replacement ewes from their own flocks and, as a matter of pride and principle, they attempt to select the superior ewe lambs.

Selection of the best ewes on the basis of visual appraisal of phenotypic fleece and body characters has had extensive application. This system is quite effective in maintaining the production of the flock at a high level.

Unfortunately the phenotype is often a poor indicator of the genotype.

Selection systems that might be more effective have limited application because they are not applicable where large numbers are involved. This is not true of the phenotypic method. In addition to its adaptability to large numbers it can be applied at any stage of growth and with a minimum of training and skill.

In large flocks it does not appear that the method of selection for replacement ewes will be changing; consequently, the rate and amount of genetic improvement will remain about the same. If any appreciable amount of genetic improvement occurs in commercial flocks, it will have to be introduced through the rams.

Thus, if a selection system, more effective than the visual appraisal system now used, could be applied to purebred Columbia sheep it could conceivably have far reaching effects. Any improvement in rams would be carried to the commercial flocks since Wyoming grown Columbia rams are used extensively in such flocks. Terrill (1957) reported that studies carried on at the U. S. Sheep Experiment Station at Dubois, Idaho showed

80 to 90 percent of the gains made in improving a trait like fleece weight came from rams and only 10 to 20 percent came from ewes.

Selection indexes are theoretically the most efficient method of selection for maximum improvement in production of several characters. Where several wool and body characters have to be considered in selection this fact becomes very important. Lush (1951 b) stated that selection indexes show promise of increasing the efficiency of selection by at least a few percent and also increasing the speed of improvement. However, the construction of selection indexes require large quantities of data for high accuracy (Turner, 1956; Morley, 1951) and are complex to construct when several component characters are included (Lerner, 1958; Falconer, 1960). Meeting such conditions limits the extent of utilization of indexes.

The U. S. Sheep Experiment Station at Dubois, Idaho (1952, 1954) has been a pioneer in both construction and application of selection indexes as applied to replacement selection of ewes and rams in the Rambouillet, Columbia and Targhee breeds.

The extent to which an index developed for one group can be applied effectively to another is not known. Lush (1954) stated that heritability may vary genuinely from one population to another. This demands caution when applying to one population estimates derived from another. However, the meager evidence indicates that such variation is ordinarily small between breeds or varieties kept for much the same economic purpose, under environmental conditions not drastically different and provided no intensely inbred individuals or lines are involved.

Morley (1951) stated that he found some justification for assuming that the results of his study could be applied to other flocks of Australian Merinos.

It is important to know if a selection index developed for one group of Columbia sheep will be effective for another group of Columbia sheep for selecting replacement ewes and how the effectiveness will compare to the system of selection based on visual appraisal of phenotypic fleece and body characters.

Steady genetic improvement of the Columbia segment of Wyoming's sheep industry could have long range beneficial effects. This would be important to the sheep industry of Wyoming which consisted in 1959 of 2,095,000 sheep with a value of $54,219,000, a wool clip valued at $9,108,000 and a lamb crop value of $30,000,000.

II. REVIEW OF LITERATURE

For convenience the literature review is divided into three main sections as follows:

A. Historical resume of the development, through selection, of modern day sheep.

B. Mass selection based on visual appraisal of phenotypic characters.

C. Development and uses of selection indexes.

Historical Resume of the Development, through Selection, of Modern Day Sheep

The modern sheep is the result of a process that was initiated by man in the remote past and has been continued up to the present time. Historical evidence indicates that sheep husbandry was practiced 7,000 to 8,000 years ago (Fairservis, 1955). Actual domestication probably pre-dates this as sheep were one of the first animals to be tamed (Wentworth, 1948). As a result of domestication sheep became less fit for natural survival and became very dependent on man for care and protection. Thus successful husbandry practices for perpetutation of the species developed a unique relationship between man and sheep. It is reasonable to believe that through this close association man became very familiar with fleece and body characters and at a very early date made definite efforts to modify type by breeding and selecting (Lush, 1945).

In many cases it appears that sheep were an important factor in man's successful migration to, and settlement of, new frontiers. Thus sheep greatly broadened man's environmental adaptation ability(Lush, 1945). That the sheep survived and became adapted to new environments is evidenced by the existence of at least 200 important and recognized sheep breeds throughout the world (Antonius, 1922; Carter, 1956). It can be assumed that man's efforts in giving better care and protection helped the sheep to survive in the changed environment. Probably man's previous selection efforts and breeding had caused sufficient diversity in type that natural selection had some effect in determining the type that could best survive (Hilzheimer, 1936). Man, no doubt, made efforts to select the better suited types once he knew what they were.

A significant migration of man to a new frontier commenced when Columbus discovered the North American Continent in 1492. While no sheep were on the initial voyage, Columbus, on his second voyage in 1493 brought sheep to America. Spanish settlers brought sheep to Hispanola and Cuba probably early in the sixteenth century. English sheep were brought into the English settlements almost as soon as they were settled. Sheep were brought to New York from Holland in 1625 while Swedish sheep were brought to New Jersey and Delware. The first Spanish Merino flock was not established in the Colonies until 1801 (Carmen, 1892; Wentworth, 1948; Allen, 1951). This influx of Merino blood into the common sheep of the day produced a much more desirable animal.

Sheep were always in the frontier movement in the migration from the Atlantic Ocean to the Pacific Ocean in North America. Vast areas of the west proved suited to sheep and vast flocks of Merino and Rambouillet crossbred type, some over 100,000 head, developed. Wyoming's vast desert areas in combination with the mountains proved adaptable for a new type of large range-flock operation. Purebred flocks and farm flocks also developed. Successful husbandry practices became established largely by trial and error. Settlers from many areas with different types of sheep, had many ideas. Out of it all came a rather stable sheep industry (Wentworth, 1948).

During the time of the western migration other great movements were being made to Australia, to South Africa, and to South America. These were the more important and about the last migrations of man and sheep to new frontiers. In these areas sheep probably have reached a higher degree of specialization for wool than heretofore achieved.

What husbandry practices were used and what principles were applied through the centuries to successfully perpetuate and improve sheep in the many varied environments is largely a matter of conjecture. That they were effective is evident from the fact that today sheep are found in all parts of the world and are a highly specialized animal (Antonius, 1936).

Mass Selection Based on Visual Appraisal of Phenotypic Characters

Kelley (1949) stated that in the beginning, the selection practiced by all constructive breeders must have been phenotypic, based on the appearance of the animal, since they had no other guide at that time.

Lush (1948) described mass selection as the kind which would be practiced if the individual's breeding values were predicted entirely from its own phenotype. This would necessarily be the case in a population in which the pedigrees were not even known. Mass selection accounts for much of the improvement that has been achieved in the past but it has undoubtedly been supplemented by observed pedigree record and progeny test type information even though no records were kept as such nor the genetic implication understood. This type of supplementation to mass selection was probably an important factor in small flocks. It probably also played a very important part during the development of breeds(Lush, 1945).

Applying mass selection to the large flocks that grazed over the plains in Wyoming presented problems that man had not been confronted with before. After management practices were fairly well established attention was turned to methods of improving wool and lamb production. Fortunately for Wyoming, the late Dean J. A. Hill had joined the staff of the State Experiment Station (about 1907) and recognized the problem confronting one of the state's important industries

(Burns, 1957). Hill (1921 ab) set up three studies (Since these are so basic to the establishment of selection practices, they are being reported in more than usual detail.) to investigate whether or not selection methods similar to those used in dealing with poultry and dairy cattle might be applied to sheep.

The first study was designed to examine the variability in the weight of fleeces produced by range sheep. Six flock owners cooperated. One hundred fleeces from each flock were weighed. In four flocks the range in grease fleece weight was from 4 to 11 pounds with an average of about 7 1/2 pounds. In the two other flocks studied, one had a range from 2 to 14 pounds and the other a range from 8 to 18 pounds. Table 1 shows how such a system of selecting could have worked in a representative flock of sheep ordinarily grazed in Wyoming about 1921.

The table was so constructed as to show the average production per head in each of two groups, one of which was called the cull group and the other the select group. Each line across the table shows what the average production would be in the two groups divided on the basis of the fleece weight stated in the first column. For example, if all the sheep from the representative flock

TABLE 1. EFFECT OF DIVIDING A REPRESENTATIVE FLOCK INTO ANY TWO GROUPS POSSIBLE ON THE BASIS OF FLEECE WEIGHT TO THE NEAREST POUND

Highest Fleece Wt. Cull Group Lbs.	% in Cull Group	% in Select Group	Av. Wt. Fleece Cull	Av. Wt. Fleece Select
4	1	99	4.0	7.9
5	2	98	4.5	7.9
6	14	86	5.8	8.2
7	37	63	6.5	8.6
8	70	30	7.2	9.3
9	92	8	7.5	10.3
10	98	2	7.8	11.0
11	100	___	7.9	___

with fleeces that were recorded as weighing not more than 6 pounds had been placed in the cull group, then this group would have contained 14 percent of the sheep in the flock and their average weight of fleece would have been 5.8 pounds. The select group made up of those sheep with fleeces that were recorded as weighing more than 6 pounds would have contained the remaining 86 percent of the flock with an average of 8.2 pounds.

As a further example of the use of the table, it is interesting to note that if the 37 percent that are shown in the table as shearing 7 pounds or less, had been placed in the cull group, then the average fleece weight of the select group remaining would have been 8.6 pounds, which is almost three-quarters of a pound more than the average fleece weight of the original flock which was 7.9 pounds. It is evident from Table 1 that if the minimum fleece weight necessary for profitable operation is known then the grower will know what percent to select to meet this minimum. These findings, considering the date of the study, were rather revealing and were suggestive of the effect which systematic selection would have on wool production in range flocks not only in Wyoming but in the entire west.

No matter how wide the range of variation in fleece weight might be, selection as it has to be carried out in sheep husbandry would be of no effect if mature sheep that were high producers one year did not continue to be relatively high producers the remainder of their lives. For this reason a study was undertaken to determine the correlation between the amount of wool which a sheep produces one year and the amount produced during the subsequent years of its life. The fleeces of thirty wethers were studied for 4 years. The wethers were two and three years old. Their individual grease fleeces were scoured separately and the clean fleece weights determined.

The correlation between the weight of scoured wool in the fleece which each sheep produced on the range with the average weight of scoured wool in the three fleeces produced while on the feed lots was $+ 0.51 \pm 0.09$. The clean wool correlation between the first year on the feed lot with the two subsequent years on the feed lot was $+ 0.70 \pm 0.07$. These correlations strongly suggested that the effect of selection would not all be lost after the first year.

Hill (1921 ab) maintained that if selection was practiced under conditions where large numbers were involved it would have to be done on the basis of the estimated value of the wool while it was still on the sheep's back rather than after it was removed. Since lengths of 2 1/4 inches or longer, brought more per pound than shorter wool and since length was one of the important factors that controlled the amount of wool in a fleece, the third study investigated the effect of these factors. Fleeces that had been graded commercially at shearing time into combing wools, 2 1/4 inches or over; and clothing wools, less than 2 1/4 inchers, were used. Thirty fleeces taken from the combing bin averaged 11.7 pounds in weight while 39 taken from the clothing bin averaged 10.0 pounds in weight. On the basis of Boston prices for 1921 the 39 clothing fleeces had a ranch value of 25½ cents per grease pound based on an estimated 64 percent shrinkage and a Boston price of $1.60 per clean pound which resulted in an average value of $2.98. The 39 clothing fleeces had a grease value of 16 cents per pound at the ranch, a shrinkage estimation of 64 percent, a clean value of $1.17 which resulted in an average fleece value of $0.60 (Cost of freight and selling was estimated at 5 cents per pound). This investigation indicated that staple was a most important factor in determining the weight and value of the fleece. Consequently, staple length was an important factor in selection, especially with large numbers, since it could be determined on the sheep.

Hill (1921 ab) stated that the conclusions to be drawn from the three foregoing investigations were not as trustworthy as they would be if they were based on larger numbers of sheep within the flocks and more flocks covering a wider area. However, they were the initial basis for the development of a systematic method of selection in commercial flocks in Wyoming which Hill applied rather extensively considering the great distances, poor roads, inadequate cars and large flocks of those early days.

McWhorter (1921) described the length-weight relationship of about 2,000 fine wool fleeces over a 5 year period. The fleeces less than $1\frac{1}{8}$ inches in length averaged 9.1 pounds and the fleeces $1\frac{1}{8}$ inches and longer averaged 11.5 pounds. This substantiated Hill's findings.

The results of some of the applied culling work along with some of the methods and techniques which were found applicable are discussed in the following paragraphs.

Hultz and Hill (1931) described a system of selecting range sheep; the process was one of selecting the best ewes on phenotypic appearance and then these ewes were put into high-grade breeding flocks from which lamb replacement could be bred. The technique consisted of looking over the flock in order to set a standard and then deciding what percent to remove. Chutes, 50 to 150 feet long and 3 or 4 feet wide, facilitated the selection process. Each sheep was examined as the operator worked down through the chute and was evaluated on the following characters: density, covering, length, purity, and body size and body type. The sheep to be removed were marked on the back with blue chalk.

Hill and Fellhauer (1943) described the first systematic procedure which was started in Wyoming about 1921. In the initial phase, it consisted of removing poor producers from the mature flock and then selecting replacements at weaning time. This was done in order to prevent low producing ewes from getting into the breeding flock. Included in this early study was a 10 year cooperative study involving a flock of 30,000 sheep. The mean grease fleece weight increased from 8 to 11 pounds in this period of time. The success of this study prompted similar work in commercial flocks and by 1940 there were 38 sheepmen, in 14 counties, with 200,000 sheep involved. By 1942 there were 350,000 sheep in cooperative sheep improvement work. In many cases the work was carried on out on the range by constructing temporary holding pens made out of lathe fencing and panel chutes, 3½ feet wide by 100 feet long, which held 75 to 125 sheep at a time.

Double chutes were frequently set up so one could be filled while the other was being worked. The first step in the program was to cull the ewe flocks when in full fleece. In cases where the inferior sheep were not disposed of, they were run separately and replacements were not saved from their progeny. The second step was to select replacements at weaning time, and where possible, in excess of 10 to 15 percent so further selection could be done at yearling time. The factors considered in selection were body type, size and conformation; wool density, length, quality and uniformity. The first consideration was to increase the quantity of wool and later on to increase selection pressure on uniformity of grade, both between fleeces and within fleeces. It was possible to work from 800 to 1,200 sheep an hour and as many as 8,000 sheep were worked in a day. This speeded up procedure made it possible to work the larger commercial outfits where previously no systematic method was used in culling the mature flock or selecting replacements. Ram flocks were culled in a manner similar to that used with the ewes except a more thorough evaluation was made with more rigid requirements. The grower was encouraged to buy good replacement rams having the wool quality that would improve the wool he was attempting to grow.

Fellhauer (1948) cited several specific cases where the initial culling in mature flocks resulted in 3 to 4 pounds differential in grease fleece weights between culls and selects. In 1941 Fellhauer and Hill culled a flock of 12,000 yearling ewes just before shearing and marked 1,000 head for removal. The groups were sheared separately and the 11,000 selects averaged 10.62 pounds and the 1,000 culls sheared 9.1 pounds. This flock had, at one time, consisted of over 100,000 sheep and the company's headquarters were in Edinburgh, Scotland. During the same spring, in the extreme western part of Wyoming, 1,025 mature ewes were removed from a flock of 2,408 sheep. Those culled had an average grease fleece weight of 8.51 pounds compared to 10.57 pounds for those retained. In northern Wyoming, a flock of 1,400 fine wooled yearling ewes were evaluated and 400 were classed as cull while 1,000 were classed as selects. The two groups were sheared separately and the culls had an average grease fleece weight of 11.92 pounds compared to 13.37 pounds for the 1,000 selects.

Hill (1948) described the "touch" system and recommended it as a quick method of discovering and marking elimination the mature ewes which produced small, low value fleeces. He also recommended it as an effective systematic method for selecting replacements at weaning time year after year. He stated that an experienced man should be able to cull 800 to 1,000 sheep per hour if 2 chutes were available and help was available to fill the chutes and operate the cutting gates as sheep were removed.

Fellhauer (1955) summarized the range sheep improvement program initiated around 1920 by the late Dean J. A. Hill in Wyoming. From 1937 to 1950 the culling and selection program was stepped up to the extent that there were few growers who did not obtain direct assistance in flock selection. The new wool program of 1954 further stimulated improvement work by culling and selection. In this program the higher the selling price of a grower's wool, the greater the incentive payment. The program adapted to range conditions consisted of (1) Using well-bred, heavy wooled, good bodied rams, (2) Selecting replacement ewes on size or growthiness, amount of wool, and quality of wool.

Riches and Turner (1955) compared an eye appraisal system of selection with selection on wool weight and found that eye appraisal at any age was shown to be only approximately 30 percent efficient in raising wool weight per head and approximately 45 percent efficient in raising money return per head. Selection on wool weight at 9 months of age was 80 percent effieient in raising wool weight per head, and 70 per cent efficient in raising money return per head, when compared with selection on wool weight at 21 months of age. In the Australian sheep industry breeding ewes are usually selected by eye appraisal in the wool from 18 months to 2 years of age.

In Australia, an evaluation of selection systems has been made in recent years and the system of "independent culling levels" appeared to offer greater scope for wide commercial use, provided the number of characters was kept small. This system (C.S.T.R.O. Conference 1954) involved a preliminary selection for "off type" fleeces, which amounted to fixing a culling level for quality. Final selection was then on fleece weight.

This selection would be done on ewes as two-tooths, with a culling margin left for subsequent selection on reproductive performance. Since wool is of such overwhelming importance compared to mutton, no criteria for the body character was included. Should the importance shift the system of selecting would have to be reconsidered (Turner, 1956; C.S.T.R.O. Conference, 1954; Morley, 1955 a; Riches and Turner, 1955). New Mexico has a problem of selection improvement similar to Wyoming in that any method of improvement must be adaptable to large flocks. The nature of the problem is different because New Mexico has predominantly fine wool where Wyoming has 4 different grades in most flocks. Neal and Ellis (1941) studied the distribution of fleece weight in an experimental flock of 1,200 sheep, a single ranchman's herd of 6,000 sheep and 6,000 random samples from 72,000 sheep. A wide range in fleece weight was revealed. Next, a study of length was made similar to Hill's (1921, ab) with very similar findings i. e., the longer stapled fleeces were heavier and more valuable. At shearing time, using fleece weight and staple length as criteria, the best ewes and the best rams were selected and these were used to raise replacements. At weaning time, the same type of selection was applied to the replacements.

Oxley (1955) investigated some fleece and body character relationships in a farm flock of 550 ewes over a period of 3 years. This information was used to supplement phenotypic selection for improvement.

A mechanical squeeze machine for estimating clean fleece weight was developed (Stauder and Neal, 1958; Neal et al., 1958). It had a high degree of accuracy for clean wool prodiction in fine wool and was used in large flock operations at shearing time in detecting the low producers which were consequently culled from the flock.

Gray (1959) carried on an extensive culling program using 75 ranchmen. Twenty-eight of these ranchers practiced selection in which desirable mutton and wool producing qualities were the determing factors while the remaining 47 ranchers did not practice any culling. The 28 practicing selection received 7.7 percent more for their wool.

The studies reviewed indicated that mass selection had been applied to both sexes at different stages of growth. It was applied to situations where large numbers were involved. It lends itself to supplementation by progeny test data and other aids. Several of the studies indicated that mass selection was effective in keeping production of the flock high and in improving efficiency of production. This is encouraging since methods have not been fully developed where more effective means of selection can be satisfactorily applied to large numbers, even though the mechanism of how inheritance operates is fairly complete.

However, if mass selection is unaided the contribution to improvement of the next generation through heredity may be low and rate of progress slow. A condition that might alter this is the heritability level of the factor or factors on which selection is being made (Lush, 1945). Turner (1956) and Frideen (1958) indicated that when correspondence between phenotype and genotype was high there was little advantage of going beyond mass selection whereby the genetic worth was predicted on the basis of the individuals own phenotype. Lush (1935, 1945, 1948) and Rae (1956) stated that when the heritability level of factor or factors was low some form of aid must be used in conjunction with mass selection if the degree and rate of genetic improvement was to be greatly increased. Lush (1945) listed some of the aids as follows:

1. The use of lifetime averages
2. Pedigree estimates
3. Progeny tests
4. More careful control or consideration of environment

Today genetic theory is far in advance of its application to practical animal breeding and selection situations. However, there is some evidence that proven genetic principles are being taken out of the laboratory into the field of application (Terrill, 1958, 1960 and Waddington, 1957). Even though mass selection continues in many instances as it has for years, full use of genetic knowledge available today should make mistakes in mass selection fewer. Aids that are genetically sound should make mass selection ever more effective, especially in instances where large numbers limit application of more scientific principles and methods (Lush, 1945).

Development and Use of Selection Indexes

Lush (Genetics in the 20th Century, edited by Dunn, 1951) introduced his essay on "Genetic and Animal Breeding" with this paragraph:

> The art of animal breeding was already well advanced before 1900. By countless centuries of trial and error, certain principles had come to be recognized as generally a bit more successful than others in producing animals more like the breeder's desire. Yet only a little was known about why things happened as they did; the art of animal breeding was far in advance of the science.

This lag of genetic theory behind animal breeding practice was considerably narrowed by the monumental works of Fisher (1918 and 1930) and Wright (1921 and 1931) who established the theoretical basis for genetic studies that followed.

Smith (1936), Panse (1940) and Hazel (1943) made rather successful attempts in working with genetic and phenotypic correlations between two or more characters of the same individual and devised techniques whereby the kind of selection to be practiced could be defined in such a way that maximum improvement in production might be obtained.

Hazel and Lush (1942) compared three methods of selection and found a selection index to be more efficient than independent culling levels and "tandem" selection. However, the loss in efficiency for independent culling levels compared with a selection index is not great when the proportion saved is small. Lush (1935, 1945, 1948) developed statistical methods for understanding traits dependent on multiple genes and presented an objective basis for determining emphasis on several traits in an index by giving emphasis in proportion to their heritability times their economic importance. Valuable contributions were made by Lush in bridging the gap between genetic theory and application to animal breeding.

Hazel's work (1943), previously referred to, presented a method of constructing an index by calculating a multiple regression equation to predict the breeding value of an animal from its various traits. The traits of relatives were included, particularly in young males where selection was practiced before their own performance could be measured. Constants which must be known for each trait in order to construct the index were the relative economic value for the different traits, heritability and standard deviation of each trait, and phenotypic and genetic correlations between each pair of traits. The economic value of a trait was obtained by determining the monetary value of a unit change in that trait.

An index (I) constructed as above for Rambouillet weanling lambs follows:

$$I = 75 - 15F + 7L + W + 0.4T + 8C - 11N$$

where F = face covering

W = weaning weight in pounds

L = staple length in centimeters

T = type score

C = condition score

N = neck folds score

The constant 75 was added to insure that the index would be positive and average around 100. Corrections for measurable environmental factors was made directly to the index by the use of the following constants:

Twins	+ 9.2
Twins raised as singles	+ 1.6
Two year old dams	+ 2.1
Age (Age in days - 130)	- 0.34
Inbreeding (Inbreeding coefficient in percent)	+ 0.31

Heritability estimates and other vital statistics on Rambouillet weanling lambs were obtained at the U. S. Sheep Experiment Station at Dubois, Idaho. This information was used in constructing a selection index by Hazel (1943) and the index was applied in 1944 (Sixteenth Report of U. S. Sheep Experiment Station, 1953-54).

At Dubois a comparison of the ratio of the selection differential for lambs saved in 1945 to those saved in 1944 indicated that the selection index was only slightly more efficient than selection by general appearance for ram lambs, where a small proportion of the lambs were selected; but the selection index was considerably more efficient for ewe lambs where a large proportion of lambs was saved (Hazel and Terrill, 1946).

Terrill (1950) reported that the use, from 1945-1948, of a Rambouillet selection for lambs had the following effect on the selection differentials as compared to selection differentials during 1934-1944 when no index was in use: (1) Both sexes showed an increase for face cover and weaning weight, (2) The ewe lambs showed a decline for body type and condition. Selection for overall merit as measured by the index was increased about 18 percent by the use of the index.

At the U. S. Sheep Experiment Station, from 1941 to 1944, heritability estimates and other vital data were obtained on Columbia and Targhee sheep from the weanling lambs produced. Indexes were constructed and applied in the fall of 1951 for Columbia weanling lamb selection (U. S. Sheep Experiment Station, Sixteenth Report). The index applied on the Columbia weanling lambs was as follows:

$$I_x = 10L - 5SGC + W + 6T + 3C$$

where I_x = index

L = length in centimeters

SGC = side grade code (range 1-9 for fleeces grading 70's to 46's respectively)

W = weanling body weight

T = type score

C = condition score

Terrill (1952) indicated that indexes developed for Rambouillets were found fairly satisfactory for Targhees.

Terrill (1955) stated that definite gains appeared to have been made in the Dubois flock in the period from 1948 to 1954. Gains measured by changes in records of all lambs weaned over this period in a non-inbred group of Rambouillets was 6 percent for weaning weight, 18 percent for open face and length of staple, and 19 percent for overall merit as measured by an index.

Morley (1950, 1951, 1952, 1955 a, 1955 b) made extensive studies determining estimates of phenotypic and genetic parameters, repeatability and heritability estimates for characters of economic importance in Merino sheep in Australia. These studies were basic for development of selection index systems and evaluation of other breeding and selection systems.

Rae (1950) developed three selection indexes for Romney Marsh sheep.

Ercanbrack (1952) constructed indexes for range Rambouillet, Columbia and Targhee weanling lambs.

Sidwell (1955) developed a selection index for Navajo crossbred range sheep.

The small numbers in most farm flocks and purebred flocks are not conducive to reliable estimates of fleece and body parameters necessary for selection index construction (Hazel, 1943). Consequently, these segements of the sheep industry have received limited attention. However, Karam et al. (1953) developed 4 indexes which included various combinations of body, staple length and face covering. The index comprised of body weight at weaning age - 2 x face covering score was the most practical.

MacNaughton (1957) studied and analyzed Rambouillet and Canadian Corriedale records for important fleece and body characters and concluded from the heritability, phenotypic and genetic correlations that the most satisfactory method of improving economic characters would be the use of selection indexes at weaning and shearing time.

Felts et al. (1957) studied records from 32 flocks in Wisconsin and made necessary estimates for construction of a selection index for use in farm flocks.

Faulkner and Botkin (1958) formulated two selection indexes, one for Rambouillet weanlings and one for Columbia weanlings. The body characters received about

2/3 of the total weight and wool received about 1/3. While these were not constructed according to the method of Hazel (1943) it allowed for a systematic evaluation of each trait.

Karam (1959) again constructed 3 indexes for selecting Rahmani sheep. The traits he worked with were body weight, fleece weight and type of birth. The index constructed from all three factors was most efficient. Selecting on body weight only was least efficient.

Givens et al. (1960) constructed 5 selection indexes for early milk fat spring lambs and compared them. They were based on various combinations of daily gain from birth to weaning, 120 day weight, and ewe market grade. Selection on daily gain seemed most practical to use and appeared to give near maximum genetic return in economic terms. Estimates of heritabilities, genetic and phenotypic correlations and economic values were calculated.

The U. S. Sheep Experiment Station at Dubois (1960) issued a list of sale sheep comprised of about 775 sheep of Rambouillet, Columbia and Targhee breeds. About 275 of these were rams. For the information of the prospective buyers pertinent data for each individual ram were listed along with a selection index. This index was explained as a combination of the adjusted records of a ram which gave a numerical estimate of his breeding value. Emphasis on various traits in the index was based on heritability, economic importance and relationship between traits. The Columbia ram index was body weight in pounds + 6 x type score + 3 x condition score + grease fleece weight in pounds + 18 x clean fleece weight in pounds + 2 x staple length in centimeters - 2.5 x coded fineness in spinning counts.

The Targhee and Rambouillet ram index was body weight in pounds + 7 x type score + 4 x condition score - 3 x grease fleece weight in pounds + 11 x clean fleece weight in pounds + staple length in centimeters - 7 x face covering - 3 x neck folds score. Terrill (1953) studied single stud rams sold at public auction at the Dubois Station from 1946 through 1951 and found while many factors were evaluated by buyers as indicators of merit the index received some attention. By furnishing the selection index to the buyer the ram breeder was able to assist the ram buyer in improving his flock through the selection of rams.

As the studies just reviewed indicate, selection indexes have been applied in a variety of situations in various countries. They are one of the more efficient selection tools yet devised as several research workers agree (Lush, 1943, 1945, 1948; Hazel and Terrill, 1946; Turner, 1957; Lerner, 1958; Rae, 1958; Terrill, 1958).

The continued and expanded use of selection indexes by the sheep industry and research will depend, in part, on improved techniques of application. If selection indexes can be developed that can be applied to similar situations (the same breed or similar type of sheep) with results superior to those from selection systems in use, greater utilization will be made of this important tool.

III. MATERIAL

Environment

Data used in this study were obtained from the flock at the University of Wyoming's Archer Sub-station which is located in the southeastern part of Wyoming in Laramie County about ten miles east of Cheyenne, near U. S. Highway 30. The station has an elevation of 6,011 feet. It consists of about 935 acres.

Precipitation in this area was 14.82 inches for a 43 year average. The type of precipitation and amounts on a quarterly basis for that period is given below:

Months	Form	Amount in Inches
September October November	Rain & Snow	2.80
December January February	Snow	1.01
March April May	Rain & Snow	4.82
June July August	Rain	6.19

The average maximum and minimum temperatures for the locality are given below:

Month	Maximum Temp. in ^{o}F	Minimum Temp. in ^{o}F
April-September	76°	40°
October-March	42°	18°

Summer temperatures may reach 100° F. for short periods of time in July and winter temperatures 40° F. below 0° F. for short periods.

The wind came predominately from the north, northwest with a yearly average of about 8 miles per hour and ranged from 11 miles per hour in winter to around 3 miles per hour in the summer.

The terrain was fairly flat with slightly rolling hills and the soil was primarily a sandy loam type, very fertile and supported a short-grass type. The dominant native type was blue grama (boutcloua gracitis) and in lesser amounts western wheatgrass (agropyron smithii), buffalo grass (buchloe dactyloides) and many other species in minor density. Introduced species were crested wheatgrass (agropyron desertorum), Russian wild rye (elymus junceus) and some intermediate wheatgrass (agropyron intermedium). The terrain and flora in the locality of the station was somewhat similar to the eastern one-third of Wyoming. The amount of rainfall was just on the border line where dry farming starts to be successful.

The sheep were usually turned out on pasture around the middle of May. Crested wheatgrass pastures were utilized until the first of June and transfer was then made to native grass pasture. The rate was approximately 36 sheep days per acre up to 90 sheep days per acre depending on the amount of moisture.

Winter grazing was on native range with the stocking rate about 60 sheep days per acre. Usually there was enough grass to last until around the middle of December at which time supplementary feeding was started, if necessary.

Supplementary feeding consisted of 2½ pounds hay, 2 pounds silage (if available), ½ pound grain and 0.1 to 0.2 pounds of 20 percent protein pellets of some sort. If silage wasn't available 3 pounds of hay were fed. After lambing the hay was usually increased by 1 pound and the grain by ½ pound. Salt was fed free choice all year long. Grain and pellets were fed in a trough in the evening. Hay was fed in the morning on the ground in the pasture or, if the weather was bad, at a feed rack in the corral. At noon the silage was fed in feed racks.

The only time housing was used was during severe storms in the winter and during lambing in March and April. At night, during lambing, all ewes were kept in the shed. After lambing all ewes and lambs were kept in, both day and night, until the lambs were big enough to stand the weather outside. The shed was fixed so that feeding could be done there if the weather was bad.

Breeding procedure was not unlike that followed in most well operated farm flocks. The ewes were not flushed. However, they were put on new pastures at the start of breeding. The rams were put in the last week of September and were left about 6 weeks. After an interval of a week a clean-up ram was put in for about 3 weeks more. One ram was used for about 20-40 ewes. The rams were not given any special care but were well nourished at all times.

The lambing procedure also followed more or less the methods for farm flocks and small purebred flocks. All lambs were weighed, ear tagged and given a body score at birth (This score was based on a visual evaluation of the body characters of body width, length and depth and ranged from 1 to 10. The one having the highest merit received the highest score.). This information was recorded in a book along with the ewe's ear tag and date of birth. Ewe and lamb were kept in a small pen, about 3' x 3' where the ewe was fed and watered for several days. Lambs were castrated and docked when they were 10 days to 2 weeks old. The mortality rates at birth were not excessive. The sheep were sheared by machine (Wyoming special comb or similar type) each year around 13 May. Starting in 1960 the shearing date was changed to February. The same shearer was employed for several years until he retired. The advantage of using one shearer was that it allowed sufficient time to collect all desired shearing data and it eliminated differences due to different shearers.

The flock was not subject to disease or parasitism. There was constant trouble from town dogs and coyotes. It presented a problem and at times the death loss was rather high. Traps, poison and shooting was employed with varying degrees of success. Housing at night helped but some trouble occurred during the daytime. Staying with the sheep 24 hours a day was about the only thing that worked.

It can be said that the management practices were very similar to the better practices followed by the more progressive Wyoming farm flock and small purebred breeder. Probably housing and feeding was above average.

The Sheep

An experimental flock of sheep was established at Archer Sub-Station about 1935. The original ewes were of a cross-bred white-faced variety and the rams were Corriedale. With the increased popularity of Columbia sheep all the Corriedale rams were replaced by Columbia rams.

In the fall of 1951 the Archer flock was reduced 120 breeding ewes. This was accomplished by the removal of ewes with faults in body conformation such as narrow, shallow bodies; extremely fine bones; and pinched heart girth. Ewes with obvious wool faults such as britchiness, short staple and lack of density were also removed. In addition to the removal of the ewes mentioned above, any small ewes were also removed. The grade of wool was not a factor in eliminating ewes. This culling process left a rather uniform flock of grade Columbia ewes (Figure 1). The writer considered this flock to be much like the Columbia type of sheep found in farm flocks in Wyoming; possibly it was a higher producing flock, especially after the culling was done, but essentially it was the same type of breeding i. e., originally Rambouillet-crossbred ewes bred to Columbia rams for a number of years.

Figure 1. Typical Archer mature ewes.

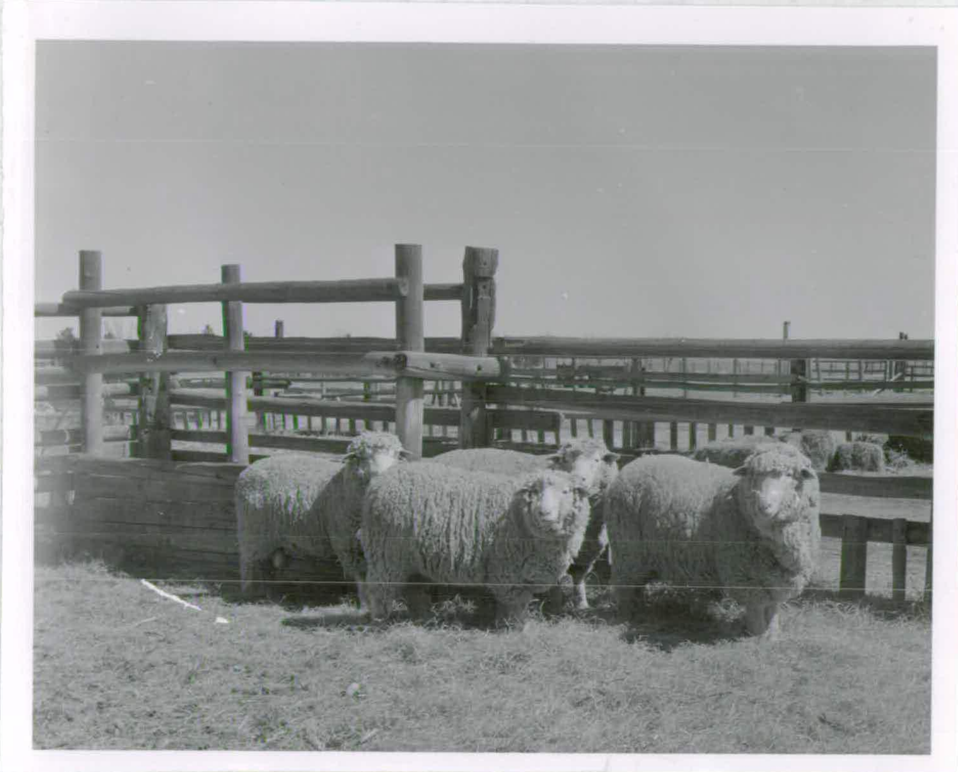

Figure 2. Typical Archer rams, side view.

Figure 3. Typical Archer rams, front view.

Figure 4. Typical Archer lambs.

The rams that were used prior to 1951 were from the University of Wyoming's Columbia pure-bred flock which was similar to the pure-bred Columbia flocks over the state. Both the University of Wyoming and the pure-bred breeders had obtained Columbia stud rams from the U. S. Sheep Breeding Experiment Station at Dubois, Idaho.

IV. METHODS

Grouping

In the fall of 1951 a flock of 120 breeding ewes was divided into two equal groups by alternate gate out method. One group was designated as Group I and the other as Group II.

Identifying Sheep

The original ewes already had numbered ear tags in their ears which were used for identification. An ear tag notch was also placed in the left ear of each sheep in Group I and the right ear of each sheep in Group II.

Each year, the new lambs received a numbered metal ear tag and at birth their ears were notched according to their respective groups. This notching facilitated separation into Group I and Group II.

Management Practices

Management practices for shearing, breeding, lambing, ewe replacement selection, and separation of wethers and cull ewes for market were done according to the pattern for the area. Scheduling of these practices was similar to those used in the area. The dates are given below:

Year	Shearing Dates	Breeding[1] In	Breeding[1] Out	Lambing[2] Start	Lambing[2] Finish	Evaluation (Culling Scoring Weighing)
1952	May 9	Sept. 25	Nov. 21	Feb. 24	May 2	Sept. 8
1953	May 16	Sept. 20	Nov. 20	Feb. 14	Mar. 24	Aug. 11
1954	May 13, 14	Sept. 19	Nov. 9	Feb. 14	Mar. 25	Sept. 8
1955	May 16, 17	Sept. 16	Nov. 9	Feb. 19	May 11	Sept. 19
1956	May 9, 10	Oct. 8	Nov. 11	Mar. 3	April 26	Sept. 19
1957	May 13, 14	Oct. 5	Nov. 15	Mar. 3	May 6	Sept. 25
1958	May 13, 14, 15	Oct. 4	Nov. 15	Feb. 25	April 7	Sept. 10
1959	May 11, 12	Oct. 6	Nov. 15	Mar. 2	April 16	Sept. 9
1960	Feb. 25, 26	Oct. 6	Nov. 15	Mar. 15	April 15	Aug. 10

Selecting by Visual Appraisal of Phenotypic Fleece and Body Characters

Each fall all the ewe lambs in Group I were separated from the other sheep and placed in a chute

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[1]The practice of using a clean-up ram was followed.

[2]A few late lambs resulted from clean-up ram.

(Figure 5). The writer selected the necessary replacements by using the touch system (terminology Dean Hill applied to his visual appraisal system) he had learned while studying and working with the late Dean J. A. Hill (Hill, 1921 a, 1921 b, 1948).

Applying the system consisted of working down through the chute and checking each sheep for wool density and wool length by grasping a hand full of wool on the back (Figure 6). The body size, width and length was noted. Those considered good enough were marked on the head with a colored wax crayon and the ear tag number was recorded. The balance were shipped to market with the wethers. If, after going through the chute the first time, sufficient numbers were not selected as replacement a second trip through the chute was made to select necessary additional ones. Physiological abnormalities were noted, especially jaw malformation which was one of the causes for rejection. The entire selection procedure was carried out as nearly as possible as if it were being done routinely to a commercial flock.

Selecting by an Index

As with Group I each fall the ewe lambs in Group II were separated from the rest of the sheep and placed in a holding pen adjacent to a smaller pen, where scoring

Figure 5. Separation of sheep into respective groups prior to scoring, visual selection and weighing. (Holding pen, right and circular pen, left.)

Figure 6. Selecting the replacement ewes for Group I by visual appraisal, using the chute in the center of the circular pen.

was done (Figure 7). The necessary information was taken in order to apply the Dubois Columbia Weanling Selection Index (Terrill, 1952). (This index was described in the Review of Literature).

This necessary information consisted of body weight, body type score, condition score, wool length and wool grade.

The weanling body weight was taken in September after the lambs had all been subjected to the same water and feed conditions. Weighing was done in a crate placed on a large dial scale at the end of a chute (Figure 8).

A few lambs at a time were moved from the larger holding pen into a smaller pen where scoring was done on body type and condition. The scores were the average of two independent scores made by the writer and one other sheep husbandryman. The scores were based on 10 points and the highest merit received the maximum number of points.

The weanling body score was a subjective evaluation of body length, depth and width. Such faults as pinched heart girth, sloping rump, crooked legs and fine bone were considered in the evaluation. A general smoothness of body conformation and a symmetry and proportion of make-up was desired.

Figure 7. Scoring the yearling ewes in Group II.

Figure 8. Weighing the entire flock in September.

The weanling condition score was determined by examining the degree of fleshing over the shoulders, ribs, back and loin; for amount of fat, evenness and mellowness.

The wool length was measured by opening the wool and mid side and inserting a plastic rule to the skin. The spinning count of the wool was also estimated at the same time the wool was measured for length. The U. S. D. A. Wool Standards were the basis for estimation of spinning count (U.S.D.A., 1926, 1953; Christie, 1939; Von Bergen and Mauersberger, 1948).

Corrections for the traits of weanling weight, staple length, and condition scores were made each year for the environmental effects of type of birth, age of dam, and age at weaning (Hazel and Terrill, 1946 b).

Index scores were computed and the required number of replacements were selected by taking the ewe with the highest index, then the one with the next highest index, etc. until all the replacements were filled. The balance of the yearling ewes were shipped to market with the wethers.

Selecting Rams and Breeding Practices

Rams used in the study came from purebred Columbia flocks in Wyoming but were not of stud quality (Figures 9, 10, 11). They were of the type (elgible for registery but not registered) produced for commercial sheep growers. They were selected on visual appraisal fo fleece and body characters as would be done in commercial practice.

At the start of the study, each ram was assigned at random to about 30 ewes. Group I was sub-divided at random into two equal groups and Group II was sub-divided at random into two equal groups. Starting in 1955 three rams were used to breed the entire flock. Care was taken that no inbreeding took place.

Ram management and procedure was very similar to that followed and practiced in well managed farm flocks and purebred flocks in Wyoming.

Culling the Mature Flock

The numbers of replacements added from year to year fluctuated between 20 and 30 percent. Once ewes had been selected for replacements they were usually left in the flock so performance data would be available. Some years the deaths from storms, especially in 1951; dogs; and coyotes made replacements higher than planned. Normal death loss was relatively low and only a few had to be discarded because of lost ear tags. Normally the

Figure 9. Side view of Columbia rams, typical of the type used in the study. Taken May, 1954. Identification of rams from left to right, C510, 170, C227, 1499.

Figure 10. Front view of rams used in 1953. Identification, left to right, C310, 170, C227 and 1499.

Figure 11. Sheared rams. Identification, left to right, C310, 1499, 170 and C227.

teeth of medium wooled sheep start to show excessive wear at about five years and are removed for this cause. Rams were kept in the flock as long as they were completely sound. Some had to be removed at an earlier age than others.

Observation of Characters on Which Comparisons Were Made

Lamb Characters

Detailed lambing records were kept showing dam, sire, date of birth, weight at birth, type of birth sex and an explanation for lamb mortality (when possible). Lamb characters of birth weight, weanling body weight and weanling staple length were taken for the years 1951 to 1957 inclusive.

Weighing Lambs at Birth. Lambs were weighed to the nearest tenth of a pound in a sling, using dairy scales. Lambs born during the night were weighed about 8:30 A.M. the following morning and those born during the day were weighed about 4:30 P.M. each day.

Determining Body Weight at Weanling Age. Weanling body weight was one of the factors used in making up the index and was described under "Selecting by an Index."

Determining Weanling Staple Length. The procedure for measuring this factor was described under "Selecting by an Index" since it was a factor considered in computing the index.

Determining Grade of Wool on Weanling Fleeces. This factor was discussed under "Selecting by an Index," since it was a character evaluated for computation of the index.

Fleece and Body Characters

Certain fleece and body characters were observed at one year, two years, three years and four years of age.

Grading Fleeces at Shearing Time. Each fleece was examined and graded by visual inspection according to the U. S. D. A. Standards (U.S.D.A., 1926, 1952; Hultz and Hill, 1931; Christie, 1939; Von Bergen and Mauersberger, 1948) (Figure 12). To be as consistent as possible year after year a U. S. D. A. Standard (mounted samples of each grade) was available for direct comparison. The standards were brought up to date as per recommendations of the U. S. D. A. Wool Laboratory (U.S.D.A., 1952). A description of these standards is shown in Table 2.

Figure 12. Weighing and grading an individual fleece. Note paper sack on fleece containing sample used for yield and length determination.

TABLE 2. U. S. D. A. WOOL STANDARDS

Blood Grade	Spinning Count Equivalent		
Fine	80's	70's	64's
1/2 Blood	62's	60's	
3/8 Blood	58's	56's	
1/4 Blood	54's	50's	
Low 1/4 Blood	48's	46's	
Common	44's		
Braid	40's	36's	

Weighing Fleeces. Each fleece was weighed immediately after shearing (Figure 12). Weighing was done on a pair of dairy scales to the nearest tenth of a pound.

Determining Clean Fleece Weight. A sample of about 150 grams of grease wool was removed from the mid-side portion of the fleece as it was shorn. This was scoured according to standard procedure used in the Wool Scouring Laboratory at the University of Wyoming and the percent yield determined. The individual clean fleece weight was calculated (Parker, 1951). The side sample provides a good index of yield for the whole fleece

(Pohle et al., 1943; Pohle and Hazel, 1944; Pohle, Hazel and Keller, 1945).

Determining Fleece Value. At the time the study was initiated the U. S. D. A. Price Support was in effect (U.S.D.A., 1943). The minimum selling price for graded territory wool (Those wools that grow west of the Missouri River but not including wools from Texas, California, Oregon, Kansas, Oklahoma and eastern Nebraska) was used as the basis for determining individual fleece value. This price structure was used for comparative price purposes throughout the study and is shown in Table 3 (Kiefer, 1952).

Determining Staple Length at Shearing Time. The staple length was obtained from the sample taken for yield determination. Staple length measurement was done according to procedure followed in the Wool Laboratory at the University of Wyoming (Parker, 1951). In the laboratory this sample was spread out and three looks were removed. Using a plastic rule the locks were measured to the nearest millimeter (unstretched). A large magnifying glass was used to increase accuracy in reading the length. The average of three locks was considered the length of the fleece. This length measurement for

TABLE 3. 1952-1953 COMMODITY STABILIZATION SERVICE PRICE SUPPORT PROGRAM FOR TERRITORY WOOL

Grade	Class Appraisal Value (Dollars per Clean Pound)
Fine 64s and finer	
Staple and good French Combing	1.64
Average and good French Combing	1.57
Short French Combing and Clothing	1.43
One-Half Blood, 60s and finer	
Staple and good French Combing	1.51
Average and good French Combing	1.41
Short French Combing and Clothing	1.26
Three-Eighths Blood, 56/58s	
Staple and good French Combing	1.30
Average and good French Combing	1.19
Short French Combing and Clothing	1.08
One-Quarter Blood, 48/50s	
Staple and good French Combing	1.17
Average French Combing	1.04
Short French Combing and Clothing	.90
Low One-Quarter Blood, 46s	
Staple and good French	1.05
Short and inferior	.90

each fleece, along with its grade, determined the commercial description. The length classification used corresponded to that generally accepted by the wool trade as standard (Van Horn and Hulbert, 1946; Rhodes, 1952). Table 4 gives this length classification.

TABLE 4. LENGTH CLASSIFICATION OF WOOL GENERALLY ACCEPTED BY THE WOOL TRADE AS STANDARD

Grade	Staple & Good French	Length Av. & French Combing	Short French Combing & Clothing
Fine	64 mm or over	under 64 mm over 38 mm	38 mm & under
1/2 Blood	76 mm or over	under 76 mm over 51 mm	51 mm & under
3/8 Blood	89 mm or over	under 89 mm over 51 mm	51 mm & under
1/4 Blood	101 mm or over	under 101 mm over 64 mm	64 mm & under
Low 1/4 Blood	101 mm or over		Less than 101 mm

__Determining Body Weight at Shearing Time.__ After shearing was completed each May, the entire flock was weighed. Care was taken to ensure that the entire flock had been subjected to the same feed and water conditions prior to weighing. Weighing was done at the end of a chute in a crate fastened to the platform of a large dial scale.

__Fall Body Weight.__ After scoring was done in September the entire flock was weighed by the same procedure as after shearing (Figure 8).

V. RESULTS AND DISCUSSION

The Breeding Flock of Ewes

<u>Ages of Ewes in Groups I and II</u>

The ages of the ewes that made up Groups I and II are shown in Table 5. The distribution by ages appears quite normal (Parker, 1953 a). It was very difficult to keep more or less comparable numbers of the same age in each group. An unfortunate accident occurred in the spring of 1951 when several ewes and lambs died in a storm right after shearing. A larger proportion of death occurred in Group I than Group II so a larger number of replacements had to be saved in Group I. Regrouping, unfortunately, was not done. Death loss from dogs and coyotes was constantly altering the numbers. By 1956 all the original ewes had been replaced except for two seven-year-old ewes in each group. Beginning in 1958 the entire lamb crop in both groups was saved. This made it necessary to sell the older ewes. The replacement selections were made by visual appraisal and selection index but data for 3 year olds and 4 year olds were not available for comparison.

TABLE 5. COMPOSITION OF EWES IN GROUPS I AND II AT SHEARING TIME

Year	Group	Ages							Total
		2	3	4	5	6	7	8	No.
1952	I	6	18	9	10	4	4		51
	II	7	14	13	7	5	6		52
1953	I	28	5	6	5	7	4	3	58
	II	16	5	12	11	6	4	5	59
1954	I	16	24	3	5	3	4	1	56
	II	16	14	3	9	9	6	0	57
1955	I	16	15	20	2	3	1	2	59
	II	19	15	15	3	7	0	0	59
1956	I	14	13	12	17	1	2	0	59
	II	16	14	15	10	3	2	0	60
1957	I	25	14	11	10	5	0	0	65
	II	18	13	12	13	2	0	0	58
1958	I	13	18	0	0	0	0	0	31
	II	17	12	0	0	0	0	0	29
1959	I	21	19	6	0	0	0	0	46
	II	15	14	5	1	0	0	0	34
1960	I	10	21	19	5	0	0	0	55
	II	10	15	14	5	0	0	0	44

Composition of Groups I and II by Grades at Shearing Time

No preference was given to any specific grade of wool in the visual appraisal system except in an indirect manner. The larger lambs were selected for replacement and they were inclined to be the coarser type. Only very slight pressure was exerted on grade by the selection index in which the finer grades were favored. There was a gradual shift toward coarser grades in both groups but a little more pronounced in Group I as shown in Table 6. This could have been due, in part, to the fact that Group II had more 1/2 blood at the beginning of the study. The range of grades in both groups was rather similar to the range in some purebred Columbia flocks (Parker, 1953a). The Columbia Breed Association recognizes 1/2 blood, 3/8 blood and 1/4 blood grades for official registration. It is very difficult to maintain a Columbia flock which has only two grades of wool in it. Both groups for the years 1957 to 1960 were more typical of most Columbia purebred flocks in which the majority of the grade is 1/4 blood with very few fine wool grades.

Some Phenotypic Parameters of Fleece and Body Characters in the Breeding Flocks of Groups I and II

The level of production for Groups I and II was indicated by the means of various economic characters as

TABLE 6. COMPOSITION OF GROUPS I AND II BY GRADES AT SHEARING TIME

Year	Group	Total No.	F No.	F %	1/2 No.	1/2 %	3/8 No.	3/8 %	1/4 No.	1/4 %	L 1/4 No.	L 1/4 %
1952	I	51	3	6	28	55	15	29	5	10		
	II	53	2	4	36	68	13	24	2	4		
1953	I	58	2	3	34	59	16	28	6	10		
	II	59	1	2	41	69	13	22	4	7		
1954	I	56	2	4	22	39	22	39	10	18		
	II	57	1	2	33	58	17	30	6	10		
1955	I	59	2	3	25	42	20	34	12	21		
	II	59	1	2	32	43	17	29	9	15		
1956	I	59	3	5	18	30	27	46	11	19		
	II	60	1	2	29	48	21	35	9	15		
1957	I	65	0	0	17	26	35	54	13	20		
	II	58	2	3	17	29	30	52	9	16		
1958	I	31	0	0	6	19	16	52	9	29		
	II	29	1	3	7	24	16	55	5	18		
1959	I	46	0	0	14	31	23	50	8	17	1	2
	II	34	3	9	10	29	16	47	4	12	1	3
1960	I	55	0	0	15	27	24	44	14	25	2	4
	II	44	0	0	11	25	24	55	7	16	2	4

shown in Tables 7 and 8. The production figures up to 1958 were indicative of the performance of Groups I and II. By 1958 the original ewes had been entirely replaced by "selects". All ewes 4 years old and older were sold in 1958 so that all the ewe lambs could be kept. Therefore at that date the breeding ewes in Groups I and II consisted of only 2 and 3 year olds. The one factor which was still comparable in the two groups was the age composition.

Some very general comparisons can be made. Compared to studies conducted by Parker (1955) on range flocks in Wyoming the general level of performance was very high for both groups. The production records for both groups were as high as most purebred Columbia flocks in Wyoming (Parker, 1953). U. S. D. A. (1960) listed the average grease fleece weight of 13 western states as 8.9 pounds. Several of the states in the Rocky Mountain area had grease fleece weights of the following:

Wyoming	10.4 lbs.
Montana	10.0 lbs.
Idaho	10.4 lbs.
Colorado	9.0 lbs.

The average of the United States was listed as 8.6 pounds.

TABLE 7. SOME PHENOTYPIC PARAMETERS OF FLEECE CHARACTERS OF THE BREEDING FLOCKS OF EWES IN GROUPS I AND II

Year	Number[1] I	Number[1] II	Grease Fleece Wt. in Lbs. I	Grease Fleece Wt. in Lbs. II	Staple Length in mm. I	Staple Length in mm. II	Yield in Lbs. I	Yield in Lbs. II	Clean Fleece Wt. in Lbs. I	Clean Fleece Wt. in Lbs. II	Fleece Value in Dollars I	Fleece Value in Dollars II
1952	51	52	11.7	13.1	87.3	86.6	43.8	42.3	5.1	5.6	7.16	7.98
1953	58	50	12.0	11.5	86.9	85.7	41.9	41.2	4.8	4.8	6.99	7.12
1954	56	57	13.1	13.7	80.8	81.8	45.5	44.7	5.0	6.1	8.25	8.71
1955	59	59	13.6	13.2	83.0	81.8	41.1	40.5	5.5	5.5	7.71	8.56
1956	59	60	12.2	11.8	84.5	79.5	47.8	47.9	5.9	5.7	7.44	8.15
1957	65	58	12.8	13.1	83.0	82.0	44.5	44.0	5.7	5.8	7.07	7.39
1958	31	29	13.9	12.5	107.0	99.5	51.4	48.9	7.2	6.1	9.25	7.87
1959	46	34	12.9	12.5	96.8	99.1	48.4	50.2	6.4	6.4	8.34	8.50
1960	55	44	13.2	12.1	82.7	88.9	49.6	54.3	7.6	6.2	6.98	7.70

[1] Number of ewes sheared--numbers may be more at lambing and less when weighed in the fall because of death loss.

TABLE 8. SOME PHENOTYPIC PARAMETERS OF BODY CHARACTERS OF THE BREEDING FLOCKS OF EWES IN GROUPS I AND II

Year	Number[1] I	Number[1] II	Lamb Wt. in Lbs. I	Lamb Wt. in Lbs. II	Body Wt. in Lbs. at Shearing I	Body Wt. in Lbs. at Shearing II	Body Wt. in Lbs. in the Fall I	Body Wt. in Lbs. in the Fall II
1952	51	52	11.4	10.4	119	125	128.4	138.9
1953	58	59	11.3	9.8	100	105	149.1	142.2
1954	56	57	10.7	10.0	114	117	134.0	135.2
1955	59	59	9.9	10.2	130	138	149.8	144.6
1956	59	60	9.3	10.2	124	119	151.6	150.0
1957	65	58	10.3	10.6			153.4	155.9
1958	31	29	10.5	10.2	131.3	121.8	153.8	149.0
1959	46	34	11.9	11.2				
1960	55	44	10.5	10.9			162.5	167.8

[1]Number of ewes sheared--numbers may be more at lambing and less when weighed in the fall because of death loss.

These figures were rather meaningless as comparisons for the shrinkage and grade of the fleece were not known.

Graphic Presentation Showing Relationships between the Means of Some Fleece and Body Characters for Groups I and II

Lamb Weights. The mean birth weight of all lambs born to ewes in Groups I and II were plotted by years (1952 to 1960) in Figure 13. The fact that in 1951 a large number of replacements were needed (There was excessive death loss from storm.) in Group I apparently accounts for the decrease in mean birth weights from 1952 to 1956. Neither selection system selected for characters that would conceivably increase lamb birth weight.

Grease Fleece Weights. The means of grease fleece weights for Groups I and II are shown in Figure 14. Few studies were reviewed that indicated how grease fleece weight might be expected to vary from year to year in the same flock of ewes. It is a well known fact that the contributing causes of variation are many. Parker (1953 b, 1955) studied 13 Wyoming flocks and found frequent instances of a 3 pound range from one year to the next in the same flock of ewes. Fluctuations in

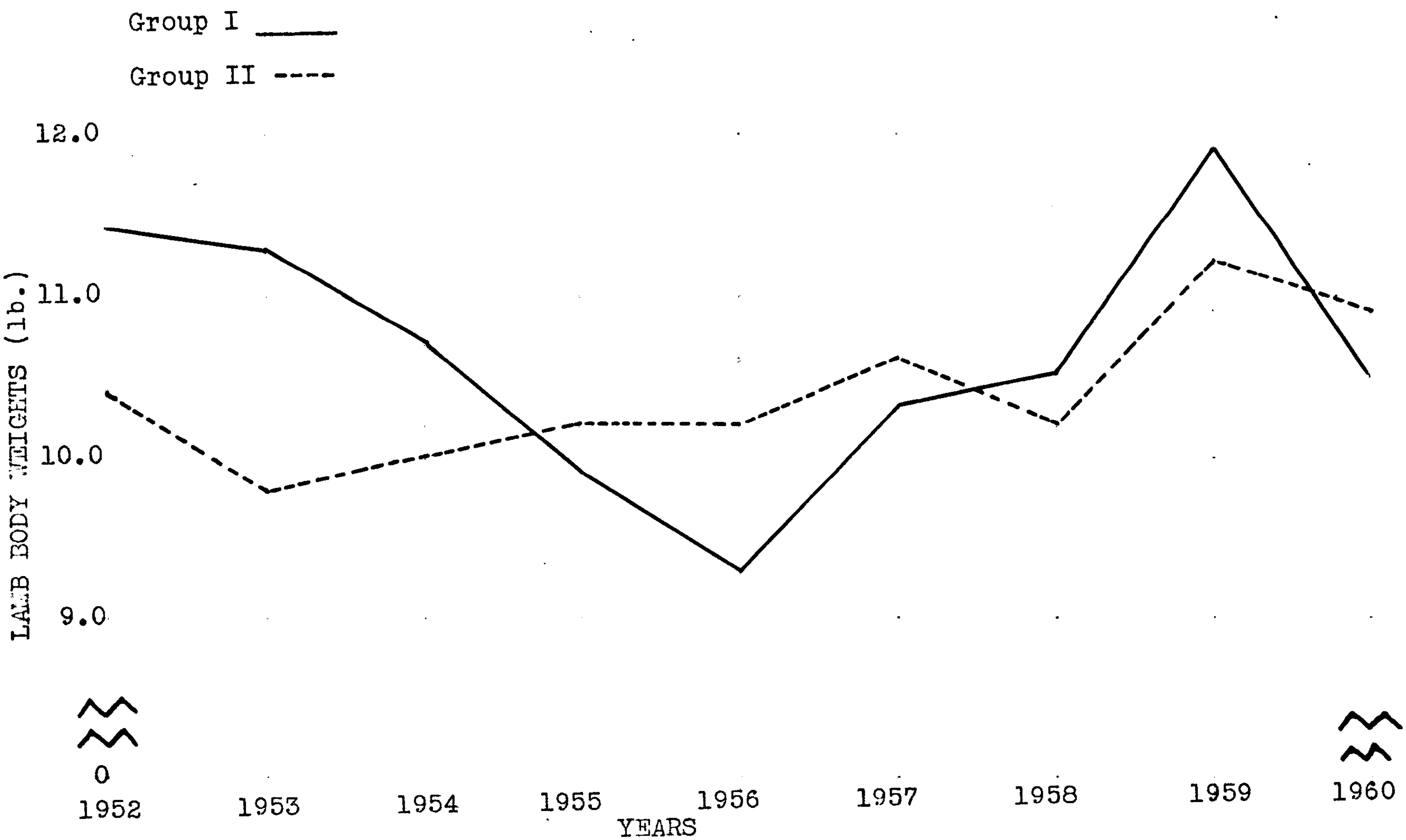

Figure 13. The mean lamb birth weights of breeding ewes for Groups I and II by years.

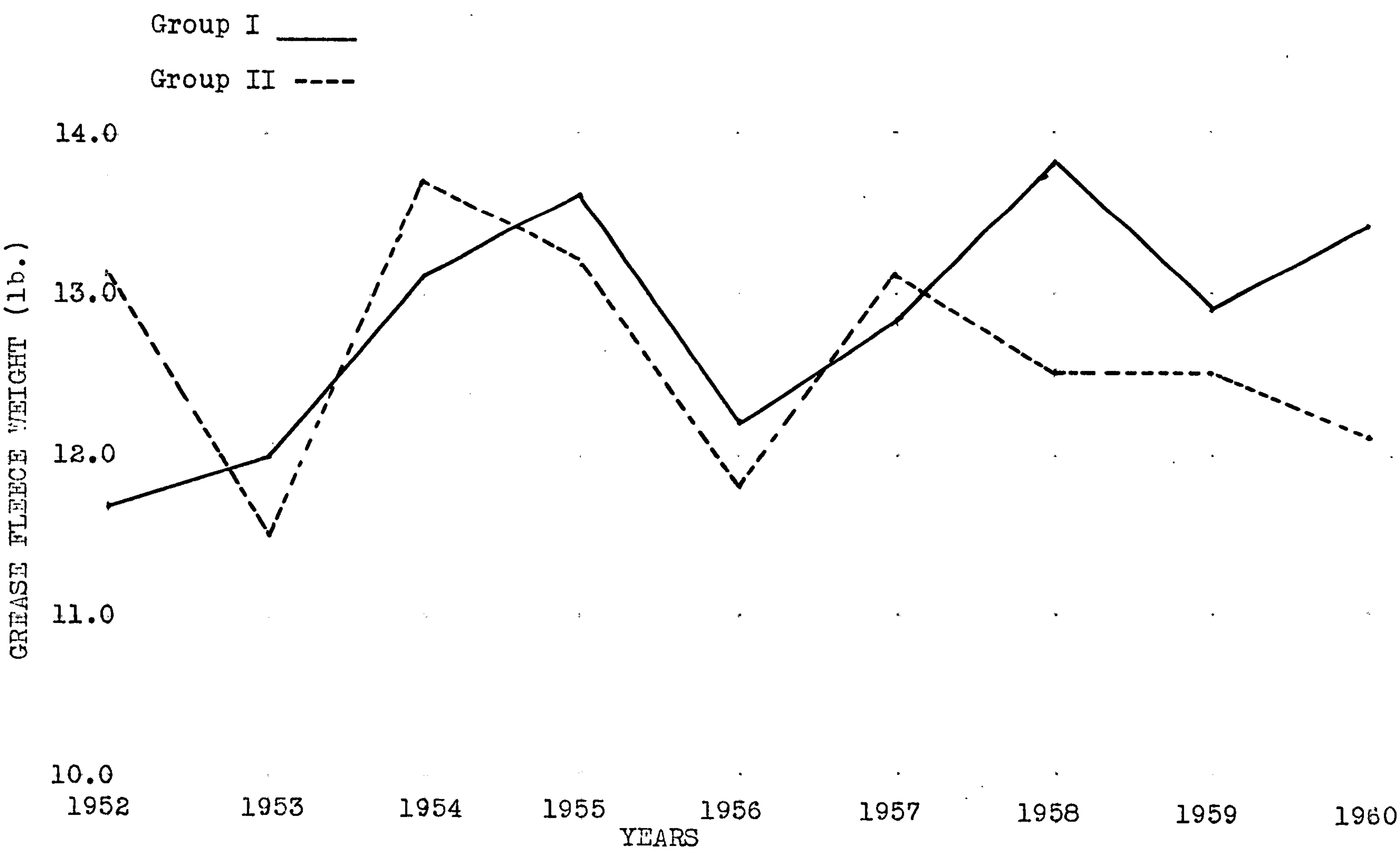

Figure 14. The mean grease fleece weight of the breeding ewes for Groups I and II by years.

purebred flocks (Parker, 1955) were more of the pattern found in Groups I and II of the Archer flock. Grease fleece is a very poor criteria of production and must be studied in relation to the shrinkage or yield.

Staple Length. Figure 15 shows the staple length fluctuations. The length for both groups fluctuated about the same. Both systems of selection considered length as an important factor but neither group responded; in fact, the length became shorter from 1952 to 1957 and the upward trend in 1958 was probably due to younger ewes making up the breeding flocks in both groups at that time. However, the length in both groups was long enough in most individual instances to be staple or strictly combing for the grades and received maximum price as was shown in Tables 3 and 4. This was true in 1954 when the shortest length occurred in both groups. The short length in 1960 was caused by shearing in February instead of May.

Yield. The mean yield was plotted in Figure 16. Comparatively speaking the yield was not as high as was expected for the grade and type of sheep. From actual contact with the wool the writer found it to be rather greasy (probably caused from a nutrition factor) thus causing a higher shrinkage. Compared to range

Figure 15. The mean staple length of breeding ewes for Groups I and II by years.

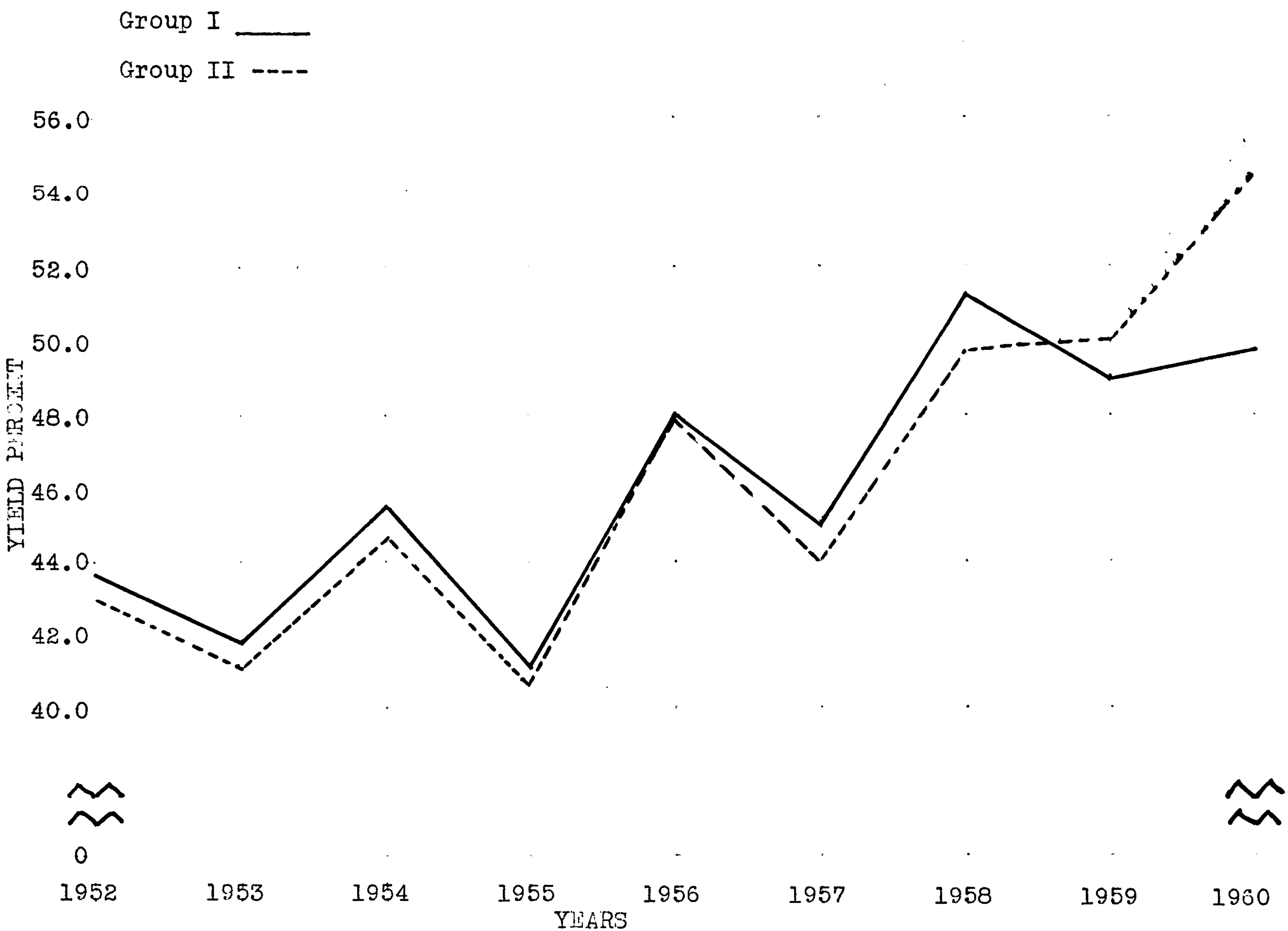

Figure 16. The mean yield of breeding ewes for Groups I and II by years.

flocks the yield was higher than 35.6 percent which was the percent yield found by Parker (1953 b) for 1,688 ewes. Ordinarily the yield increases as the grade gets coarser and length increases. This association held for the increasing coarsness but not for length. As with grease fleece weight, it is not known how much the yield might be expected to fluctuate from year to year.

Clean Fleece Weight. The clean fleece weight as shown in Figure 17 for both group's production was considerably above the average of the 1,688 range ewes which showed a clean fleece weight of 4.2 pounds (Parker, 1953 a). Clean fleece weights of Groups I and II compared favorably with the purebred Columbia flocks in Wyoming. Parker (1953 b) reported clean fleece weight of ewe flocks for 13 growers for at least 2 years in succession and while the level of production varied from 3.5 to 4.0 pounds of clean wool the change from year to year was slight.

Fleece Value. Figure 18 shows the fleece value pattern. It would generally be expected that the fleece value would follow the clean fleece weight. This would always be true if the grade and staple length remained constant. When 4 grades are involved 12 different lengths are involved and 12 different prices per pound.

Figure 17. The mean clean fleece weight of breeding ewes of Groups I and II by years.

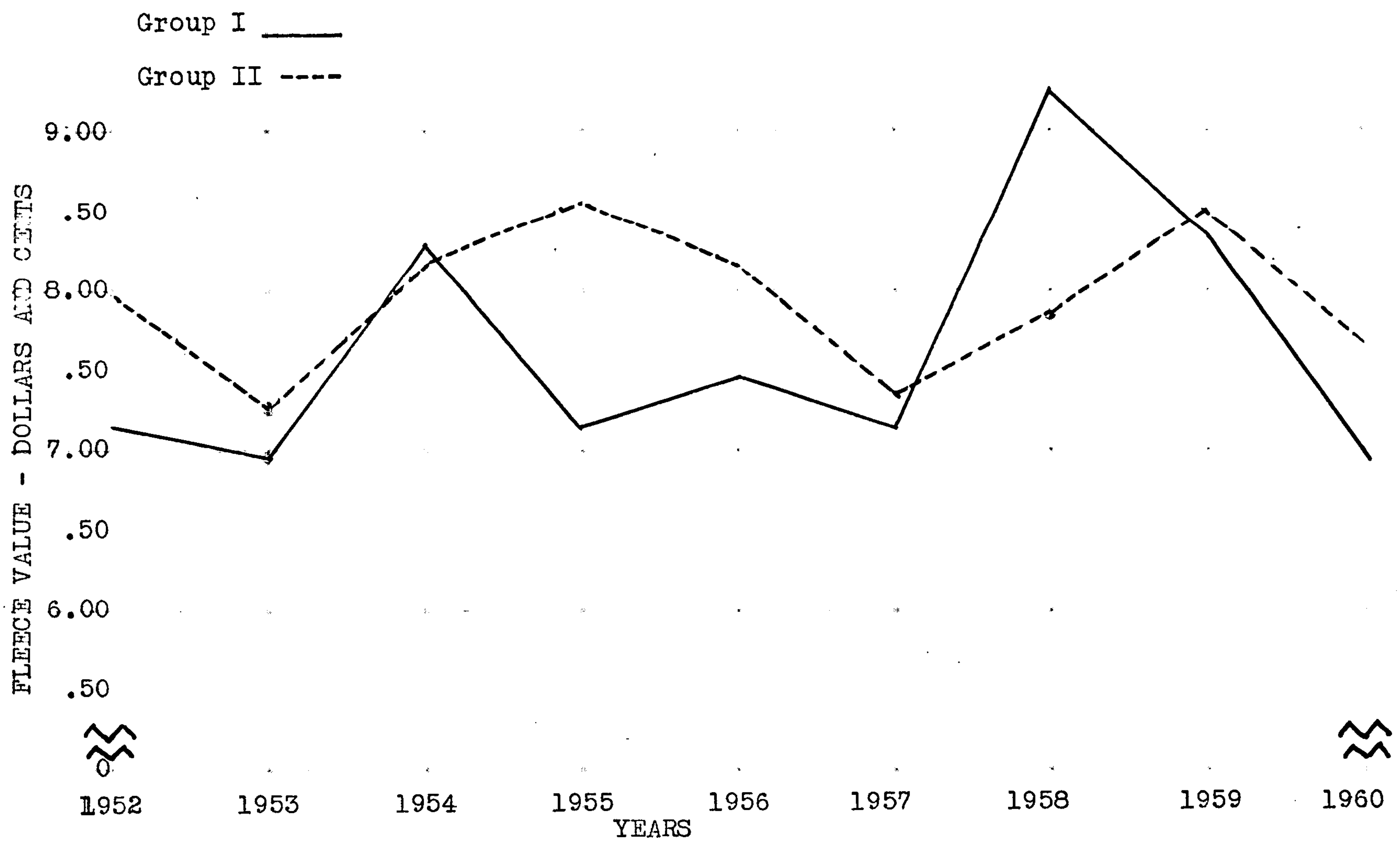

Figure 18. The mean fleece value of the breeding ewes for Groups I and II by years.

The higher level of fleece value in Group I was explained by the fleeces being slightly finer in grade; while the coarser fleeces in Group II were not heavy enough to off set the price differential. This was explained by the fact that a 3.1 pound, 1/2 blood staple, fleece was worth $4.68. To equal the same value a 3/8 blood staple fleece would have to weigh 3.6 pounds, a 1/4 blood staple fleece 4.0 pounds and a L 1/4 blood fleece 4.5 pounds. If the length decreased so that a 1/4 blood fleece falls in the 1/4 blood French Combing class it would take a 4.5 pound fleece to equal the value of a 3.1 pound 1/2 blood staple fleece.

Sheared Body Weight. The sheared body weight plotted in Figure 19 shows a wide fluctuation for both groups. The environment evidently was fairly constant each year for both groups but varied considerably from year to year.

Fall Body Weight. The fall body weights for both groups plotted in Figure 20 show a similar trend upward from 1954 to 1957. One big decrease for both groups occurred in 1954. The high weights for both groups indicated considerably more condition at this time than after shearing.

Figure 19. The mean sheared body weight of breeding ewes for Groups I and II by years.

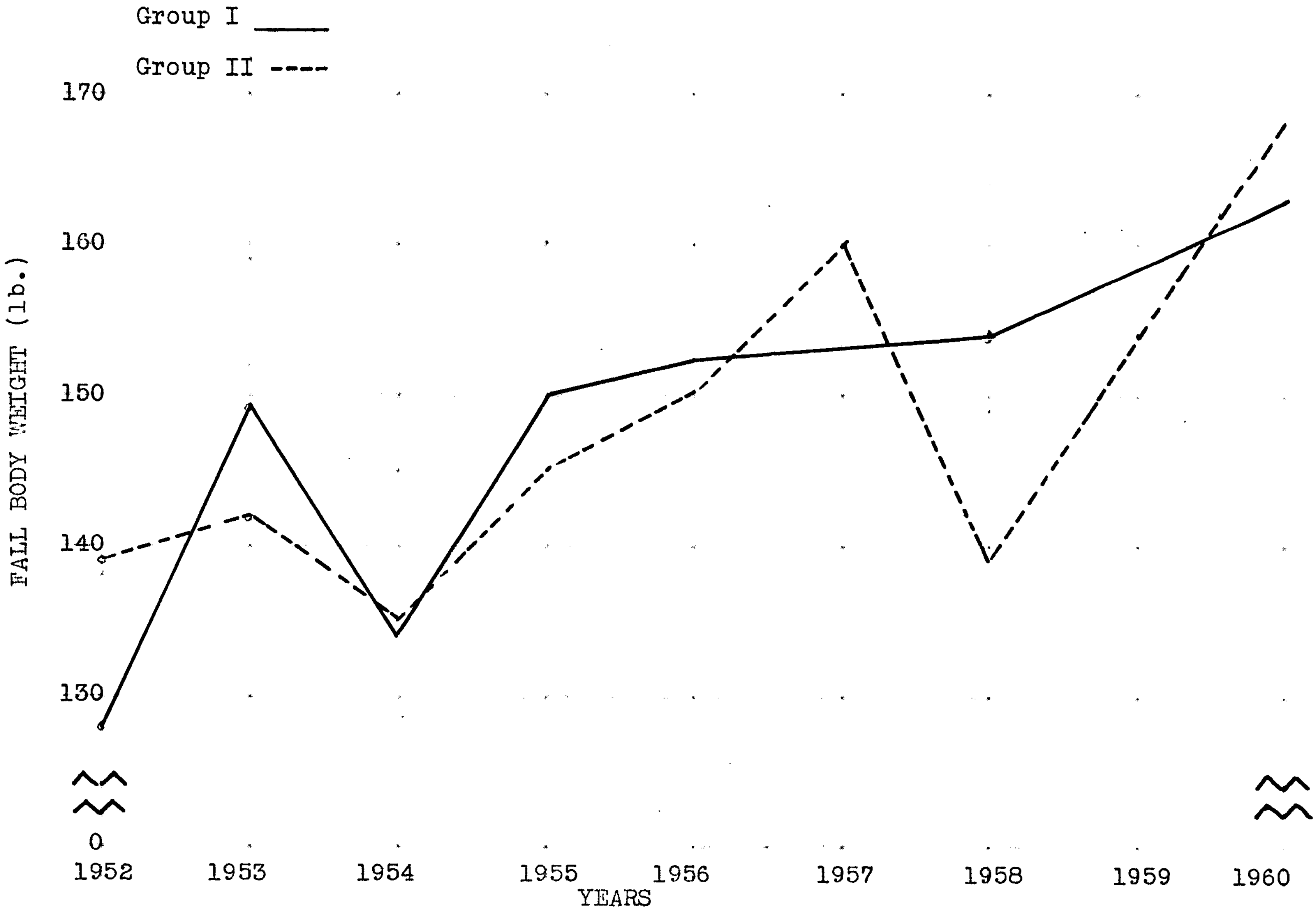

Figure 20. The mean fall body weight of breeding ewes for Groups I and II by years.

Comparisons of Mean Differences in Some Fleece Characters, Body Characters and Lamb Weights in the Breeding Flocks of Groups I and II

Table 9 shows the results of testing the difference of the mean sheared body weight, fall body weight, yield, clean fleece weight and staple length between Groups I and II by the "t" test (Snedecor, 1946, 1956). The mean weights of the lambs born to the ewes in Groups I and II were also compared. As indicated by Table 9, significant differences at the 5 percent level in 1952 were for sheared body weight, fall body weight, and grease fleece weight. An unfortunate accident probably accounts for the large differences. A heavy death loss of ewes and lambs in the spring of 1951, right after shearing, made it necessary to select 28 lambs for replacements in Group I. For some unaccountable reason the death loss was higher in Group I. Only 16 replacements were required for Group II. By 1953 growth had evidently made the difference for sheared body weight and grease fleece weight so small that they were not significant. For fall body weight in 1943 the relationship was reversed and the difference of 7.2 pounds was significant. This significance was in favor of Group I.

TABLE 9. COMPARISON OF SOME FLEECE CHARACTERS, BODY CHARACTERS AND LAMB WEIGHTS IN THE BREEDING FLOCKS OF GROUPS I AND II

Year	Item Compared	Group I Mean	Group II Mean	Mean Difference
1952	Lamb Weight Lb.	11.4	10.4	1.0
1953	Lamb Weight Lb.	11.3	9.8	1.5
1954	Lamb Weight Lb.	10.7	10.0	0.7
1955	Lamb Weight Lb.	9.9	10.2	-0.3
1956	Lamb Weight Lb.	9.3	10.2	-0.8
1952	Lamb Wt. Shearing	111.4	124.6	-13.1*
1953	Lamb Wt. Shearing	107.4	107.1	0.3
1954	Lamb Wt. Shearing	116.0	115.2	0.8
1955	Lamb Wt. Shearing	129.7	135.5	-5.8
1956	Lamb Wt. Shearing	122.8	119.0	3.7
1952	Body Wt. Fall Lb.	128.4	138.9	-10.4*
1953	Body Wt. Fall Lb.	149.4	142.2	7.2*
1954	Body Wt. Fall Lb.	134.0	135.2	-1.2
1955	Body Wt. Fall Lb.	149.8	144.6	5.2
1956	Body Wt. Fall Lb.	151.6	150.0	1.6
1952	Grease Fleece Wt.	11.7	13.1	-1.4*
1953	Grease Fleece Wt.	12.0	11.5	0.4
1954	Grease Fleece Wt.	13.1	13.7	-0.6
1955	Grease Fleece Wt.	13.6	13.2	0.4
1956	Grease Fleece Wt.	12.2	11.8	0.4
1952	Yield	43.8	42.3	1.5
1953	Yield	41.9	41.2	0.7
1954	Yield	45.5	44.7	0.8
1955	Yield	41.1	40.5	0.6
1956	Yield	47.8	47.9	-0.2
1952	Clean Fleece Wt.	5.1	5.6	-0.4
1953	Clean Fleece Wt.	4.8	4.8	0.0
1954	Clean Fleece Wt.	5.9	6.1	-0.2
1955	Clean Fleece Wt.	6.1	6.0	0.1
1956	Clean Fleece Wt.	6.2	6.0	0.2

TABLE 9. COMPARISON OF SOME FLEECE CHARACTERS, BODY CHARACTERS AND LAMB WEIGHTS IN THE BREEDING FLOCKS OF GROUPS I AND II (CONTINUED)

Year	Item Compared	Group I Mean	Group II Mean	Mean Difference
1952	Staple Length	87.3	86.6	0.7
1953	Staple Length	86.9	85.7	1.1
1954	Staple Length	80.8	81.8	-1.0
1955	Staple Length	83.0	81.8	1.2
1956	Staple Length	84.5	79.5	5.0

*Difference significant at 5 percent level.

By 1956 "selects" had replaced the original ewes in both groups with the exception of two seven-year-old ewes in each group, one six-year-old ewe in Group I and three six-year-old ewes in Group II. If either method of selecting replacements were greatly superior, differences would have begun to develop between the two groups. This did not happen. However, sheared body weight increased from 1952 to 1956 in both groups (Table 9) as did fall body weight, grease fleece weight, yield and clean fleece weight. This would seem to indicate that the selection index and visual appraisal were equally efficient in selecting replacements. A project modification required saving all ewe lambs for both groups in 1957 and comparisons made after that date had to be made with the understanding that all ewes 4 years and older had been sold. The selection by both systems continued until 1960.

While there were no differences between lamb birth weight that were significant (Table 9) there was a trend for decreased birth weight in Group I. It decreased from 11.4 pounds in 1952 to 9.3 pounds in 1956. The large number of replacements that were saved in 1951 was considered to be a contributing factor in this situation.

Staple length decreased in both groups from 1952 to 1956 (Table 9). Since staple length in both systems of selection was an important factor and since heritability was high (0.42) in a study reported by Hazel and Terrill (1946 c) some gains should have been made in increasing staple length.

The Ram Flock

Phenotypic Parameters of Some Fleece Characters

Table 10 shows the actual production of clean fleece weights and staple lengths of rams used in this study. The figures compare favorably to those of Columbia rams used in commercial flocks in Wyoming (Parker, 1953 a). The grades also were typical of Columbia rams. No attempt was made at improvement through ram selection nor

TABLE 10. PHENOTYPIC PARAMETERS OF FLEECE CHARACTERS OF RAMS

Group	Year	Ear Tag	Age Yrs.	Grade	Clean Fleece Wt. Lb.	Staple Length in mm.
I	1952	C227	2	3/8	7.5	110
		C310	1	Sheared in Jan.		
II		C4712	1	3/8	8.8	110
		275	1	Sheared in Jan.		
I	1953	C227	3	3/8	6.2	70
		C310	2	1/4	8.7	85
II		1499	2	1/4	9.7	140
		C4712	2	Died 21 March 1952		
I	1954	C227	4	3/8	7.0	50
		C310	3	1/4	10.5	110
II		1499	3	1/4	11.6	135
		170	2	3/8	8.2	94
Both Groups						
	1955	4	2	1/4	9.6	102
		170	3	3/8	7.7	85
		1499	4	1/4	12.8	130
	1956	4	3	1/4	9.5	100
		1499	5	1/4	13.0	124
		529	1	Sheared in Jan.		
	1957	4	4	1/4	9.7	96
		1499	6	1/4	12.3	125
		1200	1	1/2	8.2	128

TABLE 10. PHENOTYPIC PARAMETERS OF FLEECE CHARACTERS OF RAMS (CONTINUED)

Group	Year	Ear Tag	Age Yrs.	Grade	Clean Fleece Wt. Lb.	Staple Length in mm.
Both Groups						
	1958	4	5	1/4	7.3	95
		1200	2	1/2	7.8	109
		73	1	3/8	9.5	154
	1959	4	6	1/4	5.5	80
		1200	3	1/2	7.2	100
		73	1	3/8	8.6	118
		200	1	1/2	8.5	110
		172	1	3/8	8.9	118
	1960	4	7	1/4	4.2	67
		1200	4	1/2	5.6	95
		73	2	3/8	5.9	104
		200	2	1/2	5.6	80
		172	2	3/8	6.3	90

were any relationships studied between ram and ewe replacements.

Lambing Statistics

Percent of Dry Ewes in Groups I and II

The 10 year average for dry ewes in Group I was 4.17 percent and for Group II 4.58 percent. The year to year variation for the two groups was about the same.

Total Lamb Crop Based on the Number of Ewes that Lambed

The 10 year average lamb crop for Group I was 134.1 percent and for Group II 131.2 percent. These lamb crop percents were good.

Death Loss between Lambing and Weaning

For the years 1953 to 1956 the average percent death loss in Group I was 12.5 percent and for Group II 10.13 percent. This death loss was probably high for the type of operation and was largely caused by dogs and coyotes. This was a problem that was never solved satisfactorily.

Comparison of Differences between Fleece Characters, Body Characters, Lamb Birth Weights and Weanling Staple Lengths for Group I and II Replacements

Some explanation is necessary to understand the organization of Tables 11 through 17. Table 11 contains

TABLE 11. COMPARISON OF REPLACEMENTS FOR GROUP I AND II FOR FLEECE AND BODY CHARACTERS OF LAMBS BORN IN 1952 THROUGH 4 YEAR OLDS

Item Compared	Group I Mean	Group II Mean	Mean Difference
Birth Weight--Lbs.	11.53	10.53	1.00
Weanling Weight--Lbs.	95.00	96.13	-1.13
Weanling Staple Length--mm.	72.3	60.0	12.3*
Grease Fleece Weight--Lbs.			
1 year old	12.83	12.35	0.48
2 year old	15.20	14.30	0.9
3 year old	15.01	13.96	1.05
4 year old	13.2	12.1	1.1
Clean Fleece Weight--Lbs.			
1 year old	5.73	5.51	0.22
2 year old	7.2	6.9	0.3
3 year old	6.93	6.37	0.56
4 year old	6.0	5.9	0.1
Staple Length--mm.			
1 year old	112.94	113.25	-0.31
2 year old	95.13	88.38	6.75
3 year old	92.60	89.13	3.47
4 year old	87.25	80.87	6.38
Body Weight Sheared--Lbs.			
1 year old	93	93	0.0
2 year old	122.56	113.44	9.12*
3 year old	138	132	6.0
4 year old	145	126	19.0*
Body Weight Fall--Lbs.			
1 year old	149	144	5.0
2 year old	144.50	134.13	10.37*
3 year old	159	153	6.0
4 year old	171	152	19.0*

*Difference significant at 5 percent level.

TABLE 12. COMPARISON OF REPLACEMENTS FOR GROUP I AND II FOR FLEECE AND BODY CHARACTERS OF LAMBS BORN IN 1953 THROUGH 4 YEAR OLDS

Item Compared	Group I Mean	Group II Mean	Mean Difference
Birth Weight--Lbs.	10.99	10.44	0.55
Weanling Weight--Lbs.	87.89	83.33	4.56
Weanling Staple Length--mm.	55.56	67.00	17.44*
Grease Fleece Weight--Lbs.			
1 year old	13.71	16.04	-2.33*
2 year old	14.38	14.99	-0.61
3 year old	11.40	12.50	1.10
4 year old	11.3	13.0	-1.70*
Clean Fleece Weight--Lbs.			
1 year old	5.69	6.44	-0.75*
2 year old	6.28	7.19	-0.91*
3 year old	5.70	6.3	-0.6
4 year old	4.7	6.0	-1.3*
Staple Length--mm.			
1 year old	97.29	104.11	-6.82
2 year old	91.50	99.06	-7.56
3 year old	80.85	84.57	-3.72
4 year old	74.0	93.0	-19.0*
Body Weight Sheared--Lbs.			
1 year old	97.76	103.39	-5.63
2 year old	126.13	126.89	-0.76
3 year old	122.0	124.0	-2.0
4 year old	119	125	-6.0
Body Weight Fall--Lbs.			
1 year old	136.41	136.33	0.08
2 year old	147.71	148.57	-0.86
3 year old	152.54	150.07	2.47
4 year old	154.0	158	-4.0

*Difference significant at 5 percent level.

TABLE 13. COMPARISON OF REPLACEMENTS FOR GROUP I AND II FOR FLEECE AND BODY CHARACTERS OF LAMBS BORN IN 1954 THROUGH 4 YEAR OLDS

Item Compared	Group I Mean	Group II Mean	Mean Difference
Birth Weight--Lbs.	11.00	10.09	0.91
Weanling Weight--Lbs.	92.81	88.56	4.25
Weanling Staple Length--mm.	71.88	74.44	-2.56
Grease Fleece Weight--Lbs.			
1 year old	14.79	15.71	-0.92
2 year old	12.6	12.8	-0.2
3 year old	12.9	13.4	-0.5
4 year old			
Clean Fleece Weight--Lbs.			
1 year old	6.72	7.00	-0.28
2 year old	7.00	6.90	0.10
3 year old	6.1	5.9	0.2
4 year old			
Staple Length--mm.			
1 year old	109.69	111.81	-2.12
2 year old	93.0	94.0	-1.0
3 year old	96.0	101.0	-5.0
4 year old			
Body Weight Sheared--Lbs.			
1 year old	104.4	110.3	-5.9*
2 year old	115.0	116.0	-1.0
3 year old	118	122	-4.0
4 year old			
Body Weight Fall--Lbs.			
1 year old	143.00	145.88	-2.88
2 year old	152.00	150.00	2.00
3 year old	152.00	158.00	6.00
4 year old			

*Difference significant at 5 percent level.

TABLE 14. COMPARISON OF REPLACEMENTS FOR GROUP I AND II FOR FLEECE AND BODY CHARACTERS OF LAMBS BORN IN 1955 THROUGH 4 YEAR OLDS

Item Compared	Group I Mean	Group II Mean	Mean Difference
Birth Weight--Lbs.	10.03	10.98	-0.96
Weanling Weight--Lbs.	99.44	96.00	3.44
Weanling Staple Length--mm.	68.88	74.00	5.12
Grease Fleece Weight--Lbs.			
1 year old	13.1	12.8	0.3
2 year old	13.4	13.4	0.0
3 year old	13.4	13.1	0.3
4 year old			
Clean Fleece Weight--Lbs.			
1 year old	6.11	6.00	0.11
2 year old	5.9	6.2	0.3
3 year old	6.2	6.4	-0.2
4 year old			
Staple Length--mm.			
1 year old	99	105	-6.0
2 year old	91	87	4.0
3 year old	98	97	1.0
4 year old			
Body Weight Sheared--Lbs.			
1 year old	96.50	92.06	4.44
2 year old	114.0	113.0	1.0
3 year old	133	128	5.0
Body Weight Fall--Lbs.			
1 year old	150.62	147.41	3.21
2 year old	154.00	154.00	0.0
3 year old	155	152	3.0
4 year old			

TABLE 15. COMPARISON OF REPLACEMENTS FOR GROUP I AND II FOR FLEECE AND BODY CHARACTERS OF LAMBS BORN IN 1956 THROUGH 4 YEAR OLDS

Item Compared	Group I Mean	Group II Mean	Mean Difference
Birth Weight--Lbs.	10.7	9.9	0.8
Weanling Weight--Lbs.	101.0	100.0	1.0
Weanling Staple Length--mm.	74	72	2.0
Grease Fleece Weight--Lbs.			
1 year old	12.7	12.2	0.5
2 year old	14.4	12.1	2.3*
3 year old	13.0	11.5	1.5*
4 year old	11.3	10.5	0.8
Clean Fleece Weight--Lbs.			
1 year old	6.4	5.4	1.0*
2 year old	7.7	6.1	1.6*
3 year old	6.7	5.5	1.2*
4 year old	6.0	5.1	0.9*
Staple Length--mm.			
1 year old	107	99	8.0
2 year old	112	97	5.0
3 year old	103	87	16.0*
4 year old	87	77	10.0*
Body Weight Sheared--Lbs.			
1 year old	102	99	3.0
2 year old	129	118	11.0*
3 year old	149	141	8.0
4 year old	165	168	-3.0
Body Weight Fall--Lbs.			
1 year old	149	149	0.0
2 year old	153	148	5.0
3 year old	163	165	2.0
4 year old			

*Difference significant at 5 percent level.

TABLE 16. COMPARISON OF REPLACEMENTS FOR GROUP I AND II FOR FLEECE AND BODY CHARACTERS OF LAMBS BORN IN 1957 THROUGH 4 YEAR OLDS

Item Compared	Group I Mean	Group II Mean	Mean Difference
Birth Weight--Lbs.	10.7	11.3	-0.6
Weanling Weight--Lbs.	102	107	-5.0*
Weanling Staple Length--mm.	72	71	1.0
Grease Fleece Weight--Lbs.			
1 year old	12.9	14.1	-1.2*
2 year old	12.8	13.3	0.5
3 year old	11.2	12.0	-0.8
4 year old			
Clean Fleece Weight--Lbs.			
1 year old	6.3	6.7	0.4
2 year old	6.2	7.2	1.0*
3 year old	5.7	6.3	-0.6
4 year old			
Staple Length--mm.			
1 year old	116	124	-8.0
2 year old	95	94	1.0
3 year old	81	85	-4.0
4 year old			
Body Weight Sheared--Lbs.			
1 year old	101	103	-2.0
2 year old	126	131	5.0
3 year old			
4 year old			
Body Weight Fall--Lbs.			
1 year old	132	135	-3.0
2 year old	153	155	-2.0
3 year old	160	160	0.0
4 year old			

*Difference significant at 5 percent level.

TABLE 17. COMPARISON OF REPLACEMENTS FOR GROUP I AND II FOR FLEECE AND BODY CHARACTERS OF LAMBS BORN IN 1958 THROUGH 4 YEAR OLDS

Item Compared	Group I Mean	Group II Mean	Mean Difference
Birth Weight--Lbs.	10.2	10.3	-0.1
Weanling Weight--Lbs.	95	103	-8.0*
Weanling Staple Length--mm.	64	70	-6.0
Grease Fleece Weight--Lbs.			
1 year old	12.4	13.1	-0.7
2 year old	11.6	11.8	-0.2
3 year old			
4 year old			
Clean Fleece Weight--Lbs.			
1 year old	5.6	6.1	-0.5*
2 year old	5.7	5.9	-0.2
3 year old			
4 year old			
Staple Length--mm.			
1 year old	101	107	-6.0
2 year old	85	88	-3.0
3 year old			
4 year old			
Body Weight Sheared--Lbs.			
1 year old	113	117	-4.0
2 year old			
3 year old			
4 year old			
Body Weight Fall--Lbs.			
1 year old	153	160	-7.0
2 year old	148	155	-7.0
3 year old			
4 year old			

*Difference significant at 5 percent level.

the lambs selected for replacement in Groups I and II and the means for the following quantative characters: birth weight; weanling staple length; grease fleece weight at 1, 2, 3 and 4 years; clean fleece weight at 1, 2, 3, and 4 years; staple length at 1, 2, 3, and 4 years; sheared body weight at 1, 2, 3 and 4 years; and fall body weight at 1, 2, 3 and 4 years. The difference between the means were tested and significance indicated (Snedecor, 1956). Table 12 contains the same information except that the lambs selected for replacement were born in 1954. This same table organization was used up to and including 1958.

The object of any selection system is to pick those individuals for replacement that will produce, at the highest level, those products having the highest economic value. If the selection system was effective this would insure that a high level of production would be maintained in the flock. Where large numbers have to be dealt with, and selection by phenotypic appearance is the only applicable method of replacement selection, the genetic effectiveness may be low. The effectiveness depends to a large extent on the heritability level of the character for which one is selecting.

There were not many measurements of quantitative characters of high economic value available when the selection was actually done. The group considered superior at the original selection might not be superior at a later date. Effects might not be discernable until progeny are available.

The birth weights of those selected in Groups I and II were compared each year but the differences were not significant (Tables 1-11).

There were only two instances of significant differences for characters that persisted year after year. These were for length in 1953 and clean fleece weight in 1956 (Tables, 12 and 15). The length difference, significant at weanling age, persisted at 2 and 4 years of age. The difference was in favor of Group I. However, the following year no such difference existed. There was significant differences at 2 and 3 years of age in clean fleece weight. These differences were in favor of Group I.

There was a significant difference in weanling staple length in 1952 in favor of Group I; but the difference did not persist for ages 2, 3, and 4 years.

It would be possible for the progeny of replacements selected in 1952 to be considered for selection in 1955.

By 1957 the original ewes in both groups were entirely replaced by "selects."

There was a general tendency for improvement in all characters for both groups except in lamb weights and staple length. Staple length actually decreased in both groups.

If one group was genetically superior, evidence of this would start expressing itself; however, there was no apparent evidence. Probably more generations would be required and refined technique for detection would be necessary.

VI. CONCLUSIONS

Two methods of selection, visual appraisal used for Group I and a selection index for Group II, were applied to a commercial sheep-raising type of operation for a period of ten years.

From the data presented the following conclusions seem justified.

1. The production level of the initial ewes making up Groups I and II was high for the following characters: body weight, clean fleece weight and staple length.

2. Maintaining the numbers in the different age categories comparable for the two groups was very difficult.

3. It was difficult, also, to keep the breeding flocks for both groups up to the desired numbers, the replacements for both groups going in at a uniform rate and culls for both groups going out at a uniform rate.

4. The differences in the two groups between the means for sheared body weight, fall body weight, yield, clean fleece weight and staple length were not significant at the 5 percent level. It was not expected that they would be different in 1952 but it would have been possible for some difference to become evident as the original ewes in each flock were replaced by "selects."

However, the means for the above mentioned characters all increased about the same in both groups by 1956 except staple length which decreased about the same in both groups.

5. The mean fleece value was higher in Group I for all the years except in 1954 and 1958. It appeared that Group II, which was coarser in grade, did not have sufficiently large fleeces or long staple to off-set the price differential.

6. The rams used, from all indications, were good average rams typical of the Columbia breed.

7. A selection index used for selecting replacement ewes showed no superiority over visual appraisal.

8. Both selection systems improved the production of the quantitative traits of grease fleece weight, yield, clean fleece weight, fleece value, sheared body weight and fall body weight. The increase in each group was about the same amount for the 10 year period.

9. The visual selection method was far simpler to apply than the selection index where so many measurements and calculations had to be made.

10. There would be no advantage of using a selection index in a sheep operation like Archer for selecting replacements as it showed no superiority over the visual appraisal method. It is conceivable that an index might

be more effective genetically over a long period of time.

11. Applying a selection index was a very effective method of becoming intimately familiar with quantitative sheep characters and would certainly make a grower know more about his flock than he would by years of casual observation.

VII. SUMMARY

Because selection of replacement ewes is so important to all sheep growers it is desirable to know if there might be more efficient methods than those commonly used. This especially is true in view of the vast amount of genetic theory now known. The present study was initiated at the Archer Sub-Station near Cheyenne, Wyoming. The purpose of the study was to determine the comparative effectiveness of visual appraisal and a selection index in selecting replacement ewes.

One hundred and twenty ewes were divided into equal groups (randomized) in 1951 and the two methods of selection were applied at weanling age. By 1958 the original ewes had been completely replaced by "selects."

Necessary fleece and body measurements were made at lambing time, shearing time and in the fall so that the Dubois Columbia Weanling Index could be computed for all ewe lambs in Group II. Selections were made from this index. Measurements of important fleece and body quantitative characters formed the basis for comparison.

All management practices were those similar to ones practiced by puregred breeders. Good average Columbia breed rams were used. The study started in 1951 and terminated in 1960.

The visual appraisal system appeared to be as effective as the selection index system in selecting replacements that would maintain the groups at a high level of production. Both groups were improved about equally in the increased performance of grease fleece weight, clean fleece weight and body weight. Staple length was the only character that did not increase in both groups but decreased about the same in both groups.

The selection index requires a lot of work to use and would not be practical where large numbers were involved.

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