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A STUDY OF MILK PRODUCTION  
AS IT AFFECTS  
LAMB GROWTH IN ROMNEY and  
CHEVIOT CROSSBRED SHEEP.

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A Thesis  
Presented in partial fulfilment of the  
requirements  
For the Degree  
of  
Master of Agricultural Science  
of the  
University of New Zealand.

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By  
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## THE PURPOSE OF THE STUDY

The Cheviot sheep has been introduced into New Zealand to replace the New Zealand Romney on certain classes of poor or marginal hill country. Before the Cheviot can oust the Romney commercially, however, the fundamental features of its performance must be critically examined by means of experiments planned to compare the two breeds.

Owing to the shortage in New Zealand of pure Cheviot stock and because of the difficulty of importing large numbers of purebreds, the crossing of the Cheviot with the Romney has been resorted to. The New Zealand flock Romney is derived from basic Merino stock by repeated crossmating with Romneys and a distinctive type of Romney, now considered as pure, has been evolved. Similarly, the grading up of basic Romney stock by the Cheviot is now being attempted in order to increase the Cheviot numbers.

Since Romneys have certain qualities which could well be incorporated into any line of Cheviots, it is important to assess the qualities of these crosses in relation to their proportion of Cheviot blood.

To this end, certain aspects of the problem have been studied and are discussed in this thesis. The principal aims of the study were as follows :

- (1) To investigate the milking ability, both quantitatively and qualitatively, of the Romney, the three quarter and the half bred Cheviot 6 year old ewe. (See definition of terms.)
- (2) To investigate some of the quantitative and qualitative variations in ewe milk affecting lamb growth.

(3) To compare the cost-for-age threequarter and half bred Cheviot ewe as a producer of fat lamb, with comparable aged Romneys.

## I N T R O D U C T I O N

The suitability of any breed of sheep for a particular environment may be measured by the departure of that breed from the standard of excellence optimum for those conditions. Therefore it is necessary to postulate initially, the environment in which the Cheviot is required to replace the Romney.

While generally this may be described as poor North Island hill country, Hewitt (1) gives a more specific description when he refers to -- "poor hard birch country - the gully faces are steep and rocky. Scrub, gorse and broom are a constant menace. The carrying capacity is about half a ewe to the acre on browntop pasture which is very hard and of a run out nature."

Under such conditions an "optimum" sheep must perform as follows :

### (1) Fertility and Fecundity.

The breed must be able to reproduce normally and in order that maximum selection may be practiced, a high lambing percentage is required (Lush (2).)

(2) Thrift Inherent in ability to thrive on low levels of nutrition is the attribute of conformation which allows a sheep to climb freely and thus graze selectively from what feed exists.

Also conditioning thrift are freedom from pathogenic and metabolic disease and resistance to the rigorous climate always associated with this type of country.

### (3) Conformation for Meat Production

This arbitrary quality is difficult to define,

since true measurement of this character can only be accurately made upon the carcass of the slaughtered animal.

Meat production, being a secondary function of hill sheep, resolves mainly upon the progeny of the cast-for-age ewes brought to the "lowland" for fat lamb production.

Walker and McMeekan (74) have found, however, that good and bad conformation in the cast-for-age Romney ewe produces no significant difference in the carcass quality of the respective fat lamb progeny.

Phillips and Barton (3) found that under the present system of fat lamb grading, the marked prepotence of the Southdown as a fat lamb sire necessitates only that the cast-for-age ewe be able to fatten her lamb in the shortest possible time. For this, the ewe must produce a plentiful milk supply and criteria of conformation can be neglected.

#### (4) Wool Production

The quantity of wool produced by sheep under the hard conditions stipulated, must be at a maximum without endangering the qualities essential for high monetary return.

(5) Related to all the above attributes of the "optimum" sheep and of vital importance itself is the manner in which the young sheep is reared.

While the growth potentialities of livestock are predetermined at conception, their expression at all stages of growth is in relation to the environmental conditions in which the animal exists.

Nutrition, not the least of the environmental

agencies, determines largely how close the hereditary potential for growth will be approached.

Hammond (4) postulates that nutritional conditions in early life limiting growth can materially affect the ultimate development of the animal.

Brody (5) attempts to analyse the effect of productive improvement as it approaches the hereditary potential of the animal for either growth, muscular work or milk production. As productivity, due to increased growth rate or milk production is improved, the question of efficiency both in physiological and economic terms becomes important. Efficiency is not a simple concept - it must be viewed from the several points of -

- (1) That pertaining to the animal
- (2) That of the farmer
- (3) That of immediate efficiency, and
- (4) That of long range efficiency.

Whether increased productivity results in greater immediate efficiency depends on the relative acceleration of the productive process on one hand, and the maintenance cost on the other. But granted an increase in immediate efficiency, how will this affect the long range efficiency, viz: health, fertility and longevity? Also while energetic efficiency, the ratio of the desired form of output energy to the given form of input energy (Brody (6) ) is of importance to the farmer, monetary profit has an over-riding value.

That conversion of feed to animal products with equal energetic efficiency may not return equal profit, is explained by the fact that fixed costs per animal are less in

a small group of large animals than in a larger group of small animals. Consideration must therefore always be given to the level of production giving the optimum combination of energetic and economic efficiency.

Contrary to common belief, the most rapid growth can be associated with the highest early mortality (Dove (8) ). Thus while maximum growth rate may be economical to the farmer in saving overhead maintenance costs, it may not be profitable to the animal, whose longevity may be thereby impaired.

The relatively short period of growth considered in the production of fat lambs precludes any loss of long term efficiency.

In the rearing of hill country breeding stock, however, it may be pertinent, since constitution and longevity are more vital considerations. Whatever the destination of the young sheep, however, it is of importance to investigate the food which forms the major part of their diet for the first months of life and to see if variations in its quantity and quality affect the lambs' growth.

In common with other young animals the lamb is dependant on milk for the important period bridging dependant intrauterine and independent adult life. Hammond (4 C) states that milk is of even more importance to lambs than it is to young cattle and pigs -- "a shortage of milk causes young lambs to grow more wool than meat; they become pot-bellied, unthrifty and are forced to eat larger quantities of less digestible foods with the above-mentioned results."

The importance of milk to young sheep may be deduced from a review of its functions and properties.

Colostrum, the fluid secreted immediately post-partum, is of extreme importance since its constituents provide temporary resistance to the diseases liable to affect the suckling animal. Normal milks of various species differ considerably in the content of the various nutrients but all milk has certain common characteristics. Briefly these are,

- (1) Milk is easily digested and assimilated, the nutrients being supplied in forms particularly adapted to the undeveloped systems of mammals at birth.
- (2) Milk is rich in protein supplying an ample amount of all the essential amino acids.
- (3) Milk, on a dry matter basis, is rich in some minerals, especially calcium and phosphorus, the two minerals needed in largest quantities by growing animals.
- (4) The fat and sugar in milk furnish concentrated energy in a readily assimilable form.
- (5) Milk contains usually adequate amounts of most vitamins necessary for normal body function.

Analyses of milk from various classes of livestock have shown that the composition of the milk of different species is closely related to the relative growth rate during the suckling period. While a knowledge of the composition of the milk of domesticated animals is essential, in that it indicates the quality of nourishment available for the growth of the young, it is no accurate index of the comparative rearing ability of different individuals within the same breed.

Within a species the quantitative production of milk seems to be of greater importance in the determination of the nutritional level available for the young growing animal.

When the production of fat lambs is being considered, economical production depends almost entirely upon the rate and economy of gains in total liveweight made by lambs reared.

To this end the fertility and milk producing ability of the ewes are of fundamental importance. The attainment of maximum economy either through increased rate of reproduction or by increased rate of growth is to be considered in this study.

DEFINITION OF TERMS

- Half Cheviot - The progeny of a Romney ewe crossed with a Cheviot ram.
- 3/4 Cheviot - The progeny of a  $\frac{1}{2}$  Cheviot ewe crossed with a Cheviot ram.
- Milking ewes - Those ewes whose milk yields were estimated.
- Non-milking ewes - Those ewes which did not receive the milking treatment.
- Milking lambs - Progeny of milking ewes.
- Non-milking lambs - Progeny of non-milking ewes.
- Milking - Refers to the procedure whereby ewes' milk yields were estimated.
- Sampling - The manual expression of a representative milk sample from one half of a ewes udder.
- Half - Refers to a functional half of the mammary gland of the ewe.
- Lactation curve - The graphical representation of the trend of milk yield in response to the advance of lactation.
- Fat test - The fat % of a milk sample.
- Mean or average - Refers to the arithmetic mean unless otherwise stated.

SIGNS OF SIGNIFICANCE

- \*\* - Significance at the 1% level
- \* - " " " 5% "
- N.S. - Not significant (significance at a level greater than 5%)

Male Lambs - All lambs nominated male were castrated at 3 - 4 weeks of age.

Growth rate - Unless otherwise stated refers to the average growth rate which equals 
$$\frac{W_2 - W_1}{t_2 - t_1}$$

where  $W_2$  and  $W_1$  are weights at times  $t_2$  and  $t_1$  respectively.

Growth - Unless otherwise stated refers to the increase in liveweight.

## MATERIAL

The area used for the experiment consisted of twenty paddocks each of one acre, situated on two parallel and flattish topped ridges separated by a gully which was excluded from the experiment. The soil is classed as a yellow-grey loam but because of a somewhat impervious clay subsoil is known popularly as clay soil and tile draining to eliminate the wetness characteristic of this soil in winter and spring, is essential.

From 1939 until 1943, after an initial application of 2 tons of lime, each plot received 4 cwt. of super-phosphate per year.

From 1944 - 1951 each plot was treated with 2 cwt. of super-phosphate per year and from 1946 to 1951, five cwt. of carbonate of lime per year. Initially the area had been sown down with simple mixtures of pedigree or mother perennial ryegrass (Lolium perenne) and different strains of pedigree or mother white clover (Trifolium repens) at the rate of 43 lb. of mixture per acre.

In 1951 when taken over for this experiment, the pastures were predominantly ryegrass and white clover. Uniform shelter was provided by means of pampas hedges since the site was exposed to the prevailing winds.

## EXPERIMENTAL ANIMALS

The total number of ewes on the 20 acres in February 1951 was 136. Of these,

25	were	5½	year	Romney	ewes	(T.)
25	"	5½	"	"	"	(S.)
36	"	5½	"	"	"	(W.)
25	"	¾	Cheviot	5½	year	ewes.
25	"	½	"	5½	"	"

The S. Romney ewes were from a well known hill-country flock, having been run from the age of  $1\frac{1}{2}$  years on the flats of the College hill farm.

The W. and T. Romney ewes were cast-for-age flock ewes from hill country farms.

The visible qualities which differentiated the respective Romney strains in the eyes of a farmer were impossible to measure. The fact that the groups of ewes carried the name of a well known Romney breeder, was sufficient evidence for a farmer that the ewes would differ in certain important requisites of Romney type, e.g. wool quality, weight of bone, levelness of back and general carriage.

In spite of some common lineage in the stud flocks of the respective strains it was thought that the strains of Romneys chosen differed in their breeding ancestry sufficiently to warrant their being potentially different in the characters to be considered.

The  $\frac{3}{4}$  bred Cheviot and  $\frac{1}{2}$  bred Cheviot ewes (see definition of terms, page 9) were from the College farm, and from a Paekakariki hill farm in the Wellington district, respectively.

The size of ewes in the respective groups may be gauged from their weights on the day after arriving at the experimental area (Table 1).

T A B L E - 1

Group	Mean live weight lbs. 2/3/51	Range lbs.	Number in group
Romney W.	125.2	90 - 159	36
T.	109.6	98 - 152	25
S.	134.5	105 - 167	25
Cheviot 3/4 bred	132.4	107 - 167	25
1/2 "	106.2	86. - 113	25

RAMS

The rams used were 4 and 6 tooth, and full-mouth Southdowns.

CATTLE

The equivalent of 20 head of 2 year Black polled Angus steers came on to the area on the 15th September

FACILITIES FOR WEIGHING EWES AND LAMBS AND MILKING EWES

All ewes and lambs were weighed on a "walk on" Avery scale (weighing to the nearest pound) at approximately fortnightly intervals.

For milk yield estimation, lambs were weighed to 1/2 ounce on a steelyard accurate to 1/4 ounce.

METHODS

Management of Ewes:

The ewes were randomly selected into 4 groups of 34 animals with approximately equal number of each breed or strain in each. Each group thus selected was then allocated five paddocks, such that particular types of paddocks were equally distributed between the groups. The ewes were then started on a daily rotation of the five paddocks allocated to them. This rotation meant that each paddock had a four day

spell between grazings and also that groups would be grazing the same type of paddock at a maximum, but usually less, time interval of 4 days.

Pasture was controlled so as to give the optimum sheep grazing length of about 3 inches. The use of spare dry stock facilitated this especially in autumn and spring when the growth was too great for the 34 ewes allocated to each one acre paddock.

All ewes were weighed at fortnightly intervals until the 9th August when it was considered that the yarding of ewes and young lambs, together with ewes heavy in lamb, was a dangerous practice. Lambing commenced in the first week of August and twice daily rounds of ewes were maintained by the shepherds. The ewes which had lambed were left in the paddock in which they had lambed when their respective groups were subjected to the daily rotation of paddocks.

Lamb weights at an interval of 3 days post-partum, were used as a measure of birth weight (see Logan (23), Hammond (4) and Clarke (20B).) As well as being weighed all lambs were ear marked and particulars of sex noted. Docking and castration were performed when the majority of lambs were 3 to 4 weeks old. Searing irons were used for docking and Darouss emasculators for castration.

## 2. Mating

On the 15th March one Southdown ram was put out to each group of 34 ewes. All rams were raddled and colour of raddle changed every 10 days. Each ram was moved to a new group of ewes daily. The mating behaviour of all ewes was followed by means of the raddle marks and accordingly ewes

apparently dry were segregated at the end of tuppung.

### Experimental Techniques

If we postulate that the maximum potential milk yield of a ewe is controlled by her genetical maximum, then factors comprising the ewe's environment determine how closely this hereditary level will be approached.

One of the most important environmental factors affecting milk production is the number of offspring suckled. Bonsma and Oosthuizen (9) working with pigs found a highly significant correlation between litter size and total milk production per sow. Barnicoat et al. (11) working with Romney sheep found a significant milk yield difference between single and twin bearing ewes. Wallace (28) also supports this hypothesis and states inter alia - "that a better estimate of the milking capacities of different ewes, is likely to be obtained from a consideration of the milk yields of ewes rearing twins rather than of those with single lambs." With this consideration in mind only twin bearing ewes were selected. In order to eliminate any variation in milk production between breeds due to lactations commencing at different times, (Barnicoat et al. (25)) an effort was made in selection to pair ewes from each breed for approximately equal date of parturition. The consideration of only twin bearing ewes tended to restrict the range of selection more especially in the  $\frac{1}{2}$  and  $\frac{3}{4}$  Cheviot groups where numbers were 25 ewes per group.

Factors that tended further to limit the number of ewes selected were -

- (1) limited labour.
- (2) The necessity for allowing a sufficient time interval

between milking.

- (3) The number of lambs that could be weighed in the interval between milking with the equipment available.

These restrictions necessitated the numbers in the different milking groups being as follows :

<u>T A B L E - 2</u>	<u>Number of Ewes</u>	<u>Number of Lambs</u>
Romney W. )		
T. ) strains	12	24
S. )		
3/4 Bred Cheviots	12	24
1/2 Bred Cheviots	<u>6</u>	<u>12</u>
Total	<u>30</u>	<u>60</u>

The main reason for the pooling of the Romney strains was the impossibility of sampling more than the 30 ewes and weighing more than their 60 lambs.

#### Measurement of Milk Yield

The method used was based on that of Bonsma (17a), Wallace (18) and more specifically that of Barnicoat, Logan and Grant (11). Measurements were taken initially on the 26th of August and continued at approximately weekly intervals until the 10th November. Since only 12 weeks of lactation were considered for each ewe, the numbers milked at each milking diminished, from the 10th November, to the 18th December, as each ewe reached the 12th week of lactation. All ewes bearing twins which had lambed at least 3 days prior to the date set down for milking, were incorporated in the milking groups.

The milking procedure was as follows :

At 11 a.m., the 30 ewes were separated from their lambs, the lambs being held in a covered yard while the ewes were returned

to a convenient paddock of similar pasture to that of their rotation.

At 1.30 p.m. the ewes were driven to the yards holding the lambs. Each member of a set of twins was weighed and simultaneously the set was presented to the respective ewe which had been placed in a milking pen. After a period with the ewes, sufficient for the lamb to suckle all the milk present in the udder, the lambs were taken from the respective ewes and re-weighed. The difference in weights before and after suckling was taken to represent the amount of milk consumed by the lambs. Untimely excretions were not found to be a problem. After re-weighing the lambs were returned to their covered yard and when all the ewes had been suckled they were returned to their holding paddock. This procedure was repeated during the 24 hours according to the following plan (Table 3).

T A B L E - 3

TIMES OF MILKING DURING THE 24 HOURS

Ewes and Lambs separated	First Suckling	Second Suckling	Third Suckling	Fourth Suckling	Fifth S'ing	Sixth S'ing
11.0 a.m.	1.30 pm.	4.30 pm.	8.30 pm.	4.30 am.	8 am.	10.30am
	2.30 pm.	5.30 pm.	9.30 pm.	6.30 am.	9 am.	11.30am
Mean time	2.0 pm.	5.0 pm.	9.0 pm.	5.30 am.	8.30 am.	11.0am
Interval between Mean times	3 hrs.	3 hrs.	4 hrs.	8½ hrs	3 hrs.	2½ hrs.
	← 24 hours →					

It will be seen that the time interval between initial separation of ewes and lambs and the mean time of the sixth suckling was 24 hours. It was assumed that at the commencement of that period all the ewes were secreting milk at a normal rate, i.e. no ewe was holding excess milk in her udder. A slight error

is introduced in that the milk production of 24 hours + M minutes is measured for those ewes which are suckled after 11 a.m. in the 6th suckling. M = the number of minutes between 11 a.m. and the time of suckling. This error could be no larger than the time interval between 11 a.m. and the termination of milking. Because of the measurable period of time required for each suckling, it was impossible to treat all ewes at exactly 11 a.m. It was considered most suitable that the mean time of the sixth milking be at 11 a.m. The intakes of the lambs of each ewe, when summed for the six samplings, were taken to represent the ewes' production during the 24 hours.

It is now appropriate to assess the reliability of this method, firstly as an estimate of the 24-hour production, and secondly as an average figure for the milking production of the 7 days commencing 3 days before the sampling day and terminating 3 days after the sampling day.

#### 1. Reliability as a 24-Hour Estimate

Since the number of offspring suckled affects the amount of milk produced by the ewe, Wallace (28), Barnicoat et al. (25), it is essential to stipulate the number of offspring considered. In this experiment, since we have concluded that twins condition a level of milk production nearer the ewes' hereditary potential than do single lambs, then it is this level which we desire to estimate.

It is important to determine whether the intervals between experimental sucklings will be such as not to depress milk production (Hammond (26)) and be similar to natural conditions where the lambs (assumedly) consume all the milk that is produced. Both Barnicoat et al. (11) and Wallace (28) have discussed the effect of variation in frequency of suckling

and they conclude that six sucklings per 24 hours are sufficient to remove all available milk from the udder. Barnicoat et al. found that under natural conditions of pasture grazing, lambs, will, at the period of maximum milk supply, i.e. 4 - 6 weeks, suckle only about six times per day. The adequacy of six sucklings when the lamb is 4 - 6 weeks old seems valid but when the lamb is from 0-3 weeks old and milk production/day is only 10 - 15 ounces below the lactation maximum (at 4 - 6 weeks), it is possible that production is in excess of lamb consumption. This inequality would be further aggravated by too long suckling intervals. Wallace (28) has found that if the total milk produced by the ewe is not consumed (more especially in the first weeks of lactation) then the retention of this quantity in the udder has a depressing effect upon subsequent yield. The expedient of 6 sucklings per day with twin lambs for every ewe was thought to have overcome this discrepancy.

While the Cheviot ewe is not renowned for its docile nature, in this experiment no difficulty was experienced in effecting a normal suckling of the ewes by their lambs. During the 5 a.m. milking the presence of the sampler in the milking pen, initially had a disturbing effect upon all three breeds of ewes but this soon disappeared when the ewes became accustomed to the milking procedure.

At this early morning milking, since one half was being sampled, the contents of the other were to be equally divided, by the judgment of the sampler, between the twin lambs of the respective ewes. Through the inability of the sampler to judge this it was possible for the first lamb to consume 14 - 24% of its 24-hour intake. This led to a proportional diminution in the consumption of the second lamb whose consumption could vary from 14 to 0% of its 24-hour intake. To eliminate

the advantage received by one lamb at sampling, each lamb was alternated between weeks in being first introduced to the ewe.

If the ewe was disturbed excessively it retained milk at the fourth milking and the following milkings were correspondingly increased compared with those following a normal fourth milking. The increased intra-mammary pressure thus formed would tend to decrease milk secretion (Hammond (26)), in the period between the fourth and fifth milkings. Efforts were made therefore to treat all ewes especially the more sensitive Cheviots, in a firm but quiet manner.

Another factor of importance in assessing the reliability of estimation is the accuracy with which lambs were weighed. The steelyard used weighed accurately to  $1/4$  ounce and was read to the nearest  $1/2$  ounce. In order to estimate the repeatability of lamb weight, 16 lambs, i.e. two sets of twins from each breed, were, on 29th September, 1951, randomly selected from the 60 lambs to be weighed. Immediately following their first weighing at 1.30 p.m. they were re-weighed in similar order. The weights of respective lambs at these two times are recorded in Table 4 and give an indication of repeatability.

T A B L E - 4

Lamb No.	First weight		Second weight	
	(Tare 2 lbs. included)		(Tare included)	
	lbs.	ozs.	lbs.	ozs.
220	21	12	21	12
221	25	15	25	15½
34	26	6	26	7
33	26	7	26	7
334	19	14	19	14
333	21	7	21	7½
64	26	10	26	10
63	28	3	28	3
324	28	0	28	0
325	25	7½	25	6½
212	22	10	22	10½
213	23	3	23	3

It must be emphasised that the speed and accuracy of weighing maintained at normal weighings, was simulated in this test. The weights tend to be slightly subjective since time was not available for the complete cessation of movement in the balance. The correlation of these two sets of weighings is .99993, yielding a coefficient of determination of .99986. This means that errors of weighing etc. could account on the average for .0002% of the variation between lamb weights. Throughout the first 14 weeks of milking, the author performed all the lamb weighings in order that inaccuracies might be constant between milking days. At each milking the procedure was a copy, as far as possible, of that initially set up.

It is realised that the natural conditions of pasture grazing can only be approached as close as allowed by the

compromise between the desirability of lambs suckling at frequent intervals and the necessity for ewes to have sufficient time to graze normally between milkings. These limitations must be remembered when considering the results of this investigation.

## 2. Reliability of the Method as an Estimate of Weekly Production.

Barnicoat et al (11) and Wallace (18) have both made the assumption that milk production rises or falls in the period considered, in equal daily amounts. Assuming this is so, then it is valid to assume that the milk yield estimated on the milking day is the average yield of the week centred about it.

From the milk yield data of each ewe were constructed individual lactation curves. From each curve, the milk yield at appropriate intervals (weekly) was read off, the yield for the whole lactation being seven times the sum of the daily yields at weekly intervals during the 12 weeks of lactation.

Bonsma (17a) uses a modification of Simpson's rule to estimate milk yield. The use of this method was found to give a yield estimate very similar to that of Barnicoat et al. (11). Accordingly, the more simple procedure of determining yields from individual lactation curves was adopted.

The lactation curve is more accurately a lactation graph since no smoothing of graphed data was performed. The graphical presentation was thought to be more accurate in view of the distrust, evidenced by Snedecor (29b) for arbitrarily fitted curves.

The repeatability of this method of milk yield estimation may be gauged from the trial carried out by

Barnicoat et al. (25b). They tested the yield of 11 Romney ewes at an interval of 24 hours. From their data a correlation coefficient of .9801 may be obtained between yields of the same ewes on the two days. The resultant coefficient of determination is .9606. This in effect means that the combined action of lactational trend, weather, excessive disturbance of the ewe and inaccuracies of measurement could cause only 3.94% difference (on the average) between yield estimates separated by one day.

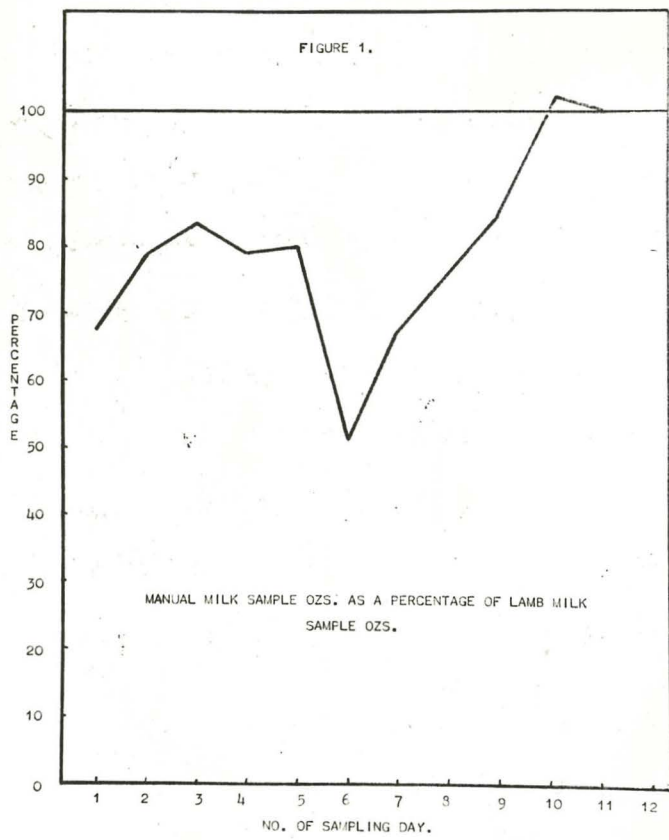
Summarising, the reliability of this method of milk yield estimation depends upon -

1. The accuracy of lamb weighing being maintained.
2. An equitable compromise between ewe grazing time and the necessity for frequent sucklings by the lamb.
3. As little disturbance of the ewe as possible.
4. The withdrawal of all available milk from the udder at each milking.
5. That the change in milk yield over a specified period take place in equal daily increments and decrements, depending upon the stage of lactation.

#### Sampling of Ewe Milk for Analysis

The sampling for analysis took place at the 4th milking. This commenced at 4.30 a.m. and its mean time 5.30 a.m. was  $8\frac{1}{2}$  hours after the mean time of the 3rd milking. The procedure was to allow one of the lambs to stimulate the "let down" whereupon the milker would express milk from the teat not being suckled. Equalisation of milk consumption and continuity of suckling was maintained by changing lambs to the 2nd member of a twin set, when it was considered that the first had gained half of the milk in one half of the udder. Whether this continued suckling maintained the hormonal let down mechanism is unknown, but it at least served to restrain the ewe. The weight of milk manually expressed was added to the weights of milk measured during the 24 hours. About 150 ml. of the

FIGURE 1.

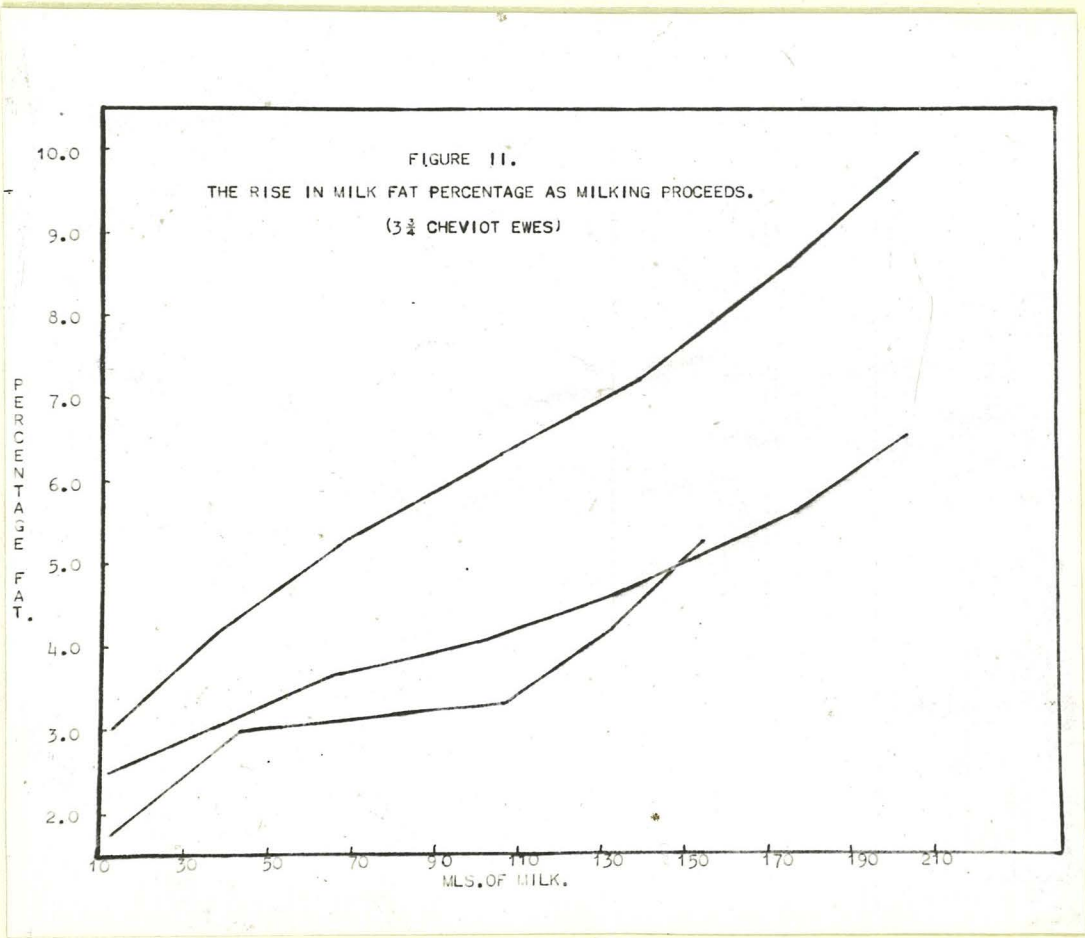


manual sample was taken for analysis.

Logan (23) has suggested that extraneous influences at sampling will tend to inhibit the expression of milk from the udder. It is considered that the lamb, with its faster rate of extraction relative to the sampler, will obtain the maximum amount of milk available and because of this superior ability be less affected by non co-operation of the ewe. An index of the representativeness of the manual sample could be gained by expressing it as a percentage of the amount gained by the lamb. Figure I shows the average manual extraction expressed as a percentage of the lamb consumption for each sampling day during the 12 weeks of lactation. The average relative extraction over the whole lactation was 80%. The low extraction % seen in Figure I for the 6th sampling was caused by the cold wet weather experienced on that day. The ewes were completely wet at this milking and while initially allowing their lambs to suckle, were soon disturbed by the reluctance of the lamb and sampler to perform in their proximity.

The reason for the high relative manual extraction is that the milk constituents may not be evenly distributed throughout the available milk. For example, Logan (23) found that in Romney ewes there is a significant rise in fat % as sampling proceeds.

In order to determine whether this phenomenon was present in Cheviot ewes, three  $\frac{3}{4}$  bred Cheviots with single lambs were separated from their lambs at 5 p.m. on the 11th September. Simulating normal milking procedure, the lambs were allowed to suckle ad lib at 8 p.m. Nine hours later, using the lamb to initiate the let down, 6 or 7 consecutive milk samples, each of about 1 ounce, were taken from one half of each ewe. The



samples were analysed for fat % by the Gerber method. Figure II illustrates the rise in fat % of milk in 3/4 Cheviot ewes as milking proceeds.

The discrepancy found by other workers in that the lamb tends to choose the best yielding half has been overcome (1) by the use of twin lambs at milking (neither half receiving preferential suckling), and (2) by always sampling from the left half of the ewe. Thus if inequality of yield exists between halves the higher yielding should be randomly distributed and neither yield estimates nor % extraction should be biased.

#### Analysis of Milk

The following constituents were determined in the milk of the three breeds :

- |                    |                |
|--------------------|----------------|
| (1) Total Solids   | (5) Lactose    |
| (2) Solids-not-fat | (6) Ash        |
| (3) Fat            | (7) Calcium    |
| (4) Protein        | (8) Phosphorus |

All were expressed as parts per cent by weight of whole milk.

The vitamin A and carotene contents of Romney and 3/4 Cheviot ewe milk fat were also determined. Fat was determined for each individual ewe at each milking whereas full analyses were made from composite samples. The composite sample constituted a 10 ml. representative aliquot from the individual sample of each ewe which had been included in the sampling. In order that ewes which were included in the composites might have a similar date of commencement of lactation, it was found necessary to exclude a number of late lambing ewes. Those for which the date of parturition was distant more than 7 days after the mean lambing date were omitted. This criterion of selection for composite groups gave a standard deviation of  $\pm 5.96$  days from the mean birth date of all ewes in composites. The range of birth dates was  $\pm 7$  days.

The mean fat test for all individual ewe samples served as a check on the fat test of the composite. All

individual and composite samples were vigorously shaken before portions were extracted for analysis. When not in use and until the necessity for repeat analysis had been determined, all samples were stored at 36° - 40°F.

Constituents

1. Total solids were determined as the % by weight in whole milk of each breed. Approximately 10 ml. duplicate samples of aliquots were initially dried on a water bath for 3 hours. The optimum subsequent period in a 100°C oven was determined experimentally (see Table 5).

T A B L E - 5

COMPARISON OF TREATMENT REQUIRED FOR  
OBTAINING REPRODUCIBLE VALUES OF TOTAL  
SOLIDS IN EWES MILK

Breed	Sample	% Total Solids - 3 hrs. on water bath followed by indicated periods at 100°C.			
		4 hours	6 hours	8 hours	9-1/3hrs.
Romney	1	16.65	16.53	16.47	16.45
	2	16.74	16.68	16.63	16.60
3/4 Cheviot	1	20.14	19.16	18.90	18.88
	2	18.97	18.88	18.84	18.83
1/2 Cheviot	1	17.47	17.41	17.28	17.27
	2	17.38	17.36	17.34	17.32

Accordingly total solids were dried at 100°C for 8 hours.

2. Solids-not-fat were estimated in composites by subtracting the fat % from total solids %.

3. Fat %. This was determined for both individual ewe samples and composites by the Gerber method.

4. Protein. Each composite was analysed for total nitrogen by a semi-micro Kjeldahl method. The % nitrogen was multiplied by 6.38 giving total (crude) protein. The factor 6.38, is used in consequence of milk protein containing on the average 15.7% of nitrogen (Jones (29) ). Whether this is referable to ewe milk protein has not been determined, but numerous workers accept this factor.

5. Lactose. This was determined by difference and consequently this constituent will be the least accurately determined since all errors in the other constituents will tend to accumulate in it.

6. Ash. The materials from the total solids determination were ashed until light grey. This was expressed as a percentage by weight of the initial T.S. whole milk sample.

7. Calcium. Determined as CaO by the method of Godden (75).

8. Phosphorus was estimated as  $P_2O_5$  by the Lorenz method.

Vitamin A and Carotene were estimated by the method of McDowell (76) using the Carr-Price reagent.

#### Analysis of Data

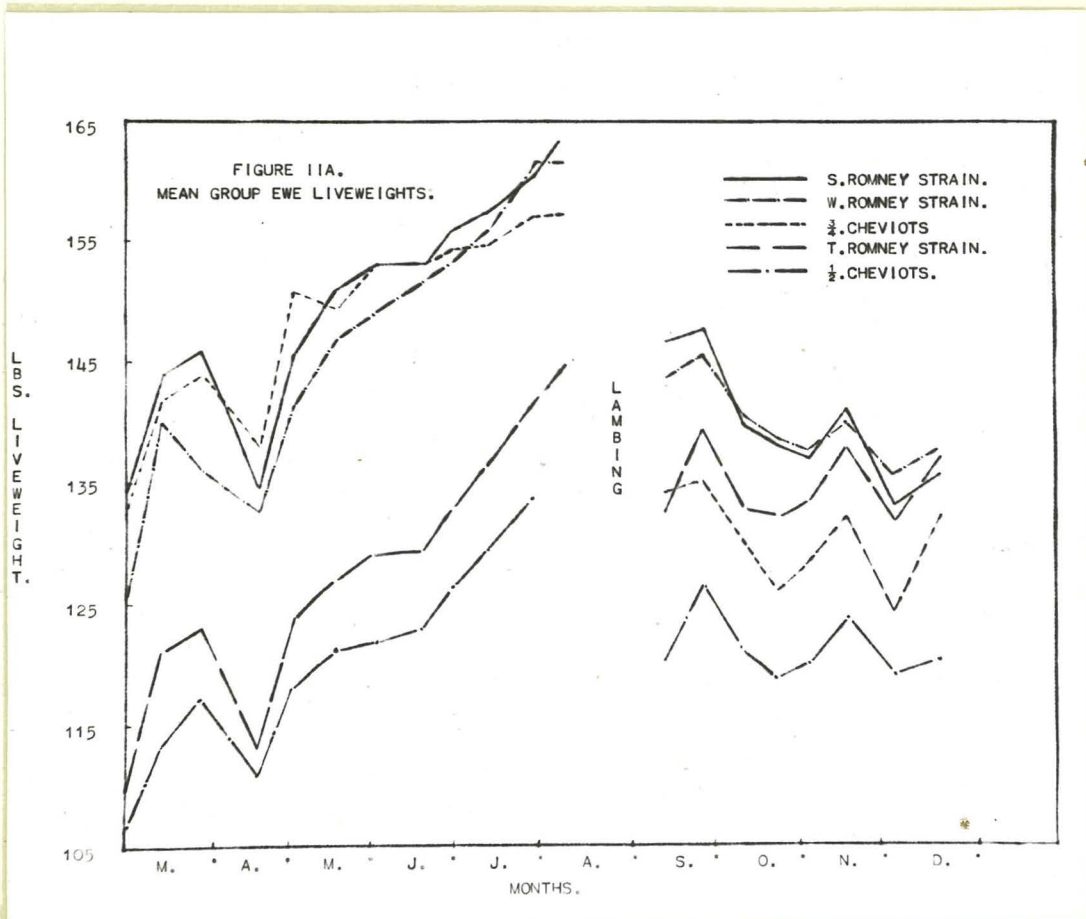
The complication caused by the death of ewe W.3 on 27th September was overcome by the inclusion in the Romney group (milking) of a ewe of similar attributes. The inclusion of this new ewe (W.19) was facilitated by her lambing date and sex of twins being the same as those of the deceased ewe. The performance of ewe W.19 up until her incorporation in the milking group was statistically estimated by the use of the missing plot technique, Snedecor (31). In subsequent analysis of variance, a degree of freedom was dropped accordingly. Elsewhere, if data were absent for one period due to disease or lambs wounding teats etc., a proportional interpolation was made.

#### Non-milking ewes

The 105 ewes remaining after the selection of the milking groups were divided into 3 approximately equal (random) groups and subjected to a rotation (of paddocks) similar to that pre-lambing. Ewes in these groups were shorn on the 18th of December with the ewes of the milking groups.

Lambs

The lambs of milking and non-milking ewes were weighed at fortnightly intervals from one month after birth. All lambs were weaned on the 19th December. After weaning the lambs were rotated in suitable mobs. Drafts of milking and non-milking lambs were sent to the freezing works at monthly intervals until the last on the 2nd of April.



RESULTS AND DISCUSSION

PART I

Ewe Performances other than Milk Production  
Comparisons of Mean Group Liveweight variations  
From Topping to Weaning

The liveweights of all ewes were recorded at fortnightly intervals from the time they arrived on the experimental area (see Figure IIA). From the 2nd March, the average relative liveweight increases in the following 4 weeks were as follows :

T A B L E - 6

RELATIVE MEAN LIVELWEIGHT GAINS AS A RESULT OF  
FLUSHING

Breed or Strain	W	S	T	$\frac{3}{4}$ Cheviot	$\frac{1}{2}$ Cheviot
Gain in lbs. as a % of initial weight on 2/3/51.	8.63	8.32	12.04	8.61	10.17

Topping commenced on the 15th March. Calculating 150 days back from the mean birth date (27th August) it is found that the 29th March is the date of maximum conception. The relative gains shown in Table 6 are for the period, 2nd March through the commencement of topping, the 15th March, to the period of maximum conception, the 29th March.

The response to the improved level of nutrition applied at flushing, is most apparent in the T. Romney and  $\frac{1}{2}$  Cheviot groups. As these two groups had the lowest mean liveweights when first weighed (Figure IIA) their relatively greater rate of liveweight gain is probably indicative of a previous poor level of nutrition since Hammond (4) stated "that circumstances causing retardation of growth temporarily, are followed by periods of accelerated growth."

The disregard for hereditary factors being the

cause of mean group liveweight difference is felt warranted because of the following :

- (1) That the mean  $\frac{1}{2}$  bred Cheviots liveweight on 2nd March is much less than that reported for comparable  $\frac{1}{2}$  Cheviot ewes run on the College hill farm (Barton (77) ), and
- (2) That the mean T. Romney ewes liveweight on the 2nd March is much less than the mean of the W. group, the S. group, or the mean of those reported by Clarke (20B) at a similar age.

The anomaly of W. ewes having a relative weight gain (Table 6) as small as the heavier weighing S. and  $\frac{3}{4}$  Cheviot ewes is accounted for by the W. ewes unexplained fall in liveweight from the commencement of tugging to the period of maximum conception. This anomalous fall is present in all the other groups but commences later, about the 29th March (see Fig. 11A).

Clarke (32) gives the liveweight trends of groups of two-tooth ewes run on the same experimental area as this experiment. Over four years, i. e. until full-mouthed, his ewes annually exhibited this autumn decline in liveweight. These variations, together with that observed by Murray (34), who found a similar drop of liveweight in 6-year Romney ewes, suggest that the decline was not of chance occurrence. It has been suggested that the presence of the ram in the ewe flock may be the cause of the phenomenon. The anomaly is, however, that a similar drop occurred in a group of  $\frac{1}{2}$  and  $\frac{3}{4}$  Cheviot hoggets in 1952 (Wilson (23) ) and at no time was a ram present in either group. Also the drop shown in the ewes of Clarke (32) was before the reported commencement of tugging.

The autumn period in which this loss of weight occurs is also the period in which outbreaks of facial eczema occur. That the loss of weight seen in various seasons is

caused by the same factor (presumably in the pasture) that causes the evident symptoms of photosensitization, is a possibility. If the toxic principle is present at a level below that required to produce the evident symptoms of clinical facial eczema, then the period preceding this decline should be characterised by some of the climatic variations which have been found to condition the disfunction. (Levy and Smallfield (35) and Cooper and Walker (36).) An investigation of these periods showed no apparent climatic trend, consistent with the conditions necessary for facial eczema. One factor, however, was found common to all the observations. This was the finding that the pastures on which all the animals have been run were predominantly ryegrass/white clover. McGillivray (66), found that in the autumn of 1952, the toxic nature of ryegrass and white clover was sufficient in small doses (2 gms.) to kill 5 week old white rats. Whether this toxic principle is related to that causing facial eczema or is a toxin of the type causing ryegrass staggers, Filmer (73), is not apparent, but either might be the cause of the observed liveweight variation.

The lowest point of the liveweight decline was reached about 19th April and from then until about 3 weeks before the mid-date of lambing (27th August) there is a steady weight increase in all groups. Expressed as a percentage of the weight at maximum conception, the average weights on the 9th August (3 weeks before mid-lambing) are presented in Table 7.

T A B L E - 7  
MEAN RELATIVE LIVEWEIGHTS OF EWES 3 WEEKS BEFORE MID-LAMBING

	W	S	T	<sup>3/4</sup> Cheviot	<sup>1/2</sup> Cheviot
Weight on 9/8/51	118.75	112.08	117.43	109.32	114.87
Weight 29/3/51					
Mean lambing date	27th Aug.	23rd Aug.	29th Aug.	27th Aug.	27th Aug.

The mean lambing date in Table 7 is the date by which half of the animals in a group have lambed. Since the spread of lambing is comparable in all groups, then according to Wallace (37), those groups with significantly more twin foetuses should show greater liveweight gains in the latter weeks of pregnancy. The following are the lambing percentages of the various groups, lambing % being the number of lambs alive 3 days post-partum expressed as a % of all ewes put to the ram.

T A B L E - 8

	W.	T.	S.	$\frac{1}{2}$ Cheviot	$\frac{3}{4}$ Cheviot
Number of ewes at end of tupping (A)	36	25	25	25	24
Number of lambs alive birth and 3 days (B)	51	28	33	29	39
Lambing % $\frac{A}{B}$	141.7	122.0	132.0	116.0	162.5

A comparison of lambing %, (Table 8) and gain from conception to 3 weeks before lambing (Table 7) shows that the highest relative liveweight gains are not made by the group with the greatest number of twin foetuses. If dry ewes are excluded from the calculation of lambing %, the order of lambing percentage still remains the same.

T A B L E - 9

LAMBING PERCENTAGE EXCLUDING DRY EWES

	W.	T.	S.	$\frac{1}{2}$ Cheviot	$\frac{3}{4}$ Cheviot
Lambing %	150.0	127.3	143.8	138.1	177.3
Number of dry ewes	2	3	2	4	2

In Fig. 11A it is to be noted that weighing was terminated approximately three weeks before the majority of animals had lambed. It is possible therefore, that marked

liveweight changes could occur in each group in the subsequent weeks. Wallace (18), however, showed that marked differences in liveweight gain should be evident from about at least the 8th week after service when comparing monotocous and ditocous ewes. Note that although Wallace did not consider relative liveweight gains, his finding re absolute gain are thought to be applicable to the relative liveweight gains of this study. The absolute gains of the respective groups are shown in Table 9A.

T A B L E - 9A

MEAN ABSOLUTE GAINS OF GROUP FROM MID-CONCEPTION  
TO 3 WEEKS BEFORE MID-LAMBING

	W.	S.	Groups T.	3/4 Cheviot	1/2 Cheviot
Mean liveweight gain (lbs.)	25.5	17.6	21.4	13.4	21.4
Lambing %	141.7	132.0	112.0	162.5	116.0

Apart from the anomalous weight gain of the W. group (explained earlier) all the groups maintain an approximately inverse relationship between mean liveweight gain during pregnancy and the % of twin foetuses in the group.

In view of this finding, it seems reasonable to assume that the greater relative liveweight gains made by the T. and 1/2 Cheviot groups were gains of body tissue rather than an increase in foetal tissue etc. This gain in body tissue is a continuation of the gain first noticed in these groups subsequent to their arrival at the site of the experiment. (See Table 6) The highest mean gain in liveweight (Table 7) is in the W. group. Since these ewes were in intermediate condition their liveweight increase during pregnancy is probably the result of (a) a smaller body tissue increment, and (b) the higher percentage of twin foetuses in this group (Table 8).

From these conclusions we may postulate that the W., T. and  $\frac{1}{2}$  Cheviot groups all made body tissue weight gains during pregnancy.

An examination of the group lambing percentages in Table 8 shows that the  $\frac{3}{4}$  Cheviot group had a marked superiority over either the average of the Romneys (128.6%) or of the half Cheviot (116%). Since all groups were given comparable feed at flushing, then the relatively unprolific nature of the T. and  $\frac{1}{2}$  Cheviot may be related to variations in nutrition at times other than flushing or to hereditary causes. Phillips (39) has reported the lambing percentage of mixed age  $\frac{1}{2}$  Cheviot ewes mated to Southdown rams. While ages are not strictly comparable, the average lambing % of 127.5% over four years, indicates that the  $\frac{1}{2}$  Cheviot ewe was remarkably more fecund than a group of comparable Romney ewes which had an average lambing % of 105.3%. Thus the lower percentage exhibited by  $\frac{1}{2}$  Cheviots in this experiment does not seem to have an hereditary basis. In Fig. II it is seen that the two groups with the lowest liveweights, at and prior to tugging, are the two groups ( $\frac{1}{2}$  Cheviot and T. Romneys) with the lowest lambing percentages. It is tempting therefore to attribute the lowered fecundity of these two groups to the previous hard conditions to which these two groups had been subjected.

The advantage in lambing % shown by the  $\frac{3}{4}$  Cheviot is not a chance occurrence. Hewitt (40) reports the performance of the same ewes in their first four years of productive life and the line of Romneys designated as "Hill bred" by him is the S. strain of this experiment. Hewitt found that over the 4 years (1947-50) when mated to Southdown rams, the  $\frac{3}{4}$  Cheviot had an average lambing % of 148.7% while the S. ewes averaged 86.6%. (Note: Hewitt calculates lambing % as the number of lambs weaned and a transformation to lambs alive at

3 days, would probably raise his percentages.) The increased number of lambs produced by 3/4 Cheviot cross ewes, when compared with comparable Romneys, is shown in Table 10.

T A B L E - 10  
COMPARISON OF 3/4 CHEVIOT & ROMNEY LAMBING %

	S.	3/4 Cheviot	Average W., S., T. Romneys
Mean 1947/50	86.6	148.7	-
1951	132.0	162.5	128.6
Number of ewes	25	25	86

The advantage exhibited by the 3/4 Cheviot is consistent over five years. A link between the higher level of nutrition in 1951 and the rise in lambing percentage within groups from the first series of observation to 1951, seems probable.

When first weighed again after lambing the average weights of each group, relative to their last weight pre-partum, were all inversely proportional to their respective lambing percentages (See Table 11). This shows that those groups with greater amounts of foetal tissue etc., consequent upon higher lambing %, lost relatively more liveweight at parturition than groups of ewes with less foetal tissue and which were also of lesser mean liveweight.

T A B L E - 11  
MEAN RELATIVE LIVeweIGHTS OF EWES TWO  
WEEKS POST PARTURITION

	W.	S.	T.	3/4 Cheviot	1/2 Cheviot
Mean group live-weights					
Post-partum 11/9/ Pre-partum 9/8/ %	88.79	89.28	91.82	85.24	89.62
Lambing % (excluding dry ewes)	150.0	143.8	127.3	177.3	138.1

In Fig. 11A are the mean liveweight curves for each group from two weeks after mid-lambing to weaning on the 20th December (the curves include dry ewes). The similarity of these curves shows that various environmental and physiological factors have similarly affected each of the five groups. These factors may be enumerated as follows :

1. Level of nutrition
2. The "cost" of lactation
3. The continuation of the tendency (previously noted) in certain groups, to make body tissue increases.
4. Disease.

The net effect of these factors may be gauged from Table 12 which shows the mean weight of groups at weaning expressed as a percentage of first weight post-partum.

T A B L E - 12

RELATIVE MEAN EWE LIVEWEIGHT AT WEANING

	W.	S.	T.	$\frac{3}{4}$ Cheviot	$\frac{1}{2}$ Cheviot
$\frac{\text{Weight 20/12/}}{\text{Weight 11/9/}} \%$	96.0	92.4	103.6	98.5	100.2

Since all ewes were on the same high plane of nutrition, factor 1. should not cause variation between groups.

Factor 2., the "cost" of lactation, could more readily be assessed by the relative weights of animals after 8 weeks of lactation. Table 13 illustrates this loss over the first 8 weeks of lactation.

T A B L E - 13

MEAN RELATIVE WEIGHT AT THE 8th WEEK OF LACTATION

	W.	S.	T.	$\frac{3}{4}$ Cheviot	$\frac{1}{2}$ Cheviot
$\frac{\text{Weight 23/10/}}{\text{Weight 11/9/}} \%$	96.7	94.1	99.6	94.0	98.8
Lambing %	150.0	143.8	127.3	177.3	138.1

Two factors will condition the mean quantity of milk produced per ewe in the respective groups. Firstly those groups with a greater number of twins will be stimulated to produce more milk than groups with a lesser number of twins (Barnicoat et al. (11) ). Secondly the hereditary capacity for milk production may differ between groups. Barnicoat et al. have found that twin-bearing ewes produce about 33% more milk than single-bearing ewes. Since strain and breed differences are not likely to be of this order, it is reasonable to assume that twin lambs conditioning a superior milk supply will therefore also condition a greater drain on the body tissue of the ewe. This supposition is confirmed in Table 13, apart from the anomalous loss in weight shown in the S. group. Between the other groups the relative weight is inversely proportional to their lambing percentage, i.e. the number of twin lambs per group. To conform to this pattern the relative weight of the S. group should be slightly greater than that of the W. group.

The period from conception to weaning is the major functional period in the year of a ewe. Table 14 shows the mean net loss or gain in liveweight, for the various groups over this period.

T A B L E - 14  
MEAN RELATIVE LIVELWEIGHTS OF EWES  
AT WEANING

	W.	S.	T.	$\frac{3}{4}$ Cheviot	$\frac{1}{2}$ Cheviot
Mean weight 20/12/ (weaning) %	92.4	85.5	102.9	85.2	97.4
Mean weight 29/3/ (mid-conception)					
Mean weight wool lbs/group	12.0	11.1	11.1	9.5	6.2
Mean weight 20/12/ + mean fleece weight	101.2	93.1	111.7	91.8	102.7
Mean weight 29/3/					

While the exact amount of weight variation attributable to specific cause cannot be determined, we can indicate the relative importance of such causes. The net change in liveweight from mating to weaning results from a combination of (1) Body tissue increment, most marked in T. and  $\frac{1}{2}$  Cheviot groups where the accelerated growth of body tissue is in consequence of the limiting nature of previous subnormal nutrition. The extent of this advantage in the  $\frac{1}{2}$  Cheviot and T. groups is sufficient to almost completely hide -

(2) the loss of liveweight occasioned by the demands of lactation. Since it has been found that variation in this loss is related to variation in the number of lambs suckled per ewe, then those groups with higher lambing percentages should have lost more liveweight from conception to weaning. This relationship holds, apart from the anomalous weight gains of the W. group. The apparently greater gain in this group is related to their relatively lower mean weight at the commencement of the period ( $\frac{2}{3}$ ). This lower mean weight was the result of the autumn drop in liveweight, and was experienced in this group before the other groups, see Fig. 11A.

(3) The different mean weights of wool grown by the various groups (see Table 14). Hewitt (40) and Phillips (39) give comparable wool weights for  $\frac{3}{4}$  and  $\frac{1}{2}$  Cheviot ewes, respectively. The  $\frac{3}{4}$  Cheviots which average 8.5 lbs. per year from  $1\frac{1}{2}$  -  $4\frac{1}{2}$  years, are the  $\frac{3}{4}$  Cheviot ewes of this experiment. In 1951, at 5 years of age, they clipped 9.5 lbs., the difference being an indication of improved level of nutrition since ability to graze efficiently will lessen with age. The half breeds produced 6.2 lbs. as against a 7.3 lbs. average reported by Phillips (39). Since surface area is a function of body weight (Brody (42)), then it is reasonable to assume that liveweight differences between groups of animals producing similar types of wool, will result in

differences in the weight of wool produced (weight of wool being a function of body surface area, Galpin (78) ). Since the  $\frac{1}{2}$  Cheviots of this experiment were smaller in size than those of Phillips, Barton (77), then it is reasoned that they would have produced less wool because of this disadvantage. The differences between the breed means (Romney 11.38 lbs.,  $\frac{3}{4}$  Cheviot 9.53 lbs.,  $\frac{1}{2}$  Cheviot 6.22 lbs.) agree with those reported by Hewitt and Phillips, loc.cit., and are probably of a genetic nature. The last weight recorded in Fig. 11A., viz: that on the 20th December, is the mean group liveweight with respective mean fleece weight included. The inclusion of the fleece weight (Table 14) in the estimation of liveweight variation, does not alter the order of the various groups.

### Teeth

All ewes were  $5\frac{1}{2}$  years of age at tugging and at this time they were examined and the general quality of teeth in each group noted (see Table 15).

TABLE - 15

### March, 1951.

W. Romneys	Relatively the best mouths, teeth fairly long and well spaced.
S. "	Fair to average teeth - tended to be open, poorest group of the Romneys.
T. "	Good teeth, only slightly inferior to those of the W. group.
$\frac{3}{4}$ Cheviots	Poor and worn down, open.
$\frac{1}{2}$ Cheviots	Also poor and worn down.

## PART II

### Milk Yield

The quantitative measurement of milk production in non-milking breeds of sheep has been reported in the literature on few occasions. As a result of the paucity of previous investigations most workers have referred to all available references to the subject. It is not proposed to review all previous works on ewe milk production in this study. The following have been deemed reliable, and relevant to this experiment :

Barnicoat, Logan and Grant (11), Bonsma (17 a, b, and c)  
Wallace (18).

From the findings of the above quoted workers, it seems evident that a number of factors can affect the quantity of milk produced by a ewe. These will now be enumerated.

#### (1) Breed:

Assumedly the maximum level of milk production is set by the hereditary potential of the ewe. The various non-genetic influences to which the ewe is subjected must therefore be controlled or allowed for, if a reliable estimate of this potential yield is to be gained. That the maxima of milk yield differ between breeds is suggested by the work of authors reviewed in Table 16.

The work of others who have published results of ewe milk yield estimates, e.g. Godden and Puddy (43), Fuller and Kleinheinz (44), Neidig and Iddings (15) and Peirce (16 b and c) suffers in worth by reason of the uncontrolled variation due to small numbers of animals, incompleteness of manual milking and the period tested not being representative of the lactation.

T A B L E - 16

REPORTED MILK YIELDS OF DIFFERENT BREEDS

Worker	Year		Length of lactation	No. of Lactations	Mean daily milk yield
Bonsma	1935	Merino	1st 11 wks.	88	028. 26.5
		Romney x Merino	-do-	24	37.5
	1943	Ryeland x Merino	-do-	24	39.9
		Border Leic. x Merino	-do-	27	44.9
		Dorset Horn x Merino	-do-	22	42.9
		Ile de France x Merino	-do-	33	45.9
		Blackhead Persian	-do-	40	13.9
		Suffolk x B. Persian	-do-	22	34.2
		Dorset Horn x B. Persian	-do-	43	43.0
Wallace	1942	Suffolk	1st 12 wks.	14	48.9
	1943/44	Border Leic. x Cheviot	-do-	22	64.0
Barnicoat, Logan and Grant	1941/45	N. Z. Romney Singles	1st 12 wks.)	200	49.0
		N. Z. Romney Twins	-do-		63.0

Note that some of the variation between breeds and crosses may be attributed to differing levels of nutrition. It seems reasonable that breeds of sheep do differ in the amount of milk they produce though Barnicoat et al. (11) have found that within breeds there is also much variation. Both Bonsma (17a) and Barnicoat et al. (11) have found that there is difference in the shape of the lactation curve between improved and unimproved breeds.

(2) Equally as important as the breed variation is that related to the plane of nutrition on which the ewes are maintained. Wallace (18) found that the milk yield of the ewe was profoundly affected by the level of nutrition during the last 6 weeks of

pregnancy.

Barnicoat et al, loc.cit. found that throughout the first 12 weeks of lactation there were significant yield differences from ewes in the various groups evolved by various combinations of high and low nutrition before and after parturition. They state that "maximum yield is only obtained by liberal feeding during late pregnancy and throughout lactation".

(3) Another important contributing factor to variation in milk yield between ewes, is the number of lambs suckled. (Barnicoat et al. and Wallace loc.cit.) The influence of this factor was even more important in Wallace's work, than the plane of nutrition before lambing. The major causal factor appears to be that single lambs cannot draw off all the milk produced by the ewe early in lactation with a resultant depressing effect on following production. Wallace suggests that even twins may not be able initially to consume all the ewe's supply since he found a ewe bearing triplets to have a production greater than that of comparable twin-bearers.

(4) Age, as in dairy cattle, seems to cause variation in milk yield. Barnicoat et al. found a 15% difference in favour of the older sheep when comparing total milk yield of two and six year old Romneys. They also quote the work of Montanaro who found an increase in yield with age in Sicilian "milking" sheep.

Bonsma (17a) reports that Merino ewes in successive lactations produced quantities of milk which were 120, 125 and 136% respectively of that produced in the first lactation. In dairy cattle a similar production increase accompanies an increase in age, (Espe (45)). Espe inclines to the view

that such an increase is almost wholly attributable to the larger size of the older animal. The influence of size on milk yield in sheep will be discussed in the next section.

(5) While Bonsma (17a) found a significant intra-breed correlation between ewe liveweight one week after lambing and total milk production, Barnicoat et al. (11) could not find a similar relationship. Any correlation would seem to be reflection on the efficiency of food utilisation by the ewe in that "good doers" are likely to have heavy lambs entailing high milk production.

(6) The effects of climate may be direct or indirect. It may indirectly affect the milk yield of a ewe through

- (a) The amount of pasture or crop produced, or
- (b) By producing an ideal environment for pathogenic and metabolic disease.

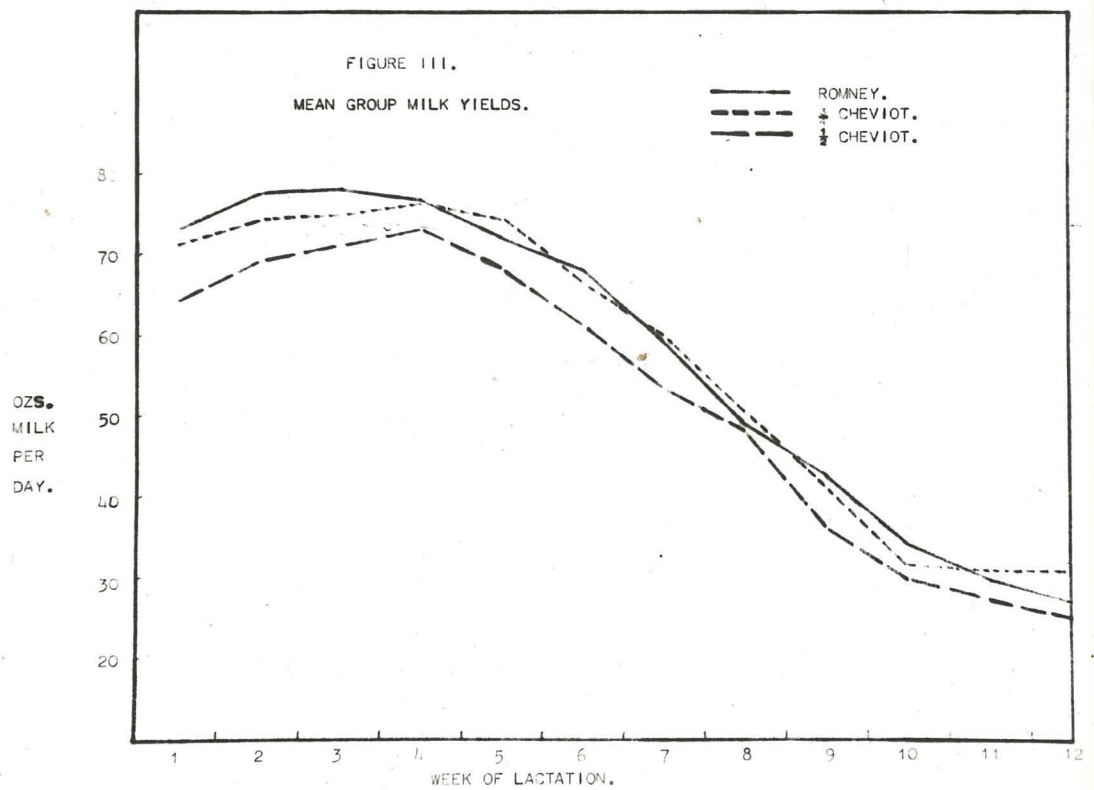
Directly it may adversely influence production, as do extremes of temperature and humidity, in dairy cattle (Espe (45b)).

Also heavy fleeced ewes persistently wet are not liable to produce as well as ewes which are dry.

(7) The time of lambing seems to have some effect on milk yield, Barnicoat et al. (11).

Any study of quantitative variation in ewe milk yield should give due consideration to the factors that have been enumerated.

FIGURE III.  
MEAN GROUP MILK YIELDS.



SECTION I - BREED

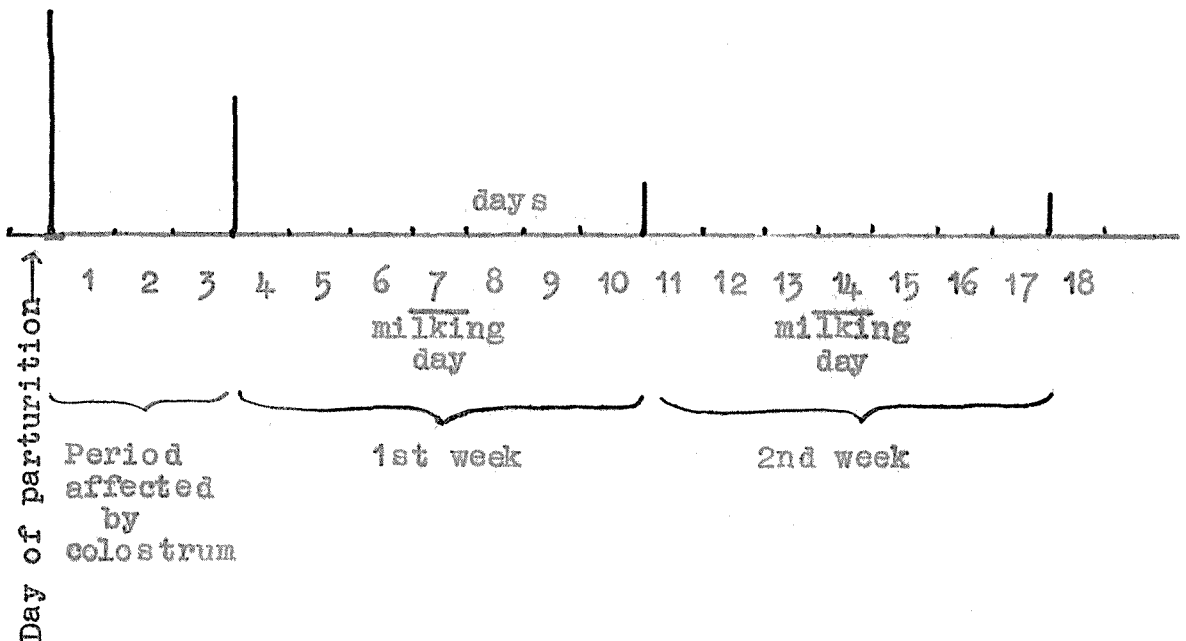
The Romney and  $\frac{3}{4}$  Cheviot milking groups each contained 12 ewes and 24 lambs while the  $\frac{1}{2}$  Cheviot was composed of 6 ewes and 12 lambs. In all 30 ewes and 60 lambs were subjected to the milking treatment. Fig. III shows the mean lactation curves for the three groups. From the individual lactation curve of each ewe, yields at weekly intervals were read off and the average of these for each week, over all ewes in the group, provided the mean group curve.

Since the abnormal effects of colostrum are of short duration, Barnicoat et al. (41), it was considered that approximately normal milk, in both yield and quality, would be secreted by 3 days post-partum. The mean yield ascribed to the first week was that of the 7th day after parturition; the first week being bounded by -

- (1) the date of parturition plus 4 days, and
- (2) date of parturition plus 10 days, see Table 17.

T A B L E - 17

THE RELATIONSHIP OF MILKING DAYS TO THE COMMENCEMENT OF LACTATION



Thus the daily yield of all ewes at weekly intervals from 7 days post-partum could be obtained. This method overcomes the difficulty referred to by Bonsma (46) of obtaining respective ewe yields at the same time stage in relation to lambing. Further variation due to animals commencing lactation at different periods of the season was overcome by pairing of animals between breeds for date of lambing (see section VII on yield variation due to different times of lambing.)

For each ewe, a series of figures, being the mean yield for each week in a twelve week lactation, was thus obtained. The twelve yields were averaged and gave an index of each ewe's milk-producing ability. Table 18 shows the indices in breed groups with respective animals paired between breeds for similar lamb-birth date.

TABLE - 18  
MILK YIELD INDICES

ROMNEY			3/4 CHEVIOT			1/2 CHEVIOT		
Ewe No.	Date of Parturition	Milk Index	Ewe No.	Date of Parturition	Milk Index	Ewe No.	Date of Parturition	Milk Index
W. 18	18/8	54.3	315	17/8	45.5			
W. 19	23/8	63.5	314	20/8	43.8			
T. 73	27/8	56.0	320	27/8	62.6	267	27/8	47.0
W. 7	27/8	59.5	304	27/8	65.2			
W. 13	27/8	64.1	323	27/8	50.5			
T. 57	22/8	49.4	303	20/8	51.9	266	24/8	61.9
S. 103	25/8	52.8	306	27/8	63.1	274	24/8	50.4
W. 31	1/9	54.2	311	13/9	61.1			
W. 11	29/8	59.5	302	29/8	55.7	264	28/8	48.4
W. 23	29/8	61.2	319	29/8	59.1	257	30/8	50.7
S. 116	30/8	67.3	325	29/8	54.9	254	31/8	54.0
W. 36	23/9	47.5	312	23/9	67.8			
Mean Index		57.4			56.8			52.1
Standard deviation		6.01			7.7			5.39
Coefficient variation		.1047			.1356			.1035

The various factors which could effect this index are discussed, together with the measures taken to control them, in the following sections. The milk index found for individual ewes and averaged to give the breed index is in effect the mean daily yield over the 12 weeks. The basis for this supposition is the assumption that during any week the changes in milk yield due to the trend of lactation are approximately constant. It is realised that environmental agencies will cause fluctuations from day to day but the variation within a week is considered to be equivalent to this trend. (See Barnicoat et al. (41A).)

An investigation of the shape of lactation curves reveals small apparent breed differences. It will be noticed that the apparent peak of lactation is reached in the 3rd week with Romneys, while both Cheviot crosses have a maximum yield in the 4th week. An analysis of variance of the week in which the apparent peak of production occurs shows no significant difference between Romney and  $\frac{3}{4}$  Cheviot. (Note that  $\frac{1}{2}$  Cheviots have been omitted from the analysis because of the small numbers in the group.)

TABLE - 19

COMPARISON OF WEEK IN WHICH MAXIMUM MILK YIELD OCCURRED

	Romney	3/4 Cheviot	1/2 Cheviot
Mean apparent peak of milk yield, in weeks from parturition	2.9	3.5	3.5

ANALYSIS OF VARIANCE

(Animals paired between groups for similar date of parturition)

Source	df	Sum Squares	M. S.	5%	1%	F
Total	23	37.3				
Breeds	1	1.5	1.5	4.84		1.58 N.S.
Ewes	11	25.3	2.3	2.82		2.42 N.S.
Error	11	10.5	.95			

The level and shape of the Romney and 3/4 Cheviot curves are remarkably similar. The half Cheviot curve, however, while being of similar shape, is consistently lower than either of the other two curves. An analysis of variance and a "t" test between the respective ewe indices (see Table 18) of the breed groups is shown in Table 20.

T A B L E - 20

ROMNEY AND 3/4 CHEVIOT MILK YIELD INDICES;  
ANALYSIS OF VARIANCE

1.

Source	df.	S.S.	M.S.	5%	1% F
Total	23	1054.0			
Breeds	1	2.7	2.7	4.84	.041 N.S.
Ewes	10	329.3	32.9	2.82	.456 N.S.
Error	12	722.0	60.1		

(1 degree of freedom has been dropped for an index determined by the missing plot technique.)

2. Owing to unequal group numbers, comparison of Romney and 3/4 Cheviot with 1/2 bred Cheviot respectively, is by the "t" test.

(a) Romney and 1/2 Cheviot

Treatment	Number of Ewes	df.	Mean Index	S.S.
Romney	12	10	51.43	408.9
1/2 Cheviot	6	5	52.07	134.2

$t = 1.86$  N.S. at 5% level but significant  
 $p = .09$  with 15 df.

(b) 3/4 Cheviot and 1/2 Cheviot

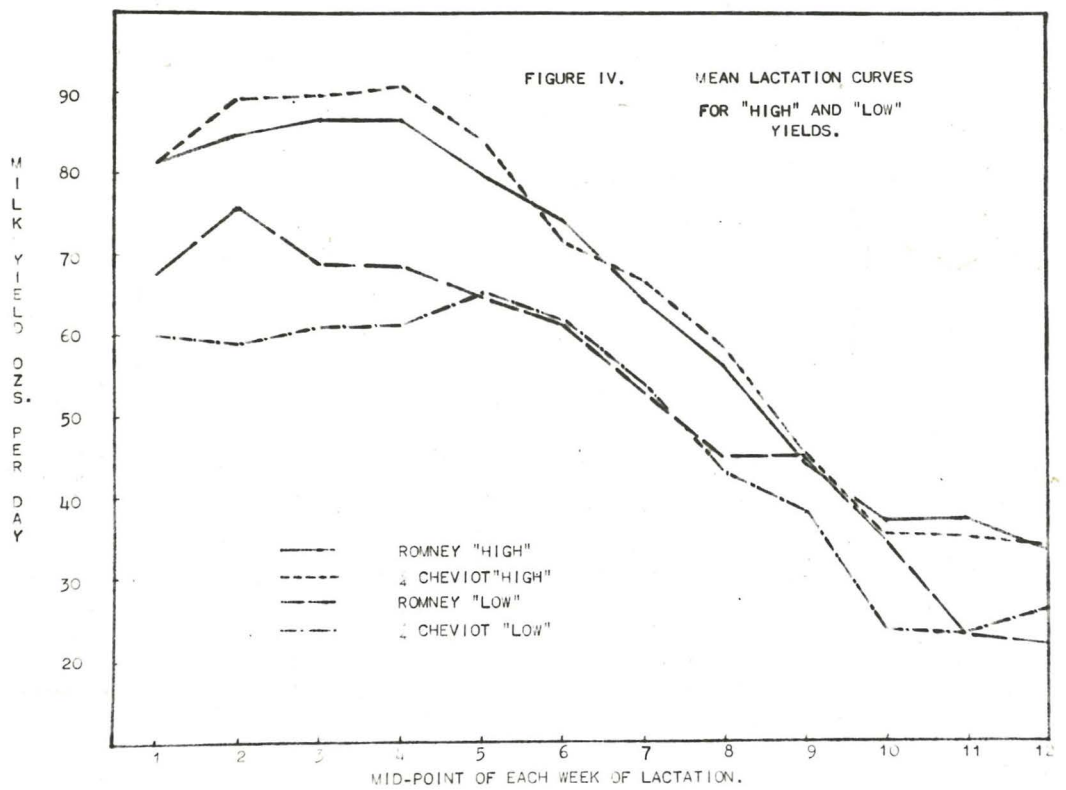
Treatment	Number of Ewes	df.	Mean Index	S.S.
3/4 Cheviot	12	10	56.77	653.9
1/2 Cheviot	6	5	52.07	134.2

$t = 1.30$  N.S. at 5% with 15 df.

From these analyses it may be concluded that

(1) The Romney and 3/4 Cheviot indices are essentially the same and that in this experiment these ewes have yielded almost equal quantities of milk.

(2) That owing to the small numbers in the 1/2 Cheviot group, random variation may have tended to obscure any existing differences. On the basis of the six animals compared it is reasonable to assume that these halfbreeds did differ in milk



yield throughout lactation from the Romney ( $p = .09$ ). When comparing indices between  $3/4$  and  $1/2$  Cheviots, the difference is significant at  $p = .20$ . No conclusion can be drawn with this probability, other than that the means tend to differ. It must be emphasised, however, that these findings refer only to the animals of this experiment and that inductive inference from this sample to any greater population must be qualified. The degree to which these animals are representative of the breed as a whole will be considered in the following sections :

Level of Production and Shape of Lactation Curve

Both Bonsma and Barnicoat et al. (loc.cit.) have shown that the high and low yielders of Merino and Merino crossbreds, and Romneys respectively, exhibit characteristic differences in shape of lactation curve.

Figure IV shows the mean lactation curves of the highest and lowest third of Romney and  $3/4$  Cheviot groups. In the Romney and  $3/4$  Cheviot high and low groups, there are 4 animals, while in the  $1/2$  Cheviot, only two. The  $1/2$  Cheviot curves are representative of too few ewes to be considered. Comparing the "high" and "low" curves in Romney and  $3/4$  Cheviot groups, it is apparent that a much greater range exists between  $3/4$  Cheviot "high" and "low" than exists between Romney "high" and "low". A comparison of the difference (in ounces) between the mean daily yield of "high" and "low" Romneys and Cheviots is seen in Table 20 for the 12 weeks of lactation.

T A B L E - 20A

THE MEAN DIFFERENCE BETWEEN THE MEANS OF  
THE RESPECTIVE BREED HIGH & LOW MILK  
YIELDING GROUPS

	Romney	3/4 Cheviot
Mean daily difference between mean yields of "high" and "low" groups for 12 weeks of lactation.	11.4 ozs.	17.1 ozs.
Mean daily yield of bulked high and low groups.	57.5 "	56.3 "

ANALYSIS OF VARIANCE

DAILY DIFFERENCE BETWEEN MEANS OF HIGH AND  
LOW GROUPS MILK YIELDS (OZS.)

Source	df.	SS.	M.S.	1%	F
Total	23	1428.5			
Breeds	1	302.9	302.9	9.65	19.05 **
Weeks	11	950.9	86.4	4.46	5.43 **
Error	11	174.7	15.9		

The analysis of Table 20A shows that throughout the first 12 weeks of lactation the difference between the mean yields of the 3/4 Cheviot "high" and "low" groups is consistently greater than the difference between the same groups in the Romney classification. The difference between the breeds (Fig. IV) is most marked during each of the first 5 - 6 weeks of lactation. Therefore it is this period which is most likely to show differences in the variability of entire groups. The variability for the period in the entire breed groups has been shown as the standard deviation in Table 20B.

T A B L E - 20B

TEST OF BREED VARIABILITY DIFFERENCES

	Mean yield index, 0-6 wks. ozs./day.	S. D. (ozs.)	df.	F (variances)
Romney	74.80	7.16	11	2.845
3/4 Cheviot	72.80	11.23	11	

This F value, calculated by a comparison of variances (Snedecor (31) ) shows that there is no significant difference between the variances ( $p = .10$ ) of milk yield indices of Romney and 3/4 Cheviot ewes during the first 6 weeks of lactation. This points to the conclusion that during the first 6 weeks of lactation -

- (1) The mean milk yields of Romneys and 3/4 Cheviots are markedly similar.
- (2) That the variability of the 3/4 Cheviots yields tends to be somewhat greater than that of the Romneys.

Viewing these results in the manner of the "Mendelian" school of genetics, it is to be expected that the 3/4 bred Cheviots, being hybrids, should be more genetically diverse than either of their pure parents. Consequently greater phenotypic variability is an expression of greater genetic variability. Robertson (67) and Lush (68) concluded that there are many genes controlling milk production in cows and Bonsma (17c) finds no reason why this should not also apply to sheep. Johansson (69) reviewing the inheritance of milk yield in dairy cattle (which may be comparable to sheep) estimates that the heritability of this character is about 0.30 and consequently that milk yield is very sensitive to environmental influences.

Applying the partition of phenotypic variance as proposed by Lush (see Johansson (69)), to the present situation, we may determine the theoretical effects of crossbreeding on

the variation in milk yield between animals. Lush states that the phenotypic variance ( $\sigma^2_p$ ) of the character in question (milk yield), may be divided into the components -

- (1) variance due to hereditary causes ( $\sigma^2_g$ ) and
- (2) variance due to environmental causes ( $\sigma^2_e$ ),

i.e.  $\sigma^2_p = \sigma^2_g + \sigma^2_e$

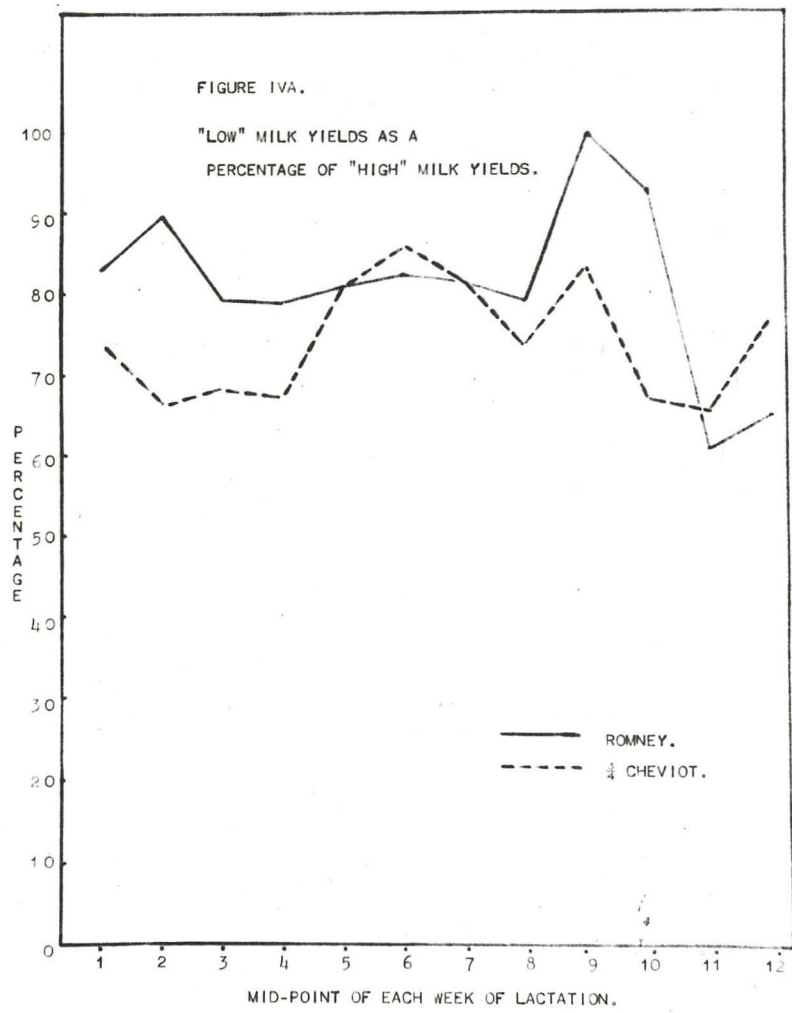
Now the effects of crossbreeding, e.g. mating Romneys x Cheviots etc., will evidently only effect the constituent  $\sigma^2_g$ , if environmental conditions are kept constant. Previously we have concluded that milk yield heritability, the ratio of additive genetic variance to additive genetic plus environmental variance, is small in dairy cows and assumedly similar in ewes. (Note heritability tends to slightly underestimate  $\sigma^2_g$  Johansson (69).) Since the effects of crossbreeding can only influence a small part of the observed variation in milk yield, it is therefore probable that any greater relative variation in the progeny of a crossbreeding system, results from environmental causes, either natural or artificial.

In the present experiment it is relevant to determine whether any environmental agency has been the cause of the apparent difference in variation between Romney and 3/4 Cheviots milk yields. The fact that the majority of the ewes comprising the Romney milking group were purchased as cast-for-age ewes, suggests that as such they would have been selected

- (1) naturally for disease resistance and longevity etc., and
- (2) artificially since ewes comprising a cast-for-age draft tend to be grouped into an even line. The relative importance of such selection in the 3/4 Cheviot group cannot be accurately determined but since they were experimental sheep and had not been purchased commercially as a line of cast-for-age ewes, they would tend to be less uniform than the Romneys. To be

FIGURE IVA.

"LOW" MILK YIELDS AS A  
PERCENTAGE OF "HIGH" MILK YIELDS.



consistent with this reasoning, it must be assumed that selection for evenness in a line of ewes over a number of years would at the same time result in reduced milk yield variation. (Note that we are not concerned with effect of natural selection on the Romneys and Cheviots since it is reasonable that this would affect each group to about the same extent.) Since we have no accurate measure of the relative degrees of selection of the two groups we cannot evaluate the apparent differences in variability.

Returning to the comparison of high and low yielders. Fig. IVA shows the mean weekly yield of the low producers expressed as a percentage of the mean weekly yield of the high group. From this can be gauged the relative effect of the advance of lactation on the high and low yielders. After the 8th week the mean yield has fallen to about 40 ounces per day and from this stage, errors of measurement, assumedly constant throughout lactation, will form an increasingly significant proportion of the variation. Allowing for this source of variation it is evident that in the Romney group for the major part of the lactation, the milk yield of the low group is an approximately constant % of that of the high group.

In the  $3/4$  Cheviots the production of the low group from the 4th to the 9th week, seems to be an increasing percentage of the high groups. This could be caused by either a relatively more rapid fall off in the high groups production or a greater degree of persistency in the low producers. The general flattening of the low producers' curve seems to indicate that they are more persistent.

Barnicoat et al. (loc. cit.) found that within an

age group, low producing Romneys reach a peak of production earlier than do high producers. In this experiment, the Romney, but not the Cheviots, exhibit this relationship. (Note that the peak shown in Figures III and IV are not necessarily coincident with the weeks in which the majority of ewes gave maximum yield since one ewe's excessively high or low yield can outweigh a greater number of less extreme yields in other weeks.) In Fig. IV (cf Fig. III) both the Cheviot groups have a later peak than the Romneys, but in both, the differences in level of production between high and low groups tend to disappear from the 5th week onwards. Since all ewes were twin bearers, it is assumed that at no stage in lactation was the lambs' ability to consume, a limiting factor to milk production (see Barnicoat et al. 41B) and that, therefore, the differences in lactation curves are indicative of the respective ewes' ability, rather than of the lambs' vigour, as suggested by Wallace (37B.).

As Wallace found, the lower milk-producers are characterised by a flattening of their lactation curves. Between the two levels of production, differences in flattening are not so marked in the Romney as they are in the 3/4 Cheviots. To illustrate this, the net weekly drop in milk yield over the first 8 weeks of lactation has been estimated :

Romney high	3.1	ozs.
" low	2.9	"
3/4 Cheviot high	2.9	"
" low	2.1	"

Only the first eight weeks of production have been considered owing to the greater possibility of measurement error after this period.

An idea of the persistency in each breed can be

gained by inspecting Fig. III. The shape of lactation curve after the peak of production has been reached gives some indication of the manner in which the level of milk production is maintained as lactation advances. The similarity of all three curves thus considered, suggests that persistency in yield in this experiment is similar between breeds.

Since the Romney group was not made up of equal numbers of each "strain", it was impossible to estimate the relative milking merit of respective strains. Some indication of their relative ability can be gained, however, by a comparison of the live-weight gains of the lambs in the respective groups up to 6 weeks of age, Wallace (37C). This will be attempted in Part IV, dealing with lamb growth.

#### SECTION II - THE EFFECT OF PRE- and POST-PARTUM LEVEL OF NUTRITION UPON MILK YIELD

In this experiment all animals have received an equally high level of nutrition. The favourable conditions for pasture growth throughout the year made ad lib feeding possible at most times. A feature which could not be controlled, however, was the level of nutrition before the animals were brought to the experimental area. In Part I it has been deduced that -

- (1) In view of low initial liveweight, and
- (2) Because of the continued deposition of body tissue throughout pregnancy and perhaps during lactation, there has been, in certain groups, a marked residual effect of a previous poor level of nutrition.

The effect of this previous treatment on liveweight may be broken up into the effect on the components of liveweight. Firstly, it is assumed that past poor nutrition has adversely affected the size of the mammary gland. Wallace (37A) does not find conclusive evidence for larger size of udder conditioning

greater milk yield but finds indications of this. It seems reasonable that a ewe with a larger udder will have a greater potential capacity for secretory tissue and therefore under normal conditions produce more milk than a ewe with a smaller udder. (Swett (50) concludes similarly for dairy cattle.)

It is to be noted, however, that an increase in udder size does not necessarily mean a proportional increase in milk-producing tissue, since the size increase may be due to the deposition of fat.

(Hammond (47) )

Secondly the size of all organs will be affected to a greater or lesser degree depending on the time and the severity of the imposed low level of feeding. Since some of these organs will facilitate conversion of feed to milk any deviation from normal size may affect the quantity of milk produced.

Bonsma (17A) with sheep, and other workers with dairy cattle, has shown that within a breed, liveweight is significantly correlated with milk production (see section IV). In dairy cattle low level nutrition from birth to 2 years of age, followed by a high level of feeding during lactation, has resulted in total fat production less than that of animals on high nutrition from birth. (22) Differences, as a result of these treatments, in fat yield, would probably be more marked if converted to milk yield. With the half Cheviot group, it is possible that not only has the period up to the first lactation been nutritionally subnormal, but also the nutrition during subsequent lactations. This continued poor level of feeding should possibly have an equivalently equal or greater effect than that reported at Ruakura. (22) It is suggested therefore, that the lower mean milk index (Table 21) of the  $\frac{1}{2}$  Cheviot

group is in part attributable to the environmental conditions imposed previously, upon its members.

T A B L E - 21

	Romney	$\frac{3}{4}$ Cheviot	$\frac{1}{2}$ Cheviot
Mean Breed Index. ozs/day	57.4	56.8	52.1
S. D.	6.01	7.7	5.39

SECTION III - THE NUMBER OF LAMBS PER EWE

Since the number of lambs suckled affects the quantity of milk produced, an effort was made to remove this source of variation. Only ewes which produced twins were "milked" as the level of milk production conditioned by twins is nearer the maximum hereditary level of the ewe (Wallace (28).) Wallace found that the expression of the major part of the milk present in the udder during the early weeks of lactation was essential for maximum lactation yields. Since he and Barnicoat et al. (41B) found that only twins could accomplish this, it is reasonable to assume that the lactation curves exhibited in Fig. III are characteristic of twin bearing ewes and that ewes of the same breed having only single lambs would exhibit different shaped curves.

The figure obtained by Barnicoat et al. (11) for five year old Romney ewes rearing twin lambs was 60 ounces of milk/day for a 12 week lactation. This is comparable to the milk index of 58 ozs. found for Romneys in this experiment (Table 18). This small difference may possibly be accounted for by the small number of twin bearers tested by Barnicoat et al.

SECTION IV - AGE

All ewes were  $5\frac{1}{2}$  years old when the experiment commenced.

SECTION V - LIVELWEIGHT

In view of liveweight and milk yield correlation found in sheep, by Bonsma (17A) and Wallace (18), and in dairy cattle by Gowen (48) and Edwards (49), the mean liveweights of the various breeds -

- (1) 2 weeks after lambing
- (2) averaged over the lactation

have been correlated with the individual yield indices (see Table 22).

T A B L E - 22

CORRELATION LIVELWEIGHT & MILK  
YIELD INDEX

Breed	No. of Ewes	Weight 2 weeks post-partum	Average lactation weight
Romney	12	.114 N.S.	.174 N.S.
3/4 Cheviot	12	.709 **	.598 *
1/2 Cheviot	6	-.213 N.S.	-.180 N.S.

Owing to the discrepancies between group weight ranges only intrabreed correlations have been calculated. The first evident conclusion is that random variation, due to the small number considered, has caused an anomalous correlation in the half-bred group. The fact that the ewes in this group were subnormally developed (see back) may also affect the relationship. In Table 23, the average breed lactation weights and coefficients of variation show a similarity to the mean breed indices and coefficients of variation shown in Table 18. In both Romney and 3/4 Cheviot groups the means are almost identical while the coefficients of variation differ, the 3/4 Cheviot being more variable.

T A B L E - 23

MEAN LACTATION LIVEWEIGHTS

	Average lactation l/weight	Coefficient of variation	"P" (Variances)	L/weight 2 weeks post-partum	Coefficient of variation	"P" (Variances)
Romney	lbs. 130.7	.0777	} 5.56 **	lbs. 134.2	.0872	} 4.75**
3/4 Cheviot	130.3	.1840		135.3	.1885	
1/2 Cheviot	113.7	.0919		116.7	.0878	
** - Significant at 2% level						

Since we have found earlier that, using this method of milk yield estimation the first 6 weeks gives a more reliable estimate of yield variability, then it is this period which has been considered in Table 23A for estimating further milk index and liveweight correlations.

T A B L E - 23A

CORRELATION LIVEWEIGHT (lbs.) 2 WEEKS POST-PARTUM & MILK INDEX 1-6 WEEKS (ozs.)

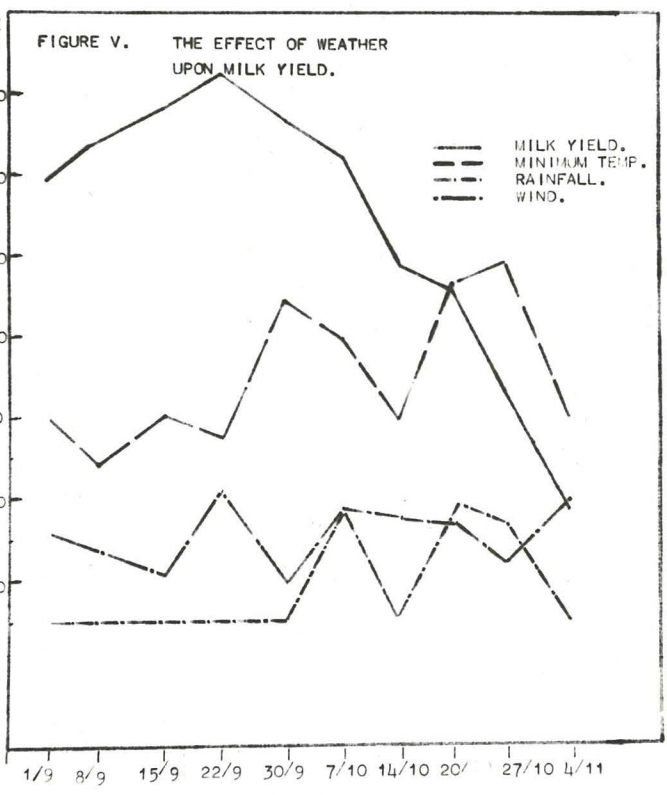
Romney	.043 N.S.
Cheviot 3/4	.566 * (P = .06)

The weight at 2 weeks post-partum has been found to be representative of a ewe's weight over the first six weeks of lactation. In spite of the significantly greater variation within the 3/4 Cheviots in this period (Tables 20B and 23) there is a significant correlation between the two variables in only this breed. Consequently in this sample of 3/4 Cheviot ewes, liveweight gives some estimate of relative milk production. No such relationship was found for the Romney ewes.

WIND MLS. PER 24 HRS.	RAIN INCHES PER 24 HRS.	MINN. TEMP. DEG. F.	MILK YIELD LBS. PER DAY
250	.60		80
200	.40		70
150	.20		60
100	.00		50
50			40
0			30
			20
			10
			0

S  
A  
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K

FIGURE V. THE EFFECT OF WEATHER UPON MILK YIELD.



## SECTION VI - CLIMATE

In dairy cattle extremes of temperature and humidity are known to directly affect the milk yield both quantitatively and qualitatively, Espe (45). The direct effect of weather on milk production in sheep has not been determined although Barnicoat et al.(11) suggest the possibility of a relationship. Fig.V. shows the mean weekly milk yield curve of 15 (mixed breeds) ewes which lambed on the 27th August  $\pm$  2 days. With the milk yield, have been plotted the minimum temperature, rainfall and wind run for the respective milking days. It will be noticed that the two days of heavy rain (7th and 20th October) have not caused a decrease in the mean quantity of milk produced by the ewes. To measure accurately the effect of variation in weather, it would be necessary to have individual daily production records but the observed milk yields on the two days (7th and 20th October) are interesting in view of the variation in milk composition found then (see later part III, Section 4).

## SECTION VII - THE TIME OF LAMBING

Any variations due to differences in time of commencement of lactation were reduced -

- (1) By pairing ewes between breeds for similar date of lambing (See Table 18).
- (2) By the fact that most ewes lambed over a small period of time. The spread of lambing was such that 73% of all milking ewes had lambed by mid-lambing (27th August)  $\pm$  3.5 days.

Also the standard deviation of all ewe lambing dates was only  $\pm$  7.09 days from the day of mid-lambing.

## SECTION VIII - EWE HEALTH

Apart from occasional cases of foot-rot, metabolic disorder and wounding of teats by the lambs, no other disfunction

was observed. The drop in milk yield as a result of the above disorders was recognised, and yields for such days determined by proportional interpolation.

SECTION IX - THE RELATIONSHIP BETWEEN EWE MILK INDEX AND THE BIRTH WEIGHT OF LAMBS.

Wallace (18) found a significant correlation between these two characters as also did Bonema (17A). It must be realised that the relationship is not as a result of any genetic association between the factors determining milk yield and birth weight of lambs but more probably a common function of the ability of a ewe to utilise her food. The fact that the level of pre-partum feeding will affect both the birth weight of the lamb and the subsequent level of milk production of the ewe has been shown by Wallace (18) and Barnicoat et al. (11).

In this experiment the following correlations have been found (Table 24).

TABLE - 24

MILK INDEX & SUMMED BIRTH WEIGHTS OF LAMBS FOR EACH EWE

	Romney	3/4 Cheviot	1/2 Cheviot	All Ewes
Correlation	- .04 NS.	.566 *(p=.06)	.470 NS.	.640 **
Number of Ewes	12	12	6	30

The small number in the 1/2 Cheviot group has probably again prevented the correlation being significant. Table 25 shows the mean birth weights of all lambs in the milking groups.

T A B L E - 25

MEAN INDIVIDUAL BIRTH WEIGHTS OF LAMBS IN MILKING GROUPE

	Mean (lbs.)	S.D. (lbs.)	Coefficient of variation	Male Lambs	Female Lambs
Romney	10.30	1.28	.124	15	9
3/4 Cheviot	9.00	1.63	.181	12	12
1/2 Cheviot	9.08	1.34	.148	5	7

While the difference between the Romney and 3/4 Cheviot birth weight variances is not significant, it is a further indication of the tendency for greater variability found previously in other 3/4 Cheviot characteristics (see back Milk Yield and Liveweights) That a significant correlation exists in the breed with greater variability in each characteristic suggests that the maintenance of the correlation is enhanced by the greater variability. No explanation for this relationship, however, can be found.

PART III - MILK COMPOSITION

Various workers have analysed ewes' milk and the most recent findings indicate that a number of factors affect its quality. In order that only comparable analysis should be reviewed, the following criteria have been applied to previous works.

- (1) That the sheep are of non-milking breeds.
- (2) The period of analysis is representative of the respective lactation.
- (3) That the method used to express the milk is likely to be almost as efficient as the lamb.

The following table has been compiled, excluding work in accordance with the above criteria.

T A B L E - 26

REVIEW OF EWE MILK ANALYSES

Author	Breed	Period of Lactation	% Total Solids	% fat	% Protein (N x 6.38)	% Lactose	% Ash	% Ca	% P	No. of lactations
Neidig & Iddings, (15)	Hampshire	Average of 10th, 20th, 30th, 40th and 50th days.		7.1	4.25	4.73	0.78			3
	Cotswold			7.7	4.25	4.78	0.82			
	Shropshire			8.1	4.69	4.50	0.88			
	Rambouillet			7.8	4.91	4.77	0.85			
	Lincoln			8.1	4.27	4.76	0.76			
	Southdown			7.5	4.86	4.70	0.91			
Pierce (160)	Merino	Average of 2nd, 4th and 6th weeks.	18.71	8.36	4.31	4.72	0.90	.28	.29	5
Barnicoat et al (11)	Romney	1-12 weeks, mean of weekly average	16.25	5.30	5.45	4.60	0.90	.27	.36	40

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The exclusion of the analyses of Bonsma (16A), Fuller and Kleinheinz (13), Godden and Puddy (43) and Wallace (18) is on the grounds that the manual method of milk expression used, would not facilitate truly representative sampling of the milk as it was in the udder, since the fat % of their sample would be proportional to the % of milk extracted from the half.

The various factors affecting the composition of milk produced by a ewe are -

(1) Breed In spite of the inaccuracy of some reported ewe milk analyses they show trends which though not quantitatively accurate, give an indication of true variation. In this class are the findings of Godden and Puddy (43) who analysed the milk of Cheviot ewes at about the 4th, 7th and 11th week of lactation. They found that fat, total protein, lactose and ash percentages were all higher to a greater or lesser degree than those reported by Barnicoat et al. (11) as being characteristic of New Zealand Romney milk.

Ritzman (52A and B), Fuller and Kleinheinz (13), Pierce (16D), Bonsma (17A) and Stewart (53) have all found interbreed variation in ewe milk constituents but their findings are not relevant to this experiment. The relatively higher fat % quoted by Neidig and Iddings (15) could be attributed to restricted period of lactation considered.

Since Barnicoat et al. (11) and Ritzman (52B) have shown that intrabreed variation, especially in fat%, is often very marked, it is possible that the small number of animals tested by Neidig and Iddings could account for part of their breed differences. Drozdova et al. (54), working with Russian Merinos, "coarse wools" and their crosses, have also shown interbreed qualitative variation.

(2) Stage of Lactation

Both Barnicoat et al.(11) and Wallace (18) have shown that immediate post-partum ewe milk is vastly richer in total solids than at any other stage of lactation.

Barnicoat et al. have also found that in Romneys this abnormally high solid fraction is present for only a few days (as in dairy cattle) and that throughout lactation there is a weak inverse relationship between the amount of milk produced and the percentage of various milk constituents secreted. That is, the percentage of each constituent in the milk is at its lowest when the total yield of milk is at a maximum and that as yield declines so the percentage of most constituents tends to rise.

Drozдова et al.(54) report that in Siberian Merinos and their crosses, the protein content of the milk increases towards the end of lactation as also does the ash, calcium and phosphorus percentage but to a lesser degree. They report that the lactose content was almost constant throughout lactation but Barnicoat et al.(11) found that lactose alone of the milk constituents, tends to drop as lactation proceeds. Since Barnicoat et al. have determined lactose by difference, this constituent is at the mercy of all errors made in determining the other components and accordingly its variation must be assessed in this light.

The vitamin A or carotene content of ewes' milk has not been determined at regular intervals during lactation, but Barnicoat et al. have shown that Romney colostrum contains about 25 ug/gram of fat and that after about 6 weeks of lactation, the level had fallen to about 8 ug/gms. of fat. They also found carotene to be present in only traces in

colostrum and mid-lactation milk.

The influence of the stage of lactation will have been clouded in the work of Barnicoat et al. to the extent that the ewes commenced lactation over a period of eight weeks (Logan (23) ).

(3) The Influence of Level of Nutrition

Barnicoat et al. (11) applied different levels of nutrition to Romney ewes both pre-and post-partum. The effects of these treatments may be gauged from the following table showing the average lactation composition of milk in the various groups.

T A B L E - 27

EFFECTS OF VARIATION IN PRE-and POST-PARTUM NUTRITION ON COMPOSITION OF EWE MILK

Nutrition Pre-partum	Nutrition post-partum	% Fat	% S.N.F.	% Protein	% Lactose	% Ash	% CaO	% P <sub>2</sub> O <sub>5</sub>
High	High	5.60	10.86	5.55	4.42	0.89	0.26	0.37
Low	Low	7.10	10.08	5.08	4.15	0.85	0.24	0.33
High	Low	7.30	9.83	5.09	3.92	0.82	0.24	0.33
Low	High	6.30	10.87	5.65	4.32	0.92	0.27	0.37

From Barnicoat, Logan and Grant (11) )

The similarity of the milk from the two groups "high high" and "low high" leads to the conclusion that the plane of nutrition during lactation is more important for the maintenance of normal milk quality than is the level of feeding before parturition. Barnicoat et al. found that in general, a decrease in milk yield due to either the advance of lactation or to environmental causes, produces a drop in fat and solids, - not - fat per cent.

(4) Climate

No work has been reported concerning the effect of

climatic variation upon the percentage of constituents in ewe milk. In dairy cattle, extremes of temperature have been found to affect milk quality, more especially fat %, Espe (45C). Low temperatures have been found to increase fat % and consequently total solids %, Ragdale and Turner (55). Regan and Richardson (56) have found that solids-not-fat may drop in response to high environmental temperatures.

(5) Age

Barnicoat et al. have shown that six year old Romney ewes produce milk significantly richer in fat than do 2 year old ewes. The percentages of other constituents were not found to differ significantly.

Other factors such as interval between suckling, health of the ewe, are thought to influence the quality of milk produced but no estimate of their effect has been reported.

. . . . .

The importance of these factors in this investigation will now be discussed.

(1) Breed

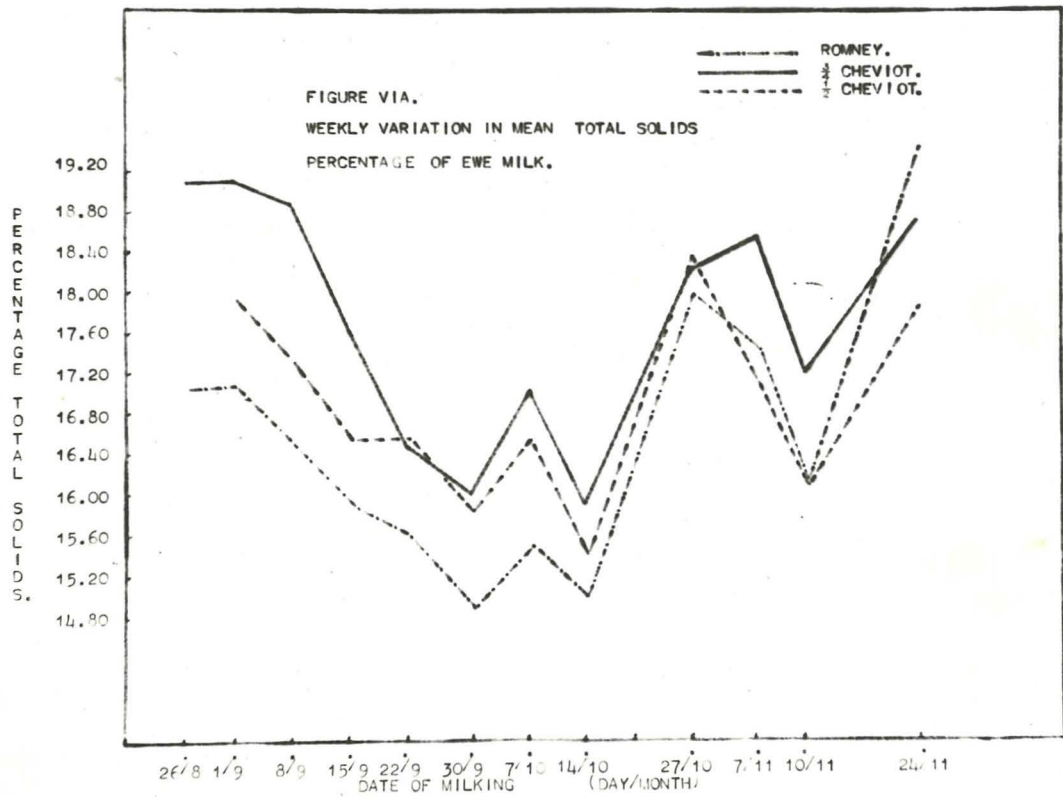
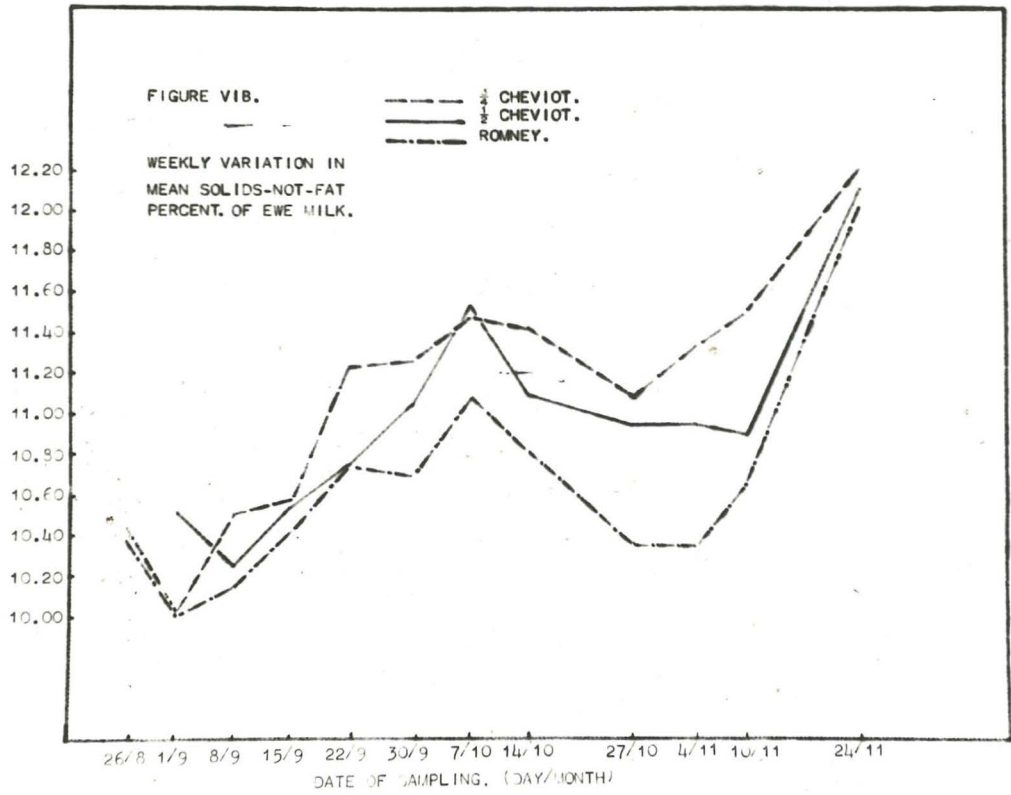
To gain an overall picture of the qualitative performances of the three breeds tested, the average percentage of each constituent over the 12 weeks of lactation is presented in Table 28.

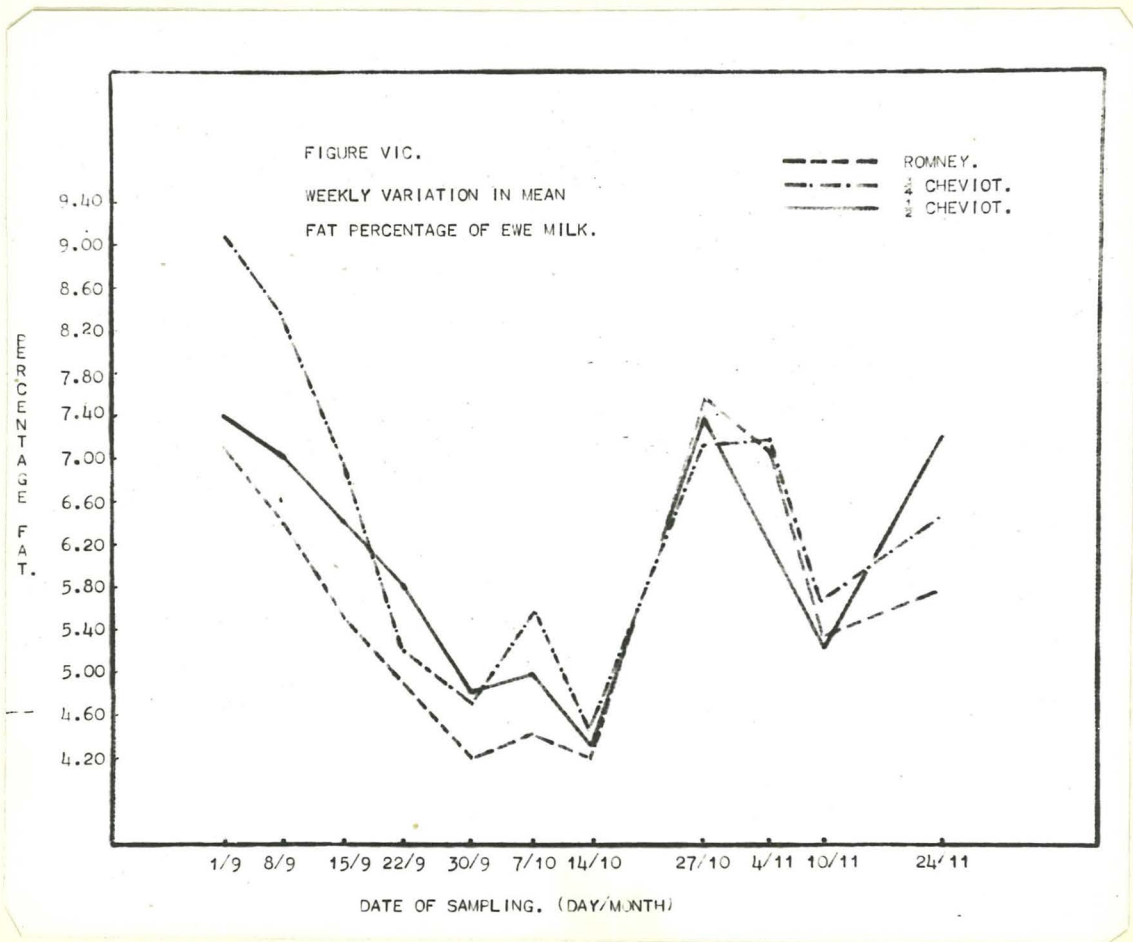
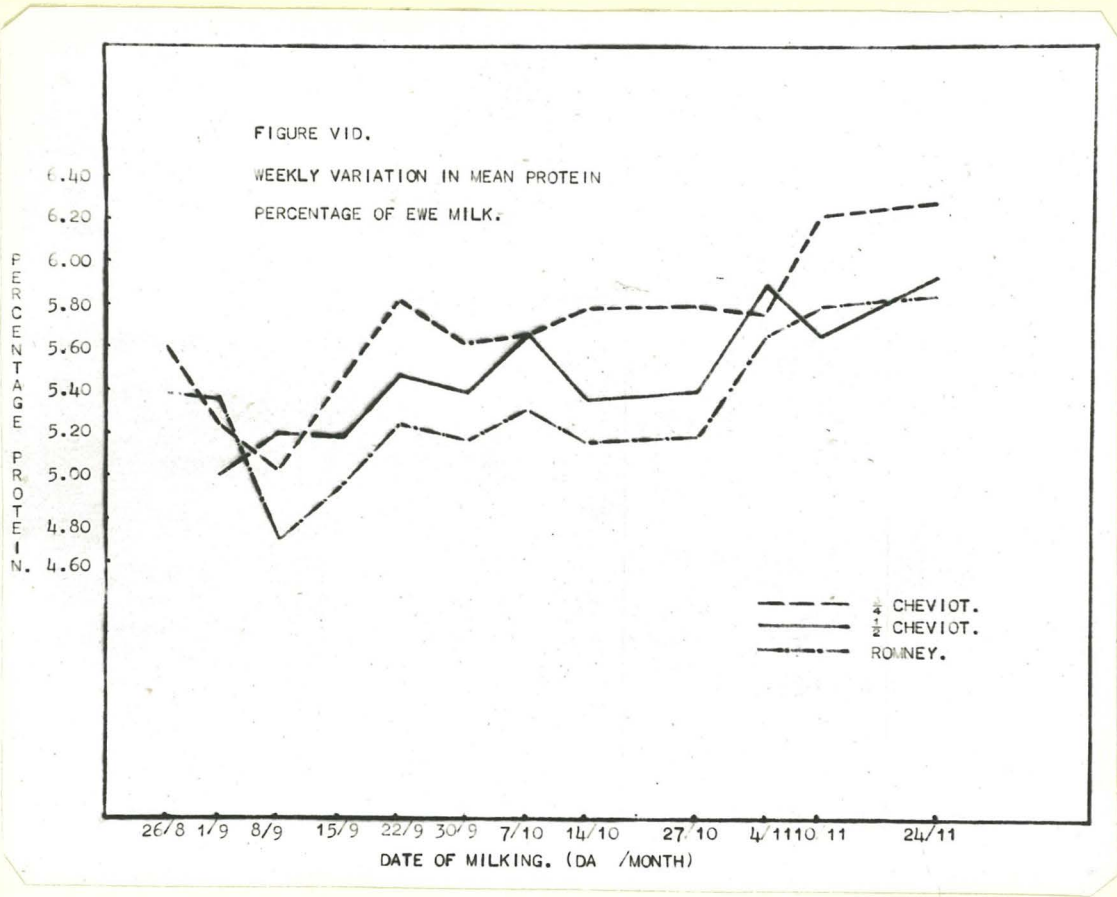
T A B L E - 28

MEAN WEEKLY COMPOSITE MILK ANALYSES

Breed	No. of Ewes	Total Solids %	Solids-not-fat %	Fat %	Protein % (N x 6.38)	Lactose % difference	Ash %	CaO %	P <sub>2</sub> O <sub>5</sub> %	Vit. A.* ug/g. fat	Carotene* ug/g. fat
Romney	10	16.42	10.65	5.76	5.31	4.44	0.90	0.29	0.35	10.0	.37
S. D.		1.06	.52	1.19	.10	.44	.059	.023	.023		
3/4 Cheviot	10	17.74	11.09	6.64	5.71	4.48	0.90	0.29	0.35	9.5	.20
S. D.		1.19	.60	1.53	.10	.25	.063	.020	.020		
1/2 Cheviot	6	17.00	10.97	6.03	5.43	4.67	0.87	0.28	0.34	-	-
S. D.		1.16	.51	1.11	.30	.33	.040	.017	.018		

\* - During fifth and sixth weeks.





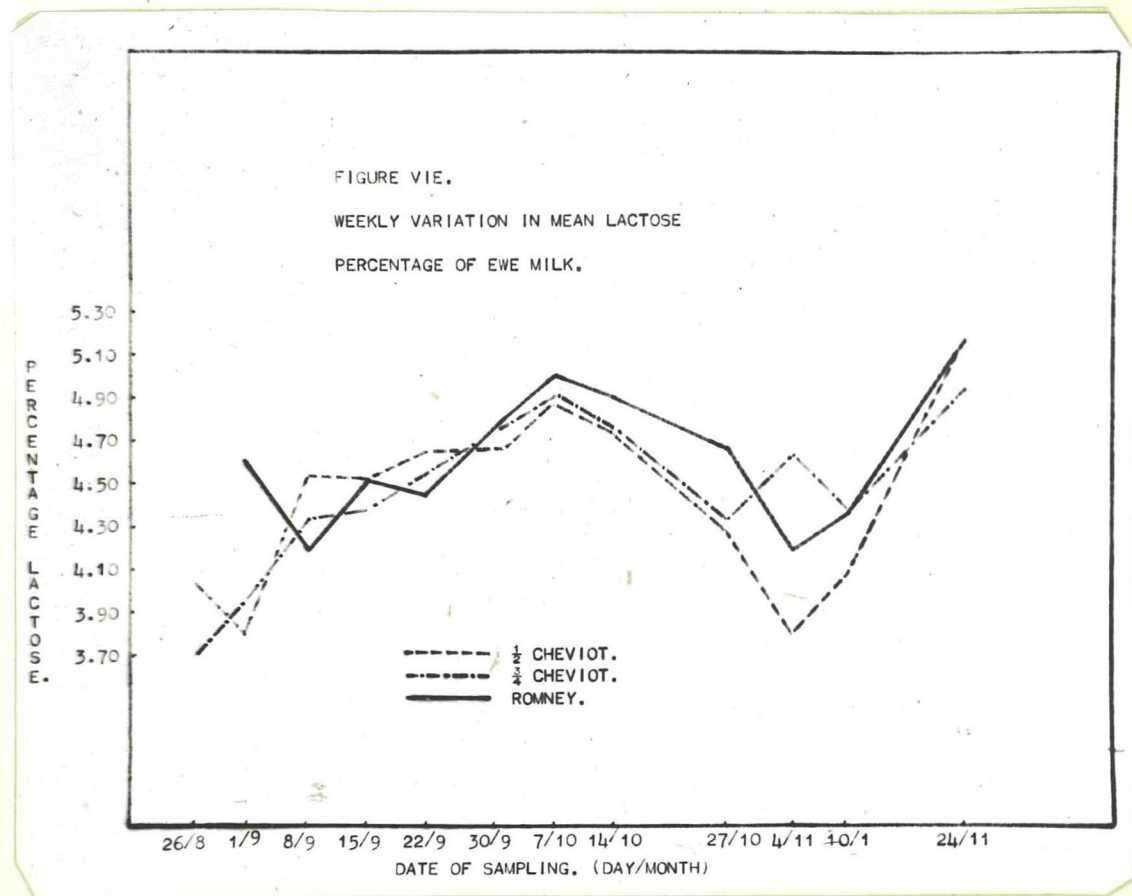
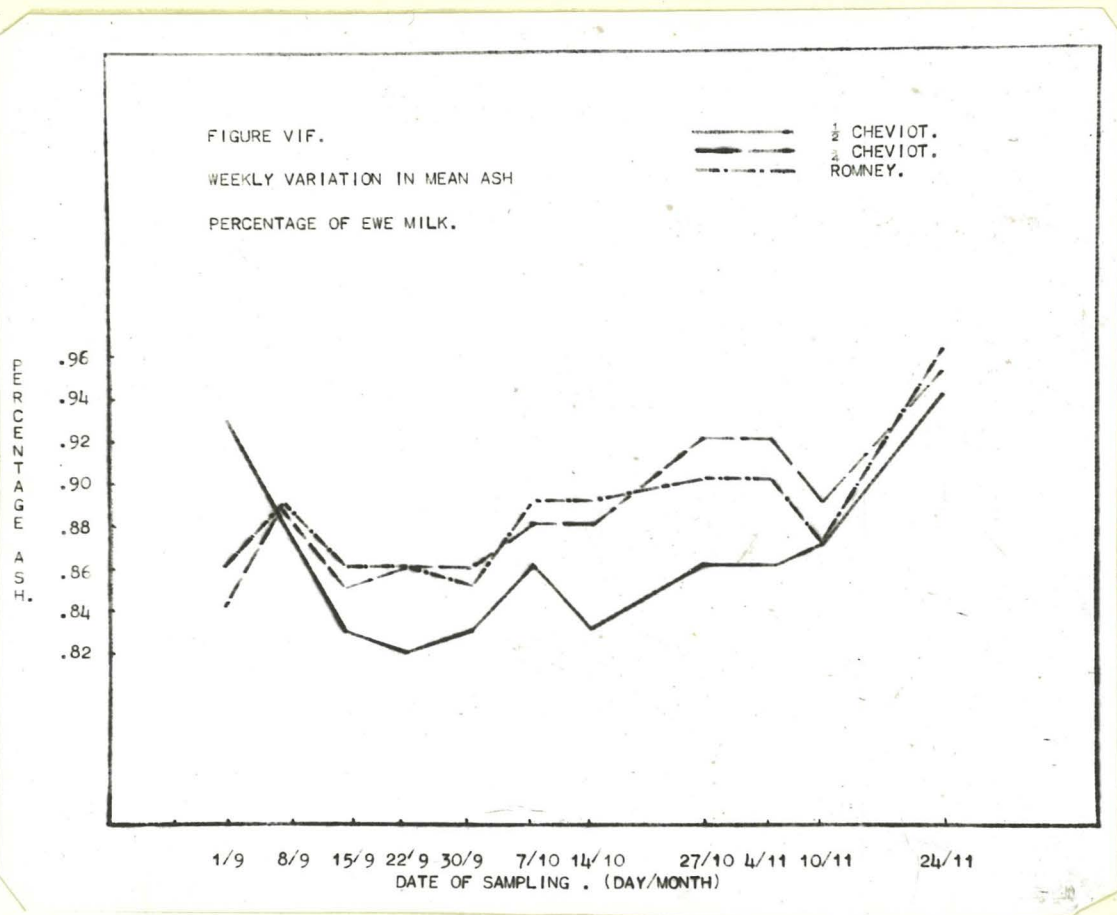
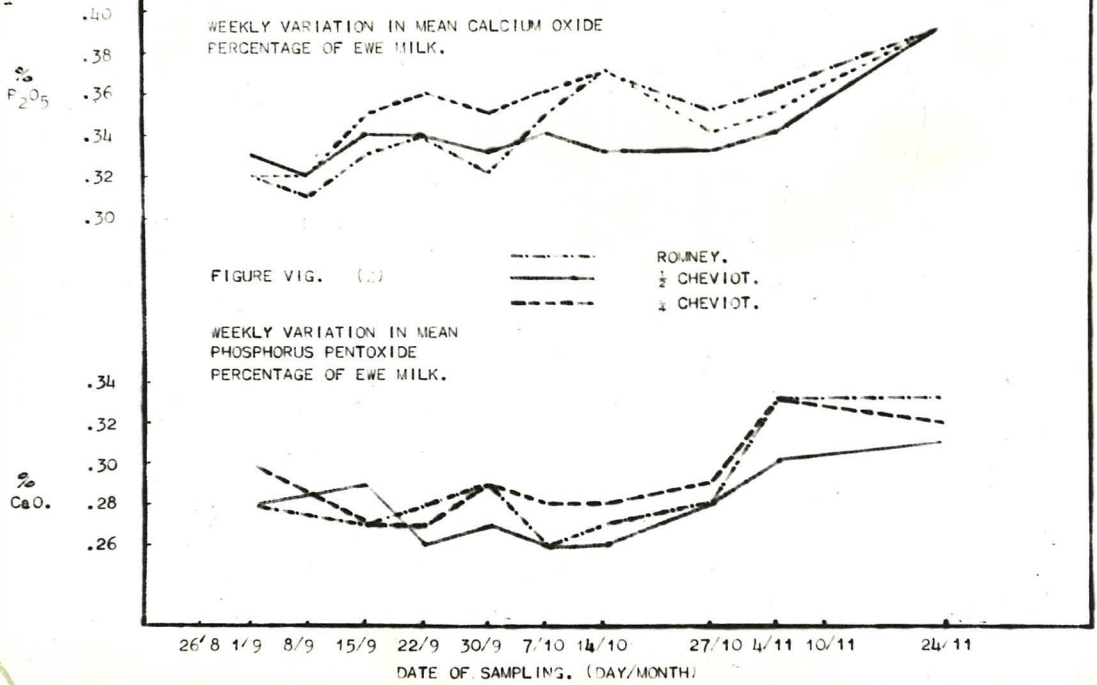


FIGURE VIg. (1)



As stated previously all of the reported constituents were determined from composites for each breed. Each of the figures in Table 28 is the mean % of the respective constituent for the first 12 weeks of lactation and an analysis of variance has been performed to determine if the breed means differ significantly. Since each constituent is presented as a percentage it is first necessary to determine whether these weekly figures form a normal distribution. Using the method proposed by Bartlett (Snedecor (57)) it was found that in all cases the distribution of weekly composite percentages was normal and recourse to a transformation was therefore not found necessary. The respective analyses of variance have been relegated to the Appendix Table 3, while the significance of the differences between breeds means has been present in Table 29.

T A B L E - 29

SIGNIFICANCE OF DIFFERENCE BETWEEN MILK CONSTITUENT MEAN %'s (Means see Table 28)

Highly Significant = H.S. = 1% level Significant = S = 5% - 1% level.  
 Not Significant = N.S. = 5% level

	Romney : 3/4 Cheviot	Romney: 1/2 Cheviot	3/4 Cheviot: 1/2 Cheviot
Total Solids	H.S.	H.S.	S.
Solids-net-fat	S.	H.S.	S.
Fat	H.S.	N.S.	N.S.
Protein	H.S.	S.	H.S.
Lactose	Since this constituent was determined by difference it was not subjected to statistical analysis.		
Ash	Means almost identical	Means almost identical	Means almost identical
CaO	-do-	-do-	-do-
P <sub>2</sub> O <sub>5</sub>	-do-	-do-	-do-
(All constituents as a % of whole milk.)			

While the results published by Barnicoat et al. (11) are not necessarily representative of the Romney breed as a whole, they are derived from a sufficiently large number of lactations to eliminate chance variation. Their 6 year old ewes (1944) seem most comparable with the Romneys of this experiment. (Note, however, that they have considered a lactation as long as 130 days whereas in this work only the first 12 weeks have been sampled.) Both groups have been run on pasture, a requisite which disqualifies, for comparative purposes, the milk analyses of Barnicoat's 1945 ewes. Table 30 shows the composition of the Romney milk of this experiment compared with that of the 1944 Romneys of Barnicoat et al.

TABLE - 30

COMPARISON OF ROMNEY MILK COMPOSITION

	T.S.	S.N.F.	Fat	Prtn.	Lactose	Ash	CaO	P <sub>2</sub> O <sub>5</sub>
Romney 6 year old 1944 (Barnicoat et al. (11))	16.38	10.98	5.40	5.48	4.60	0.90	0.27	0.36
Romney Group 1951, 6 year old	16.41	10.65	5.76	5.31	4.44	0.90	0.29	0.35

In spite of -

- (1) different lengths of lactation
- (2) between-year environmental variation, e.g. amount of feed and disease,

there are remarkably small differences between the two series of analyses. The author therefore assumes that the Romney group tested in this experiment is as representative of Romney six-year olds as is the group of Barnicoat et al.

## (2) Stage of Lactation

Before the apparent breed differences in milk quality can be evaluated, the effect of the state of lactation found previously to affect the composition of milk, should be discussed. The following figures for each milk constituent illustrate the weekly variation for the 12 weeks of lactation. That the proportion of individual constituents in ewes' milk has a significant relationship to the number of days from the initiation of lactation, can be verified by inspection of the curves in Fig. VIA, B, etc. In order that such variation in composites due to ewes being at different stages from the commencement of lactation be minimised, the date of parturition for all ewes was restricted to that within the bounds of a mean date  $\pm 7$  days. The standard deviation for all ewes supplying aliquots to the breed composites was 5.96 days. Within this range of 14 days, pairing of ewes between breeds for day of freshening, still further reduced variation.

Since the weekly composites contain equal portions of milk from ewes at almost equal stages of lactation, they may be regarded as representing the true effect of the advance of lactation as shown by the mean analyses of the specified ewes of each breed.

## (3) Level of Nutrition

All ewes were maintained at an equally high level of nutrition during pregnancy and lactation. Barnicoat et al. (1) found that the post-partum level of feeding was more important than the pre-partum level in determining the quality of ewes' milk and that an inverse relationship existed between milk yield and percentage of fat and solids-not-fat. Whether this inverse relationship still holds when level of production is reduced as a result of poor growth (as in the  $\frac{1}{2}$  Cheviots) has not been determined. It

is reasonable to assume, however, that in the  $\frac{1}{2}$  Cheviots no profound physiological disturbance, a necessary antecedent to compositional variation, would have an effect as strong as the effect of the high level of feeding throughout pregnancy and lactation.

#### (4) Climate

From an inspection of the constituent curves in Figures VI A - G, it would seem that total solids % and fat % have responded most markedly to the climatic variation occasioned by the heavy rain on the 7th and 27th October. These two sampling days are characterised by approximately half an inch of rain in the 24 hours. For both constituents there are marked apparent peaks in all three breeds (Figs. IVA and IVC). If it is considered that fat and total solids % do vary in response to heavy rainfall, then the variation derived from the rain of the 7th and 27th October can be considered as a representative sample of the total variation caused by similar days of rain throughout the whole lactation.

#### (5) Age

All ewes were  $5\frac{1}{2}$  years old at tugging (6 years at lambing).

### INDIVIDUAL MILK CONSTITUENTS

The mean lactation %'s for the various constituents (Table 28) and the lactational trends as illustrated in Figs. VI A - G for the three breeds, will now be considered.

#### A - Total Solids

Table 29 shows that the mean lactation percentage for this constituent differs significantly between the breeds. If the trend indicated by Godden and Puddy (43) is to be

accepted then total solids of at least 18 - 19% are characteristic of pure Cheviot ewes. Barnicoat et al. (11) and the author have found that Romney milk contains about 16.4% total solids. The mean  $\frac{3}{4}$  and  $\frac{1}{2}$  Cheviot percentages in Table 28 indicate that the increase of total solids % in these breeds is roughly proportional to the amount of Cheviot "blood" in the breed.

The similarity of the shapes of the three breed curves (Fig. VIA) suggests that -

- (1) the groups have been subjected to the same environmental variation
- (2) that they may have reacted to these variations in a comparable manner.
- (3) the physiological basis for the lactational trend of total solids % in milk is similar in all breeds and this trend (after eliminating variation due to climate) is characterized by a steady fall until about the 5th or 6th week of lactation. From then until the 12th week there is a continued rise.

The division of total solids variation into variation of specific constituents follows :

#### B - SOLIDS-NOT-FAT

The slight rise in solids-not-fat% during lactation (as found by Barnicoat et al. (11) ), has also been found for all three groups in this experiment. The rise is of the order of 2%, spread over the 12 weeks whereas Barnicoat et al. found a maximum rise of 0.5% over a longer period. The significant differences (Table 28) between breed lactation means would seem to be a reflection of differences in protein content.

#### C - Fat %

Table 28 shows that only  $\frac{3}{4}$  Cheviots and the Romneys differ significantly in mean lactation fat percentage. The three breed lactation curves (Fig. VIC) are all very similar and in

general are comparable to those reported by Barnicoat et al. (11). The trend of fat % is similar to that found in Section A for total solids %. Since s.n.f. % is relatively constant in this work and that of Barnicoat et al. (11), then total solids % (which is s.n.f. + fat) and fat % should have a similar lactational trend.

The increase in fat percentage seemingly in response to heavy rain is shown in all three breeds on the 7th and 27th October, the ewes being so wet that neither ewe, lamb nor sampler was willing to perform in each other's proximity. On this day it is likely that fat % (and total solids %) were much higher than are shown in the respective curves (Figures VIA & C).

In dairy cattle, fat is one of the more variable constituents of milk (Black and Voss (58) ). In this experiment the variation in % fat between weeks differs between the breeds, but not significantly, see Table 31.

TABLE - 31

MEAN FAT % OF MILK OF EWES AND WEEKS OF LACTATION

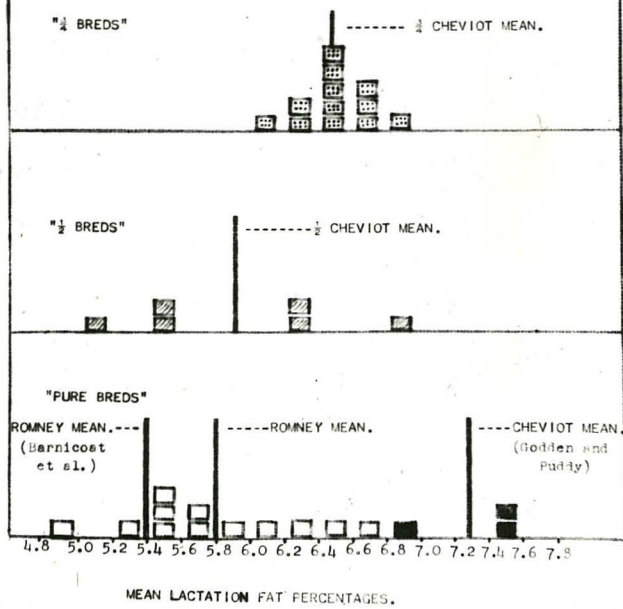
Breed	WEEKS		Significance of difference of Means	EWES		Significance of difference of Means
	Variance	Mean %		Variance	Mean %	
Romney	15.75	5.76	* * } N.S.	3.29	5.81	* * } N.S.
3/4 Cheviot	25.57	6.64		.76	6.51	
1/2 Cheviot	12.36	6.03		2.67	5.92	

It is evident that within the breeds variation between weeks is much greater than between ewes. This indicates that variation in fat % is more readily effected by environmental variation and inaccuracy of measurement than by variation in the physiological ability of ewes to produce milk fat.

Wriedt (59), working with Jersey and Red Danish

FIGURE VII.  
 THE FREQUENCY DISTRIBUTION OF INDIVIDUAL EWE, MEAN  
 LACTATION MILK FAT PERCENTAGES.  
 (EACH SQUARE REPRESENTS A EWE'S MEAN FAT TEST FOR  
 A 12 WEEK LACTATION.)

ROMNEY EWES  
 CHEVIOT EWES  
  $\frac{1}{2}$  CHEVIOT EWES  
  $\frac{3}{4}$  CHEVIOT EWES



dairy cattle, has shown that the milk fat % of various crosses (comparable to the  $\frac{1}{2}$  and  $\frac{3}{4}$  Cheviot) is related to the amount of "blood" of either breed in the cross, e.g. the first cross ( $f_1$ ) is intermediate in fat % between the two pure breeds, while the  $\frac{3}{4}$  bred of either breed has a fat test intermediate to that of the  $f_1$  and the pure parent.

Because of -

(1) the small numbers in the  $\frac{1}{2}$  Cheviot group.

(2) The quantitative inaccuracy of the fat percentage of pure Cheviot milk as reported by Godden and Puddy (43)

(owing to manual extraction of the milk), it is felt that in this investigation, a relationship similar to that found by Wriedt, can only be indicated in the form of a trend. Such a trend is influenced by the following factors :

(1) The method used by Godden & Puddy would tend to underestimate the milk fat % of pure Cheviots and that therefore Cheviots are characterised by a mean lactation fat% of at least 7%.

(2) Romney 6 year old ewes have a mean lactation fat% of 5.50 - 5.80% as indicated by Barnicoat, Logan and Grant and the author.

(3) The mean lactation fat% for  $\frac{3}{4}$  Cheviots is about 6.5% and for  $\frac{1}{2}$  Cheviots about 6.0%.

(4) The significant difference (Table 31) found in the analysis of week means between Romney and  $\frac{3}{4}$  Cheviots is accompanied by a significant difference between  $\frac{1}{2}$  Cheviot and  $\frac{3}{4}$  Cheviot in the ewe means. This extension of significance is facilitated by the reduced variation found, between ewes, in all breeds.

From these findings it is suggested that a trend similar to that found by Wriedt (59) is evident in the milk fat % of Romney,  $\frac{1}{2}$  Cheviot and  $\frac{3}{4}$  Cheviot ewes (see Fig.VII).

### D - Protein

Table 29 shows that all three breeds differ significantly in the amount of total protein (total nitrogen x 6.38) in the respective milks. These figures are the averages of weekly composite analysis. The greater constancy of this constituent relative to the percentage of fat, facilitates the extraction of significant differences in the analyses of variance. The degree to which protein exhibits relatively less lactational variation, may be gauged from the standard deviation for each constituent shown in Table 28.

Fig. VID shows that in all breeds, % protein rises about 1% during the first 12 weeks of lactation. The small amount of variation evidenced in these curves plus the significance of the difference between their means, suggest that they are characteristic of the respective groups true protein content of milk. The mean weekly protein percentages (Table 28) of the various breeds were all found to differ significantly (Table 29). The extent to which such differences are characteristic of the respective breeds true milk protein percentage and are thus differences as a result of cross-breeding, (c.f. Wriedt (59) for Milk Fat) cannot be conclusively determined on weekly composite percentages. While the average of weekly composite percentages is the same as the average of individual ewe lactation mean protein percentages, the variation between ewes (which we have not measured) may be greater than that between weeks and so render the small differences found between breeds non-significant.

### E - Lactose

Since lactose has been determined by difference, errors in the determination of the other constituents will accumulate in this estimate. The resultant variability is

evidenced by the standard deviation in Table 28 and the lactose curve Fig. VI E). Note, however, that the mean figure found for Romney ewes in this experiment is similar to that previously reported.

#### F - Ash

The % of Ash in the milks of all breeds tested, is remarkably similar. The mean percentages agree well with those reported by Barnicoat et al. (11) p. 240. The method of estimating the mineral constituents of milk as Ash gives no indication of their nature or original availability. Because of this no great significance can be attached to the slight rise during lactation exhibited by Ash % (see Fig. VI F). Because of the arbitrary nature of this constituent, more importance should be attached to the calcium and phosphorus fractions since they are the main sources of bone growth in the suckling lamb.

#### G - Calcium (Expressed as CaO)

Mean calcium oxide percentages in the milk of the three breeds during 12 weeks of lactation are almost identical. The lactational trend of CaO, as seen in Fig. VI G, is characterised by a slight rise from the first to the 12th week of lactation. The variability of CaO%, as gauged by the standard deviations (Table 28) and Fig. VI G, is equally small in all breeds.

#### H - Phosphorus (expressed as P<sub>2</sub>O<sub>5</sub>)

This constituent exhibits similar variation to that found for calcium oxide in (G) above. Generally, P<sub>2</sub>O<sub>5</sub> 5% is similar in mean lactation %, variability and trend during lactation in all three breeds. The CaO and P<sub>2</sub>O<sub>5</sub> percentages are similar to those reported previously for Romney ewe milk.

(I)

Vitamin A and Carotene

The Romney and threequarter bred Cheviot ewes in this experiment have been found to produce milk fat containing only traces of carotene but the content of vitamin A is slightly greater than that reported in New Zealand cow milk fats. In table 28 is shown the micrograms of vitamin A and carotene per gram of milk fat; the milk fat samples being collected during the 5th and 6th weeks of lactation. The figures shown are the mean contents for these two periods. The vitamin A contents are similar to those reported by Barnicoat et al.(11) as being characteristic of New Zealand Romney milk fat.

## PART IV

### The Growth of Lambs

The growth of a lamb may be represented in a number of different ways. The method used in this experiment is to determine changes in liveweight over a given period of time; i. e., the average gain in liveweight per unit of time or the average growth rate. The extent to which such a procedure will give an accurate estimate of the true growth rate will be determined by the duration of the period over which changes in weight are measured. As the length of time diminishes so the average growth rate will approach the true growth rate (Brody (60) ).

In lambs, a number of factors have been found to affect the average growth rate. The most important of these is the quantity and to a lesser extent the quality, of the nutrients supplied to the lamb, since these nutrients are the raw materials from which the lamb must elaborate all the constituents of liveweight gain. For a number of weeks from birth, the lamb's diet is solely in the form of milk and consequently during this period variations in milk are likely to cause variations in growth. Bonsma (17 A, B and C) Wallace (18) and Barnicoat et al. (11) have demonstrated the all important association between the quantity of milk consumed and the gain in liveweight of the lamb. Equal importance is not attributed to the qualitative adequacy of milk yield (Ritzman (52 A and B) ), but little critical work has been done in this field.

Wallace (loc. cit.), in considering the period of growth characterised by the intake of nutrients in addition to those in milk, has shown that total nutrient intake is by far the most important factor conditioning growth. He states that, "no better example could be provided of the paramount importance of the

level of the diet in the rearing of lambs than our finding that 96% of the variation in weight gains made by individual lambs between birth and 112 days, can be accounted for by the differences between them in respect to the consumption of milk and supplements." All factors found to affect the milk yield of the ewe (see Part II) and those conditioning the quantity and quality of other constituents of the diet will therefore, indirectly affect the growth of the lamb.

Another important determinant of lamb growth is the breed of lamb. Bonsma (17A) has shown that lambs of the first cross between mutton breeds and Merinos exhibited a greater inherent growth impulse than pure-bred Merino lambs. Hammond (4) also found that growth differences were apparent in different breeds. The extent to which the milk supply of the ewe, by preventing full expression of growth potentialities, tends to disguise true growth variation between breeds has not been accurately determined.

Many workers have found significant correlations between birth weight of lambs and the weight at subsequent ages. Phillips and Dawson (62), Donald and McLean (61), Hammond (4) and Logan (23). Phillips (64) could find no advantage in subsequent rate of gain for Welsh lambs which weighed heaviest at birth. (Note that Phillips did not use statistical techniques to evaluate his results.) Wallace (18) however, found that birth weight was strongly correlated with liveweight gain to 28 days, this being in accordance with his view that the size of the lamb at birth largely determines its ability to utilise to the full, the milk available from the ewe.

Since both sex and birth rank will influence the birth weight of a lamb (Bonsma, Wallace, Donald and Mclean, loc. cit.) these factors will have an indirect effect on the lamb's

subsequent rate of growth. More directly sex may affect rate of growth by varying the internal physiological environment of the lamb but Bonsma (17A) could find no evidence for this. Similarly the direct effect of a lamb being a member of a twin set is to reduce the amount of milk each lamb consumes relative to what one lamb would receive from the same ewe. Since milk consumption limits liveweight gain, then lowered milk consumption consequent upon twin birth rank will result in reduced gain as long as milk is the major part of the lamb's diet.

Bonsma, loc.cit, found that ewes in their first pregnancy produced lambs which were lighter at 12 weeks of age than lambs produced in subsequent pregnancies. Barnicoat et al.(11) comparing the amount of milk produced by ewes which had commenced lactation at different times found they varied about a certain seasonal period of maximum yield. Since variation in lamb gain is closely associated with variation in milk supply (Bonsma, Wallace and Barnicoat et al, loc.cit.) it is possible that lamb growth may be influenced by the date of birth. It is considered that growth of lambs is more adequately represented by liveweight gain than by the weight at a specific age since differences in weight up to 12 weeks may largely be due to differences in birth weight. The extent to which the factors, which have been reviewed, affect the growth of lambs will now be considered.

#### (1) Birth Weight

The mean birth weights etc., of all lambs in the three breeds are presented in Table 32.

T A B L E - 32

MEAN BIRTH WEIGHTS ALL LAMBS

Breed	SINGLES		TWINS	
	Male lbs.	Female lbs.	Male lbs.	Female lbs.
Romney	12.83	11.80	10.55	9.55
S.D.	1.66 (21)	2.04 (15)	1.42 (36)	1.13 (38)
3/4 Cheviot	11.50	12.00	9.25	9.03
S.D.	1.80 (3)	2.00 (2)	1.62 (12)	1.15 (16)
1/2 Cheviot	12.50	10.50	8.96	9.22
S.D.	1.32 (9)	1.29 (4)	1.37 (7)	1.28 (9)

(Figures in brackets = Number of lambs per group)

Since in only the twin classification were there sufficiently large numbers of lambs in each group, tests of significance of differences between mean birth weights have only been performed for this birth rank. These are presented in Table 32A.

T A B L E - 32 A

ANALYSIS OF VARIANCE OF TWIN BIRTH WEIGHTS  
Romney, 3/4 Cheviot and 1/2 Cheviot Twin Birth Weights

Source	df	S. S.	M. S.	F
Sex	1	501.12	501.12	950.80 **
Breeds	2	23.80	12.90	24.48 **
Interaction	2	12.39	6.15	11.67 **
Error	109	57.45	.527	

"t" tests show that Romney twin lambs are significantly heavier at birth than either 3/4 Cheviot or 1/2 Cheviot lambs.

In order that the significance of difference between birth rank might be estimated, an analysis of variance as proposed by Snedecor and Cox (65) was modified for application to the birth

weights of the Romney and 3/4 Cheviot groups. Interactions between pairs of factors were calculated and found to be non-significant in all cases. Though no second order interactions were thus estimated, it was assumed that they were not significant and accordingly in the final analysis of variance (Table 33) interaction was not considered.

T A B L E - 33

ANALYSIS OF VARIANCE OF BIRTH WEIGHTS OF ROMNEY and 3/4 CHEVIOT MILKING LAMBS

(Modified Method of Fitting Constants)

Source	df	S. S.	M. S.	F.
Sex	1	2,497.570	2,497.570	11.56 **
Breed	1	7,162.895	7,162.895	33.40 **
Birth Rank	1	15,193.095	15,193.095	70.85 **
Error	139	29,807.340	214.44	

The highly significant nature of mean birthweight differences in Table 33, indicates that the Romneys produce a heavier lamb at birth than do the 3/4 Cheviots. The superior birthweights of single and male lambs respectively is also apparent. The Romney group, treated as a whole in the above analysis, could be broken up into constituent strains. Table 34 shows an analysis of variance of these strains mean birthweights.

T A B L E - 34

A. ROMNEY STRAINS - MEAN BIRTHWEIGHTS (lbs.)

Strain	Singles		Twins	
	Males	Females	Males	Females
W.	12.05 (10)	11.00 (2)	10.71 (12)	9.59 (6)
T.	14.30 (5)	12.38 (8)	12.00 (1)	11.14 (7)
S.	12.10 (5)	10.25 (8)	9.90 (4)	9.92 (6)
Lamb numbers per group in brackets				

B. ANALYSIS OF VARIANCE

(Modified method of fitting constants, Snedecor & Cox, 65)

Interaction assumed absent

Source	df	S.S.	M.S.	F.
Strains	2	606.49	303.24	1.01 N.S.
Sex	1	1,883.33	1,883.33	6.24 *
Birth Rank	1	3,355.80	3,355.80	11.13 **
Error	69	20,810.00	301.59	

From the above analysis it is apparent that the three Romney strains produce lambs which do not differ significantly in birthweight but that within these strains single or male lambs are significantly heavier at birth than twins or females respectively. In the light of these findings it is now necessary to determine whether birth weight variation does influence the subsequent growth of the lamb. Since all twin lambs in the  $\frac{3}{4}$  Cheviot and  $\frac{1}{2}$  Cheviot groups were selected for the milking groups, it was found necessary to determine birthweight - liveweight gain correlations within birth ranks, rather than over all the lambs. Table 35 shows the correlation between birth weight and liveweight gain (lbs.) from 0-6 and 0-12 weeks for (1) the Romney, (2) bulked  $\frac{1}{2}$  and  $\frac{3}{4}$  Cheviot non-milking, and (3) within all milking groups.

T A B L E - 35

CORRELATION BIRTHWEIGHTS and LIVELWEIGHT GAINS

	No. of Lambs	0 - 6 weeks	0 - 12 weeks
<u>(Singles)</u>			
<u>Non-Milking</u>			
(1) Romney	74	.561 **	.533 **
(2) Bulked $\frac{1}{2}$ and $\frac{3}{4}$ Cheviot	20	negative N.S.	negative N.S.
<u>(Twins)</u>			
<u>(3) Milking</u>			
Romney	24	.160 N.S.	.161 N.S.
$\frac{3}{4}$ Cheviot	24	.673 **	.229 N.S.
$\frac{1}{2}$ Cheviot	12	.221 N.S.	-
Bulked groups	60	.338 **	.179 N.S.

It will be noticed that in both milking and non-milking groups the liveweight gain made by lambs from birth to 6 weeks of age is significantly correlated with birthweight. This relationship is attributable to the increased growth capacity of the larger lamb (Wallace (18) ) and also to the common relation between ewe liveweight, milk yield of the ewe (Section V. Part 2) and lamb birthweight (Donald and Mclean (61) ).

In some of the milking groups the treatment received weekly at milking has apparently inhibited their growth (see later section) and consequently it is not surprising that the relationship between birthweight and gain has been masked. In the Romney strains, however, both 0-6 weeks and 0-12 weeks gain are significantly correlated with birth weight.

If the growth rates of lambs in the breed groups are to be compared, each group must be considered on an equal basis with regard to sex and birth rank. Since it has been found that there is a significant breed difference in birthweights, liveweight

FIGURE VIIA. MEAN DAILY LIVELWEIGHT GAINS OF ALL MALE AND FEMALE MILKING LAMBS (BREEDS BULKED)

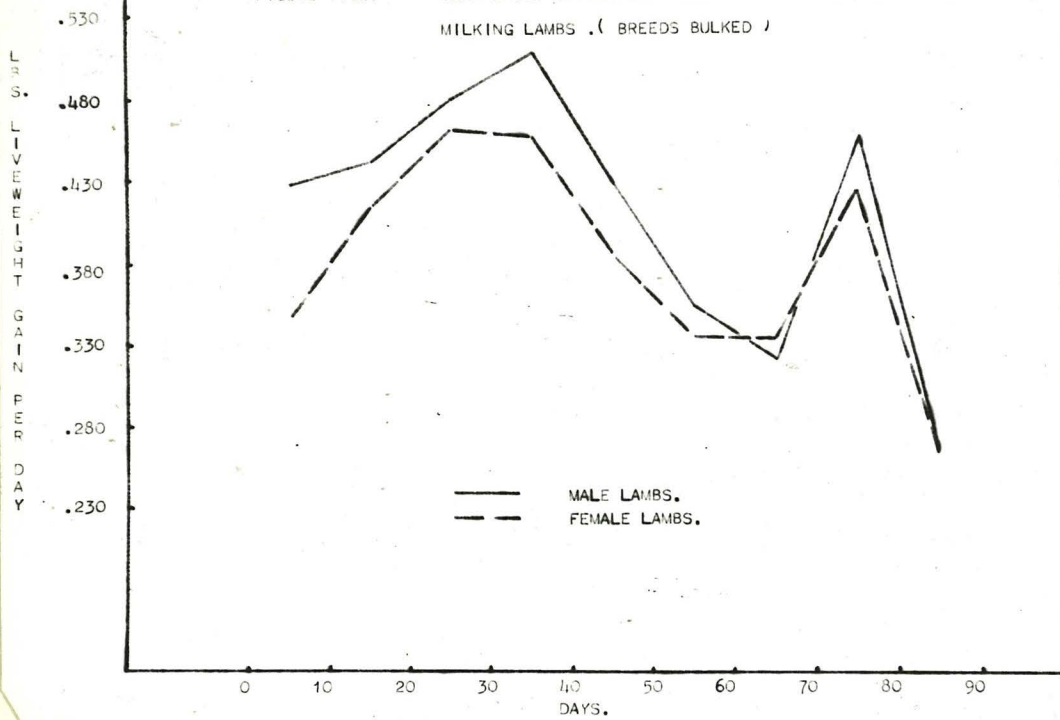
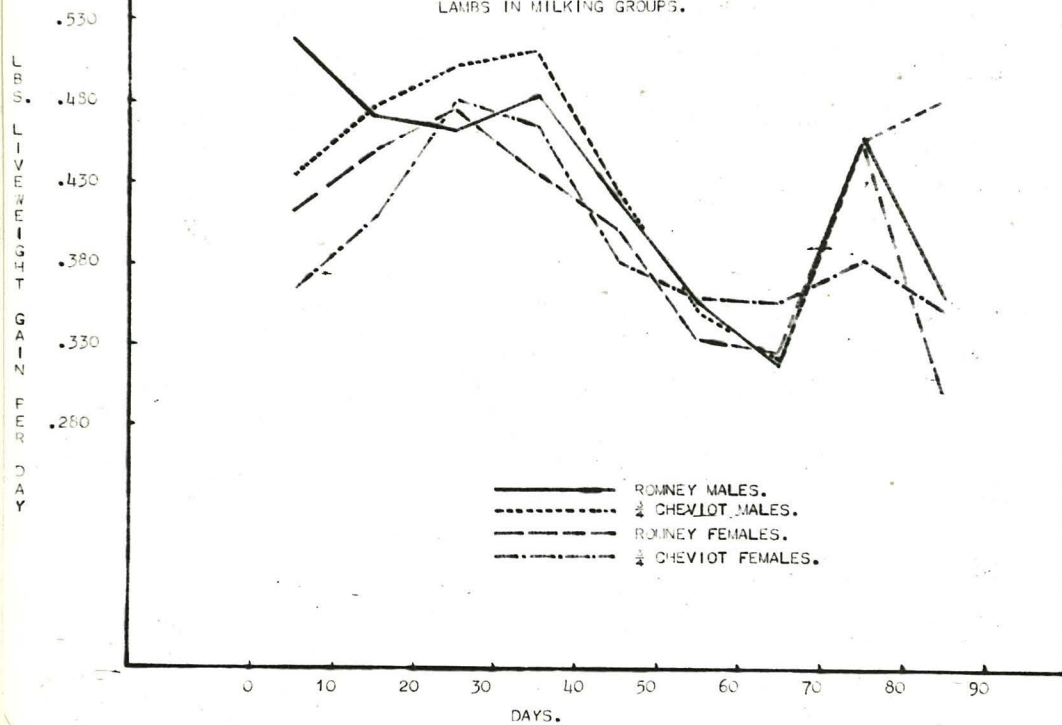


FIGURE VIII. MEAN DAILY LIVELWEIGHT GAINS OF MALE AND FEMALE LAMBS IN MILKING GROUPS.



gain differences between breeds may in part be attributable to these initial inequalities. The adjusting of means by the technique of covariance has been found impracticable because of the dissimilar numbers of like sexed lambs in the breed groups.

(2) Sex

In addition to the indirect effect through birthweight, sex may directly influence rate of liveweight gain in lambs, (Donald and Mclean (61), Phillips (64) and Hammond (4), ). Bonsma (17A), however, found no significant differences when comparing the growth rates of female and castrate male lambs of equal birthweight.

In this investigation the effects of sex upon the daily growth rate (lbs. liveweight gain/day) of male and female Romney x S.D. lambs, are shown in Figure VIIA. Since all male lambs were castrated at an age of about 2 - 4 weeks, this treatment may possibly have retarded their reaching maximum daily gain relative to the female lambs. Evidently, in Fig. VIIA, male lambs have, during most of the first 12 weeks of life, maintained a greater average growth rate per day. Within sexes, the correlations between birth weight and gain to 6 and 12 weeks are still maintained.

T A B L E - 36

CORRELATION WITHIN SEXES OF LIVELWEIGHT GAIN  
AND BIRTHWEIGHT

	0 - 6 weeks gain	0 - 12 weeks gain
Romney male	.519 **	.552 **
Romney female	.562 **	.337 *

Covariance was possible only in the Romney groups in which equal numbers of like sexed lambs allowed all liveweight gains to be compared as though produced by lambs of equal

birthweight. Table 36A shows the mean liveweight gains of the various sex - birth rank groups adjusted for equal birthweight. The respective analyses of covariance have been relegated to the appendix, Table 4.

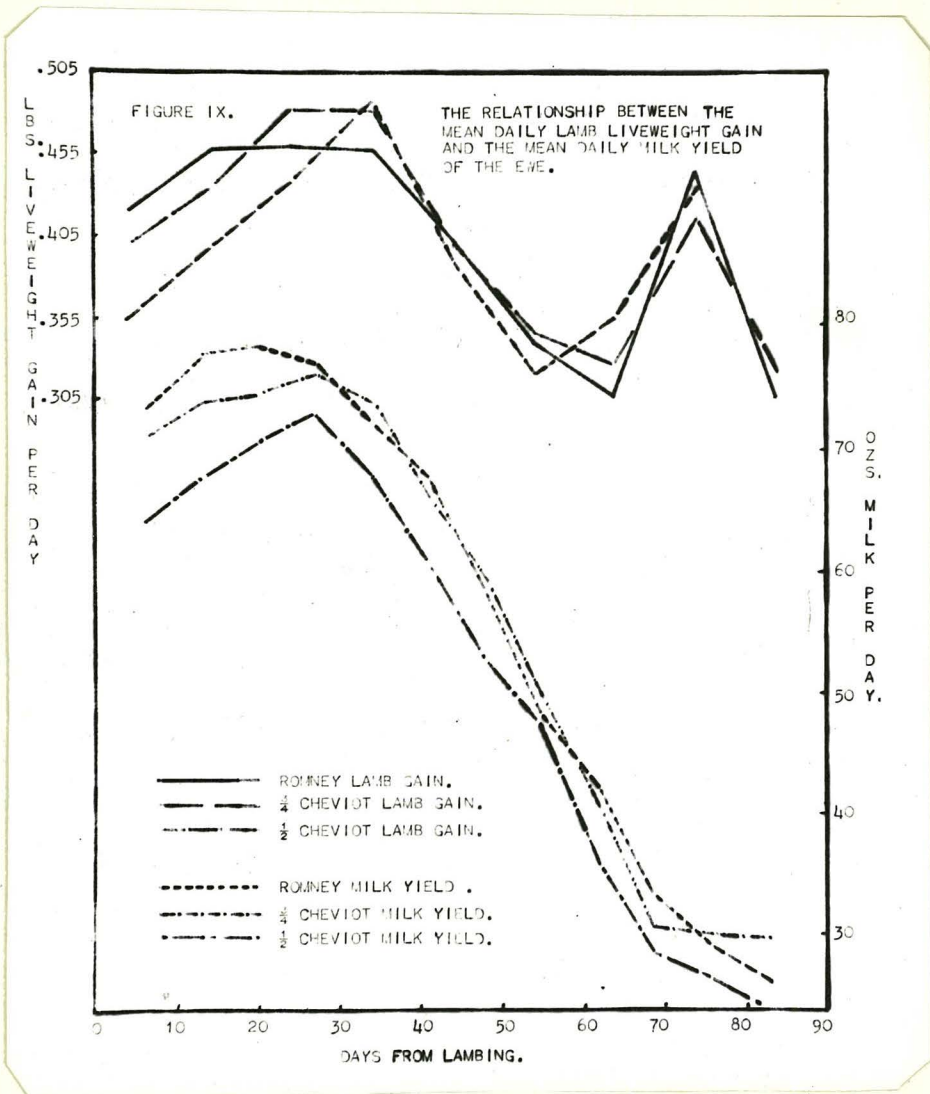
T A B L E - 36A

THE DIRECT EFFECTS OF SEX UPON 0 - 6 WEEKS  
LIVWEIGHT GAIN OF ROMNEY X S. D. LAMBS.

Birth Rank	Sex	No. of Lambs	Mean Birthweight lbs.	Mean gain lbs.	Mean gain (lbs) Adjusted for B/weight
Single	Male	17	12.59	25.06	23.23
Single	Female	17	11.18	23.84	23.71
Twin	Male	17	10.59	21.40	21.98
Twin	Female	17	9.94	18.47	19.82
<u>0 - 12 weeks gain</u>					
Single	Male	17	12.59	48.21	45.56
Single	Female	17	11.18	44.47	44.29
Twin	Male	17	10.59	41.50	42.80
Twin	Female	17	9.94	36.79	38.68

For two mean gains (adjusted) to differ significantly:  $\bar{X}_1 - \bar{X}_2$  must be  $> 2.02$  lbs.

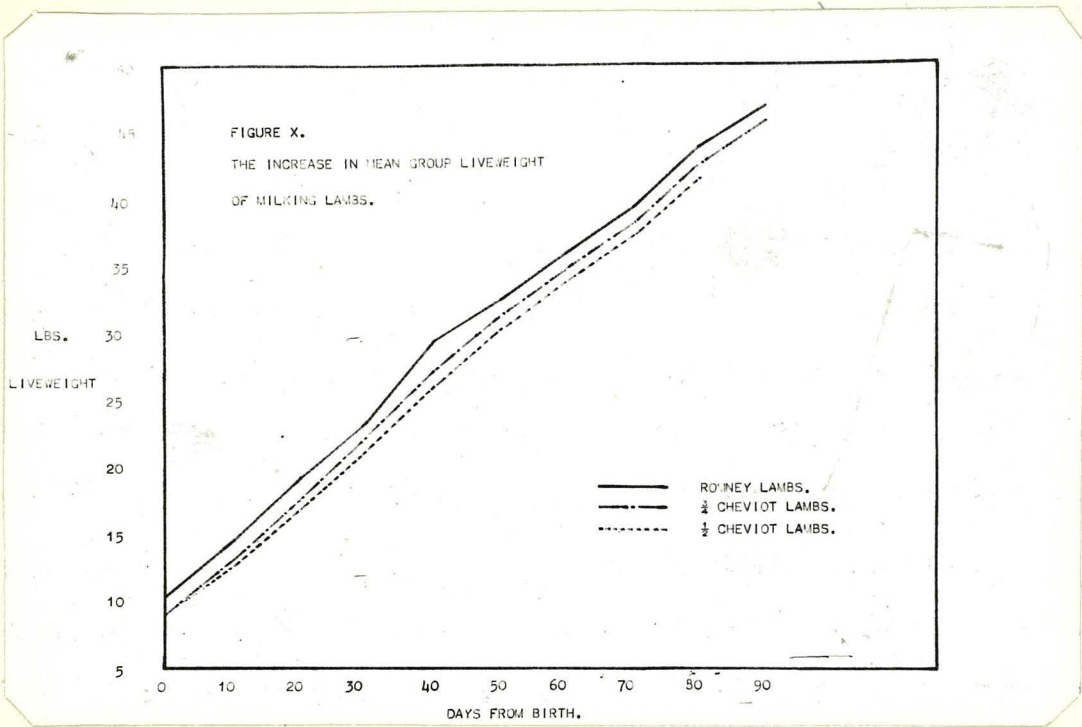
The tests of significance between the adjusted means (appendix, Table 4) show that when the groups are compared on equal birth weight basis, the direct effects of sex up to 6 weeks of age have not significantly differentiated the rates of liveweight gain. It seems probable that the abnormality of castration has disguised any superior growth rate potential in the male lambs. The division of male and female lambs into single and twin classes is made to overcome the added variation consequent upon the different amounts of milk available to lambs of differing birth ranks.



In the period 0 - 12 weeks, liveweight gains, and therefore growth rates of male twin lambs are significantly greater than those of female twins when on an equal birth weight basis. It is noticeable, however, that in the single classification, male and female lambs grow similarly when variation due to birth weight differences is eliminated. The possibility of an interaction between sex and the higher level of milk consumption of single lambs is apparent in the adjusted means for both 0 - 6 and 0 - 12 weeks since the advantage in growth rate exhibited by twin males has been vastly reduced in the single group.

If the relationship found for Romney lambs in Table 36, is applicable to the lambs of the three milking groups in Fig. VIIA, then the apparently greater growth rate exhibited by the male lambs is not only attributable to their greater birth weights. Because of smaller numbers the average daily growth curves for half Cheviot male and female lambs have not been included with those of the Romney and 3/4 Cheviot (Fig. VIII). Considering the Romney and 3/4 Cheviot curves, it is evident that both groups of male lambs show markedly superior average daily gains for at least the first 5 weeks of life, with the Romney males characterised by an initially higher rate than the 3/4 Cheviot males. This advantage is probably a function of the greater birth weight of Romney males (compared with Cheviot males), allowing them to make superior growth until the abnormal effects of castration cause a temporary levelling of growth rate. Thus the stimulating effect of superior birth weight will result in wether lambs attaining a greater size at 6 or 12 weeks than ewe lambs and consequently when the different breed milking groups growth rates are considered, the unequal numbers of like sexed lambs in the breed groups are to be allowed for.

Fig. IX shows these milking group average growth



curves for all lambs, average daily liveweight gains being estimated from the mean gain for a 10 day period. The characteristics of the different breed curves are the result of the combined action of the following factors -

- (1) Birth weight variation between breeds and sexes.
- (2) The variation in milk yield between breeds.
- (3) Sexual differences directly influencing liveweight gains; the normal differentiation being affected by the castration of the male lambs.
- (4) Variation in breed growth potential.
- (5) Chance variation, since the numbers of lambs considered are not large.

Because the mean birth weights of the Romney twins is greater than either the  $\frac{1}{2}$  or  $\frac{3}{4}$  Cheviots (Tables 32 and 32A), it is likely that this advantage has allowed them to reach their maximum daily gain earlier than the other groups. If liveweight is plotted against time for the milking lambs (Fig. X), it is seen how the differences in liveweight apparent at birth are maintained during later periods. Bonama (17A) has found that variation in weight at birth accounts for 16% of the variation in weight at 12 weeks. At birth the mean Romney birth weight is 10.29 lbs, i.e. 1.29 lbs. heavier than either the  $\frac{3}{4}$  Cheviot (9.00 lbs.) or the  $\frac{1}{2}$  Cheviot (9.01 lbs.). At 6 weeks of age the Romneys average 30.5 lbs. which is 2.00 and 3.25 lbs. greater than the  $\frac{3}{4}$  and  $\frac{1}{2}$  Cheviot respectively. The slight divergence of liveweight between Romney,  $\frac{1}{2}$  and  $\frac{3}{4}$  Cheviots can be attributed firstly to the greater birth weights of the Romneys and secondly to the fact that the Romney group had a preponderance of male lambs, the  $\frac{3}{4}$  Cheviots equal numbers of male and female, and the  $\frac{1}{2}$  Cheviot a greater number of females. (Though no significantly greater growth rate was found in Table 36 for Romney male twin lambs

from 0 - 6 weeks, there is a trend, which is found to be significant later, in the 0 - 12 weeks period.)

The fact that -

(1) the  $\frac{1}{2}$  Cheviot liveweight curve in Fig. X diverges from the  $\frac{3}{4}$  Cheviot curve (both groups of equal mean birth weight) and (2) the average daily gain curve of  $\frac{1}{2}$  Cheviots is markedly below that of the  $\frac{3}{4}$  Cheviots, (Fig. IX), suggests that the lesser quantity of milk consumed by the  $\frac{1}{2}$  Cheviot lambs has limited their increase in liveweight. Below the daily growth curves in Fig. IX, the mean group milk yield curves have been plotted. The similarity of these two curves during the first 7 weeks post-partum is apparent for each breed and verifies the strong relationship found by other workers between milk yield and lamb liveweight gain. It is to be noted that the true peak of daily lamb gain could fall on any day with the range of  $\pm$  ( $\frac{1}{2}$  the measurement interval) from the apparent peak.

### (3) Milk Yield

The correlations between lamb liveweight gains (bulked for each ewe) and the average milk yield in ounces per day for the respective periods, are presented for the various breeds in Table 37.

T A B L E - 37

CORRELATION LAMB LIVEWEIGHT GAIN (lbs.) AND  
MILK YIELD (ozs.)

Period	Romney	3/4 Cheviot	1/2 Cheviot	Total (Romney, 3/4 and 1/2 Cheviot)
Number of ewes	12	12	6	30
0 - 3 weeks	.741 **	.835 **	.103 N.S.	.355 (P = .061)
0 - 6 "	.762 **	.820 **	.142 N.S.	.652 **
0 - 9 "	.682 *	.797 **	negative N.S.)	.657 **
0 - 12 "	.641 *	.750 **	negative N.S.)	.570 **
0 - 3 weeks	.741 **	.835 **	.103 N.S.	.355 (P = .061)
4 - 6 "	.665 *	.745 **	negative N.S.)	.501 **
7 - 9 "	negative) N.S.)	.343 N.S.	.679 N.S.	negative N.S.
10 - 12 "	.158 N.S.	.605 *	negative N.S.)	.378 *

Because of the small size of the 1/2 Cheviot group it is not proposed to evaluate the significance of the anomalous correlations found in this group. Also the bulking of the various groups to give the "total" correlation is liable to cause a decrease in strength of the gain : milk yield relationship, if the ranges and means of the two characters differ markedly between breeds. Similarly the bulking of breeds may give a significant bulked breed correlation whereas the intra-breed correlations are all non-significant.

In the Romney and 3/4 bred Cheviot the strength of the correlation found in the 0 - 3 weeks period is largely maintained over the ensuing 0 - 6, 0 - 9 and 0 - 12 weeks periods. Wallace (18) also calculated these correlations and found a similar relationship. The method of considering 0 - 3, 0 - 6, etc. in lieu of 0 - 3, 4 - 6, 7 - 9 and 10 - 12, may however, conceal variations in the periods which are successively accumulated,

since a strong correlation in an earlier period may conceal a lesser relationship in a later period. Therefore an anomaly arises when the effect of the 7 - 9 week period is allocated solely to the difference in 0 - 6 and 0 - 9 weeks correlations. When the accumulated correlation (0 - 3 and 0 - 6 etc.) are considered they tend to disguise the disruption of the correlation found in the 7 - 9 weeks period (Table 37). This decrease in the milk consumption/lamb gain relationship is also apparent during the 7th - 9th weeks in Fig. IX where daily liveweight gain of all lambs tends to rise rather than follow the rapidly falling trend of milk yield.

In Fig. IX the drop in the daily liveweight gain from the period of maximum daily growth, follows closely the trend of milk consumption. Since the lamb is dependent almost wholly upon milk until about the 5th or 6th weeks, this relationship is not unexpected. However, as the capacity and ruminant function of the lamb's stomach increase, growth will be related increasingly to the amount of food, other than milk, which is consumed. It seems probable that the rise in daily lamb gain consequent upon the increased nutrient intake (from pasture), has caused the milk consumption/lamb gain relationship to disappear. Barnicoat et al (11) also found this 2nd peak of liveweight gain but with their lambs the peak and the following fall were not as pronounced. Why the Romney and 3/4 Cheviot lambs should exhibit this sudden decline in daily growth after an equally sudden increase is not apparent.

The return, in the 3/4 Cheviot and total groups, of the milk yield/gain correlation during the 10 - 12 weeks period, is probably only a function of variation in lamb gain in a similar direction to that in milk yield; not an indication of milk yield variation causing comparable variation in lamb growth.

The overall conclusion may therefore be reached that up to 6 weeks of age variation in the quantity of milk produced by Romney and 3/4 bred Cheviot ewes is strongly correlated with variation in the liveweight gain of the respective lambs. It was noted earlier that only the 1/2 Cheviot ewes differ appreciably from the Romney or 3/4 Cheviots in the amount of milk produced. It is important therefore, to see if the gains made by their lambs have conformed to this pattern. In Table 38 are presented the analyses of variance of the gains made by lambs of the different breed milking groups up to 6 weeks of age.

TABLE - 38

MILKING GROUPS MEAN LAMB LIVELWEIGHT GAINS  
0 - 6 WEEKS

	Romney (S.D.) lbs.	3/4 Cheviot (S.D.) lbs.	1/2 Cheviot (S.D.) lbs.
Wether lambs	19.2 4.02	20.6 6.05	18.8 5.59
Ewe lambs	18.8 2.87	18.7 5.51	17.6 3.28

ANALYSIS OF VARIANCE 0 - 6 WEEKS MILKING LAMB GAINS

(weighted squares of Means)

Source	df	S.S.	M.S.	F.
Breeds	2	1,659.80	829.90	1 N.S.
Sex	1	1,836.72	1,836.72	1.954 N.S.
Interaction	2	6,918.94	3,459.50	3.68 *
Error	51		939.88	

Apparently there are no significant differences between the breeds in the mean liveweight gains made from birth to six weeks. This conclusion is in contrast to the mean birth weights of the breed groups where the Romney male and female lambs are larger than either of the similarly weighted Cheviot groups (see Table 39).

T A B L E - 39

MEAN BIRTH WEIGHTS (lbs.) OF LAMBS IN MILKING GROUPS

	Romney	3/4 Cheviot	1/2 Cheviot
Male	10.67 (15)	9.25 (12)	9.20 (5)
Female	9.65 (9)	8.75 (12)	9.00 (7)

Since it has been shown that birth weight is significantly correlated with gain to 6 weeks then it would seem that the order of liveweight gains (Table 38) should conform to the birth weight placings. However the trend of gains to 6 weeks does not conform to this, showing that other factors have helped in producing the apparent variation. The fact that the 1/2 Cheviot gains tend to be less than those of the 3/4 Cheviots suggests that the amount of milk consumed is more important than birth weight in determining the gain to 6 weeks. Another factor to be considered is that the lambs of the different breeds may have differed in the extent to which their normal growth function was disturbed by the treatment received each week at milking. Similarly the ewes' milk yields may have been effected.

Table 38 shows that in both sexes the mean gains for Romney and 3/4 Cheviots are very similar but that the variability (standard deviation) of the 3/4 Cheviots is greater, though not significantly, than that of the Romneys. Since we have found earlier that the 3/4 Cheviot exceeds the Romney in milk yield, ewe liveweight and lamb birthweight variabilities, then lamb gain, which is affected by all these, should exhibit some consequent variation.

So far the components of the lambs liveweight at 6 weeks of age have been considered. Since this age is physiologically important in the life of a lamb, being the period when the digestive system changes from simple to ruminant function,

it is relevant to consider the liveweights of the lambs at this stage. Table 39A shows the mean liveweights of the various groups of milking lambs at 6 weeks of age.

T A B L E - 39A

MEAN, MILKING GROUP LAMB LIVEWEIGHTS(lbs.)  
AT 6 WEEKS

	Romney	(S.D.)	3/4 Cheviot	(S.D.)	1/2 Cheviot	(S.D.)
Wether lambs	29.93	3.96	29.80	3.65	27.90	3.23
Ewe Lambs	28.50	2.86	27.36	3.58	26.57	2.43
"t" tests show no significant differences, within sexes, between any of the breeds.						

The difference that exists between the breed means would seem to be the result of the combined action of variation in ewe milk yield, lamb birth weight and unknown factors.

Milking Ability of the Romney Strains  
as measured by Lamb Growth.

Both Barnicoat, Logan and Grant (11) and Wallace (18) have suggested that the liveweight gain of lambs from 0 - 6 weeks gives a reasonable estimate of the relative level of the ewe's milk supply in that period. This relationship (correlation) has been confirmed for both Romney and 3/4 Cheviot ewes and lambs in this experiment. Accordingly, in order to detect any marked differences existing between the milk yields of the three Romney strains, a comparison of their lambs' mean liveweight gains, to 6 weeks of age, has been made (see Table 39B).

T A B L E - 39B

ROMNEY STRAINS MEAN 0 - 6 WEEKS LIVELWEIGHT GAINS (lbs.)

	Strains	W.	S.	T.
Single	{ Wether lambs	25.40 (10)	25.50 (5)	25.60 (5)
	{ Ewe Lambs	24.25 (2)	21.65 (8)	25.69 (8)
Twins	} Wether lambs	22.38 (12)	19.25 (4)	19.50 (1)
	} Ewe Lambs	16.91 (6)	18.83 (6)	20.71 (7)
(Numbers/group in brackets)				

ANALYSIS OF VARIANCE OF ROMNEY STRAIN  
MEAN 0 - 6 WEEKS LIVELWEIGHT GAINS -  
Modified Method of Fitting Constants

Source	df	S. S.	M. S.	F
Breeds	2	409.98	204.99	1 N.S.
Sex	1	654.16	327.08	1 N.S.
Birth Rank	1	3,366.54	3,366.54	1.60 N.S.
Error	69	144,784.84	2,098.33	
(Interaction assumed absent)				

Since it was found earlier that twin lambs give a more reliable estimate of a ewe's maximum milk yield potential then the liveweight gains of twin lambs (in Table 39B) should give a more accurate indication of alleged differences existing between the milk yields of the respective strains. The analysis in Table 39B shows that there are no significant differences between milk yields of strains, sexes and birth ranks. There are, however, certain qualifications which must accompany any inference from the findings of this analysis. The first of these is that the lack of significant differences between mean birth weights of the respective groups (Table 34) is no sure indication that the effect of the respective birth weights upon the subsequent liveweight gains, have been equal in the various groups. To

eliminate this variation it would be most appropriate to use a covariance technique reducing all liveweight gains to an equal birth weight basis and then determine if the adjusted mean gains in the strains differed. Because of the unequal numbers of lambs in the twin subclasses, covariance has not been attempted. Secondly, the analysis of variance (Table 39B) shows that the method of utilising liveweight gain as an indication of relative milk yield has not been very accurate in this instance since the established difference between the milk yields of single and twin bearing ewes has been evidenced as a non-significant difference by the 0 - 6 weeks gains of single and twin lambs. That this is a function of the small numbers or large variation in subgroups seems likely. In view of these restrictions it is not possible to suggest that the lack of significant difference between strain 0 - 6 weeks mean gains is indicative of an approximately equal mean yield of milk in the strains.

#### Lamb Liveweight Gain to 12 weeks of age

##### (a) Milking Groups

It has been found that the gain from 0 - 12 weeks of age, is less correlated with lamb weight at birth and the milk yield of the ewe, than the gain from 0 - 6 weeks. (Note that the difference between 0 - 6 weeks and 0 - 12 weeks correlations should not be attributed solely to the 7 - 12 week period, see back.) Because of the reduced dependence upon the quantity of milk consumed, gain from 0 - 12 weeks may be taken to indicate in part the ability of the lamb to utilise pasture nutrients as a material of growth. Table 40 shows the milking group mean 0 - 12 week gains.

T A B L E - 40

MILKING GROUP, MEAN LAMB LIVELWEIGHT GAINS (lbs.)  
0 - 12 WEEKS

	Romney (S.D.)	3/4 Cheviot (S.D)	1/2 Cheviot (S.D.)
Wether Lambs	35.4 4.06	37.8 6.06	35.5 5.58
Ewe Lambs	34.1 2.87	34.3 5.50	33.6 3.28

ANALYSIS OF VARIANCE OF MILKING LAMB 0 - 12  
WEEKS MEAN LIVELWEIGHT GAINS

Source	df	S.S.	M.S.	F
Sex	1	2,026.41	2,026.40	2.16 N.S.
Breed	2	1,845.50	922.83	1 N.S.
Interaction	2	6,918.94	3,459.51	3.68 *
Error	51		939.88	

This analysis shows that when lamb gains from birth to 12 weeks are compared the lambs in the different milking groups exhibit no significant differences. The means, while not significantly different, show differences which are contrary to those exhibited in Table 38 for the 0 - 6 week gains. These changes are due to the slightly greater rate of gain made by the 1/2 Cheviot and 3/4 Cheviot lambs in the period 7 - 12 weeks, see Table 41 and Fig. IX.

T A B L E - 41

MEAN LAMB LIVELWEIGHT GAINS (lbs.) 7 - 12 WEEKS

	Romney	3/4 Cheviot	1/2 Cheviot
Wether	16.2	17.2	16.7
Ewe	15.3	15.6	16.0

It will be noticed that in Fig. IX. the mean daily gain curve for the 1/2 Cheviots commences to rise to the second

peak before that of either the Romney or  $\frac{3}{4}$  Cheviot. This superiority in the 6 - 12 weeks period is consistent with the fact that the  $\frac{1}{2}$  Cheviot lambs have been receiving a milk supply less than that required for maximum growth, for Hammond (4) has stated, "that circumstances causing a retardation of growth temporarily, are followed by period of accelerated growth." The new-found ability of the lambs to utilise nutrients from pasture will remove the growth-limiting effect of sub-optimum milk yield and allow the lambs growth curve to accelerate. Most probably the sub-optimum milk yield will cause the  $\frac{1}{2}$  Cheviot lambs to seek a supplement to their milk diet before the lambs in the other groups, and accordingly their daily growth should respond to this supplementation before those of the other breeds. This relationship seems to exist in Fig. IX.

Since we have examined the components of the various breed liveweights from 0 - 12 weeks of age it is pertinent to present the mean figures for the actual liveweights at 12 weeks. These are shown in Table 42.

T A B L E - 42.

MEAN LIVEWEIGHTS (lbs.) AT 12 WEEKS OF ALL MILKING LAMBS

	Romney	$\frac{3}{4}$ Cheviot	$\frac{1}{2}$ Cheviot
Wether	36.07	37.05	34.70
Ewe	33.75	33.05	32.60

These weights have not been statistically analysed, firstly because weight at 12 weeks is neither physiologically nor economically important in itself and secondly because each of the components of this figure has received discriminate treatment. Here, as in the liveweight at 6 weeks, the combined effects of variation in ewe milk yield, lamb birth weight, lamb intake of pasture nutrients and chance, have resulted in the small liveweight

differences apparent between breeds of lambs.

(b) Romney Strains

The mean 0 - 12 week gains for the Romney strains are shown in Table 43 along with the analyses of variance.

T A B L E - 43  
ROMNEY STRAIN 0 - 12 WEEK MEAN LIVELWEIGHT  
GAINS (lbs.)

Strains		W.	S.	T.
Single	{ Wether lambs	48.60 (10)	48.60 (5)	48.70 (5)
	{ Ewe lambs	43.75 ( 2)	46.06 (8)	42.50 (8)
Twin	{ Wether lambs	43.50 (12)	36.00 (1)	36.89 (4)
	{ Ewe lambs	35.50 ( 6)	37.36 (7)	38.59 (6)

ANALYSIS OF VARIANCE OF 0 - 12 WEEK ROMNEY  
STRAIN LIVELWEIGHT GAINS

(Modified Method of Fitting Constants)

Source	df	S.S.	M.S.	F.
Breeds	2	45,822.07	22,911.03	5.57 **
Sex	1	31,540.82	31,540.81	7.67 **
Birth Rank	1	85,388.63	85,388.63	20.76 **
Error	69	283,787.25	4,112.86	

"t" tests to determine which strain produced the greatest liveweight gain from 0 - 12 weeks showed that -

(1) S. ewes produced lambs with 0 - 12 week liveweight gains greater than those of either W. or T. ewes' lambs.

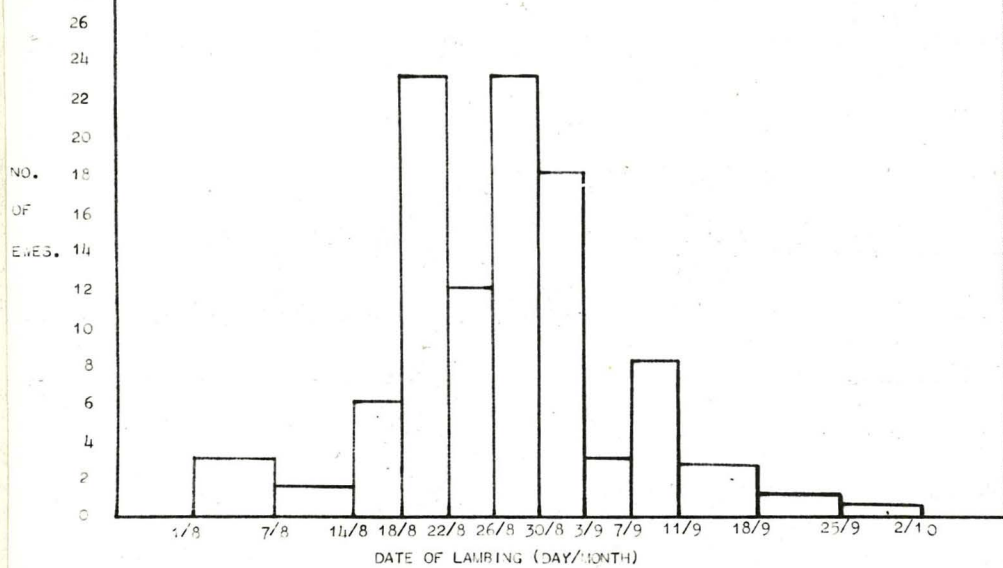
S. Lambs      W. Lambs     $t = 1.955$      $p = .06$     69 df.

S. Lambs      T. Lambs     $t = 3.296$      $p = .01$     69 df.

(2) W. and T. ewes produced lambs with similar 0 - 12 weeks liveweight gain.

W. : T. Lambs       $t = 1.349$      $p = .19$     69 df.

FIGURE XI.  
THE FREQUENCY DISTRIBUTION OF LAMBING DATES.  
(ALL EWES)



The method of fitting constants used in the above analyses of variance, allows for chance variation when there are small numbers of lambs in some sub-groups (see Table 43). Such variation is liable to obscure the relative merits of a group's performance and consequently the mean weights given for sub-groups in Tables, 34, 39 and 43 must be evaluated in conjunction with the appended size of the sub-group. Since covariance cannot easily be applied to the strain sub-groups, containing as they do, unequal numbers of lambs, it is only possible to show the apparent cause of the superiority exhibited in 0 - 12 weeks gain by the S. lambs. These lambs do not have any marked birth weight or 0 - 6 weeks liveweight gain advantage. They can be shown (Table 44) to have made greater gains in the period 6 - 12 weeks than the T. lambs.

TABLE - 44

6 - 12 WEEK LAMB LIVELWEIGHT GAIN MEANS (lbs.)  
ROMNEY STRAINS

		W.	S.	T.
Single	Wether lambs	23.20 (10)	23.10 (5)	23.10 (5)
	Ewe lambs	19.50 (2)	24.41 (8)	16.81 (8)
Twin	Wether lambs	21.12 (12)	16.75 (4)	17.93 (1)
	Ewe lambs	18.59 (6)	18.53 (6)	17.88 (7)

Lamb Growth and Date of Lambing

Variation in lamb growth rate due to lambs being born at different times in the season has been considered negligible. This assumption is made because 96% of all ewes lambed within mid-lambing (27th August)  $\pm$  11 days. Fig. XI shows the spread of lambing throughout the season. No tendency was observed for any of the ewe groups to lamb consistently before or after the majority of ewes (i.e. the mean lambing date).

The Energy & Fat content of Milk in Relation to Lamb Growth.

In Part III it has been found that the 3/4 Cheviot ewes produce milk which is significantly richer in fat than that produced by Romney ewes. Since, however, the mean quantities of milk produced by these groups are very similar then the yields of fat and energy are likely to differ between the breeds. Table 45 shows the mean group yields of fat and energy for the first 6 and 12 weeks of lactation, together with the respective analyses of variance.

Energy This was estimated in large calories (1000 Calories being equal to 1 therm.) The formula for converting milk of known fat % to these units was that proposed by Overman and Sanmann and modified by Gaines (71)., i.e.

$$E = 52.312 M (2.5064 + f)$$

where E = the energy value of the milk in Calories

M = weight of milk in pounds

f = percentage of fat in the milk.

The use of this formula, derived initially for dairy cattle, to express the energy value of ewe milk, was substantiated by Pierce (16B). The 0 - 12 week yield was that estimated by weekly milk and fat measurements from the 4th to the 87th day of lactation inclusive; or from the 4th to the 45th day inclusive for the 0 - 6 weeks yield.

Fat Fat yield is expressed as total ounces for the 0 - 12 and 0 - 6 weeks of lactation, commencing for each ewe on the 4th day post-partum and ending on the 87th and 45th day respectively. If the sampling day did not fall exactly on the 4th day of a week, then the fat % recorded was still taken to be the average test for that week.

In both Table 45A and 45B and the respective analyses

of variance, there are 12 ewes in each of the Romney and 3/4 Cheviot groups and six in the 1/2 Cheviot. All ewes are paired in the Romney and 3/4 Cheviot groups for similar date of parturition.

T A B L E - 45

A. MEAN TOTAL ENERGY YIELDS OF MILKING GROUPS (Calories)

	Romney (S.D.)	3/4 Cheviot (S.D.)	1/2 Cheviot (S.D.)
0 - 6 weeks	80,331 6,871	85,565 10,243	77,415 10,854
0 - 12 "	129,137 11,969	135,275 14,875	120,263 15,090
7 - 12 "	48,806 -	49,710 -	48,848 -

ANALYSIS OF VARIANCE OF ROMNEY and 3/4 CHEVIOT  
0 - 6 ENERGY YIELDS

Source	df	S. S.	M. S.	F.
Total	23	1,836,687,490		
Ewes	1	164,399,942	164,399,942	3.526 N. S.
Breeds	1	687,300,438	687,300,438	14,651 **
Error	21	984,987,110	46,904,148	

"t" test 0 - 6 weeks energy yield :

Romney and 1/2 Cheviot "t" = 0.35 N.S. with 16 df.

3/4 Cheviot and 1/2 Cheviot "t" = 1.39 N.S. with 16 df.

B. MEAN FAT YIELDS OF MILKING GROUPS (ozs.)

	Romney (S.D.)	3/4 Cheviot (S.D.)	1/2 Cheviot (S.D.)
0 - 6 weeks	169.2 13.2	184.8 25.1	157.5 (32.5)
0 - 12 "	275.3 27.5	294.1 31.7	227.9 (59.7)
6 - 12 " (0-12, minus 0-6)	106.1 -	109.3 -	70.4 -

ANALYSIS OF VARIANCE OF ROMNEY and  
3/4 CHEVIOT 0 - 6 WKS. FAT YIELD

Source	df	S. S.	M. S.	F.
Total	23	1,032,207		
Breeds	1	280,214	280,214	9.735 **
Ewes	1	145,392	145,392	5.033 *
Error	21	606,601	28,886	

"t" test 0 - 6 weeks - Fat Yield				
Romney - 1/2 Cheviot	t = 0.11	N.S.	with 16 df.	
3/4 Cheviot - 1/2 Cheviot	t = 1.09	N.S.	with 16 df.	

The analyses of Table 45 A and B show that the 3/4 Cheviot ewes produce more ounces of milk fat in the 0 - 6 week period than do Romney ewes. The conclusion therefore, that the energy value of the 3/4 Cheviot milk is greater in this period is also verified in Table 45. The importance of the fat fraction of milk to lambs has been discussed at length by Ritzman (52A and B) and Neidig and Iddings (15). Both conclude that as a constituent influencing the growth of the lamb, the fat % of milk is of no apparent importance. Ritzman asserts that milk fat functions as a growth stimulant and that it confers on the lamb the ability to both fatten and grow. The irregular pattern exhibited by the fat contents of the milks analysed by Ritzman may be in part attributed to the fact that he expressed his milk sample without the aid of a lamb-conditioned milk let down and only expressed a portion of the available milk fat present in the udder.

In this work, apart from variation due to climatic conditions, each ewe's fat percentage during her lactation conforms to a regular trend consequent upon the advance of lactation. Also the mean lactation fat percentages of ewes

within breeds tend to be grouped around a mean figure which differs between breeds. Ritzman (52) and Neidig and Iddings (15) have considered the fat percentage of milk, but it is possible that this criterion is not a true indication of a ewe's fat yield, i. e. the amount of fat consumed by the lamb. Table 45a shows that there is the tendency for milk yield and fat percentage to be inversely related to each other.

T A B L E - 45a

CORRELATION MEAN 0 - 12 WK. MILK YIELD (ozs.)  
PER DAY & MEAN FAT PERCENTAGE 0 - 12 WEEKS.

Romney ewes	-	.168	N.S.	10	df.
3/4 Cheviot ewes	-	.442	N.S.	10	df.

While these correlations (Table 45a) are not significant, they are sufficient to show that fat percentage is not proportional to fat yield. Accordingly the individual ewe fat and energy yields, the means of which are shown in Table 45, have been correlated with bulked liveweight gains of each ewe's lamb (Table 46).

T A B L E - 46

A. FAT YIELD & BULKED LAMB GAIN CORRELATIONS

	Romney	3/4 Cheviot	1/2 Cheviot
No. of ewes	12	12	6
<u>Period</u>			
0 - 3 weeks	.242 N.S.	.255 N.S.	negative N.S.
0 - 6 "	.402 N.S.	.301 N.S.	" N.S.
0 - 9 "	.428 N.S.	.445 N.S.	" N.S.
0 -12 "	.864 **	.457 N.S.	" N.S.
0 - 3 weeks	.242 N.S.	.255 N.S.	negative N.S.
4 - 6 "	.550 (P = .07)	Negative N.S.	" N.S.
7 - 9 "	-.630 *	.575 *	.598 N.S.
10 -12 "	.241 N.S.	.646 *	negative N.S.

B.

ENERGY YIELD & BULKED LAMB GAIN  
CORRELATIONS

	Romney	3/4 Cheviot	1/2 Cheviot
No. of Ewes	12	12	6
<u>Period</u>			
0 - 3 weeks	.257 N.S.	.473 N.S.	.563 N.S.
0 - 6 "	.587 *	.605 *	Negative N.S.
0 - 9 "	.464 N.S.	.342 N.S.	" N.S.
0 -12 "	.733 **	.565 (P = .065)	" N.S.
0 - 3 "	.257 N.S.	.473 N.S.	.563 N.S.
4 - 6 "	.093 N.S.	Negative N.S.	Negative N.S.
7 - 9 "	Negative N.S.	.550 (P = .07)	.05 N.S.
10 -12 "	.165 N.S.	.688 *	.323 N.S.

Fat yield being the product of fat percentage and milk yield should show some of the variation peculiar to milk yield. Since milk yield is strongly related to lamb gain during the first 6 weeks of the lamb's life (see back) then it is in this period that a milk fat lamb growth relationship is most likely. Disregarding the anomalous 1/2 Cheviot correlations, Table 4.6A shows that neither in the accumulated nor the separate correlations from birth to 6 weeks is there any significant relationship between fat yield and lamb gain. In the same period, energy : lamb gain correlations are only significant in the accumulated 0 - 6 weeks period. The only conclusion that can be reached therefore, is that the total energy value of milk from birth to 6 weeks is significantly related to the amount of liveweight gain made by the Romney and 3/4 Cheviot lambs. No evidence can be given for the nature of this relationship.

It is suggested, however, that components of the liveweight gain made from birth to six weeks are predominantly

muscle and bone, (Manyard (72) ). Since, therefore, the expression of food value in the form of energy or fat does not indicate its value to the lamb for the synthesis of these components, it is not surprising that energy or fat intake does not correlate as well with lamb growth as does the total intake of milk. As the major part of lamb growth immediately post-partum is comprised of protein as opposed to fat, it may be that the quantity of protein consumed in milk is more directly related to differential lamb growth. It is suggested that while the lamb can synthesise the non-nitrogenous fraction of protein from carbohydrate and fat, the limiting nature of certain amino acids or even total protein may be the qualitative link between milk and lamb gain.

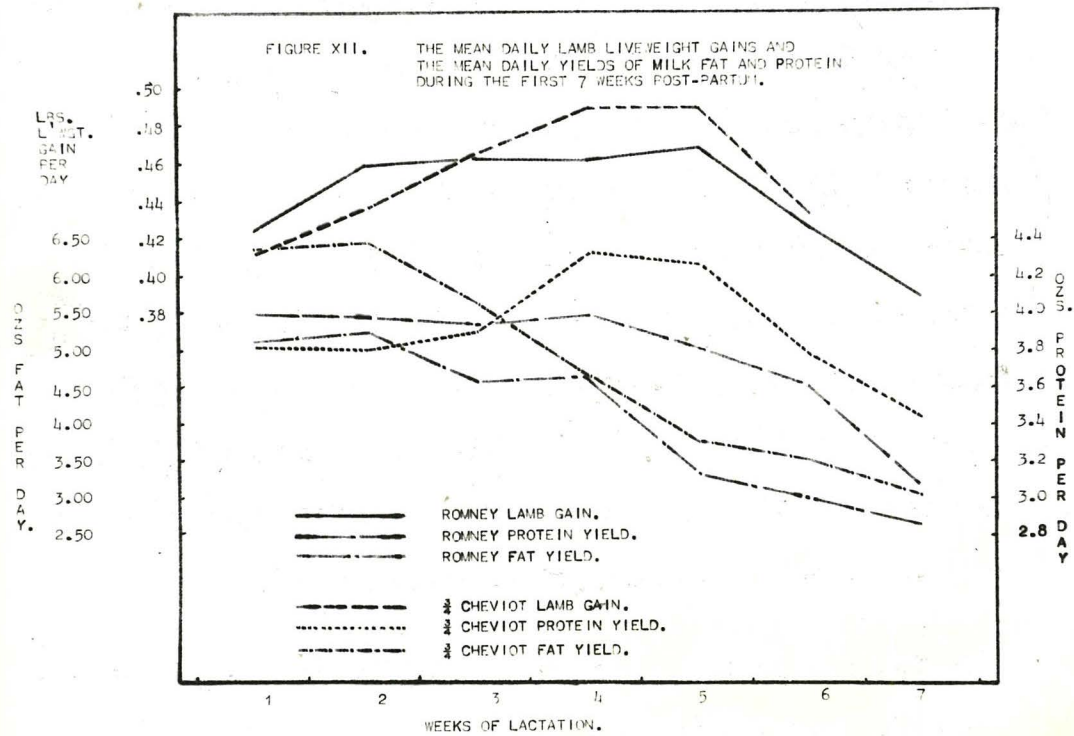
In this experiment no individual ewe milk protein analyses were made. The composite samples, however, were analysed for total protein (total N x 6.38) at weekly intervals. From these figures and the mean breed milk yield per week, the yields of protein etc. have been estimated for each breed. Table 47A shows the mean daily yield of protein per week for the first 7 weeks of lactation together with the mean daily liveweight gains for the same weeks.

T A B L E - 47

A. MEAN DAILY MILK PROTEIN YIELDS AND LAMB LIVWEIGHT GAINS PER WEEK FOR 1st SEVEN WEEKS OF LACTATION

	Mean daily Protein yield	Mean daily Lamb gains	Mean daily Protein yield	Mean daily Lamb gains
Weeks 1	3.97 ozs.	.433 lbs.	3.83 ozs.	.410 lbs.
2	3.92	.458	3.82	.435
3	3.79	.461	3.89	.464
4	3.93	.460	4.31	.489
5	3.78	.467	4.24	.489
6	3.57	.424	3.75	.431
7	3.09	.386	3.41	.386

FIGURE XII. THE MEAN DAILY LAMB LIVE-WEIGHT GAINS AND THE MEAN DAILY YIELDS OF MILK FAT AND PROTEIN DURING THE FIRST 7 WEEKS POST-PARTUM.



B. Table 47

CORRELATION MEAN DAILY LIVELWEIGHT LAMB  
GAIN & MEAN YIELDS OF MILK, PROTEIN &  
FAT ozs/day FOR THE FIRST 7 WEEKS OF  
LACTATION

	Gain : Milk Yield	Gain : Protein Yield	Gain : Fat Yield
Romney	.911 **	.840 *	.595 N.S.
3/4 Cheviot	.813 *	.936 **	.039 N.S.

Since protein yield is the product of milk yield and protein percentage, it is evident that the significant correlations found in Table 47B. are partly a function of the strong relationship between milk yield and lamb gain (also see Table 47B). If this is so, it is not valid to allocate undue importance to protein since other milk constituents exhibiting similar lactation variation would give similar correlations. The lactational trend of the other constituents (Figs. VI A - G) together with the percentage of each present in milk relative to protein, indicates that only fat could exert an effect comparable to that found for the total quantity of milk. But we have found that the fat content of the milk ingested by a lamb shows no apparent relationship to the lamb's daily growth (Table 47B).

It is therefore suggested that during part of the period of the lamb's life characterized by protein increment in contrast to fat deposition, the protein fraction of the ewe's milk exerts some significant influence on the amount of liveweight gain of the lamb, (Fig. XII). This problem could only be solved conclusively if the protein content of each ewe's milk was estimated throughout a lactation.

(4)

Lamb Growth to a "Killable" Weight

Since the relative value to the farmer of a breed of lambs is determined largely by the time taken to reach a 'killable' weight, then this measurement can usefully be compared for the breeds under consideration. Clarke (20B) has

stipulated that to yield the optimum-weighted carcass, Romney x Southdown lambs should have a liveweight of about 70 lbs. Assumedly the time taken by lambs to attain this weight will vary according to sex, birth rank etc. of the lamb. Lambs comparable for the above criteria, reaching 70 lbs. at widely different intervals from their respective births, will carry an amount of wool varying with the time taken to reach the killable weight.

To eliminate this variation, the weight of wool slipped from Romney x Southdown lambs at varying intervals during the season has been determined. The figures presented in Table 48 were obtained from a local freezing works in the 1951/52 season.

T A B L E - 48

WEIGHT OF DRY WOOL SLIPED FROM LAMBS KILLED  
ON THE STATED DATES

Date	Average lbs. wool/lamb.	No. of Lambs
15/12/51	2.20	27,000
22/12/51	2.40	20,000
1/ 1/52	2.60	14,000
8/ 4/52	2.84	41

The drafts of lambs recorded on the 15th and 22nd December and on 1st January were almost exclusively of Blackface woolly lambs (i.e. Romney x Southdown). The last draft, (8/4/52) was the tail end of lambs remaining from this experiment.

In view of these weights of wool, the following liveweights were specified as being indicative of "killable" condition.

<u>Lamb Liveweight</u>	<u>Period Considered</u>
70 lbs.	Before 15th December
70.5 lbs.	15th to 31st December
71.0 lbs.	After 31st December.

The liveweight that indicated "killable" condition therefore varied with the stage of the season. For example, if a lamb reached 70 lbs. before the 15th December, then 70 lbs. was the criterion of selection. If, however, it reached 70 lbs. on the 16th December, then 70.5 lbs. was the criterion. The weight on any day was estimated by interpolation from the weight at 10 to 14 day intervals. Table 49 shows the mean days to reach "killable" weight - (1) for single lambs, and  
(2) for twin milking lambs.

T A B L E - 49

A. AGE IN DAYS AT "KILLABLE" WEIGHT  
NON-MILKING SINGLE LAMBS.

	Ex Romney Ewes	Ex 3/4 Cheviot Ewes	Ex 1/2 Cheviot ewes
Wether Lambs	110.1 (19)	101.3 (3)	126.1 (8)
S.D.	18.7	7.0	29.1
Ewe Lambs	134.6 (19)	129.3 (4)	122.6 (5)
S.D.	35.1	12.1	18.3

(Numbers of Lambs/Group in brackets)

B. AGE IN DAYS AT "KILLABLE" WEIGHT  
MILKING TWIN LAMBS.

	Ex Romney Ewes	Ex 3/4 Cheviot Ewes	Ex 1/2 Cheviot Ewes
Wether Lambs	164.7 (15)	162.8 (12)	156.6 (5)
S.D.	35.0	40.7	18.8
Ewe Lambs	185.6 (9)	164.5 (12)	188.0 (7)
S.D.	54.9	32.8	24.0

(Numbers of Lambs/Group in brackets)

(A) ANALYSES OF VARIANCE                      SINGLES

Source	df.	S. S.	M. S.	F.
Sex	1	5,101.30	5,101.30	4.56 *
Breed	2	542.00	271.00	<1 N. S.
Interaction	2	1,990.22	995.11	<1 N. S.
Error	49		1,119.60	

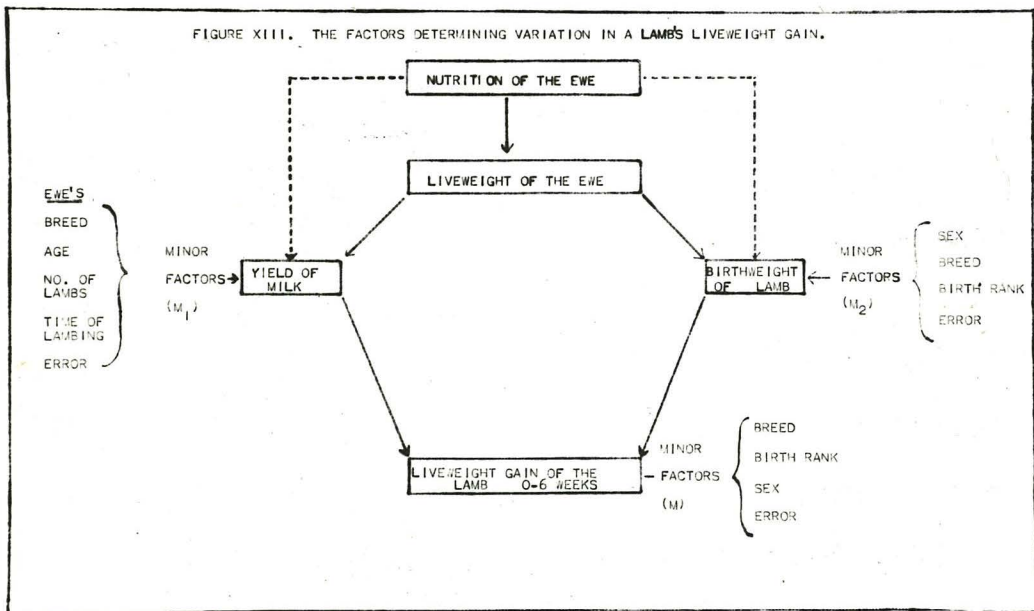
TWINS (Milking Lambs)

Source	df.	S. S.	M. S.	F.
Sex	1	3,044.42	3,044.42	2.07 N. S.
Breed	2	1,014.43	507.22	<1 N. S.
Interaction	2	2,020.82	1,010.41	<1 N. S.
Error			1,416.30	

Apparently there are no significant breed differences in the time taken to reach a "killable" weight. The small numbers in sub-groups in Table 45A, the growth retarding effects of the milking treatment (Table 45 B) and the influence of birth weight differences existing between breeds, have all tended to reduce any existing true differences to a minimum. The significant sex differences seen in Table 49A are consistent with the greater birth weight of the male lambs (see back, Table 32).

Because of the conflicting nature of the variables enumerated, these variables, must, on this occasion, be considered as part of the respective breeds ability to grow, and consequently it may be concluded that no breed shows a consistent advantage in the time taken to reach a "killable" weight.

FIGURE XIII. THE FACTORS DETERMINING VARIATION IN A LAMB'S LIVEWEIGHT GAIN.



GENERAL DISCUSSION.

One of the evident findings of this study is that the various factors affecting the growth of lambs are interrelated. While the milk consumed by the lamb is apparently the most important of these, its true value relative to the other determinants, is not known as long as the effects of each are combined. In order to estimate their relative separate value, a diagrammatic plan of factors affecting the liveweight gain of a lamb has been constructed, see Fig. XIII.

Since milk exerts a profound influence on the lamb's liveweight gain early in its life, only the first 6 weeks after birth have been considered. Fig. XIII shows that 5 main factors determine the amount of liveweight gain made by the lamb. These may be divided into 2 classes -

(1) enumerative factors, which limit the lamb to one of a few types such as sex, lambs being either males or females; and birth rank or breed, and

(2) measurable factors which vary from lamb to lamb, viz: quantitative milk consumption and birth weight.

Because the enumerative factors are considered to be only functions of variation in milk yield and lamb birth weight, they have been grouped with error variation and termed the "minor factors" (M). Each of the measurable factors of lamb gain will now be considered.

The quantity of milk consumed by a lamb has been found to determine largely, the extent of the lambs growth. The milk yield of the ewe, will vary in response to factors conditioning its production and these also may be divided into enumerative and measurable groups. Breed, age, number of lambs, time of parturition and error, constitute the group of enumerative factors ( $M_1$ ) affecting the milk yield of a ewe. Nutrition, both pre- and post-partum, and the liveweight of the

ewe, are the measurable factors affecting milk yield. Wallace (18) has found that the quantity of milk produced by a ewe is predominantly determined by the ewe's liveweight and food consumption. In this work all the ewes were pasture fed and no measure of their nutrient intakes was made. Consequently, nutrition and the "minor" factors ( $M_1$ ) have been grouped together and will be contrasted with ewe liveweight as determinants of milk yield.

Similarly the birth weight of a lamb is determined by (1) enumerative factors comprising breed, sex and birth rank etc ( $M_2$ ), and

(2) measurable factors of which the ewe's liveweight and nutrition are the most important. As in the determination of milk yield, nutrition of the ewe has been grouped with the ( $M_2$ ) factors and this group will be contrasted with ewe liveweight. While the series of causes is now terminated, it must be realised that each factor shown in Fig. XIII has its respective assemblage of causes but they are beyond the scope of this investigation.

As is shown in Fig. XIII, all the main measurable factors, nutrition of the ewe, liveweight of the ewe, milk yield, lamb birth weight and lamb liveweight gain, are interrelated.

It is proposed to determine, from the correlations existing between them, some measure of their relative individual effects (excluding ewe nutrition) on the growth of the lamb.

Wright (78) proposed the method of "path coefficients" for determining the relative value of sets of interrelated factors. The coefficients express the degree to which variation of a given effect is determined by each particular cause. It has been found previously that only the  $3/4$  Cheviot ewes and lambs have given significant correlations between all the factors under

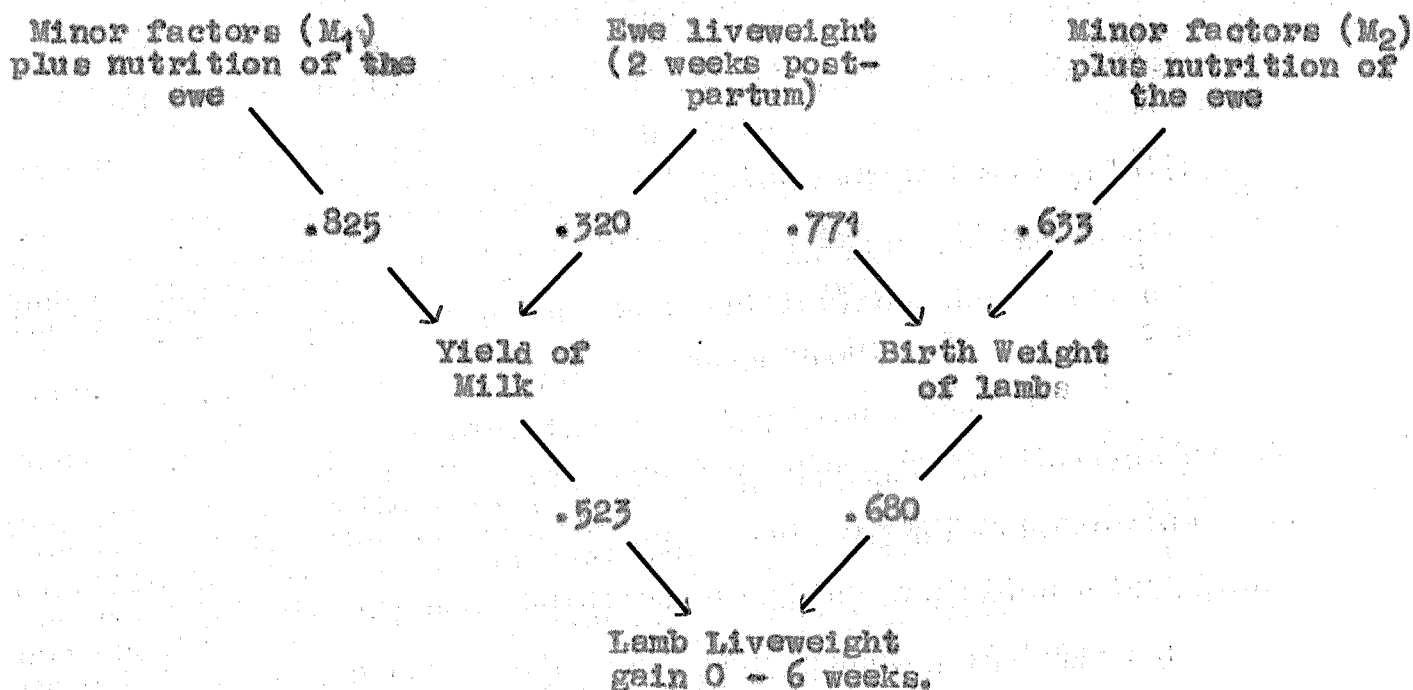
consideration. It is possible that the milking treatment has disguised the relationships in the Romney group and may have altered the true form in the 3/4 Cheviots. In spite of this qualification the correlations found for the 3/4 Cheviots have been assumed to indicate the true relationship existing between the determinants. Wright (78) in presenting the method, stresses that the coefficients are only mathematical functions and that the value of the analysis depends upon the validity of the graphical presentation of the casual relations.

It will be assumed that the graphical presentation in Fig. XIII does show the true situation and accordingly the values of the path coefficients shown in Table (50) are representative of the normal relationship between 3/4 Cheviot ewes and their lambs.

TABLE - 50

THE RELATIVE IMPORTANCE OF FACTORS AFFECTING  
3/4 CHEVIOT X SOUTHDOWN LAMBS LIVEWEIGHT GAINS  
FROM 0 - 6 WEEKS.

(Illustrated by Path Coefficients (24 Lambs & 12 Ewes))



It must be remembered that variation in the quantity of nutrients consumed by the ewe (pre-partum) will influence both the yield of milk and the birth weight of the lamb. The effects of milk yield and birth weight on lamb gain, though apparently separate, each contain a portion attributable to the effect of variation in pre-partum level of nutrition. If it is assumed that this effect is equal in both milk yield and birth weight, then it can be shown that the birth weight of the lamb was possibly more important as a determinant of growth (liveweight gain) than milk yield. The accuracy of this assumption, however, cannot be estimated because of the nature of the available data and consequently the greater apparent importance of lamb birth weight as a determinant of lamb growth is postulated with this qualification.

It is also shown that the liveweight of the  $\frac{3}{4}$  Cheviot ewe is more important than the bulked group of minor factors ( $M_2$ ) and level of nutrition in determining the birth weight of the lamb.

In the determination of milk yield the minor factors ( $M_1$ ) and nutrition, exert a much greater influence than does the liveweight of the ewe. It would seem that the individuality of the ewe was the main factor since the components of  $M_1$  (viz: age and number of lambs) and the level of nutrition, were equal for all the  $\frac{3}{4}$  Cheviot ewes; whether this individuality is of a true genetic or true environmental nature or even a function of an environmental-genetic interaction, cannot be determined from the present data.

.....

The  $\frac{3}{4}$  Cheviot and Romney ewes of this investigation have been considered representative of the 6 year old ewes which form their respective populations. No similar inference has been made concerning the  $\frac{1}{2}$  Cheviot ewes, however. That the  $\frac{3}{4}$  Cheviot

and Romney ewes produce almost equal quantities of milk is sufficient recommendation for the  $\frac{3}{4}$  Cheviot in itself, since the Romney ewe has previously been established as an excellent milker. Because of the disturbing effect of the milking treatment on the growth of the "milking" lambs, the small differences in growth exhibited by the respective breeds should not be taken as indicative of true differences existing between them. An alternative plan of experiment envisaging this effect would be necessary if the merits of the two breeds as producers of fat lamb were to be accurately determined.

It is suggested that the amount of protein in milk is the limiting factor to lamb growth in the first weeks of life. The determination of variation in individual ewe's milk protein would have to be measured in order to verify this.

In view of the apparent growth similarity of the  $\frac{3}{4}$  Cheviot and Romney lambs, the selection of the Cheviot to replace the Romney will depend upon finding some other character in which the  $\frac{3}{4}$  Cheviot is superior. The relatively greater prolificacy of the  $\frac{3}{4}$  Cheviots, resulting in a greater number of lambs being produced, per ewe, is one of the evident advantages exhibited by the Cheviot ewes. The resulting increase in immediate efficiency of fat lamb production is an aim of this type of farming where speedy "turn round" of stock is essential.

The problem of increasing the number of such Cheviot ewes can be accomplished either by crossbreeding from purebreds or by interbreeding the crossbreds. Since the first alternative entails the added maintenance of the purebreds, it seems likely that the fixing of an inbred crossbred (cf Corriedale) is the most logical course. That the advantage in prolificacy exhibited by the Cheviot crossbred is a function of its hybrid breeding and

would tend to be lost in the process of obtaining uniformity, can only be suggested, but to elucidate such problems the need for further investigation is felt warranted.

SUMMARY AND CONCLUSIONS

PART I

The liveweight variations of three groups of Romney ewes of different strains, one group of half bred Cheviot ewes and one group of threequarter bred Cheviot ewes have been traced from mating to the weaning of their lambs.

The T. Romney strain and the half bred Cheviots made marked body tissue increments during pregnancy and possibly to a lesser extent during lactation. This feature accompanying their relatively low initial liveweight, points to a previous subnormal level of nutrition.

The relative loss in body weight of ewes during lactation was found to be greater in those groups with a larger number of twin lambs. This is consistent with the finding that twin lambs condition a greater milk supply and therefore tend to deplete the ewe's body reserves more than single lambs.

The threequarter bred Cheviot ewes produced a greater percentage of twin lambs when mated to Southdown rams than either the mean of the Romney strains or any individual strain. The half Cheviot group did not exhibit any twin-bearing superiority though it produced more twin lambs than two of the Romney strains.

An anomalous autumn drop in liveweight was found in all groups of ewes and was possibly related to the toxic nature of ryegrass (Lolium perenne) white clover (Trifolium repens) pasture.

PART II

The quantities of milk produced during a 12 week lactation were measured for ewes of Romney,  $3/4$  Cheviot and  $1/2$  Cheviot breeds, all rearing twin lambs. A mean daily yield for the 12 weeks of lactation was calculated for each ewe in the milking groups. These mean lactation daily yields or indices were averaged for each breed and those of the Romney and  $3/4$  Cheviot groups were found to be very similar, the  $1/2$  Cheviot group being less than either of the former groups. The lower milk yield of the  $1/2$  Cheviots could in part be attributed to their lesser development, consequent upon a previous subnormal level of nutrition.

The variability of the milk indices of the  $3/4$  Cheviot group tended to be more than that of the Romney group. This diversity was considered to be due not to the genetic effect of crossbreeding, but rather to the lesser degree of artificial selection applied to the  $3/4$  Cheviots.

The mean lactation ewe liveweight and also the weight at 3 weeks post-partum were found to be significantly correlated with milk index in only the  $3/4$  Cheviot group. (Again the weights of the  $3/4$  Cheviot and Romney ewes exhibited similar means but widely diverse variances. The greater variability in liveweight found in the  $3/4$  Cheviot ewes was considered to be caused by the relatively lesser amount of selection applied previously to them.)

Birth weight of the lamb was found to be significantly correlated with the ewes subsequent milk yield again in only the  $3/4$  Cheviot group. The variability of the  $3/4$  Cheviot birth weights tended to be greater than that of the Romneys. The significant lamb birth weight - milk index and ewe liveweight - milk index correlations, have been attributed to the interrelation of these factors.

### PART III

The milk produced by the experimental ewes was analysed from composites taken at regular weekly intervals during a 12 week lactation. Romneys and threequarter Cheviots were found to differ significantly in the percentage of the following whole milk constituents - Total Solids, Solids-not-fat, Fat, and Protein. In all constituents the threequarter Cheviot percentage was the higher. Significant differences between the percentage of Total solids, Solids-not-fat and Protein were found between (1)  $\frac{1}{2}$  Cheviot and Romneys, and (2)  $\frac{1}{2}$  Cheviot and  $\frac{3}{4}$  Cheviot ewe milks for a 12 week lactation. Lactose, Ash, Calcium and Phosphorus were not found to differ between any of the breeds. The fat percentage of the milk produced by  $\frac{1}{2}$  Cheviot ewes was not significantly different from that expressed from either the Romney or the  $\frac{3}{4}$  Cheviot ewes. The milk produced by the Romney ewes was qualitatively similar to that reported by other workers for ewes of the same breed.

Adverse weather conditions, (rain) were assumed to have raised the percentage of total solids and fat in milk on two occasions.

It was found that fat variation between sampling days was much greater than that between ewes, indicating that variation in fat percentage is more readily effected by environmental agencies and inaccuracy of measurement than by variation in the ewes' physiological ability to produce milk fat.

The advance of lactation was found to influence significantly the percentage of each constituent in milk to a greater or lesser degree.  $\frac{3}{4}$  Cheviot ewes, similar to Romney ewes, produce little carotene in their milk fat but there tends to be more vitamin A in the fat than is present in dairy cow milk fat.

PART IV

The birth weights of all lambs were recorded and these indicate that Romney ewes mated to Southdown rams produce twin lambs significantly heavier than those produced by  $\frac{3}{4}$  Cheviot or  $\frac{1}{2}$  Cheviot ewes (insufficient single lambs available for comparison). It was also found that male and single lambs in the three breeds were significantly heavier at birth than female and twin lambs respectively. A comparison of birth weights of lambs produced by three groups of Romney ewes of different strains showed no significant strain differences. Male and single lambs were again heavier within these strains than female and twin lambs respectively.

The abnormal treatment received at milking served to disturb the correlation between birth weight and subsequent liveweight gain of the lambs. In the bulked Romney strain group, however, this correlation was highly significant for gain from birth to 6 weeks and birth to 12 weeks. The strain group had not been subjected to the milking treatment. When the liveweight gains of the Romney lambs (non-milking) were compared on an equal birth weight basis, it was found that the differential effects of sex were not apparent in the gain to 6 weeks of age. This can be attributed to the depressing effect of castration on the liveweight gain of male lambs. In the period birth to 12 weeks, however, the wether lambs (compared with females on an equal birth weight basis) showed significantly greater liveweight gains. It was concluded therefore that factors, in addition to greater birth weight, probably of an endocrine nature, have resulted in greater rate of growth in wether lambs.

The quantity of milk produced by the ewe was found to influence significantly the liveweight gains of the lambs in the first 6 weeks of life. This relationship was only found

in the Romney and  $3/4$  Cheviot groups since chance variation, consequent upon small numbers in the  $1/2$  Cheviot group, disguised the correlation. From 7 to 12 weeks of age the liveweight gain of lambs in the Romney and  $3/4$  Cheviot groups was found to be uncorrelated with the milk supply of the ewe.

The method of considering such correlations on an accumulative time basis was found to over estimate the strength of the milk - lamb gain relationship in the 7 - 12 weeks period. The combined effects of -

- (1) variation in birth weight between breeds and sexes
  - (2) variation in milk yield between breeds
  - (3) sexual differences directly influencing liveweight gains, and
  - (4) the disturbing influence on growth of the milking treatment upon the liveweight gains of the lambs of the milking groups,
- was found to condition no significant differences between breed liveweight gains from birth to 6 weeks of age. No differences were found for the same groups when birth to 12 week liveweight gains were considered.

To estimate relative milking ability between the Romney strains, a comparison of their lambs liveweight gains from birth to 6 weeks of age, was made. The lack of significant difference between any of the sub-groups of this comparison, (viz: sex, birth rank and strain) more especially birth rank, suggests that on this occasion, liveweight gains of the lambs were not an accurate measure of the ewes relative milk yield.

The quantity of fat or energy in the milks of the respective breeds over the 12 weeks of lactation have been calculated. The  $3/4$  Cheviot ewes, because of their higher milk fat percentage, have yielded significantly greater quantities of fat (and energy) in the period 0 - 6 weeks. The  $1/2$  Cheviot

ewe, while having a higher mean milk fat percentage for the period, have yielded less fat (and energy) because of the smaller quantity of milk produced from birth to 6 weeks. The difference in yield between the  $\frac{1}{2}$  Cheviot and the Romney and  $\frac{3}{4}$  Cheviot is, however, not significant.

The fat percentage of ewe milk tended to have a negative relationship to the quantity of milk produced by the ewe, indicating that fat percentage is not indicative of the quantity of fat yielded over a given period. Since the quantity of fat was considered more important in determining lamb growth, it was correlated with the amount of liveweight gain made by the respective ewes' lambs. In the period from birth to 6 weeks of age no relationship was found between the quantity of fat yielded by the ewe and the growth of her lambs. In the same period, however, an accumulated energy correlation was found significant in both  $\frac{3}{4}$  Cheviot and Romney groups. This finding can be considered as indicating a general relationship between the total calories consumed by the lamb and the increase in liveweight from birth to 6 weeks of age. It is suggested that any significant correlations between lamb gain and either fat or energy yield in the period 7 - 12 weeks, are indicative of variation in the two variables in the same direction and not of variation in fat or energy yield causing comparable variation in lamb liveweight gain.

A possible relationship between the amount of protein yielded in milk by Romney and  $\frac{3}{4}$  Cheviot ewes and their respective lambs' gains, was found.

A comparison of the age of lambs when considered to be of "killable" weight, showed that  $\frac{3}{4}$  Cheviot x Southdown lambs

took slightly less time to reach this weight than did lambs from Romney and  $\frac{1}{2}$  Cheviot ewes. These differences, however, were not found to be statistically significant.

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ABSTRACT

Romney and Cheviot Threequarter bred 6 year old ewes, all with twin lambs, were found to produce similar quantities of milk in a 12 week lactation.

The Cheviot halfbred ewes produced less milk than either the Romney or  $3/4$  Cheviot ewes but the disadvantage was not thought to be of an hereditary nature.

Both Cheviot groups of ewes gave significantly richer milk than the Romney group.

When mated to Southdown rams the ewes of the Romney and each Cheviot breed produced lambs which made similar liveweight gains.

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APPENDIX TABLE - 1

MILK YIELDS OZS./DAY, AT WEEKLY INTERVALS DURING LACTATION

Ewe No.	Mean Yield of Week												Milk Index (mean of 1-12 weeks)
	1	2	3	4	5	6	7	8	9	10	11	12	
Romney W. 18	85.5	69.5	67.0	63.5	55.0	63.5	60.0	46.0	56.5	37.0	26.5	21.0	54.3
W. 19	79.7	84.1	84.7	83.4	78.9	75.0	76.0	49.5	43.0	38.5	35.5	33.5	63.5
T. 73	71.5	82.0	84.0	83.0	83.5	70.0	54.5	41.0	29.0	27.5	24.0	22.0	56.0
W. 7	69.0	79.0	81.5	81.5	78.0	68.5	58.0	53.5	41.0	35.5	32.0	30.5	59.5
W. 13	82.0	80.5	84.5	81.0	72.5	77.0	65.5	64.5	47.5	32.0	42.0	40.5	64.1
T. 57	71.2	75.5	71.5	60.0	57.0	59.5	48.5	39.0	38.5	29.0	23.0	20.5	49.4
S. 103	71.0	83.5	74.0	74.5	62.0	65.0	52.0	37.0	47.5	27.0	18.0	21.0	52.8
W. 31	51.5	74.5	65.5	75.0	75.5	59.0	73.0	47.5	41.0	37.0	29.5	21.5	54.2
W. 11	64.1	68.0	81.5	82.5	80.5	73.0	62.5	63.0	42.0	37.5	32.5	26.5	59.5
W. 23	81.6	86.5	91.5	85.5	78.0	68.5	58.5	51.5	39.5	33.5	31.5	28.5	61.2
S. 116	81.1	86.0	94.5	95.5	89.0	75.5	64.0	58.5	46.5	44.0	40.0	31.5	67.3
W. 36	76.0	69.0	63.0	63.5	64.0	61.0	36.5	34.5	31.5	25.5	21.0	24.0	47.5

Appendix Table 1 (Contd.)

Ewe No.	Mean Yield of Week												Milk Index (mean of 1-12 weeks)
	1	2	3	4	5	6	7	8	9	10	11	12	
<u>3/4 Cheviots</u>													
315	58.2	58.5	45.5	47.5	57.0	59.5	52.5	45.5	47.5	34.0	18.5	22.0	45.5
314	52.5	51.0	51.0	51.5	55.0	50.0	59.0	36.5	35.5	28.5	23.5	31.0	43.8
320	68.0	79.0	85.0	92.0	88.5	81.0	65.0	59.0	40.5	31.5	31.5	29.5	62.6
304	74.0	90.5	91.0	100.0	83.5	83.0	75.5	61.5	47.0	23.0	25.0	28.0	65.2
323	61.5	58.5	69.0	67.5	77.5	68.0	55.0	44.5	36.5	21.5	21.5	24.5	50.5
303	68.5	68.0	79.0	79.0	70.0	68.5	47.0	45.0	32.5	10.0	28.5	27.5	51.9
306	85.0	91.5	85.0	87.5	77.0	65.5	63.0	53.0	38.0	36.0	40.0	35.5	63.1
311	83.5	94.0	84.5	81.0	78.0	66.0	50.0	38.5	38.5	42.0	40.5	36.5	61.1
302	75.6	76.0	79.5	79.5	77.0	68.5	60.5	46.5	32.5	25.0	22.5	25.5	55.7
319	68.2	68.5	70.5	75.5	73.5	67.0	68.5	59.0	45.0	39.5	38.0	36.5	59.1
325	60.2	60.5	72.0	73.5	71.5	65.0	59.0	56.0	42.5	34.5	33.5	30.5	54.9
312	97.0	94.5	86.5	84.5	83.0	55.0	61.5	59.0	56.0	49.5	43.5	43.0	67.8

Appendix Table 1 (Contd.)

Ewe No.	Mean Yield of Week												Milk Index (mean of 1-12 weeks)
	1	2	3	4	5	6	7	8	9	10	11	12	
<u>½ Cheviots</u>													
276	59.5	65.5	61.5	73.5	67.0	47.5	45.0	35.0	29.5	23.5	25.5	25.5	47.0
266	75.0	84.0	80.5	78.5	73.5	77.5	69.5	67.5	44.5	34.5	31.5	26.0	61.9
274	59.5	56.5	60.5	66.5	67.5	67.0	53.5	48.0	38.5	30.5	28.3	27.0	50.4
264	66.0	72.0	69.5	75.5	72.0	59.5	49.0	40.5	31.5	27.0	24.5	21.5	50.7
257	66.4	69.5	80.0	77.5	65.5	54.5	53.5	47.5	41.0	35.5	31.0	26.5	54.0

APPENDIX TABLE 2  
ANALYSIS OF BREED COMPOSITES

	26/8			1/9			8/9			15/9		
	R	3/4	$\frac{1}{2}$	R	3/4	$\frac{1}{2}$	R	3/4	$\frac{1}{2}$	R	3/4	$\frac{1}{2}$
Fat	6.55	8.60		7.1	9.10	7.4	6.40	8.35	7.05	5.5	7.0	6.0
Protein	5.39	5.61		5.36	5.25	4.99	4.70	5.30	5.20	4.94	5.44	5.18
Ash	1.06	1.07		.86	.84	.93	.89	.89	.88	.86	.85	.83
Lactose	4.05	3.82		3.79	3.94	4.60	4.56	4.33	4.18	4.53	4.38	4.53
T. S.	17.05	19.10		17.11	19.13	17.92	16.55	18.87	17.31	15.93	17.57	16.54
S. N. F.	10.39	10.45		10.01	10.03	10.52	10.15	10.52	10.26	10.43	10.57	10.54
CaO	.30	.31		.28	.30	.28				.27	.27	.29
P <sub>2</sub> O <sub>5</sub>	.36	.36		.32	.32	.33	.31	.32	.32	.33	.35	.34

Appendix Table 2 (Contd.)

## ANALYSIS OF BREED COMPOSITES

	27/10			4/11			10/11			24/11		
	R	3/4	$\frac{1}{2}$	R	3/4	$\frac{1}{2}$	R	3/4	$\frac{1}{2}$	R	3/4	$\frac{1}{2}$
Fat	7.6	7.15	7.4	7.1	7.2	6.15	5.35	5.7	5.2	5.8	6.5	7.2
Protein	5.18	5.80	5.4	5.66	5.76	5.90	5.79	6.21	5.66	5.84	6.28	5.93
Ash	.90	.92	.86	.90	.92	.86	.87	.89	.87	.96	.95	.94
Lactose	4.28	4.35	4.67	3.79	4.67	4.19	4.09	4.40	4.37	5.23	4.96	5.24
T.S.	17.96	18.23	18.34	17.45	18.55	17.10	16.10	17.20	16.10	17.83	18.73	19.31
S.N.F.	10.36	11.08	10.94	19.35	11.35	10.95	10.75	11.50	10.90	12.03	12.23	12.11
CaO	.28	.29	.28	.33	.33	.30				.33	.32	.31
P <sub>2</sub> O <sub>5</sub>	.35	.34	.33	.36	.35	.34				.39	.39	.39

Appendix Table 2 (Contd.)

ANALYSIS OF BREED COMPOSITES

	22/9			30/9			7/10			14/10		
	R	3/4	1/2	R	3/4	1/2	R	3/4	1/2	R	3/4	1/2
Fat	4.9	5.25	5.8	4.20	4.75	4.80	4.45	5.55	5.00	4.2	4.50	4.30
Protein	5.24	5.82	5.47	5.17	5.61	5.39	5.31	5.66	5.65	5.18	5.78	5.35
Ash	.86	.86	.82	.85	.86	.83	.89	.88	.86	.89	.88	.88
Lactose	4.64	4.55	4.54	4.67	4.79	4.82	4.88	4.92	5.03	4.74	4.76	4.92
T. S.	15.64	16.48	16.34	14.89	16.01	15.84	15.53	17.03	16.54	15.01	15.92	15.40
S. N. F.	10.74	11.23	10.74	10.69	11.26	11.04	11.08	11.48	11.54	10.81	11.42	11.10
CaO	.28	.27	.26	.29	.29	.27	.26	.28	.26	.27	.28	.26
P <sub>2</sub> O <sub>5</sub>	.34	.36	.34	.32	.35	.33	.35	.36	.34	.37	.37	.33

APPENDIX TABLE - 3

ANALYSIS OF VARIANCE OF CONSTITUENT PERCENTAGES  
OF ROMNEY, 3/4 CHEVIOT AND 1/4 CHEVIOT EWE MILK,  
SAMPLING AT WEEKLY, INTERVAL 14-DAY PERIODS;  
EACH CONSTITUENT (%) BEING FROM THE COMPOSITE  
SAMPLE OF EWES LAMBING WITH A STANDARD DEVIATION  
OF  $\pm 5.96$  DAYS FROM THE MEAN BIRTH DATE, RANGE  
OF BIRTH DATE  $\pm 7$  DAYS

(All data tested by Bartlett's Test (Snedecor 57)  
and found to be normally distributed.)

FAT - Romney and 3/4 Cheviot

Source	df	S.S.	M.S.	1%	F
Total	23	45.87			
Between breeds	1	4.73	4.73	9.65	14.33 **
Between sampling days	11	37.48	3.41	4.46	10.33 **
Error	11	3.66	.33		

PROTEIN - Romney and 3/4 Cheviot

Source	df	S.S.	M.S.	1%	F
Total	23	3.24			
Between breeds	1	0.95	.95	9.65	47.5 **
Between sampling days	11	2.02	.18	4.46	9.0 **
Error	11	.27	.02		

TOTAL SOLIDS - Romney and 3/4 Cheviot

Source	df	S.S.	M.S.	5% 1%	F
Total	23	39.86			
Between breeds	1	10.84	10.84	9.65	12.21 **
Between sampling days	11	28.15	2.56	2.82 4.46	3.24 *
Error	11	.87	.79		

Appendix Table 3 (Contd.)

PROTEIN % - Romney and  $\frac{1}{2}$  Cheviot

Source	df	S.S.	M.S.	5%	1%	F
Total	21	2.16				
Between breeds	1	0.13	0.13	4.96		5.91 *
Between sampling days	10	1.81	.181		4.85	8.23
Error	10	0.22	.022			
<u><math>\frac{1}{2}</math> and <math>\frac{3}{4}</math> Cheviot</u>						
Total	21	2.30				
Between breeds	1	0.35	0.46		10.04	2.30**
Between sampling days	10	1.75	.18		4.85	9.00**
Error	10	.20	.02			

TOTAL SOLIDS - Romney and  $\frac{1}{2}$  Cheviot

Source	df	S.S.	M.S.	5%	1%	F
Total	21	27.59				
Between breeds	1	2.20	2.20	4.96	10.04	11.52 **
Between sampling days	10	24.11	2.41		4.85	12.62 **
Error	10	1.91	.191			
<u><math>\frac{1}{2}</math> and <math>\frac{3}{4}</math> Cheviot</u>						
Total	21	29.13				
Between breeds	1	2.09	2.09	4.96	10.04	8.43 *
Between sampling days	10	24.56	2.46		4.85	9.92 **
Error	10	2.48	.248			

Appendix Table 3 (Contd.)

S.N.F. - Romney and 3/4 Cheviot

Source	df	S. S.	M. S.	5%	1%	F
Total	23	8.20				
Between breeds	1	1.20	1.20	4.84	9.65	8.00 *
Between sampling days	11	5.40	0.49	2.28	4.46	3.27 *
Error	11	1.6	.15			

FAT % - Romney and 1/2 Cheviot

Source	df	S. S.	M. S.	5%	1%	F
Total	21	28.01				
Between breeds	1	0.75	0.75	4.96		4.11
Between sampling days	10	25.43	2.54		4.85	13.88
Error	10	18.31	.1831			**
<u>1/2 and 3/4 Cheviot</u>						
Total	21	35.01				
Between breeds	1	1.15	1.15	4.96		3.97
Between sampling days	10	30.94	3.01		4.85	10.65 **
Error	10	2.92	.29			

APPENDIX TABLE 3 (Contd.)

SOLIDS-NOT-FAT - Romney and  $\frac{1}{2}$  Cheviot

Source	df	S.S.	M.S.	5%	1%	F
Total	21	6.11				
Between breeds	1	.48	.48		10.04	17.14 **
Between sampling days	10	5.35	.54		4.85	19.29 **
Error	10	0.28	.028			
<u><math>\frac{1}{2}</math> and <math>\frac{3}{4}</math> Cheviot</u>						
Total	21	6.30				
Between breeds	1	0.19	.19	4.96		5.00 *
Between sampling days	10	5.63	.56		4.85	14.74 **
Error	10	.38	.038			

APPENDIX TABLE - 4

COVARIANCE OF LAMB LIVELWEIGHT GAINS.  
MEAN GAINS ADJUSTED FOR BIRTH WEIGHT

1. 0 - 12 weeks; 68 Romney x Southdown Lambs.

Source of Variation	df	Sums of Squares & Products			Errors of Estimate		
		Sx <sup>2</sup>	Sxy	Sy <sup>2</sup>	SS.	df	M.S.
Total	67	239.64	560.99	4386.75	3073.49	66	
Sex - Birth Rank Combinations	3	<u>64.98</u>	<u>268.47</u>	<u>1185.96</u>			
Error	64	174.66	292.52	3200.79	696.05	63	11.05
					2377.44	3	792.48
					F = 71.72 **		

ANALYSIS OF ADJUSTED GAINS (FISHER (70) )

Source	df	SS.	M.S.
Error	63	696.11	11.05

Therefore differences between adjusted mean gains (see Table 36) required for significance is 2.024 lbs. at 5% level.

2. 0 - 6 weeks; 68 Romney x Southdown Lambs.

Source	df	Sums of Squares & Products			Errors of Estimate		
		Sx <sup>2</sup>	Sxy	Sy <sup>2</sup>	SS.	df	M.S.
Total	67	239.64	362.06	1798.92	1251.70	66	
Sex - Birth Rank Combinations	3	<u>64.98</u>	<u>152.05</u>	<u>429.88</u>			
Error	64	174.66	210.01	1369.04	<u>1116.53</u>	63	17.72
					135.17	3	45.06
					F = 1.54 N.S.		
					F.05, 3 & 63 df = 2.75		

APPENDIX TABLE - 5

ANALYSIS OF VARIANCE OF MEAN FAT %  
BETWEEN EWES, FOR 12 WEEKS OF  
LACTATION.

ROMNEY and 3/4 CHEVIOT (12 Ewes/group,  
paired for similar date of parturition)

Source	df	S.S.	M.S.	F
Total	23	6.94		
Ewes	11	2.14	.195	1.18
Breeds	1	2.98	2.98	18.06 **
Error	11	1.82	.165	
<p>"t." test : <math>\frac{1}{2}</math> and <math>\frac{3}{4}</math> Cheviots      12 - <math>\frac{3}{4}</math> cheviots  <span style="margin-left: 150px;">6   <math>\frac{1}{2}</math>      "</span></p> <p align="center">"t" = 2.18 * (16 df)</p>				
<p>Romney and <math>\frac{1}{2}</math> Cheviot : Means very similar</p>				