CONFIDENTIAL H.F.R.O. 182

HILL FARMING RESEARCH ORGANISATION

ANNUAL REPORT for the Year 1969

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(as at 1st January, 1969)

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STAFF CHANGES

Appointments:	Miss H. M. Thomas, B.Sc.(Agr.) - A.E.O. as from 1/8/69
	R. G. Bolton, B.Sc.(Agr.) - A.E.O. as from 1/8/69
	W. I. C. Lamb, H.N.C. - A.E.O. as from 1/8/69
	D. Suckling, H.N.C. - A.E.O. as from 1/8/69
	A. G. Lowe, B.Sc. - A.E.O. as from 8/9/69
	Miss B. Rudd, B.Sc. - A.E.O. as from 6/10/69
Resignations:	A. Currie - A.E.O. as from 31/3/69
	C. J. W. Torrance - A.E.O. as from 13/8/69

CONTENTS

Page

ANIMAL PRODUCTION

THE NUTRITION OF THE GRAZING SHEEP

GRAZING INFLUENCES ON VEGETATION AND SOILS

CONTENTS

PLANT-ENVIRONMENT INTERACTIONS

Page

SYSTEMS DEVELOPMENT

ANIMAL PRODUCTION

Early growth and lifetime production (R. G. Gunn)

In the Glensaugh experiment which was started in 1965, the responses to two levels of adult nutrition are being compared in ewes reared differentially from before birth to 12 months. In two age groups, high and low nutritional levels were imposed up to 12 months giving mean live weights of 38 kg compared with 27 kg and 50 kg compared with 32 kg. Half of each group was then transferred to the opposite treatment. The low plane adult treatment consists of one of the traditional hill systems, with mating and lambing on enclosed ground and some supplementation during late pregnancy and lactation. The high plane adult treatment consists of 0.2 acre/head of reseeded, fertilised pasture, plus 0.8 acre/head of rough heather and grass hill pastures, with considerable supplementation in late pregnancy and in lactation when necessary. Responses being compared are live-weight, life-time lamb production, and ewe survival.

The older age group have now produced three lamb-crops and the younger age group two. Mean interim results over the first two years were as follows:-

(Both age groups and two years pooled)

		HH	LH	HL	LL
Pre-mating weight (kg)	1st year	59	49	51	42
	2nd year	61	56	52	46
Number of ewes at lambing with	eild	1	8	12	9
	singles	37	41	53	59
	twins	62	40	32	15
	triplets	2	0	0	0
Lamb mortality to marking (no.)		14	18	29	20

At this stage of the experiment, in both adult environments, the ewes which had received high plane rearing produced significantly more lambs at birth; a result in keeping with their pre-mating live-weight advantage.

Over the first three lamb crops in the older age group, the high plane reared ewes maintained a significant advantage in the high plane adult environment but there was no difference in the low plane adult environment.

Conclusions from this experiment must await its completion.

Influence of variation in body condition on feed requirements for maintenance and liveweight change (A. J. F. Russel and J. M. Doney)

Results from a programme of research on the factors governing individual animal productivity in the hill environment indicate that the relatively small amounts of body fat found in hill ewes under traditional systems of management may be limiting production. Although some of the likely consequences of increasing the amount of body fat in hill ewes are fairly well understood, a number of important questions remain unanswered, e.g. What effect will increased fatness have on the maintenance requirements of the individual, and will it have any effect on the efficiency of food utilization? With these questions in mind, experiments were initiated to examine the relationship between body fat and feed requirements for maintenance and live-weight change.

The design of the first experiment was a 2 x 2 factorial in which feed requirements were measured in ewes in two body conditions (condition score 3; 29% fat in fleece-free empty body: and condition score 1.5; 16% fat in fleece-free empty body) and in two environments (outdoor pens and sheephouse at Glensaugh). Results relating to the environmental component of the study are presented elsewhere in this report. Constant restricted levels of intake, ranging from 6.5 to 26.5 g dried grass pellets/kg live weight/day, were fed to 84 Scottish Blackface ewes for a period of six weeks during early pregnancy (December and January). The standard technique of estimating food requirements from the regression of live-weight change on intake could not be used in this experiment as the increases in weight due to pregnancy were large in relation to the weight changes due to level of intake. The energetic cost of increases in intra-uterine weight at this stage of pregnancy are, however, negligible, and food requirements can be legitimately calculated, at least in relative terms, from the relationships between plasma free fatty acid concentrations and food intake.

In both environments the maintenance requirements of the fatter ewes were approximately 5% higher, per unit of live weight, than those of the thin ewes. This difference, of the order of 4% increase in maintenance requirements per 10% increase in body fat, was not statistically significant.

The second experiment was conducted in only one environment (the outdoor pens at Glensaugh) and was carried out using 48 non-pregnant Scottish Blackface ewes (24 in condition score 1.8 and 24 in condition score 2.8) during a period of six weeks in September and October. The technique was similar to that described above, intakes ranging from 5 to 27 g dried grass pellets/kg live weight/day, plus 100 g hay/head/day. Live weights were recorded twice weekly, and food requirements were calculated from relationships between rate of live-weight change and food intake. Quadratic relationships showed least deviation from regression in both groups, and gave estimates of maintenance requirements of 8.9 g DOM/kg live weight/day for the thin ewes, and 9.2 g DOM/kg live weight/day for the fat ewes. Estimates of maintenance requirements calculated from relationships between plasma free fatty acid concentration and level of intake indicated a similar difference (0.4 g DOM/kg) between groups. These differences, of the same order as that in the first experiment, were again statistically non-significant.

Although the results of these experiments show no statistically significant difference in maintenance requirements per unit of live weight between ewes in widely different body condition, it is perhaps noteworthy that in all cases the estimates of maintenance requirements of fat ewes were marginally higher than those of thin ewes. Plasma protein-bound iodine concentrations, which are considered to be an index of metabolic rate, ranked in the same order as the estimates of maintenance requirements in all instances, and in the second experiment were significantly higher ($p < 0.001$) in the fatter ewes (3.8 μg%, compared with 3.3 μg% in the thinner ewes). In earlier studies of differences in maintenance requirements between three breeds of sheep, it was noted that plasma protein-bound iodine concentrations ranked in the same order as maintenance requirements in each of three experiments.

As far as efficiency of food utilization is concerned, the results show quite clearly that at levels of feeding above maintenance, thin ewes use food more efficiently for live-weight gain than do fat ewes. Actual requirements calculated from results of the second experiment were of the order of 2.6 g DOM/ g gain in thin ewes and 4.2 g DOM/g gain in fat ewes, i.e. an increase of more than 60% associated with a 10% increase in body fat. This difference in apparent efficiency of food utilization for live-weight gain is almost certainly attributable to differences in the composition of the gain, which in the thinner ewes would be likely to contain a substantial proportion of muscular tissue (i.e. protein and water) and a small proportion of fat, whereas the gain in the fatter ewes would contain more fat and less muscular tissue. Had it been possible to measure energy storage, it is probable that little if any difference in efficiency of energy storage would have been found between groups.

The results of the studies reported above provide information on two factors which must be considered in advocating higher levels of fatness in hill ewes at certain times of the year, viz. (1) the food requirements to attain the higher levels of body condition, and (2) the costs of maintaining the increased live weight which improved condition implies.

<u>The influence of body condition on voluntary food intake</u> (Janet Z. Foot)

There have been reports in the literature of reduced voluntary food intake or inappetance in 'very fat' sheep. In contrast to this there have been indications of very high intakes of food by animals recovering from a period of undernourishment. These observations led to a study designed to examine the effect of body condition on voluntary food intake.

Thirty-six non-pregnant Blackface ewes were selected to give as wide a range of body condition as possible. Condition was assessed subjectively by lumbar palpation as described in last year's report (p.3 - Russel, Doney and Gunn). Twelve of the ewes had previously been offered hay and grass pellets ad libitum for 11 weeks and were in condition score 3 to $3\frac{1}{2}$. The other 24 ewes had been offered a restricted diet; 11 were comparable to the 12 described above (3 to $3\frac{1}{2}$), the rest, with two exceptions, had a score of 2 or less, 6 of these being less than $1\frac{1}{2}$. The range in liveweight was from 32 to 70 kg.

The ewes are at present penned individually in the sheephouse at Glensaugh and are being offered wafered dried grass ad libitum. Voluntary food intake is being measured daily for a period of six weeks. The sheep are weighed and scored weekly. The relationship between body condition and voluntary food intake will be examined.

Observations on the relationship between plasma free fatty acid concentration and food intake in sheep (A. J. F. Russel)

In a number of investigations concerning the determination of food requirements for maintenance and live-weight change in different breeds and classes of sheep, live-weight change has been used as the principal parameter. Plasma free fatty acid (FFA) concentrations have also been determined in these investigations with the object of studying the possible use of this parameter as an alternative means of estimating food requirements. A preliminary report on this work, which has been published, concluded that further studies were required to establish more precisely the statistical or mathematical nature of the response of plasma FFA concentration to change in level of food intake.

Recent experiments on the relationship between body fat and food requirements for mtaintenance and live-weight change, which are described in more detail elsewhere in this report, provided suitable material for a further study of the nature of the relationship between plasma FFA concentration and level of food intake.

In the first experiment 84 Scottish Blackface ewes in four groups were fed at constant restricted levels of intake ranging from 6.5 to 26.5 g dried grass pellets/kg live weight/day for a period of six weeks during early pregnancy. The food was offered once daily, and blood samples were collected on one day in each week immediately before feeding. Relationships between mean plasma FFA concentration for each sheep and various functions of food intake were computed within groups. Deviations from regression were least when the reciprocal of intake was used as the independent variate. Correlation coefficients between plasma FFA concentration and the reciprocal of intake ranged from 0.94 to 0.98 between the four groups.

In the second experiment 48 non-pregnant Scottish Blackface ewes in two groups were fed at constant restricted levels of intake ranging from 5 to 27 g dried grass pellets/kg live weight/day, plus 100 g hay/head/day, for a period of six weeks during September and October. Blood samples were again collected weekly before feeding. Correlations between mean plasma FFA concentrations and the reciprocal of intake were much poorer than in the previous experiment ($r = 0.77$ and 0.86). Although the reason for these poorer relationships is not apparent, the correlations are still highly significant, and the form of the relationship still provides a better fit to the data than other types of transformation.

The use of plasma FFA concentration as an index of nutritional state, and particularly of undernourishment, is now generally accepted. Further information on the nature of the relationship between plasma FFA concentration and level of intake will enable the degree of undernourishment measured by FFA's to be expressed more meaningfully in terms of food or energy deficits, an advance which could be of considerable benefit in many types of field study.

Variation in intake among group-fed Blackface ewes (Janet Z. Foot and A. J. F. Russel)

Ewes which are off-wintered or in-wintered are feeding in a confined area and are normally given restricted amounts of food. Under these conditions, which differ so greatly from those of their grazing environment, competition between animals may result in a large variation in food intake between individual sheep. Since the apportionment of the food is unlikely to be related to estimated requirements of the individual animals, sheep that are poor competitors may suffer undernutrition when they are group-fed. The effect might be more marked in Blackface sheep, which are usually territorial in behaviour, than it is in sheep which are adapted to a less extensive habitat.

The object of the experiment was to measure the variation in food intake among individual Blackface ewes in two group-feeding situations. Both groups consisted of 11 barren ewes with a similar weight and age distribution. Each group was kept in an outside pen with a slatted floor at Glensaugh; approximately 12 inches of trough space was allowed for each ewe. The sheep were fed once daily, those in group A on dried grass pellets (15g/kg liveweight) with a small amount (4g/kg dried grass, approx. 50 mm in length, and those in group B on chopped hay of a similar length (20g/kg liveweight) and 1.32 kg (120g/head) oat pellets containing chromic oxide. After 3 weeks of group-feeding the ewes were harnessed and total faecal collections were made during two consecutive 5-day periods. The concentration of silica in the faeces from animals of both groups and of chromic oxide in the faeces from animals in group B are currently being estimated, together with the concentrations in the food, by X-ray spectrometry (C. C. Evans). The results will be used to estimate the intake of oat pellets by individual animals in group B and the digestibility of the foods and hence the intake of each food by animals in both groups. Additional information on the apparent digestibility of known proportions of oat pellets and hay will be obtained from the results of a trial with 12 caged sheep at Fulford; these sheep were drawn from groups A and B after the group-feeding trial at Glensaugh had been completed.

The individual intakes of each animal will be related to studies of the behaviour of the sheep at feeding time and to liveweight changes noted during the group-feeding period.

The distribution and mobilization of body fat in Blackface ewes
(A. J. F. Russel, J. M. Doney and R. G. Gunn)

Earlier studies of the seasonal changes in body composition of free-grazing hill ewes provided evidence of a marked pattern in the distribution and mobilization of fat throughout the animal body. These studies, the results of which have been published, were carried out on animals in which the range of fatness was relatively small (11 to 18% of weight of fleece-free empty body), and it was considered that the subject was of sufficient interest and importance to merit further investigation.

Thirty Scottish Blackface ewes, in a much wider range of fatness (8 to 30% of weight of fleece-free empty body) were slaughtered to meet the requirements of another experiment. The bodies, excluding fleece and gastro-intestinal contents, were dissected and chemically analysed. The ewes came from two sources: 16 from Glensaugh and 14 from an Animal Breeding Research Organisation farm (Stanhope). Although the Glensaugh ewes were appreciably larger than those from Stanhope (approximately 10 kg heavier at comparable levels of fatness) there were no statistically significant differences between the two groups in the relationships between body condition score, percentage of fat in the fleece-free empty body, and distribution of fat throughout the various depots.

The results of the investigation agree closely with those of the previous study, confirming the general pattern of fat distribution and mobilization. However, the larger number of animals and wider range of body condition in this study allow greater confidence to be placed in the statistical relationships between the total amount of fat in the body and its distribution in the various depots. These relationships enable predictions to be made of the amounts of fat in the six principal depots from a knowledge of total body fat. This latter measurement can be estimated, with sufficient accuracy for many practical purposes, from body condition score, as outlined in a previous report and a recent publication.

The following table contains examples of the distribution of fat in sheep of varying fatness. Similar calculations for other sheep must be made from the original statistical relationships, and cannot be derived from the table, which is presented merely as an illustration of the use of such relationships.

Weights (kg) of Chemical Fat in the Principal Fat Depots in Sheep of Varying Fatness

Condition Score	1.0	1.5	2.0	2.5	3.0
Live weight (kg)	43.9	49.1	53.4	59.7	65.0
Fat in Muscular Tissue and Associated Fatty Tissue	1.4	2.0	2.8	3.7	4.6
Subcutaneous Fat	0.2	0.9	1.7	2.9	4.3
Bone Fat	0.7	0.8	0.8	0.8	0.8
Omental and Mesenteric Fat	0.3	0.7	1.1	1.8	2.5
Perirenal Fat	0.1	0.2	0.4	0.6	0.8
Remainder	0.9	1.2	1.5	1.8	2.2
Total Fat	3.6	5.8	8.3	11.6	15.2

The underlying relationships, from which the data in the table have been computed, also provide a measure of the rate of change in the amount of fat in each depot, per unit change in total fat. In every 100 g total fat gained or lost, the subcutaneous depot shows the greatest rate of change (42 g), followed by the muscular tissue plus associated fatty tissue (24 g) and the omental plus mesenteric fat (23 g). Perirenal fat (8 g) and that in the Remainder (i.e. skin, viscera and organs) (7 g) exhibit lesser rates of change. Skeletal fat, a depot with a relatively finite storage capacity, shows a small negative change (- 4 g) on a proportional basis, although, as can be seen from the table, this does not occur on an absolute weight basis.

Unsubstantiated statements have been made from time to time on the probability of a relationship between the ability of certain breeds of sheep to survive under adverse conditions, and the distribution of fat throughout their bodies. This study provides information on fat distribution in one reputedly hardy breed, but further studies on other breeds are required before any conclusion can be drawn on the existence of such a relationship.

Responses to climatic exposure

The energy cost of climatic stress in sheep has been evaluated mainly in the non-productive animal and in relatively short term experiments. Evidence of the long-term effect of climate, and specially of cooling conditions, on productive sheep is very limited. Important endocrine changes are known to occur in the cycling, pregnant, and lactating sheep and since the endocrine system is so closely linked with the heat production system it is likely that the climatic tolerances differ from those of the non-pregnant animal. Two experiments to look at the effect of climatic exposure at certain critical times in female sheep have been completed during the past year. We have looked firstly at the effect of cooling exposure on ovulation rates and embryo loss, and secondly, the response of the pregnant ewe to cooling and nutritional stress and also the long term effects of climatic exposure.

Effect of climatic stress on ovulation rate and embryo loss
(J. G. Griffiths, R. G. Gunn and J. M. Doney)

Recent work of the Organisation has shown the positive effect of nutrition and body condition at mating on ovulation rate in Blackface ewes. In the course of these and other studies there has been a suggestion that climatic factors may influence ovulation rate and embryo loss, and an experiment was designed to examine these factors.

Seventy B.F. draft age ewes were clipped, housed and fed pelleted dried grass at a level to bring them into a pre-mating body condition of between grade 2½ and 3. At this body condition Gunn, Doney and Russel (see 1968 report) have shown that ovulation rates are of the order of 200%.

The ewes were oestrus synchronised with vaginal pessaries. After withdrawal of the pessaries 64 ewes of similar body condition were divided into two groups: one group was housed indoors, the other group confined on slats in an exposed position outdoors and subjected to artificial wetting for 6 hours daily. Ewes were group fed, once daily, and initially both groups received 3 lbs. per head, but after 8 days the outdoor group received 3.3 lbs. per head. Both groups of ewes maintained body condition and weight throughout the experiment. Three rams were introduced to each group prior to the start of the second oestrus cycle after pessary removal. The pattern of mating was normal with most joinings occurring on the 18th and 19th day after pessary removal. After mating was complete, 16 ewes from each group were interchanged between the two environments. One ram remained with each group and returns to service were noted. At 24-27 days after the original mating all the ewes were slaughtered and an examination of the reproductive tract, pituitary, thyroid, and adrenal glands was made.

The health of both groups of sheep was satisfactory, and there was no evidence to suggest, at this level of feeding, that nutritional requirements out-of-doors were greater than indoors. The increase in food given to the outdoor group was to ensure that nutrition was completely adequate to counteract any possible energy cost of climatic stress.

The preliminary results are shown in the following tables.

1. Returns to Service.

Group:		
	In	3
	In/Out	4
	Out	1
	Out/In	4

2. No. of corpora lutea (excluding return to service)

No. of corpora lutea	Out	In
1	12	3
2	14	19
3	1	2

3. No. of corpora lutea without corresponding embryo at 25 days

Group:		
	In	2
	In/out	4
	Out	3
	Out/In	0

The results indicate that the climatic stress as imposed caused a significant difference in ovulation rates between the two environments. There was no difference in numbers of returns to service in any group, but there was a suggestion that embryo loss increased as a result of stress.

<u>The effects of nutritional and climatic stress on oxygen consumption and F.F.A. level during late pregnancy</u> (J. G. Griffiths)

It is known that metabolic rate and total heat production increase as a result of pregnancy. It has been postulated, however, that in certain stress situations during pregnancy a form of adaptation may occur whereby metabolism is reduced. To examine this hypothesis 10 pregnant and 2 barren Blackface ewes were studied in potential stress situations during the late pregnancy period.

The amount of food given was 17 g/Kg of body weight in late January when the ewes were approximately 60 days pregnant. This level of feeding, calculated as being sufficient for maintenance of the non-pregnant ewe, remained constant during the remaining pregnancy period. At intervals of 6, 4 and 1 week prepartum the ewes were exposed to a wind of 12 m.p.h. for 4 hours. Measurements of oxygen consumption were made at intervals during the experimental period, and during the wind exposures. Difficulties associated with training the animals to wear a face mask were experienced and consequently only the data near the end of the pregnancy period were reliable. Blood samples were also taken at intervals for estimates of F.F.A. level. During wind exposure body and skin temperatures were recorded. The ewes were weighed weekly, and lamb birth weights were recorded.

The ewes remained in good condition throughout, liveweight increased in the pregnant ewes and was maintained in the non-pregnant ewes.

F.F.A. levels at approximately 45 days prepartum were below 650 μeq/1, around 20-25 days prepartum they were elevated in ewes found to be carrying a heavier foetus; at 7 days prepartum, the range in F.F.A. values was between 2190 and 620 μeq/1. This wide variation in F.F.A. levels was significantly related ($P < 0.05$) to single lamb birth weights which ranged between 10.1 and 6.6 lbs. F.F.A. values in two twin bearing ewes were lower than those of some ewes carrying only single lambs, although the total weight of lamb being carried was considerably more. Mean F.F.A. levels in the 2 non-pregnant sheep were 393 and 376 μeq/1.

Oxygen consumption values in single bearing ewes showed a significant negative linear relationship immediately prepartum with lamb birth weight. The relationship can be expressed as:

O_2 consumption = 35.4 - 1.52 lamb birth weight ($P < 0.01$).

The O_2 consumption values of twin bearing ewes did not conform with this relationship. In the single bearing ewes, the relationship between O_2 consumption and lamb birth-weight suggests that metabolism declines with increasing nutritional stress. Further support for this suggestion was provided by a limited number of P.B.I. estimations which showed a decline during the last month of pregnancy.

Wind exposure is known to cause some stress in sheep. In the present observations O_2 and F.F.A. values generally showed an increase during exposure. The increase in O_2 consumption as a result of exposure was of the order of 1 - 3 1/hr. but there was no apparent difference between pregnant and non-pregnant sheep, or with the stage of pregnancy. F.F.A. values, with some exceptions, increased with exposure, and the level of increase was usually greater in the pregnant sheep. There were a small number of instances when F.F.A. levels declined as a result of exposure. These could have been caused either by emotional factors, or they may be indicative of some adaptive feature. There were no differences in body and skin temperatures between pregnant and non-pregnant sheep during the wind exposure.

<u>The nutritional cost of prolonged climatic exposure</u> (A. J. F. Russel and J. M. Doney)

Various attempts have been made over the years, in this Organisation and at other research centres, to assess the effect and cost of climatic exposure of sheep. The most commonly adopted approach has been to measure differences in live weight or some index of performance, such as lambing percentage or lamb birth weight, between two or more groups of sheep kept in different environments. Differences in performance between groups have generally been small and often difficult to interpret, and virtually no attempt has been made in these experiments to assess the effect or cost of climatic exposure in terms of food or energy requirements. Experiments specifically designed to provide estimates of the increased energy requirements in adverse climatic conditions have generally been short term studies conducted in calorimeters, and have not allowed the animals an opportunity to adapt to the more severe environment.

Techniques used with some success to study differences in food requirements between various breeds and classes of sheep offered a means of assessing the cost of climatic exposure in more meaningful terms than those adopted in earlier studies. An experiment was conducted at Glensaugh during December 1968 and January 1969 using a 2 x 2 factorial design, to study the effects of body condition (condition scores 1.5 and 3.0) and environment (sheephouse and outdoor pens) on food requirements. Eighty-four Scottish Blackface ewes were fed at constant restricted levels of intake, ranging within groups from 6.5 to 26.5 g dried grass pellets/kg live weight/day. Blood samples were collected before feeding on one day in each week for a period of six weeks during early pregnancy. Food requirements for maintenance were computed for each group from the relationships between plasma free fatty acid concentration and level of food intake. The largest effect noted was that due to environment, the requirements of the outdoor groups being some 15% (1.3 g DOM/kg live weight) higher than those of the groups in the sheephouse. There was no apparent effect of body condition on the increase in food requirements due to climatic exposure.

This estimate of a 15% increase in food requirements due to climatic exposure is higher than in previous reported experiments. Over a period of time and a large number of animals, an effect of this magnitude would represent a considerable quantity of food. Nevertheless, the cost is still small in monetary terms compared with the annual depreciation of most types of housing now being erected. Provided that the ewe is in good body condition at the beginning of pregnancy, and has adequate reserves on which to draw, there appears to be little reason why the cost of climatic exposure during winter should not be met from reserves laid down inexpensively at other times of the year. In certain management systems there may be good agronomic and economic reasons for removing the ewe stock from pasture during part of the year, but this can frequently be achieved without recourse to housing.

Influence of body condition and post-mating intake on egg survival in Scottish Blackface ewes (R. G. Gunn, J. M. Doney and A. J. F. Russel)

The design of this experiment was described in detail in last year's Report (p.2). It entailed differential feeding (high and low) for 25-28 days post-mating of ewes held in "fat" and "thin" condition for 2-3 weeks prior to and at mating. Half of each treatment sub-group was killed 25-28 days post-mating and the other half permitted to lamb at term. Data were therefore available on ovulation rate at mating, embryo implantation rate at mating plus 25-28 days, and lambing rate (of a different sample).

As observed in last year's Report, there were considerable and significant differences in ovulation rate between Glensaugh and Stanhope ewes in both levels of condition and between "fat" and "thin" ewes in both flocks, with the Glensaugh and "fat" ewes producing more. There was significantly less wastage between mating and mating plus 25 days from the "fat" ewes, but no significant difference in loss during this time between single and multiple ovulators in either "fat" or "thin" ewes. Post-mating nutritional differences of the order imposed (high = 35 g feed/kg live-weight, low = 5 g/kg) for 25-28 days had no effect on wastage. Comparison between ovulation and implantation in the killed sample and lambing in the remainder indicated a decline in the "fat" ewes in the percentage of multiples from mating to 25 days thereafter, then no change to lambing. Similarly, in the "thin" ewes a large proportion of all ovulations failed during the period up to 25 days after mating, but thereafter there was no change.

The data from this experiment are at present being prepared for publication.

The utilization of body reserves during pregnancy (A. J. F. Russel, J. Z. Foot and J. M. Doney)

It is known that ewes which are in "good condition" at mating are more likely to conceive twins than are ewes in poorer condition, and it has been assumed that, because such ewes have substantial reserves of stored energy, they will be better able to nourish their foetuses, better able to withstand the undernourishment which invariably occurs during late pregnancy, and will require less supplementary feeding to produce viable lambs than ewes in poorer condition. An experiment designed to test these assumptions is now in progress at Glensaugh.

One hundred and fifty Scottish Blackface ewes, all in similar body condition (condition score 2.5) were mated in November following oestrus synchronization. After mating the ewes were allocated at random to one of two nutritional treatments; the first treatment is designed to reduce the condition of ewes to score 1.5 (16% fat in the fleece-free empty body) by early January, and the second to increase condition to 3.0 (29% fat) by that time.

From early January until immediately before parturition in April, the majority of ewes will be fed to meet only maternal maintenance requirements, i.e. requirements for foetal growth and development will be met from the catabolism of maternal tissues. Rates of fat mobilization in fat and thin ewes will be determined from plasma free fatty acid concentrations, and changes in body composition within the fat and thin groups will be estimated from the chemically determined composition of sample animals slaughtered at different stages of pregnancy. Ten ewes from each group will be fed to meet full energy requirements throughout the latter part of pregnancy. These animals will provide information from which the effects on lamb production of the undernourishment in the remaining animals may be judged.

Foetuses from ewes slaughtered immediately before parturition will be chemically analysed to determine the effects of maternal nutrition and body condition during pregnancy on foetal reserves of fat and glycogen.

The effects of restricting nutritive intake of Blackface ewes in early lactation on their subsequent milk production (J. N. Peart)

This study was concerned with influence of live weight and body condition on the subsequent milk production of ewes which had been undernourished in early lactation. The experiment was conducted with 72 ewes and 108 lambs over 2 years and involved ewes in either a high or low state of body condition at parturition, followed by either a 2- or 4-week period of undernutrition in early lactation. The results of the treatments on ewes in a high state of body condition were presented in the 1968 Report. During the past year similar treatments were applied to ewes in a very lean state of body condition. Details of the methods and treatments are contained in the 1968 Report. A paper combining the results of the two years has been prepared for publication.

The principal findings are:

1. A moderate degree of undernourishment in early lactation depresses milk production of both fat and lean ewes.

2. Ad libitum feeding following restricted feeding during the first 2 weeks of lactation resulted in a rapid increase in milk production of from approximately 2.1 to 2.7 kg/day and from approximately 1.3 to 1.7 kg/day for all groups of twin-suckled ewes and all groups of single-suckled ewes. In contrast, all groups of ewes which were undernourished during the first 4 weeks of lactation showed little increase (0.1 kg/day) when food was offered ad libitum.

3. From about the sixth week of lactation there was little difference in milk production between groups of single-suckled ewes regardless of previous treatments or state of body condition.

4. The milk production of twin-suckled ewes in fat condition at parturition was significantly greater than that of twin-suckled lean ewes during the extended period of undernourishment. This effect was not apparent with single-suckled ewes.

5. The average daily live-weight gain of the lean ewes during the 6-week period following ad libitum feeding was significantly greater than that of the ~~lean~~ fat ewes. The values were 339 v 222 and 356 v 250 g/day for twin- and single-suckled ewes respectively. However, they did not attain parity by the end of lactation.

6. The results suggest that when body reserves of ewes are severely depleted, factors other than nutrient intake may become limiting to milk production.

Regulation of wool growth (J. M. Doney)

Further analyses (with C. C. Evans) of variation in sulphur content of wool have tended to confirm the hypothesis that the percentage of sulphur at any stage of growth of the fibre is dependent on the fibre growth rate (follicle activity) and on the availability of high S substrate to the prekeratinised fibre. Since both of these may vary with such factors as genotype, nutrition, season, etc. it was concluded that the use of sulphur content as a descriptive or analytical parameter in the study of wool growth regulation can only be justified in well defined conditions. In a comparison of Scottish Blackface and Romney ewes a number of sheep of each breed were group-fed to achieve three patterns of liveweight change between mating and parturition. One group had a net maternal gain of around 8%, the second a loss of about 5% and the third a loss of around 16%. Wool growth rates and sulphur content were measured in 6-8 week periods starting in early autumn. During the period immediately before parturition (late February to early April) the wool growth rate in the Blackface breed was low and, as indicated by previous work, there were no significant differences amongst treatments. Differences in sulphur content, however, were highly significant, ranging from 3.97% and 3.46% (fine and coarse fractions respectively) in the well-nourished group down to 3.68% and 3.20% in the most undernourished group. This result was reversed in the Romney breed. Differences between treatment groups in wool growth rate were highly significant in the pre-partum period but there were no significant differences in S content. At a mean of 3.68% it is likely that all were below the maximum potential.

Studies on the factors affecting the casting of the fleece before shearing have been extended using the technique of quantitative analysis of changes in the rate of fibre brush-end formation. The following results have not been statistically analysed and, because of uneven distributions, may be difficult to confirm. In the first pilot experiment the objective was to determine the time of onset of brush-end formation in what one normally regarded as continuously growing fibres and to assess the influence of nutritional variation in early pregnancy (that is before the 'expected' time). Plucked samples were taken at intervals from a concurrent experiment on maintenance requirements (page 1) in which sheep were well fed or undernourished from the beginning of September and to the end of November. After mating a range of food intake (from 6.5 g/kg to 26.5 g/kg) was given within each group (fat and thin). Throughout the period half the sheep were housed and the other half were kept in individual outdoor pens. All sheep were returned to hill grazings at the end of January. Changes in fibre type ratio occurred during the period (mainly an increase in the proportion of non-hair fibres without any medullation), lattice type fibres (mostly kemp by October) had an increasing proportion of brush-ends as part of the natural replacement cycle but brush-ends did not appear in any significant numbers amongst the fine fibres until the beginning of March. There were no apparent differences associated either with housing from September to mid-January or with the wide range of intake during December-January. The overall mean values of 'fat' (grade 3 in November) and 'thin' (grade 1½ in November) for fibre type ratio and for the percentage of each type with brush-ends are shown in Table 1 (britch samples only).

	'Fat'			'Thin'		
Fibre Type %	Lattice	Medullated	Non-Med.	Lattice	Medullated	Non-Med.
Per 1 (1/10/68)	22	48	30	24	49	27
Per 3 (13/1/69)	17	39	44	20	38	42
Per 4 (12/3/69)	27	19	54	24	35	41
Per 5 (10/4/69)	26	9	65	19	26	45
% Brush-end	Lattice	Medullated	Non-Med.	Lattice	Medullated	Non-Med.
Per 1	14	0	0	14	0	0
Per 3	64	0	0	63	0	0
Per 4	94	4	21	77	1	8
Per 5	94	8	34	76	1	21

In both groups the most interesting feature is the increase in proportion of non-medullated fibres and the incidence of brush-ends between March and April. It would appear that the group which were in better condition at mating had a greater proportion of non-medullated fibres in late pregnancy and that more of these had formed brush-ends. However, a consequence of the condition at mating was that the 'fat' group comprised over 80% twin pregnancies as against only 10% in the thin group. With such an unbalanced distribution the obvious suggestion that the difference was due to type of pregnancy rather than original state of body reserve could not be tested. However, a further pilot series of observations were made on sheep involved in the current lactation experiment (J.N.P.). These ewes were severely undernourished until the beginning of March after which the ration was increased until parturition in early April.

Differences between single and twin bearing ewes in fibre type proportion and in percentage of brush-end with each type are shown in Table 2 (overall mean values, not tested statistically).

	Single bearing ewes			Twin bearing ewes		
Fibre type %	Lattice	Medullated	Non-Med.	Lattice	Medullated	Non-Med.
3/3/69	32	27	41	35	12	53
31/3/69	26	35	39	27	21	52
Brush-end %	Lattice	Medullated	Non-Med.	Lattice	Medullated	Non-Med.
3/3/69	81	2	13	85	3	28
31/3/69	66	2	13	79	2	45

These two sets of observations suggest (1) the incidence of brush-end formation in the wool fibres of Blackface sheep (with consequential effect on the subsequent casting of the fleece before shearing) is likely to occur at a fixed time of the year namely at or around the beginning of March. (This occurrence might be related to a fixed stage of pregnancy rather than time of year although a few non-pregnant sheep also had some brush-ends at this time), (2) neither the time of onset nor the extent of brush-end formation in non-kemp fibres seems to be affected by previous treatment such as a considerable variation in nutrition or body condition between September and January, (3) the extent of fibre shedding but not time of incidence does seem to vary with type of pregnancy (multiple or single). The effect may be due to current nutritional state, twin-bearing ewes being more undernourished than singles at this stage but other factors may be implicated.

More critical experiments can now be designed to follow up these preliminary observations.

Dentition and mineral status (R. G. Gunn)

It is now clear from the work done at Glensaugh over a number of years that broken mouth is a condition not yet fully understood and which is aggravated by the management practice of grazing turnips but may be improved by raising the standard of nutrition during the spring, summer and autumn.

Data on the effect of broken mouth on ewe performance over a number of years have been analysed and a note prepared for publication. This has shown that ewes becoming or already broken-mouthed during their third lamb crop at Glensaugh gave birth to the same number of lambs of similar weights as whole-mouthed ewes but reared significantly lighter twin lambs and became themselves significantly lighter in live weight. This then led to broken-mouthed ewes giving birth to and rearing significantly fewer and lighter lambs in the following year. The results suggest that the broken-mouthed condition, particularly during its onset, restricts the ewe's ability to ingest sufficient food during periods of high energy demand, possibly due to pain associated with the teeth being loose prior to falling out.

Work on broken mouth is now moving away from the purely descriptive to more critical study of certain of the possible contributing factors. Mineral nutrition was shown in a recently published paper to bear some relationship with the incidence of broken mouth and an experiment has been designed in collaboration with the Animal Diseases Research Association to examine the mineral intake and body composition of free-ranging whole- and broken-mouthed BF ewes at Glensaugh by means of faeces collection and total body analysis of sample ewes.

Influence of oestrus synchronisation on fertility in hill ewes (R. G. Gunn and J. N. Peart)

In some of the critical work on fertility in hill ewes, synchronisation of oestrus could simplify experimental design and management, provided it had no effect on fertility itself, in particular, on litter size and on viable mating.

There is some evidence that the use of progestagens alone for synchronisation has no effect on litter size but there is some doubt on the effect on viable matings.

In October, on the Park Law heft at Sourhope, 115 North and 115 South Country Cheviot ewes were allocated to two groups by breed, age, rearing in the previous lamb crop, and body condition. In one group, Cronolone vaginal pessaries were inserted. This constitutes the treatment group while the other is the control. Mating will take place at the second oestrus after removal of the pessaries in the treatment group and will start in the control group at the same time. Matings will be recorded throughout the period 19th November till 15th January. Lambing performance will also be recorded subsequently.

Preliminary studies on the nutritional physiology of hill cows
(A. J. F. Russel and J. Z. Foot)

Opportunities were taken during the year to collect blood samples from hill cows with the objective of establishing whether the concentrations of plasma metabolites used as indices of nutritional state in sheep could be used effectively for the same purpose in cattle.

Blood samples were collected on three occasions during late pregnancy from a number of outwintered cows receiving supplementary feeding at Lephinmore. Plasma glucose, free fatty acid, ketone and urea concentrations were all within the expected ranges and similar to values found in ewes receiving liberal supplementary feeding during late pregnancy. It was not possible to relate concentrations of metabolites in individual animals to any other parameters as measurements of food intake and calf birth weights were not available.

During the course of an experiment carried out by The Edinburgh School of Agriculture on the nutrition of inwintered hill cows, blood samples were collected on a number of occasions from 27 pregnant animals. The three nutritional treatments in the experiment were reflected to a marked degree in plasma free fatty acid concentrations, but levels of undernourishment were not sufficiently severe for clear effects to be noted in either plasma glucose or ketone concentrations. In two of the treatments part of the nitrogen intake was given in the form of urea, and marked differences in blood urea nitrogen concentrations were noted, suggesting that the level of energy intake in one of the treatments was limiting the degree of utilization of this non-protein nitrogen source.

These preliminary investigaions indicate that techniques used with some success in experiments on the nutritional physiology of sheep are likely to be useful in similar studies with cattle. The principal difference between the species is likely to stem from the virtual absence of twinning in cattle. The lower variance of foetal weight which this implies will tend to make energy intake relatively more important as a factor determining the severity of undernourishment in the pregnant cow. Although the very low incidence of twinning in cattle has certain advantages from an experimental point of view, in that fewer numbers may be required than in similar work with sheep, critical studies of the effect of nutrition on individual animal performance still require closely controlled experimentation which must await specialized facilities.

In the meantime blood samples are being collected from pregnant heifers at Sourhope as part of the programme of monitoring changes in the nutritional status of animals in the Hairney Law - Auchope development work.

The influence of Moniezia and Helminth infestation on the live weight gain of lambs (W. N. M. Foster)

Moniezia segments and eggs are commonly found in the faeces of lambs on all hirsels at Sourhope. There is, however, little information concerning the pathogenicity of Moniezia in Great Britain. The following study, which partially complements the foregoing helminth investigations, was therefore undertaken to determine whether Moniezia and/or helminth infestation had any influence on the live weight gain of Cheviot lambs on the Park Law hirsel at Sourhope.

One hundred and twenty single north and south country Cheviot lambs were divided on a breed, weight, sex and age basis into four evenly matched groups. These groups were dozed as shown below at fortnightly intervals from May 20th (3-5 weeks of age) until 11th August (2 weeks post weaning). Live weights were recorded fortnightly and faeces samples examined for helminth and Moniezia eggs.

Group	A	B	C	D
	Control Undosed	Dosed with Buban (Moniezia free)	Dosed with Nilverm (helminth free)	Dosed with Buban and Nilverm

Moniezia eggs were not detected during the course of the investigation in the faeces samples from lambs in groups B and D which received Buban, but became apparent in a small number of samples from lambs in groups A and C in the latter part of May. The percentage of infested lambs in these two groups rose to a peak at the end of July when 70% of the lambs exhibited eggs or segments in the faeces. Thereafter the infestation, or egg output declined and on the last sampling date in August only 5% of the lambs were excreting eggs. The fortnightly dosing with Nilverm (groups C and D) either eliminated or reduced the helminth egg output to a negligible level. In contrast the undosed groups A and B showed an early rise in the Nematodirus egg count, eggs becoming apparent towards the end of May. The peak output occurred in June and the count declined again in July/August. Strongyle eggs also appeared in small numbers at the end of May, and continued to rise gradually throughout the period of observation. Helminth egg output was not, however, excessively high, maximum average counts of 500 e.p.g. and 800 e.p.g. being recorded respectively for Nematodirus and typical strongyles.

Oocysts of three species of coccidia were observed in the faeces samples. Oocysts counts were quite high in May/June but declined markedly in the second half of July. Although coccidia are known to be pathogenic in some parts of the country, the weight gain of the lambs on Park Law, which averaged approximately 0.4 lbs per day, does not suggest that coccidiosis in lambs is currently a problem on this hirsel.

Analysis of the weight data from each group of lambs at the termination of the trial, however, showed that treatment with Nilverm or Buban, either singly or in combination, did not result in a live weight gain significantly greater than that achieved by the undosed control group (Table 1). This result confirms the findings in the helminth studies with lambs on Hairney Law and Auchope, and is perhaps more significant since the stocking rate on Park Law has been considerably higher for a number of years. It also demonstrates that the current level of Moniezia infestation on Park Law is not a limiting factor in the growth of lambs which are adequately nourished.

These results should not, however, obscure the potential danger of Nematodiriasis. As intensification and an increase in stocking rate proceeds, this disease could occur with few premonitory signs. Unless an 'early warning' system can be developed it may be necessary in due course to employ a strategic dosing to combat this disease.

Table 1

Weight gain (lbs) (May-August) of Cheviot lambs dosed at fortnightly intervals with Nilverm and Buban singly and in combination

	A	B	C	D	Av. wt. gain/day (all groups)
South country (16 lambs)	29.9	31.0	30.6	30.8	0.37
North country (14 lambs)	31.5	33.9	33.7	34.3	0.40

Tick-borne Fever in sheep (W. N. M. Foster)

Although the lowered 'resistance' associated with tick-borne fever infection allows organisms such as Pasteurellae and Staphylococci to take their annual toll of hill lambs, relatively little is known about tick-borne fever and dipping remains the only suggested method of control.

In an attempt to augment this fragmentary knowledge, initial studies on immunity and resistance to tick-borne fever were commenced in the spring of 1969 and have followed two separate but interrelated lines;

(a) A study of the immune status of lambs born to immune ewes, and the subsequent development of immunity in these lambs following natural infection;

(b) preliminary investigations into the role of the spleen following infection with tick-borne fever;

(a) Studies in Finland have demonstrated the presence of an anti body in the blood of sheep and cattle immune to tick-borne fever. Previous field studies at Sourhope have, however, shown that lambs born to immune hill ewes still contract tick-borne fever in the first 7-14 days of life. It would, therefore, seem that either the circulating anti body in the dam is not transmitted to the lamb via the colostrum, or alternatively that the anti body per se is not sufficiently protective in nature or quantity to prevent the onset of disease.

Serum samples have been obtained from a number of lambs born to tick-borne fever immune ewes at Sourhope. These samples were taken both before and after the lambs received colostrum and thereafter at approximately weekly intervals for ten weeks whilst the lambs were running on tick infested pasture. The temperature of the lambs was recorded daily for the first 14 days of life and the date of onset of tick-borne fever, confirmed by blood smears, is known in each case.

The anti body content of these sera will shortly be examined utilising a fluorescent microscopy technique to determine whether the lambs received anti body from the colostrum, and the subsequent quantitative changes in the anti body level following natural infection.

As a corollary to this study a number of the above lambs were challenged with tick-borne fever at given periods after the initial onset of the natural disease to determine their resistance to reinfection. A relatively high degree of resistance was present at 3 and 5 weeks but there was a suggestion, based on the reaction to challenge, that resistance had fallen somewhat at the 7th week. This contrasts with the strong resistance which develops in experimentally infected susceptible ewes and lambs 5-7 weeks after infection and may suggest that a passive immunity is present in the lambs born to immune ewes which inhibits the development of a strong active immunity.

It is, however, questionable whether this hypothetical passive immunity has any marked protective value since a small experiment has shown that the subcutaneous administration of 100 ml immune serum to young lambs fails to appreciably affect the severity of the ensuing experimental infection.

(b) Haematological studies on sheep and lambs infected both experimentally and naturally with tick-borne fever have shown that with the onset of fever there is normally a sudden and frequently very high degree of parasitism of the blood neutrophil cells. This is succeeded after approximately 5 days by a relatively rapid diminution in the number of infective organisms in the blood. It appears, therefore, that at this time the host is able to effectively clear the organism in the blood.

Although a number of factors may be responsible, the role of the spleen perhaps merits special attention since earlier studies have shown that tick-borne fever is more prolonged and more severe in the splenectonised animal. Moreover, it is also known that the only gross pathological lesion of tick-borne fever is splenomegaly. Of the recognised ovine diseases in G.B. only tick-borne fever gives rise to this phenomenon.

There is, however, no information on the time sequence of splenic enlargement and regression or on the histological changes which occur in the spleen at this time. Studies on young Blackface lambs infected experimentally with tick-borne fever and examined post-mortem at selected intervals after the onset of fever have shown that splenic enlargement is rapid and regression to a normal size is usually achieved approximately 3 weeks after the onset of disease. These weight changes are depicted in Table 2.

Table 2

Weight changes in the spleen of Blackface lambs following infection with tick-borne fever
(live weight (lbs) in parentheses)

Days after onset of fever	5-6	12	21
Control	22.6 gms (26.0) 17.4 (22.8)	18.6 (23.0) 15.0 (26.0)	15.0 (19.0) 17.1 (22.25)
T.B.F. (Strain 1)	77.5 (23.0) 58.5 (23.0)	31.0 (20.5) 43.0 (23.25)	37.2 (19.0) Died (Pasteurella)
T.B.F. (Strain 2)	61.7 (22.5) 43.0 (23.5)	32.1 (19.25) 28.1 (22.25)	19.8 (20.75) 13.0 (18.25)

Histological changes in these spleens and other selected body organs are currently being studied in co-operation with A.D.R.A. Moredun. Preliminary results suggest that splenic enlargement may be at least partially attributable to an increase in the number of reticular histiocytes (macrophages). It is of interest that the degree of infection in the circulating blood diminshes at approximately the time of maximum splenic enlargement, although it is premature to attempt to correlate these two observations.

Tick-borne Fever in hill cattle (W. N. M. Foster)

Although abortion in cattle due to tick-borne fever has been recorded in Scotland, the distribution and occurrence of this disease remains virtually unknown.

Prior to the establishment of a Brucella free herd at Sourhope in the spring of 1969, and the introduction of unacclimatised stock, it seemed advisable to determine whether or not cattle tick-borne fever occurred in the locality.

Transmission tests with blood from cattle at Sourhope and an adjoining farm have demonstrated that the cattle on both farms are infected with tick-borne fever. It is unknown if this particular strain of the disease would cause abortion in susceptible in-calf heifers, but it appeared prudent to avoid the purchase of this class of stock.

The tick-borne fever which developed in the susceptible calves employed in the transmission tests appeared to be a relatively benign disease causing a mild febrile reaction for approximately five days. However, shortly after the fever subsided three of the four calves developed bronchitis with associated coughing. A similar syndrome has been recorded in adult cattle experimentally infected with tick-borne fever (Hudson 1950).

A more recent attempt to isolate tick-borne fever from cattle at Glensaugh has been unsuccessful, and although this does not necessarily prove that cattle on this farm are not infected with this disease, it would seem that the incidence or level of infection must be very much lower at Glensaugh than at Sourhope.

It is, moreover, of interest that in November 1966, 30 Sourhope cows were transferred to Glensaugh and would, therefore, constitute a reservoir of infection. The current failure to detect tick-borne fever in Glensaugh cattle must, therefore, raise doubts about the degree of vector tick infestation at Glensaugh, although ticks do occur on parts of the farm and tick-borne fever has been isolated from the sheep stock.

It must, therefore, be borne in mind that conditions prevailing at Glensaugh, namely a susceptible herd and a low level of infected ticks, could favour the occasional abortion due to tick-borne fever.

Further studies on strains of Tick-borne Fever (W. N. M. Foster)

The design of the foregoing spleen study incorporated the use of the two strains of tick-borne fever which previous investigations (1968 Annual Report) had shown to be immunologically similar but which appeared to differ in virulence in adult ewes. A similar difference in virulence was confirmed in the lambs, and although both strains caused similar haematalogical changes the more severe strain appeared to cause a more profound and prolonged neutropenia.

Two cases of diagnosed Pasteurella infection (one adult ewe and one lamb) which developed during the course of these investigations occurred in the groups infected with the more severe strain of tick-borne fever. It may be significant that this strain originated from a farm which also experiences annual losses from enzootic staphylococcal infection.

NUTRITION OF THE GRAZING SHEEP

Lamb growth studies (J. Eadie, R. H. Armstrong and A. J. F. Russel)

The programme of work whose aims and objectives were set out in the introduction of this topic in the 1968 Annual Report (page 17) has been continued.

1968 At the time of writing the 1968 Report much of the analytical work remained to be done. In particular the calculation of the energy intakes (as D.O.M.I.) for the grazing lambs was not possible. These have now been carried out and a regression of liveweight gain on D.O.M.I. per $Kg^{0.73}$ calculated for each of the four pasture treatments. Each regression equation was significant but the overall relationship was poor due mainly to the high quality Agrostis-fescue group whose gain relative to their energy intakes was high.

This result could be explained on the grounds of differences in maintenance requirement; Lambourne in particular has reported lower maintenance requirements in pastures of greater dry matter availability, and the high quality Agrostis-fescue treatment had the most lax grazing intensity.

However, there remains the possibility that the prediction of ingested herbage digestibility from faecal constituents, using a "general" regression equation derived from previous studies has introduced a bias, and in 1969 continuous digestibility trials using lambs fed cut material from the pastures used in these experiments have been carried out. The analytical results are not yet to hand.

The lamb growth rates in the 1968 grazing experiment were poor. Even at best they were little better than those which occur in practice on the open hill. One contributory factor is the difficulty of maintaining ingested herbage quality at a high level, and the energy intakes which are obtained from ingested herbage of digestibility around 70 are clearly insufficient to promote high rates of gain. But much improvement is unlikely in ingested herbage quality in regrowths following the reproductive stage of the grass plants' annual cycle of activity.

Allied to this problem is the fact that, in 1968 at any rate, those lambs on the better quality pasture treatments (and this occurred on both the ryegrass and the high quality Agrostis-fescue groups) had lower faeces outputs than those on the poorer Agrostis-fescue groups. That this is attributable to pastoral rather than to factors of animal origin is suggested by the faeces outputs of the wether sheep which accompanied the lambs; these behaved relatively in the same way (see Table 1). At the end of the grazing experiment the wethers were interchanged between plots, and subsequent faeces outputs again reflected the characteristics of the plots.

Table 1

Experiment 2/68
($g.O.M./Kg.^{0.73}$)

Faeces outputs (Group Means)

	Lambs	Wethers (3 y.o.)
Ryegrass	13.7	18.1
"Good" A/F	13.6	21.3
"Mod" A/F	19.2	29.6
Poor A/F	16.6	25.5

The broad conclusions to be reached from the 1968 experiments would appear to be that lambs have relatively high maintenance requirements. This contention is supported by data given in the A.R.C. Technical Review on the fasting metabolism of lambs.

Furthermore all-grass diets are unlikely to provide energy intakes sufficient to promote marked improved rates of gain in grazing lambs in the post-lactation period.

Lamb growth studies 1969

In the light of the 1968 findings it was decided to elucidate the role of milk in the lamb's diet in the period subsequent to that during which milk is known to be the prime determinant of lamb growth rates. It was also decided to have a preliminary look at the impact of a proportion of clover in the diet.

Experiments were again made indoors (Expt 1/69) and at pasture (Expt 2/69).

(1) Experiment 1/69

Eighteen lambs were weaned from their mothers at approximately 8 weeks of age. Nine of them were introduced to milk substitute so that milk intakes could be directly measured.

The milk-substitute contained 30% fat and 22% protein in the dry matter, and was given warm in two feeds per day. The lambs sucked by teat from individual containers and the feeding level was 160 g. dry matter per day diluted with water to 25% dry matter.

The original intention was to subdivide the lambs among three herbage diets, allocating to each herbage 3 milk-fed and 3 non-milk fed lambs. Difficulties with two of the milk-fed lambs, however, led to a reorganisation of the experiment and the resulting treatments were:-

I (a) Ryegrass alone
(b) Ryegrass + milk

II (a) Agrostis-fescue alone
(b) Agrostis-fescue + milk

III (a) Agrostis-fescue + 13% clover
(b) Agrostis-fescue + 27% clover

Results

(a) The herbage feeds analyses are given in Table 2
(b) The experiment ran from 20/7 to 23/8

Table 2

Experiment 1/69

Herbage Feeds Analysis

	Cutting Date	N (% in DM).	C.W.C.* (% in DM)	DMD
Perennial Ryegrass	29/5	2.76	55.2	79.8
Agrostis-fescue	13/6	2.96	59.0	75.3
Agrostis-fescue/ clover I		3.11	56.4	75.0
Agrostis-fescue/ clover II		2.91	51.8	74.9

* Van Soest

Daily herbage intakes were measured for each lamb, and during two periods, one in the early part of the experiment (22 - 31/7) and one towards the end (12 - 21/8), total faeces outputs were measured.

Dry matter intakes and dry matter digestibilities for all treatments on these two occasions are given in Table 3.

Table 3
Experiment 1/69
Voluntary Intakes and Digestibilities on Two Occasions
(Group Means)

	I (22 - 31/7)		II (12 - 21/8)	
Treatment	DMD	Herbage Intake (g. DM /Kg.$^{0.73}$)	DMD	Herbage Intake (g. DM /Kg.$^{0.73}$)
RG + milk	73.5	46.9	77.7	67.4
RG	80.0	79.9	79.6	79.1
A/F + milk	66.4	57.1	69.8	60.0
A/F	76.4	62.4	74.3	70.7
A/F/Cl (1)	73.5	80.3	76.6	76.6
A/F/Cl (2)	72.1	66.5	77.7	77.7

Herbage digestibility values were broadly similar in both periods, and the voluntary intakes in the non-milk fed lambs were as expected from the 1968 results in the ryegrass and Agrostis-fescue herbages. The digestibilities and voluntary intakes of the clover-rich feeds were greater than those of the Agrostis-fescue without clover.

The feeding of milk substitute substantially depressed the intakes of ryegrass, but depressed the Agrostis-fescue intakes to a much smaller extent.

(c) The liveweight gains and computed energy intakes (as D.O.M.I.) of each of the treatments are shown in table 4.

Table 4

Experiment 1/69
Intakes and Liveweight Gains (Group Means)

Treatment	Intake ($g.D.O.M.L./Kg^{0.73}$)			L.W.G. (g/hd/day)
	Herbage	Milk	Total	(22/7 - 25/8)
Ryegrass + milk	43.8	12.5	56.3	269
Ryegrass	63.1		63.1	102
Agrostis/fescue + milk	41.8	11.6	53.4	174
Agrostis/fescue	51.5		51.5	76
Ag./F./Cl. (1)	61.3		61.3	126
Ag./F./Cl. (2)	56.1		56.1	109

The effect of the milk substitute on lamb gains with both herbages was striking; gains were more than doubled in each case. The efficiency of utilisation of the energy intakes of both groups of milk-fed lambs is very much greater than in the non-milk-fed lambs.

The liveweight gains of both groups of clover-fed lambs were markedly greater than those of the Agrostis-fescue non-milk lambs. Lamb gains per unit of ingested D.O.M. are rather less in this experiment than those obtained with similar herbages in 1968.

(2) Experiment 2/69

Twenty-four lambs were weaned at the same time as those in the previous experiment; 12 were introduced to milk substitute.

Half of each of the 12 milk-fed and the 12 non-milk fed lambs were grazed on Agrostis-fescue pasture as a "leader" group and half as a "follower" group. The intention was to create a "higher" and "lower" quality of ingested pasture, and on each pasture the milk-fed and the non-milk fed lambs were run together.

The milk-fed lambs received their milk substitute by teat, in a small pen, on two occasions each day.

The experiment ran from 15/7 to 5/9. The milk substitute was given at 160 g/hd/day (as in Expt 1/69) from 15/7 to 19/8, when it was reduced to 116 g/hd/day.

Results

(a) The liveweight gains (group means) are shown in Table 5.

As in the indoor experiment the effect of the milk substitute is striking.

Table 5

Experiment 2/69
Liveweight Gains and Faecal Outputs
(Group Means)

Treatment	LWG (g/hd/day) 22/7 - 25/8	Faeces Outputs (g. DM /$Kg^{0.73}$) 15/7 - 15/8	19/8 - 5/9
Good A/F + milk	151	18.5	21.6
Good A/F	56	19.3	22.5
Moderate A/F + milk	128	15.7	22.5
Moderate A/F	31	19.7	25.2

(b) The faeces outputs of the grazing lambs are given in Table 5. Those of the milk-fed lambs are slightly lower on both pastures indicating that the depression of grass intakes is broadly in accord with the intake depression obtained indoors in Expt 1/69 with Agrostis-fescue herbage.

Further consideration of these results and of those of the 1968 grazing experiment must await the completion of the chemical analyses of this experiment and of the associated continuous digestibility trials carried out in 1969.

Input/output Studies (J. Eadie)

The Organisation's system synthesis programme is based on a two-pasture concept involving the integration of areas of improved pasture with the unimproved hill vegetation in a production system.

Hill land improvement has generally come to mean reseeding. It is, however, clear that this is only one means, albeit the most dramatic in terms of increased productivity, of hill pasture improvement. Previous work, for example, has demonstrated that grazing control without any other inputs on Agrostis-fescue pastures leads to improved utilisation and better nutrition.

Technically, on some hill pasture types, notably the grassy pastures, there is a range of improvement possibilities, from low cost/unit area to high cost/unit area. But little is known in a comparative way about the improvements in productivity and nutritive value to which the range of inputs and combinations of inputs gives rise. Information of this kind, across the spectrum of economically important hill pasture types, is vital to the assessment of cost-effectiveness in hill land improvement.

The range of possible inputs will vary from site to site, but will include enclosure and subsequent grazing control, improvements in soil base status and pH, in soil nutrient status, and the introduction of new plant material, both clovers and grasses.

Many of the processes and mechanisms which lie behind the responses to inputs are specific to the grazing situation, and could not be satisfactorily simulated in the absence of the grazing sheep. If the consequences of any input are to be realistically assessed the effect of that input or plant nutrient cycling must be allowed to express itself. The pasture changes induced by the various inputs will be effective to the extent to which they contribute to improvements in utilised pasture output and/or improved nutrition. The appropriate measurement tool is therefore the grazing animal.

The basic requirement for each site is a fairly uniform soil/pasture area. This is a difficult requirement to satisfy with respect to some pasture types and in practice areas of 2-3 acres are probably as large as is compatible with the degree of site uniformity thought necessary. This effectively limits the number of plots and therefore the number of possible inputs at any one site. For this reason, and because of the work load, replication in this work is not possible. Some 5-6 "treatments" per site is probably as many as can satisfactorily be handled, which highlights the importance of carefully selecting the inputs appropriate to each site.

The major technical difficulty to be faced in this work derives from the fact that what one might loosely call management decisions have to be made concerning when to graze and with how many animals to graze each plot in the series at any one site. These decisions are important not only in the short term, in that grazing pressure is our important determinant of ingested pasture quality, but also in the longer term, in that decisions at one point in time have consequences at future points in time.

In an attempt to preserve the integrity of the comparisons between plots two decisions have been made. The first is that all plots shall be grazed at the same time, and for the same length of time, and that the stocking rates for any particular grazing at any given site shall be set so as to equalise grazing pressure across all plots on that site.

The general management plan for all sites will be similar in that the intention is to have two grazing periods each of one month's duration between the start of pasture growth in spring and mid-August, and a grazing period of one month's duration in October. The reason for this is that we require to interpret the results of this work within the context of the two-pasture concept now being developed on a large scale. The more closely the conduct of grazing experiments approaches the management framework within which their results are to be applied the less hazardous becomes interpretation (Morley and Spedding 1969).

<u>Experiment 1</u>

<u>Introduction</u> In the spring of 1969 a start was made on this work on two sites. The first was a site which had formerly been used for studies on the influence of grazing on pasture dynamics (see "The Influence of Grazing on Pasture Dynamics" by I. A. Nicholson, H.F.R.O. Rept. 1966). The treatments applied in the years 1966-68 had led to differences in botanical composition and in sward productivity. Since the site was being abandoned for the purposes for which it was originally set up, although the range of inputs was not ideal for present purposes, it was thought that the opportunity to gain some useful information and some experience in handling the problems generated by this kind of experimentation should not be missed.

<u>Treatments</u> Four plots each of $^1/_7$ acre were used. The treatments were

(A)- Soil treatments; Lime-$2\frac{1}{2}$ t/acre
K$_2$O-80 lb/acre
P$_2$O$_5$-150 lb/acre
N - 100 lb/acre
Seeds: Perennial Ryegrass, Red Fescue and Kent Wild White Clover) 1966

Subsequent fertilizer treatment - N at 100 lb/acre/year

Grazing treatments - standing crop maintained at approximately 500 lb. DM/acre throughout the grazing season in 1966, 1967, 1968.

(B)- No soil treatments, no seeds. Grazed at an intensity approximately to current utilisation on the open hill

(C)- Annual dressings of 100 lb. N/acre in 1966, 1967, 1968. Grazed to maintain standing crop of 500 lb. DM/acre throughout the grazing season in 1966, 1967, 1968.

(D)- No soil treatment, no seeds.
Grazed to maintain standing crop of 500 lb. DM/acre throughout the grazing season in 1966, 1967, 1968.

The fertilizer treatments were maintained in 1969.

Plots A, C and D were grazed on three occasions during 1969

(a) 6/6 - 7/7
(b) 16/8 -15/9
(c) 25/10- 7/11

Plot B was grazed for the first week only on each occasion.

The four plots form a series in which B corresponds roughly to the Nardus dominant pasture in the state and at the grazing pressure in which it exists on the open hill.

Plot D measures the effect of increased grazing pressure only.

Plot C has received a grazing pressure similar to that of B, but also has had its nitrogen status improved by the application of 100 lb. N/year.

Plot A represents the results of a complete soils upgrading and reseeding on the same soil resource and under a management treatment which uses the primary production as efficiently as possible.

Procedure

The amount of available pasture DM is measured in the week prior to grazing by a cutting technique and also by means of the grass meter. The 1969 results are being used as a basis on which to devise a combined cutting and grassmeter productivity estimating technique.

Cheviot wethers are then put on the plots, their numbers per plot determined from the available pasture DM data so as to equalise grazing pressure. Grazing pressure is computed in terms of available dry matter per sheep per acre at the inception of grazing. The intention of the chosen grazing pressure is to reduce all plots to approximately 500 lbs. DM /acre in the course of one month's grazing. Measurements of available DM /acre are made as the grazing period proceeds so that any stocking adjustment necessary can be made in the last week of the grazing period. Little adjustment has so far been necessary, presumably because the differences in available DM between plots reflect quite well the relative growth rates of the plots during the grazing period. Attempts are also being made to measure these growth rates.

The sheep are run together in a common paddock for three days before each treatment begins. Immediately grazing of the plots is begun the sheep are fitted with faecal collection bags and total collections are made on each week-day during the grazing period.

The collected faeces are sub-sampled, and dry matter, organic matter, nitrogen and phosphorus determinations made. The unused faeces is stored in deep-freeze and returned to the appropriate plots at the end of the grazing period.

Herbage samples from the pre-grazing cuts are similarly analysed.

Results

Only a limited amount of the chemical analytical work has so far been completed. When this has been done the intention is to use the results to evaluate as completely as possible the magnitude of the errors involved in the approach described here, and to incorporate any changes in procedure thought desirable in future work.

Some results relation to stocking rates, grazing days and ingested pasture quality are given in Tables 1, 2, and 3.

Table 1

Available Herbage, Stocking Rates and Grazing Pressures at two grazings (Site 1)

1st Grazing Period. (11/6 - 7/7)

Treatment	A	B	C	D
Available herbage (lb. DM/acre)	2060	3573	1399	527
Mean grassmeter reading (mean of 25/plot)	9.3	5.3	6.8	3.6
Stocking Rate (sheep/acre)	28	7	21	7
Grazing Pressure (lb. DM/sheep/acre)	18.8	-	16.7	18.9

2nd Grazing Period. (19/8 - 15/9)

Treatment	A	B	C	D
Available herbage (lb. DM /acre)	2490	2469	1517	730
Mean Meter Reading (of 25/plot)	11.1	9.4	8.5	5.8
Stocking Rate (Sheep/acre)	35	14	21	14
Grazing Pressure (lb. DM/sheep/acre)	17.8	-	18.1	13.0

Table 2

Grazing Days/Acre (Site 1)

Grazing Period	Dates	A	B	C	D
1	6/6 - 7/6	784	35	616	224
2	16/8 - 15/9	875	112	547	406
3	25/10 - 7/11	308	112	231	42
Total		1967	259	1394	672
Sheep/acre over 200 day growing season		9.8	1.3	7.0	3.4

Table 3

Ingested Pasture Quality (O.M. Digestibility) in first and last weeks of grazing, first grazing period (Site 1)

Week	Date	A	C	B
I	10/6	73.1	72.7	73.3
	11/6	75.8	74.8	73.1
	12/6	76.7	74.7	73.3
	13/6	77.1	73.2	72.6
IV	1/7	70.4	64.8	61.7
	2/7	70.0	64.9	61.2
	3/7	69.6	64.4	62.1
	4/7	70.1	64.5	60.9

Experiment 2

A second site, this time a new one, was enclosed in the spring of 1969. The intention here was to conduct a uniformity trial in 1969, pending the results of the work described in site 1 above, with a view to applying the treatments in 1969-70.

The area chosen on this occasion was an Agrostis-fescue pasture overlying a Brown Earth soil (pH 5.8-6.0). This is intended to be the best site of the series.

The area was previously markedly undergrazed, and was first burned and then pretrimmed with a forage harvester in early April.

Six plots each of 0.25 acres were enclosed making five treatment plots and one to be used as a common pregrazing area.

Treatment in 1969 Two grazing periods were obtained, each of four weeks duration. The dates of grazing were

(a) 27/6 to 28/7
(b) 29/9 to 27/10

Available D.M. estimations were made and the stocking rates set as in Site 1 above. The herbage was taken down to 500 lb. available DM /acre at the end of each grazing.

Total faecal collections were made as before and the herbage and faecal material treated in the same way.

(The soil treatments will be made this winter and clovers and grasses introduced to the appropriate plots in the spring of 1970).

Results Again, the chemical analytical work will not be completed till the spring. The accumulated grazing days information adequately demonstrates the uniformity of the site.

Table 4

Grazing Days per Acre (Site 2)
(Uniformity trial)

Grazing Period	Date	Treatment	A	B	C	D	E
1	27/6 - 28/7		528	464	528	464	464
2	29/9 - 27/10		336	336	336	336	336

The effect of previous nutrition and ration quality on the growth of lambs (C. S. Lamb)

The aim of this experiment was to study, using animals which had completed a previous series of studies (see Lamb Growth Studies 1968 Annual Report), the effect of two different rations on the performance of two groups of lambs which had different nutrition regimes during the summer.

The experiment was a 2^2 factorial involving 24 wethers (6 month old N.C.C. x S.C.C.). Two groups of similar high previous liveweight gain and two of similar low previous gain were formed. High and low quality of ration were allocated to these groups to form the four combinations shown below:-

High Nutrition - High Quality feed
High Nutrition - Low " "
Low Nutrition - High " "
Low Nutrition - Low " "

The experiment was conducted indoors where each lamb was fed individually a dried grass ration. Both rations were pelleted and fed to 20 per cent excess of intake. Liveweight was recorded each week and two 9-day faecal collection periods were employed to determine digestibilities. A blood sample was taken weekly from each lamb over the period 4-7 weeks inclusive. The plasma was analysed for glucose, N.E.F.A., B.U.N. and P.B.I.

Digestibility of dry matter and organic matter varied very little between the two digestibility periods (weeks 4-5 and 8-9) and so the mean results have been used in analyses. Previous nutrition treatment had no effect on digestibility while the difference between rations was highly significant ($P < 0.001$). The composition and digestibilities of the rations are shown in Table 1:

Table 1

Ration composition and digestibility

	Composition (% on Dry matter basis)			Apparent digestibility (%)	
	Ash	Crude Protein	CWC	Dry Matter	Organic Matter
High Quality	10.8	21.8	47.4	70.0	70.8
Low Quality	7.8	16.1	52.9	65.3	65.6

The intake and performance data were obtained from the period 4-9 weeks of the experiment. Results for blood parameters relate to this 4-7 week period. Main treatment means of these results are shown in Table 2.

Table 2

Means for intake, performance and blood parameters

	Intakes ($g/Kg.^{0.73}/day$)						Blood Parameters		
	DMI	DDMI	DOMI	LWG (g/day)	FCE (g DM/g gain)	Glucose (mg %)	NEFA (μequiv/l)	BUN (mg %)	PBI (μg %)
High Nutrition	92.4	62.2	56.9	128	9.6	57.2	262	23.0	2.11
Low Nutrition	98.3	66.2	60.6	139	9.2	53.9	225	24.8	2.63
High Quality Feed	99.5	66.9	60.3	144	8.6	57.0	265	27.7	2.61
Low Quality Feed	94.8	61.9	57.2	124	10.2	54.2	223	20.0	2.12

There was no significant difference between treatments in DM intake although intakes of DDM and DOM were significantly ($P < 0.05$) greater for the high quality ration. Treatment differences in liveweight gain and food conversion efficiency were not statistically significant, although with both these parameters the interaction of level of nutrition and feed quality was significant ($P < 0.05$). No significant differences occurred between treatments in plasma glucose or NEFA levels but for BUN the difference between high and low quality feed was highly significant ($P < 0.001$) which most probably reflects differences in nitrogen content of the feeds and synthesis of body tissue, as no significant correlation ($r = + 0.391$) was found between B.U.N. and liveweight gains over the 4-7 week period. Over the same period there was a significant ($P < 0.05$) difference in plasma PBI concentrations between the nutrition treatments while the difference between rations was almost significant.

Throughout this experiment it was apparent that the animals which were previously less well nourished and particularly those given high quality feed showed greater intakes, liveweight gains and better food conversion efficiency. The difference in efficiency is most likely to be attributable to the different composition of the gains exhibited by low and high previous nutrition groups.

This study has shown that lambs which have not expressed their full potential for growth after early weaning and lowered plane of nutrition throughout the summer will compensate with a faster growth rate when given a suitable feed. Over the 9 weeks of this study the low previous nutrition group did not achieve the same final weight as those of higher previous nutrition although the difference was narrowed from 18 per cent to 10 per cent in these 9 weeks. The economics of this situation appear to be closely dependent on the choice of ration.

A study of the effects of supplementing all roughage diets with cereals

The effect of different levels of barley supplement on intake and digestibility of three good quality roughages (C. S. Lamb)

This is part of an integrated study of the variables of plant origin which appear to influence the energy intakes of sheep fed mixed rations. This study involves feeding barley supplements with good roughages - two dried grasses and one hay - to observe the relative importance of different variables of feed origin affecting intake. Similar experiments are visualised using oats and maize as supplements with the same roughages. Incorporated in this study is an "in vitro" digestibility technique which will provide data on the digestibility of each ration component.

Three groups of four 18 month old N.C.C. x S.C.C. wethers were used in this experiment which comprised three periods. In period one, one roughage was fed to each group of sheep at 20% excess. In period two a supplement of 250g of barley was given daily in two equal feeds, while 500g/day were fed in period three. Each period consisted of a 19 day run in period followed by a 9 day faecal collection period. At the end of each digestibility period rumen liquor was taken by stomach tube from each sheep and bulked to give one sample for each group. This liquor was used to inoculate in vitro cultures of each hay and the barley. The residues, after the "in vitro" determination were retained and analysed for cell-wall constituents and acid detergent fibre.

Before this experiment began a study was made comparing rumen liquor from a rumen cannula with that obtained by stomach tube from the same animal. The results, shown in Table 1, indicate no differences between the sources for determining digestibility of three roughage samples.

Table 1

In vitro dry-matter digestibility of hays using two sources of innocula (%)

	Rumen Cannula liquor	Stomach tube liquor
Hay (1)	66.1%	67.6%
Hay (2)	63.5%	63.1%
Hay (3)	63.6%	63.0%

To date two periods have been completed and the mean composition of the ration components fed are shown in Table 2.

Table 2

Composition of feeds offered - Periods 1 and 2

	Ash	Crude Protein	CWC	ADF
Hay 1	N.A.*	14.1%	57.0%	N.A.
Hay 2	N.A.	15.1%	60.9%	N.A.
Hay 3	N.A.	11.1%	66.4%	N.A.
Barley	N.A.	N.A.	N.A.	N.A.

* Not available at time of writing

The roughages were all of good, to very good, quality by the analyses while the % of CWC showed a steady increase from hay (1) to hay (3). The in vivo dry-matter digestibilities obtained in the first period are shown in Table 3, together with the in vitro results.

Table 3

In vivo and in vitro dry-matter digestibilities and in vitro digestibility of cell-wall constituents

	In Vivo	In Vitro	In Vitro CWC
Hay (1)	69.0%	68.8%	75.7%
Hay (2)	69.2%	68.9%	75.9%
Hay (3)	67.4%	65.7%	63.6%

Very little difference was found between the hays in dry-matter digestibility and in vivo and in vitro results were very similar. The digestibility of CWC was notably greater in hays 1 and 2 than in hay 3. Intakes of dry-matter by each group levelled off after 9-12 days and the daily mean intakes for each ration, calculated over the 9 day digestibility period are shown in Table 4.

Table 4

Mean daily dry-matter intakes

	Intake (g/day)	Intake ($g/KgW^{0.73}/day$)
Hay (1)	1537	90.4
Hay (2)	1412	83.6
Hay (3)	1299	79.2

These results show that there is no correlation between dry-matter digestibility of the hays and intakes. Intake of dry-matter does appear to move closely related to the CWC of the roughage fed although until feed refusals are analysed a connection between intake and CWC intake can only be a tentative suggestion.

Period two of the experiment has just ended and intakes and digestibilities are not yet available. However, it appears that feeding 206g dry-matter of barley has reduced intakes of all hays by approximately 400 g. dry-matter. No calculations on the energy status induced by these changes have yet been carried out.

GRAZING INFLUENCES ON VEGETATION AND SOILS

Circulation of nutrients in soil - plant - animal systems

The research programme is concerned with both laboratory and field studies of those parts of the cycle which are characteristic of, and are important in, the hill pasture situation. Laboratory studies have included an investigation of the effects of temperature and moisture upon the mineralisation of carbon, nitrogen and phosphorus from plant materials and sheep faeces. Factors which may be of importance in affecting the decomposition rate of organic materials include soil acidity and the related properties of soil and plant aluminium. Studies of these factors are continuing.

Field experiments have included a continuation of the return of sheep excreta to small plots to assess the re-circulation of plant nutrients via the animal, and to compare organic and inorganic sources of these nutrients. Under traditional management systems only a very small fraction of the soil pool of nutrients participates in the nutrient cycle. One of the objectives of the new series of input-output experiments is to measure that proportion of the soil nutrient pool which is re-circulating under a progressive series of improvement treatments.

1. Fence-line effects (M. J. S. Floate and I. A. Nicholson)

Five pairs of soil profiles, on soils of the Ettrick, Bemersyde and Balrownie soil Associations have been studied in order to make some assessment of the long-term effects of minor differences in grazing management. Details of the sites and vegetative differences have been given in earlier Annual Reports (1966, 1967).

Comparisons have been made between the soils of the more intensively grazed (A) member of each pair with the less intensively grazed member (B). The results for organic-C, total-N, total-P, acetic acid soluble-P, C/N ratio, pH, and depth of A_0 horizon were discussed in 1967. These may be summarised: there was an overall reduction in the weight of organic-C and of acetic acid soluble-P in the (A) profiles, and an overall increase in the total-P, while the total-N in the profile remained more or less constant.

A more detailed examination has been made of the changes in phosphorus distribution in these soils. The weights of phosphorus (total, organic and two inorganic fractions) have been calculated in g/m^2 to a depth of 40 cm and these are presented in Table I:I. When comparing site A with site B these results showed that in every case there was an increase in both total and organic-P.

Table I:I

Weight of phosphorus in soil profiles (g/m^2)*

Site	Total phosphorus	Organic phosphorus	Acid-soluble inorganic phosphorus	Acid-insoluble inorganic phosphorus
Spartleton A	312	227	66	17
Spartleton B	264	176	55	33
Dirrington A	238	160	29	49
Dirrington B	183	100	49	34
Comrie A	263	178	59	26
Comrie B	232	148	71	13
Bogrie A	267	217	39	11
Bogrie B	165	121	32	12
Romanno A	245	178	33	34
Romanno B	208	150	20	37

* $g/m^2 \times 10$ = Kg/ha.

At Spartleton, Bogrie and Romanno there were increases in acid-soluble-P which were coupled with decreases in acid-insoluble-P. At Dirrington and Comrie on the other hand the increases were in the acid-insoluble fraction coupled with decreases in the acid-soluble inorganic-P. On average there was an increase of 54.6 g total-P, of which 53.2 g was organic and 1.6 g was acid insoluble inorganic-P, but there was a loss of 0.2 g acid-soluble inorganic-P.

These changes in the weight of phosphorus in the whole profile were accounted for by increases in both total and organic-P in the mineral soil horizons of all (A) sites, and in the surface Ao horizons of all (A) sites except Dirrington and Comrie where there was a considerable reduction in the thickness of these horizons.

It may be concluded that the increased animal influence at the (A) sites has led to a consistent increase in phosphorus in these soils, and that this increase has been very largely in the organic fraction. Similar observations of increased organic phosphorus in the soils of grazed pastures have been made in Australia and New Zealand, and it is possibly due to the relatively slow mineralisation of the organic phosphorus in sheep faeces. Analysis of the soils under small plot dung and urine return experiments, and in the input-output grazing experiments may provide further information on this aspect.

The lack of any significant increase in the acid-soluble inorganic-P (or more readily available fraction) may indicate that it is rapidly taken up by the plants. The whole subject of the circulating fraction of the soil pool of nutrients requires further study.

2. Nutrient circulation in grazing experiments (M. J. S. Floate and J. Eadie)

As indicated earlier one of the objectives of the grazing experiments, which involve a progressive sequence of improvement treatments, was to measure that fraction of the soil nutrient pool which circulates via the animal.

To date experimental work has been carried out on two sites. The first of these was originally set up by I. A. Nicholson (Annual Reports, 1966, 1967) and the work carried out during 1969 was designed to assess the effects of the treatments in terms of animal production parameters. In addition, data have been collected on the uptake of nitrogen and phosphorus by the plants in each plot, and data have also been collected on the return of these nutrients in dung and urine by grazing sheep. Some analyses of these materials have been completed but the majority remain to be done. The results will be discussed when these analyses and those from a final set of soil samples from the experimental area have been assessed. The second site was established in the early part of 1969 and after preparation of the experimental area sheep have been under grazing control on five plots. No improvement treatments have yet been applied and this season has been used to assess the present situation under controlled grazing. A sequence of three (4 week) grazing periods and three recovery periods was documented during 1969. Data were collected on plant dry matter production, and N and P uptake, on excrement return of N and P, and on animal performance. In addition soil samples were taken over the whole experimental area. The soil of this site is a Brown Earth of the Sourhope series and carries an *Agrostis-Festuca* pasture which includes some native *Trifolium repens*. The site represents an example of the best available native hill pasture types. The plant material, sheep excrement and soil samples are currently being analysed and when the results are available it will be possible to make an assessment of the first year's data.

3. Application of faeces and urine to hill pastures (M.J.S. Floate and J. S. Black)

Details of a field experiment in which faeces and urine, and inorganic sources of N and P are applied to small plots in proportion to plant dry matter production, were described in the Annual Report (1968).

During 1968 three cycles of cutting and return were described and measured and in 1969, due to the late start to the growing season, again only three cycles were completed. Data for 1968 are now available but the data for 1969 are incomplete due to sheep damage prior to the third cut and return cycle. Despite this limitation the results for 1969 have been calculated and show increased dry matter production over 1968 on most plots.

In the 1968 season dry matter production ranged from 2500 to 3500 lb./ac. (highest yields were from (N_4 P_4) and U_4 plots). In each sequence of return levels (x ½, x 1, and x 4) there was a progressive increase in production whether treatments were applied as inorganic N and P (equal in amount to N content of urine, and inorganic P content of faeces), as urine or faeces alone or together. In the 1969 season production ranged from 2200 to 5400 lb./ac. This year the highest yields were on those plots receiving urine or urine + faeces at the x 4 return level. Again there was a progressive increase in production in each return sequence except on the F_4 plot. In all other cases there were very considerable responses at both x 1 and x 4 levels to inorganic N + P, to urine and to urine + faeces applied together. It is to be noted that the highest yields were recorded on those plots which had been treated at the x 4 return level for two seasons and it is possible that there had been some carry-over of applied nutrients from 1968 to 1969.

In each sequence of return treatments there was a progressive increase in N uptake (through x ½, x 1 to x 4) in both 1968 and 1969. The amounts of N taken up by plants ranged from 60 to 85 lb./ac. in 1968 (when the highest values were recorded for the (N_4 P_4) treatment): in 1969 the amounts ranged from 40 to 140 lb./ac. and the highest value was recorded for U_4 D_4 treatment. In both seasons uptake exceeded return at x ½ and x 1 return levels but at the x 4 return level there was an excess of N applied over that taken up by plants. Increased amounts of plant uptake of N, above the levels measured for N_0 return, indicate that there has been considerable re-circulation from both inorganic and urine sources. This may account for 15 - 25% of the total N uptake at x 1 return and up to 50% of the total N uptake at the x 4 return level. There appears to be no significant re-circulation of faecal-N: although F_1 plots showed higher uptake of N than $F_{\frac{1}{2}}$, these were not significantly greater than N uptake on the N_0 treatment. It is noteworthy that in 1968 the highest N uptake levels were from inorganic sources while in 1969 the highest uptake levels were from combined urine and faeces. This may indicate some mineralisation of faecal-N applied in the previous season which appears only to take place in the presence of adequate supplies of inorganic-N from urine.

P uptake increased through all return sequences in both seasons: in 1968 the amounts taken up by plants ranged from 7 to 10 lb./ac. and in 1969 from 6 to 13 lb./ac. In the 1968 season highest values were recorded for (N_4P_4) and (N_1 P_1) treatments while in 1969 the greatest uptake was recorded on the (U_4 F_4) treatment. This may indicate some carry-over of P from one season to the next or the mineralisation of organic faecal-P. Carry-over is possible since in both seasons return exceeded uptake at the x 4 return level while uptake was greater than return at both x ½ and x 1 levels.

Although many P-treated plots showed uptake of P in excess of that on N_1 plot (= P_0), there was also an increased P uptake through the sequence of $U_{\frac{1}{2}}$, U_1 U to which no P had been applied. It is therefore not yet possible to conclude that significant amounts of P have been re-circulated.

It is intended to continue the return treatments through one more season and then to take soil samples from each plot to measure the effects of the treatments on the reserves of soil nutrients.

4. Decomposition - mineralisation experiments (M. J. S. Floate)

An account of preliminary experiments and the development of the incubation technique has been accepted for publication in the Journal of the Science of Food and Agriculture. The paper is entitled: "Decomposition of the organic materials from hill soils and Pastures. I. An incubation method for studying the mineralisation of carbon, nitrogen and phosphorus", and is concerned with a technique for studying mineralisation from organic materials in the absence of mineral soil.

The results of a series of experiments in which plant materials and sheep faeces were incubated at 30°C were described in the Annual Report (1968). Further series of incubation experiments have been conducted to test the effects of variation in incubation temperature and moisture levels. Mineralisation products were analysed after 1, 2, 3, 6, 9 and 12 weeks incubation as before and while there were some fluctuations during the 12 weeks, the final results summarise the major effects.

Table 4:1

Effects of Variation in temperature on the production of CO_2 and mineral N and P
(Incubation at 100% moisture holding capacity for 12 weeks)

Incubated Material	30°C	10°C	5°C
CO_2 as per cent of original organic-C			
Agrostis-Festuca (A)	48.2	31.3	16.9
Nardus (A)	31.3	18.7	7.3
Agrostis-Festuca (B) faeces	14.8	3.3	1.2
Nardus (B) faeces	16.2	3.9	2.3
Total net mineral-N as per cent of original total-N			
Agrostis-Festuca (A)	9.2	1.2	-0.1
Nardus (A)	1.6	0.6	-0.4
Agrostis-Festuca (B) faeces	6.9	7.6	4.3
Nardus (B) faeces	4.8	9.8	7.2
Total net mineral-P as per cent of original total-P			
Agrostis-Festuca (A)	-5.2	-29.0	-48.8
Nardus (A)	5.5	-24.1	-33.9
Agrostis-Festuca (B) faeces	7.0	2.2	-12.9
Nardus (B) faeces	13.0	2.8	-11.0

These results, presented in Table 4:1, showed that lowering the incubation temperature reduced the rate of decomposition as reflected in the production of CO_2. The amounts of mineral-N produced from plant materials were lower at 10°C than at 30°C and at 5°C immobilisation of nitrogen occurred. From faecal materials, however, the production of mineral nitrogen (mainly in the form of NH_4^+-N) was stimulated at 10°C and mineralisation continued down to 5°C. The effect of reduced temperature on mineral-P production was to decrease the amounts produced progressively from 30°C to 5°C or if these became negative, to increase the amount of phosphorus immobilisation. At 5°C both plant materials and faeces immobilised phosphorus but this accounted for a smaller percentage of the original phosphorus present in the faeces than in the plant materials.

It may be concluded that the lower soil temperatures normally encountered in the field between October and May, are likely to reduce very considerably the rate of organic matter decomposition but it is possible that the production of mineral-N from faeces may be slightly stimulated in the temperature range 5 - 10°C and soil temperatures within this range have been recorded for two periods each of about 6 weeks duration at the beginning and end of the summer.

The results presented in Table 4:2 summarise the effects of variation in moisture content on the production of CO_2 and mineral-N and P from plant materials. Experiments on faeces are in progress. The results showed that the magnitude of the effects were small compared with those due to temperature. Although there were some indications during the first three weeks that decomposition was enhanced at 25% moisture holding capacity, by the end of 12 weeks the production of CO_2 was highest at 50% or 100%. These values did not differ greatly from those obtained at 10°C in the temperature experiments. Total net-mineral-N production from plant materials was highest at 50% moisture holding capacity but at the higher moisture levels (50% and 100%) immobilisation of phosphorus was greater than at 25% moisture holding capacity.

Table 4:2

Effects of variation in moisture content on the production of CO_2 and mineral N and P (incubation at 10°C for 12 weeks)

Incubated material	25% moisture holding capacity	50% moisture holding capacity	100% moisture holding capacity
CO_2 as per cent of original organic-C			
Agrostis-Festuca (A)	22.8	28.4	31.9
Nardus (A)	17.5	20.2	19.2
Total net mineral-N as per cent of original total-N			
Agrostis-Festuca (A)	0.9	1.5	0.5
Nardus (A)	1.6	3.0	2.5
Total net mineral-P as per cent of original total-P			
Agrostis-Festuca (A)	-9.6	-14.4	-12.3
Nardus (A)	2.8	+1.7	-11.5

Final conclusions must await the results of the experiments with sheep faeces but it does appear that soil temperature is likely to be a factor of greater importance in the field than moisture content.

5. Ammonia evolution from decomposing organic materials (M. J. S. Floate)

Preliminary experiments indicated losses of nitrogen during incubation of organic materials in both open and closed systems. By including tubes to absorb gaseous ammonia in the incubation vessels almost 100% recovery of the original total nitrogen was achieved. The results of these experiments have been published in a paper entitled "Decomposition of organic materials from hill soils and pastures, I".

Further experiments to study the effects of variation in incubation temperature and moisture levels have been conducted. The results, summarised in Table 5:1, showed that lowering the incubation temperature reduced the evolution of NH_3 and that this reduction was greater from plant materials than from faeces.

Table 5:1

Effects of incubation temperature and moisture level on evolution of NH_3

Incubation period (weeks)	*Agrostis-Festuca* (A)[1]			*Nardus* (A)			*Agrostis-Festuca* (B)[2] faeces			*Nardus* (B) faeces			Remarks
	30°	10°	5°	30°	10°	5°	30°	10°	5°	30°	10°	5°	
3	41.1	0.2	0.1	16.5	0.2	0.0	90.2	1.4	0.0	14.8	6.6	0.1	Incubations
6	52.9	0.3	0.1	9.1	0.6	0.0	122.9	6.0	1.2	26.3	27.6	5.6	all at 100%
12	66.1	1.1	0.8	10.1	3.4	0.3	147.8	42.0	3.3	53.0	68.7	20.9	moisture
	25%	50%	100%	25%	50%	100%	25%	50%	100%	25%	50%	100%	holding capacity
3	0.5	0.0	0.7	0.0	0.0	0.2	5.4	3.1	5.9	1.7	5.4	4.1	
6	1.7	1.3	2.1	0.5	1.7	0.9				4.6	8.2	14.9	Incubations
12	3.6	3.9	3.5	3.8	3.6	3.4	Experiment still in progress						all at 10°C

1 Treatment (A) = annually accumulated plant material
2 Faeces collected from sheep fed monthly-cut plant material (Treatment - B)

The experiments on the effects of moisture level are still in progress, but it appears that variation between 25% and 100% moisture holding capacity had only minor effects on the evolution of NH_3.

Thus the effects due to temperature are much more pronounced than those due to moisture and it may be concluded that under field conditions on the hill the losses of NH_3 from decomposing plant materials are likely to be very small. The losses of NH_3 from decomposing sheep faeces under similar conditions may be considerably higher, especially when soil temperature are $\geqslant$ 10°C (approximately June-September).

6. <u>Phosphorus content of herbage and faeces</u> (M. J. S. Floate)

Thirty-one samples of hill pasture herbage obtained from a variety of pasture types, and at different times of the year were available for this study. The composition of these plant materials, and of the faeces derived from pairs of sheep fed on the same materials have been determined. The results are summarised in Table 6:1.

Table 6:1

Phosphorus concentration in herbage and sheep faeces

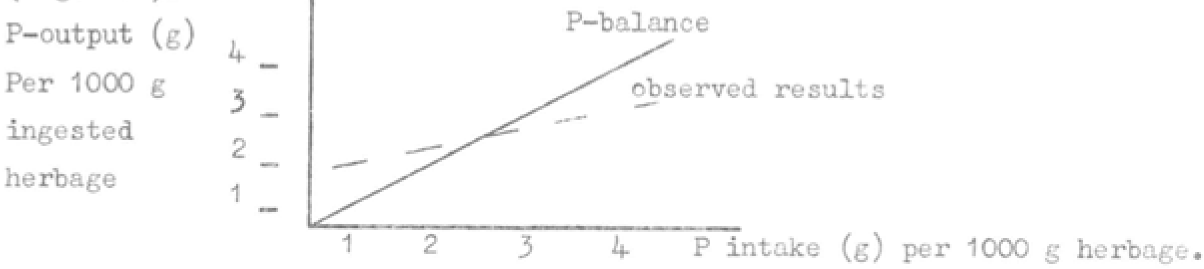
Material	Total-P (mg/100g)	Inorg-P (mg/100g)	Inorg-P as % of Total-P	Mean OM Digestibility
Herbage (31 samples)				
Minimum	110	53	48	38.6
Maximum	452	291	75	76.4
Mean	228	143	62	57.7
Faeces (58 samples)				
Minimum	209	105	48	
Maximum	1371	1160	88	
Mean	622	464	73	

In general the highest concentrations of phosphorus occurred in the materials of highest digestibility which were usually derived from *Agrostis-Festuca* pastures cut in early summer. In contrast, the lowest concentration of phosphorus, and lowest digestibility values were associated with winter-cut herbage from *Nardus* and *Molinia* pastures.

These results also showed a large increase in phosphorus concentration when feed was converted to faeces. In both plant materials and sheep faeces the inorganic fraction of phosphorus accounted for an increasing percentage of the total as the phosphorus concentrations increased. There was, therefore, a higher proportion of inorganic phosphorus in faeces than in plant materials (mean values were 73% compared with 62%).

Based upon measured organic matter digestibility values, the weight of phosphorus excreted per 1000 g food intake has been calculated for each material. When these weights were compared with the weight of phosphorus ingested some interesting results became apparent.

Output of P per 1000g food intake was highly significantly correlated with P intake but when P intake was low (i.e. there was a low concentration of phosphorus in the herbage), P output was higher than expected; and when P intake was high the output was below the expected level for animals in P balance. (Fig. 6:1).



These results could be explained as endogenous loss of phosphorus from sheep fed on herbage of low phosphorus content but this would appear to lead to the expectation of endogenous loss from a wide range of hill herbage materials. The results could also be an artefact of the 21 day feeding period from which the digestibility data were collected and this possibility remains to be investigated. When similar calculations are made for inorganic phosphorus there appears to be greater excretion than intake of inorganic phosphorus throughout the concentration range available. This result could be due to conversion of organic -> inorganic phosphorus within the sheep. It is of importance since it is the inorganic fraction of the faeces which is known to be most readily available for plant growth. The conversion of plant material to faeces is thus beneficial to the plant nutrient cycle since it results in an increased proportion of inorganic phosphorus which may be available for plant nutrition.

Some experiments have been carried out in an attempt to make an assessment of the availability of faecal phosphorus to plants.

Extraction studies have shown that after 5 successive water extractions practically all the inorganic phosphorus was removed (Table 6:2). This water-soluble inorganic phosphorus may become available for plant growth.

Table 6:2

Extraction of water soluble-P from sheep faeces

Inorganic-P in faeces (mg/100g)	Inorganic-P extracted in water					Total water-soluble Inorganic-P (mg/100g)
	1	2	3	4	5	
105	107	9	3	0	0	119
256	217	29	8	6	0	260
410	317	63	19	9	5	413
481	353	83	27	13	6	482
838	618	121	50	28	14	831
1145	428	130	65	42	30	695

The remaining phosphorus in the faeces is in organic form and can only become available through mineralisation during decomposition. This aspect has also been investigated and the results are discussed in the decomposition and mineralisation section (4).

7. Soil acidity, aluminium and organic matter decomposition (M. J. S. Floate)

Due to the resignation of C. J. W. Torrance his M.Sc. programme: " A study of some properties of hill soils affecting the decomposition of native and added organic materials" was brought to a close. However, A. G. Lowe has taken up this project and it is proceeding as follows:-

A study is being made of the distribution of aluminium in selected hill soil profiles in relation to soil pH and the exchange properties of these soils.

A technique is being developed in which the Biological Oxygen Monitor will be used to monitor the changes in decomposition rate of organic materials containing varying amounts of aluminium. Plant materials which contain varying concentrations of aluminium are available from preliminary experiments which were described in the Annual Report (1967).

Analytical service (C. C. Evans and M. J. S. Floate)

There has been a marked increase in the provision of routine analytical services during 1969. The scope of the service has been increased by the installation of a semi-micro Kjeldahl apparatus for nitrogen analysis. This method permits rapid analysis of large numbers of samples. When it is necessary to sub-sample from a much larger sample a limitation may be the relatively small weight (0.1g) which can be digested prior to steam distillation. This limitation can be minimised by replicated analyses.

Analysis completed during 1969 included faecal silica content as an indicatator of soil ingested by grazing sheep (Dr. Cunningham); nitrogen, phosphorus, potassium, calcium and magnesium content of four grass species in relation to soil moisture and aeration studies (Mr. Davies); phosphorus content of sheep faeces and herbage in relation to the effects of faecal application to hill soils (Dr. Floate) and nitrogen, phosphorus and potassium levels in two grass species grown in competition (Dr. King). The analysis for the mineral elements was by X-ray methods outlined in the 1967 and 1968 annual reports.

X-ray method development

It has been necessary to develop an X-ray method for the analysis of sheep feed and dung for chromic oxide content. The method is similar to those outlined in the 1967 annual report (p. 26). Interelement interferences were predicted, by theoretical calculation, due to the modification of the mass absorption coefficient of the samples by variation in the potassium, calcium and silicon concentrations. These interelement effects were established experimentally and overcome by the use of the background count rate as an internal standard. Excellent agreement was achieved between the results obtained by the X-ray method and a chemical procedure. The standard deviation of the differences for 32 samples was $<$ 0.003% chromic oxide for a range in concentration of 0.068% and 0.245% with the lower limit of detection of 0.0008%.

PLANT ENVIRONMENT INTERACTIONS

Introduction

With only a comparatively small number of exceptions the contribution made by pasture improvement to the productivity of hill sheep flocks in Scotland has been very small indeed. This has been due principally to the fact that there has been no satisfactory means whereby improved pasture can be integrated in a system of management with the natural pasture to increase the production level of the hill sheep flock and in particular the production level of the individual animal. Pasture improvement leading to an increase in the area of in-bye land separated from the hill tends to have little effect on sheep production, though it may lead to increases in cattle production.

However, the new management systems now proposed to achieve this integration depend on the existence of a considerable area of Agrostis-Fescue or better pasture in enclosed blocks amounting to between 150 and 200 acres for every 1000 ewes. This is a considerable area to find in the difficult soil and topographic conditions of hill farms. In addition it is very important that the recurrent costs of maintaining such improved pasture be kept as low as possible. It is therefore desirable that in the future careful consideration be given to the precise function for which the improved pasture is required and full use made of those pasture types both natural and improved which fulfil this function at the lowest cost. The main functional requirements are (1) early spring grazing, (2) late spring and early summer grazing for lactation, (3) foggage in November and December. This means that the defoliation regime must be optimised with respect not only to the needs of the animal but also to the needs of the plant, bearing in mind that the ability to provide for any one requirement will be affected by the previous management. It also means that preference must be given, other things being equal, to species with the least exacting requirements and those which are tolerant of adverse environments (e.g. anaerobic soils, low soil base status). The object must be to create swards which are in equilibrium with the management and the physical environment and which therefore need incur no replacement costs. Broadly similar objectives can be stated for the unimproved hill vegetation: the enhancement of the value of a vegetation type for a particular function (e.g. winter grazing) while ensuring that changes in grazing management and pressure do not bring about degeneration.

Such considerations underlie much of the present botanical programme and also form the basis for future work which will become possible with the advent of the new facilities at Bush.

Work in progress comes under four heads:

(1) Studies of production and the influence of management on production by grass species at specific times of the year and for specific purposes, e.g.

(a) Growth in winter and early spring under low light and low temperature conditions;

(b) Growth in summer and late autumn in relation to management and nutrient levels;

(c) Balance between senescence and growth in autumn, winter and spring.

(2) Studies of plant competition: identification of the factors for which competition is taking place and measurement of changes in pasture composition consequent upon changes in management. This includes observations made as part of the process of monitoring sheep systems trials.

(3) Evaluation of heather as a pasture plant. This involves a study of the effect of defoliation and burning on growth-form and productivity. This will be associated with agronomic studies of digestible O.M. intake by grazing animals on various heather types. This in turn will lead to further studies of the effect of grazing and selective defoliatitn on the maintenance of these types.

(4) The evaluation of poorly drained soils for improved pasture and the parallel evaluation of the tolerance of species to such conditions. This is being carried out on a range of surface water gleys, soil types which are not readily drained but which are found on the lower and more accessible hill slopes and which are frequently of relatively high base status.

Summer pasture production: animal/pasture interactions (J. King)

During the growing season the requirement is for a low cost pasture providing herbage of a quality suitable for grazing by lactating animals. This can be provided either by Agrostis-Fescue or by Ryegrass dominant swards. Between the possible extremes of species-poor Agrostis-Fescue and Ryegrass dominance there is a continuous series of sward types usually associated with a gradient of increasing soil fertility. For all these the aim is to maximise production. At any given level of soil nutrient supply production is to a considerable extent a function of the defoliation regime, operating both through its effect on the production by individual species and its effect on pasture composition. These are major components in the interaction between stocking rate and pasture growth and it is apparent that our present understanding of this relationship is not adequate either as a basis for grazing management decision or to enable functional models of grazing systems to be constructed. An experimental programme is being started on the effects of grazing defoliation on pasture and at present a small number of pilot experiments are being carried out with the object of defining the problem more precisely and of developing a suitable experimental approach.

Some of the results obtained in one experiment are shown in the following three tables. They were obtained from swards of *Agrostis tenuis*, S23 Ryegrass and S59 Red fescue, grown in large boxes and subjected to pre-treatments over 6 weeks simulating severe and lenient pasture defoliation. Yields for a regrowth period following the pre-treatments were measured for all species while measurements of Leaf Area Index and the level of labile reserves were made for *Agrostis* and Ryegrass only.

There were no significant differences between species in respect of yield, final LAI or initial reserve level, but the pre-treatments had highly significant effects on all these parameters. The yield response to the defoliation appears to be more related to the initial level of reserves than to the initial LAI.

Effects of defoliation on pasture re-growth

Table 1

	Defoliation pre-treatment	Re-growth over 2 weeks after pretreatment DM gm/box: Agrostis	Ryegrass	Red Fescue	
	Defoliation:-				
Severe	weekly to 2 cm to give a short dense vegetative sward	36.4	35.4	36.5	***
Lenient	3 weekly to 3 cm to give a taller vegetative sward	47.6	44.7	44.7	

*** P = 0.01 level of significance

Table 2

	Initial LAI at start of two week growth period		Final crop LAI after 2 weeks growth	
	Agrostis	Ryegrass	Agrostis	Ryegrass
Severe	1.8 ←—— *** ——→	0.9	3.9	3.3
	***	***	*	*
Lenient	0.5	0.3	5.8	4.2

Table 3

	Index of labile reserve level at start of 2 weeks growth period	
	Agrostis	Ryegrass
Severe	23.4	18.7
	***	***
Lenient	43.2	52.0

Plant growth at low light and temperature (Sheila A. Grant)

The earlier experiments in this series clearly indicated that growth in the sense of tillering, production of new leaves, leaf extension growth, etc. does occur, though slowly, at temperatures as low as the upper thirties Fahrenheit. Growth occurs intermittently throughout the winter and, for grasses, the year cannot be divided sharply into a 'growing' and 'non-growing' or 'dormant' season. However, as has been pointed out by Davies and Calder (1969) net growth, i.e. increase in weight of the above ground parts is determined by the balance between leaf death and leaf formation. In winter the low light levels and frosting so influence leaf death rate that net increases in above ground parts are very small and on occasions disappear and become net decreases.

Leaf senescence caused by low light levels can be reduced by ensuring that the LAI of a sward is not excessive when light levels are falling, i.e. by suitable autumn management. However, severe defoliation should be avoided as this could lead to reduced spring yields. Future work should take account of management effects on sward senescence rates. It may also be worth investigating the effects of the nutritional status of the plant on its susceptibility to frost damage.

The experiments to date have concentrated on production of new foliage. They have indicated that there is considerable variation between and within species and that different aspects of leaf production show different relationships with temperature and light. Such information is useful to the plant breeder and with grasses selected for grazing, where LAI's are usually maintained below the optimum, ability to expand leaf area rapidly is an important consideration. Sufficient variation existed in the relationship between temperature and rates of leaf appearance and extension growth to indicate that the selection of genotypes with better than average growth at low temperatures may be worthwhile.

The fourth experiment in the series was carried out mainly to collect more data on relative growth rates (R.G.R.) in relation to low temperature and light. Analyses of variance of the data from the separate growing periods indicated that significant differences existed between species in only one out of the six growing periods. Temperature effects were significant in five out of the six growing periods and shading (25% light reduction) significant in only one growing period. At first sight this data could be taken to indicate that, during winter, light is relatively unimportant in its effects on R.G.R., low temperature being limiting. However, it is worth remembering that light variation between growing periods was of a greater order than that within growing periods, e.g. mean hours of sunshine for period 2 = 0.75 hrs./day; for period 5 = 3.49 hrs./day. Daylength also varied being shortest in period 3.

In regression analyses examining the relationship between temperature and the various parameters of growth, over all growing periods, it is possible to calculate the percentage variation accounted for. Table 1 below summarizes the results. The unexplained variation is due to error and light effects taking account of both between and within growing period variation.

Table 1

Percentage of variance due to regression of various growth parameters on temperature

Species	Festuca Rubra				Poa Pratensis			
Temperature	Mean	Mean	Mean	Max	Mean	Mean	Mean	Max
Regression	Lin	Quad	Lin	Quad	Lin	Quad	Lin	Quad
Growth Parameter								
Rate of leaf elongation	91.8	93.1	90.0	92.1	89.7	92.9	91.7	96.6
Rate of leaf appearance	84.0	85.1	82.1	82.2	76.1	77.5	82.5	85.3
Rate of tillering	58.0	58.5	58.6	59.4	70.9	71.9	58.4	61.1
Leaf Area per unit weight	84.6	84.7	69.5	69.6	83.1	83.5	69.1	70.2
R.G.R.	52.9	53.1	62.4	64.0	71.9	71.9	82.2	84.0

Clearly temperature is of over-riding importance during winter. For every parameter more than 50% of the variation is explained by the regression against temperature. For some parameters, e.g. tillering and R.G.R., there is a considerable amount of unexplained variation. For both these parameters light is known to account for a large amount of variation (over-riding for R.G.R.) at higher temperatures and it is probable that some of this variation is due to light. The large amount of variation explained by the effect of temperature on leaf area per unit weight (L.A.R.) is surprising, since this is known to be influenced by light. Not unexpectedly over 90% of the variation in rate of leaf extension growth is accounted for by the temperature regressions.

It should be remembered that these results were measured on plants growing in pots. Any facet of growth affected by light will be affected by cultural conditions; light effects on potted plants will be less than on swards.

Competition between indigenous and sown species (J. King)

The analysis of the yield data from this experiment is complete. The species were Festuca rubra and Ryegrass S23 and Donald's divided pot technique was used. Treatments were as follows:-

Nutrient level				Order of Sowing		Mode of Competition
High P Low P	x	High N Low N	x	Lolium sown first F. rubra " " Both sown together	x	for Light only for Nutrients only for Light + Nutrients No competition

Competition for nutrients emerged as a most important factor. In respect of yield both species responded in a similar way to increased levels of N and P. Yield increased with increased N irrespective of P level, but responded to increased P only at high N.

For both species yields were greatest where there was no competition or competition was for light only. Competition for nutrients alone or nutrients and light depressed the yield.

The ratio of the two species in mixed culture was largely determined by competition for nutrients. Thus the ratios of the species in a mixture tended to be the same when competition was for nutrients only as when it was for both nutrients and light.

Any factor therefore which enhanced the ability of one species or the other to compete for nutrients was of great importance.

The prior occupation of the available soil volume was a great advantage and whichever species was sown first was able to dominate the other. Lolium by virtue of its more rapid establishment was able to do this more completely than could F. rubra and when both species were sown simultaneously it was Lolium which became dominant.

However, if F. rubra was sown first it was able to dominate Lolium and this was due almost entirely to its ability under these circumstances to compete successfully for nutrients. The effect of different nutrients and nutrient level on the species ratio was much less marked. Where a response occurred, increasing level of P tended to increase the proportion of F. rubra while increasing N increased the proportion of Lolium.

These data suggest that for these two species competition for nutrients is of central importance and suggest that any change in the species ratio brought about by defoliation may be due more to the effect of defoliation on root extension and nutrient uptake than to the more direct effect on competition for light.

Data on nutrient uptake is also available, but is at present being analysed.

Effects of sensitivity to defoliation on competition between species growing in 50:50 mixes (Sheila A. Grant)

Four species with differing sensitivity to defoliation were grown in various pair combinations as 50 : 50 mixes. Defoliation was uniform throughout the first summer after planting, but in autumn one series of boxes was rested and one cut. The effect of this differential autumn treatment on growth the following spring was measured. The first experiment (1966 - 1967) indicated that competition of the less sensitive species of any pair was favoured in the cut as opposed to the rested boxes. However, high variability among the replicates as a result of rabbit damage necessitated a repeat run of the experiment in 1968 - 1969. The results for each mix investigated are reported briefly below:-

1. Agrostis tenuis and Festuca rubra

At reasonable levels of fertility Festuca rubra because of its taller and more erect growth competes successfully (for light) against Agrostis tenuis (see previous annual reports).

In both experiments of this series Agrostis tenuis accounted for only a small proportion of the mix, on a dry matter basis. Though there was no significant difference in early harvests between each series of boxes the recovery growth of Agrostis tenuis, in the boxes cut in autumn, became progressively poorer as the season advanced. By midsummer in the second experiment the difference in proportions of Agrostis in the cut as opposed to the rested boxes was significant ($P < .01$).

2. Festuca rubra and Holcus lanatus

Festuca rubra is much less sensitive to defoliation than Holcus lanatus and thus in spite of the much more robust habit of the latter it is able to compete successfully with this species. In the establishment period, Festuca accounted for about 20% by weight of the mix (being slower to establish than Holcus), but with each successive cut it increased in proportion. In the first spring harvest of each experiment following the autumn treatment, Holcus was reduced in the cut as opposed to the rested boxes the reduction being significant in the second experiment ($P < .05$). As the season advanced the mixture in the cut boxes remained fairly stable, Festuca now accounting for over 70% by weight. In the boxes rested in autumn, each succeeding harvest in the following spring resulted in an increase in the Festuca contribution thus narrowing the gap between the two series.

3. Holcus lanatus and Anthoxanthum odoratum

Both species in this mix are relatively sensitive to defoliation. They are similar in habit, Holcus being slightly more robust and on the whole slightly more successful when in straight competition with Anthoxanthum. However, it would appear that if anything, Holcus is a little more sensitive to defoliation than Anthoxanthum, its percentage contribution to all spring harvests following autumn cutting being reduced compared with its contribution to the mix in autumn rested boxes. However, variability among replicates was high and the difference was significant on one occasion only - the second cut of the three harvests of 1969 ($P < .05$).

4. Anthoxanthum odoratum and Agrostis tenuis

Anthoxanthum is more sensitive to defoliation than Agrostis. Under a defoliation regime considered to be more lax than grazing Anthoxanthum dominated the mix. In spring harvests subsequent to differential treatments the percentage of Anthoxanthum in the autumn cut was reduced when compared with the autumn rested series. Variability among replicates was high and no differences were significant though two harvests approached significance fairly closely ($P > .05 < .10$, $P < .10$).

The sensitivity to defoliation of the four species studies was assessed in a spaced-plant experiment (Grant and Hunter 1968) and the experiments reported above were performed to test whether this assessment had any relevance to the species performance when grown in competition - as they would be under natural sward conditions. It does appear to have relevance in that competitive abilities of plants are modified, but it does not necessarily follow that the 'winner' in the competitive struggle is always the species least sensitive to defoliation. Other factors, e.g. those affecting competition for light, nutrients or water may decide the issue though presumably the more severe the defoliation regime the more likely it is that sensitivity to this will be important.

Heather moorland management: The Finella grazing and burning experiment (Sheila A. Grant)

Heather stands differing widely in growth form have been produced adjacent to one another as a result of the management (grazing and burning) experiment initiated in 1957. The stands at present range from 6 - 12 years of age and grazing of the plots is on an on-off basis because of the small size and lack of watering facilities. Stocking rates vary at levels equivalent between 2.75 acres per sheep to 2 sheep per acre. During 1968 and 1969 effort has been concentrated on the measurement of production characteristics of the wide range of stand types obtained.

In last year's report it was noted that standing crops varied from 2,340 Kg/Ha to 9,970 Kg/ha and that annual dry matter production varied from 16% (by weight) to 55% of the standing crop depending on age and grazing regime. Standing crop by itself gives no useful index of either current or past production of a heather stand. It is essential that the distribution of dry matter among the various plant fractions also be known. Hand separation into the various plant fractions (flowers, current season's shoots, other green material, dead shoots and wood) is the most obvious method of estimating this, but it is extremely laborious and time consuming and could not be attempted on a large number of samples. Other methods of characterising the heather shoot are at present being investigated. The obvious distinction is between weight of green photosynthetic tissue (current seasons shoots and older green shoots) and non-green and supporting tissue (flowers, dead shoots and wood). The method currently being looked at is a modification of the technique used by Hunter and Grant (1961) to estimate green dry matter in a herbage sample. The method involves the extraction of chlorophyll pigments and the determination of their concentration using a spectrophotometer.

Another difficulty in studies of grazing effects on swards is to find a meaningful measure of grazing pressure or utilization, i.e. a measure of the proportion eaten in relation to the proportion available. Such a measure involves the use of cages, serial sampling techniques, etc. and enables extrapolation and or comparison of results from different situations. Using hand separation and a single sampling at the close of the summer grazing treatment utilization was measured on the Finella plots. The morphology of the plants differed on the different plots. On hard grazed plots of any age or young, more lightly grazed plots, current seasons growth is a large proportion of the crop and its distribution is such that a bite by the animal removes only current season's shoots. Older green material forms a very small percentage of the stand. On lightly grazed, older, or undergrazed stands, current seasons growth is a much smaller proportion of the crop and its distribution is such that older green material will also be ingested by the grazing animal. In calculating utilisation using the hand separation technique two methods were used:-

a) Calculations based on differences in proportions of current seasons vs other plant parts

b) Calculations based on differences in proportions of current seasons and older green material vs other plant parts

The results of these calculations are shown in Table 1 below:

Table 1

Plot No.	Grazing Regime	Age of Stands	Utilization* Method (a)	Utilization* Method (b)
1)	Lightly grazed	Young	4.81	18.98
2)	(summer only)	Old	-ve	-ve
3)		Young	5.47	15.06
4)		Old	-ve	1.23
9)	Very hard grazed			
)	(summer and winter)	Old	66.65	67.07
10)		Young	66.02	62.03
11)		Young	68.95	65.14
12)		Old	58.26	57.88
13)	Very hard grazed	Young	69.79	67.81
14)	(summer only)	Young	58.03	55.38
15)		Old	44.90	41.18
16)		Old	43.01	45.57
17)	Lightly grazed	Old	-ve	-ve
18)	(summer and winter)	Young	4.43	22.56
19)		Old	8.70	32.01
20)		Young	46.26	52.01

* Percentages for the proportion of 'edible' dry matter utilized out of total available.

As would be expected both methods give very nearly the same result for hard grazed heather, but there is a difference in the values obtained from lightly grazed stands. Method a) underestimating and method b) overestimating utilization.

Another aspect of utilization under investigation is that of the nutritional value of heather to the grazing animal. During 1969 serial samples of current seasons growth (for a few plots 2nd yr material too) were collected at intervals throughout the year. Regrowth samples were also collected in September. These samples have been prepared for 'In vitro' digestible organic matter determination. To date results are only available for the first sampling date. These are disappointingly and puzzlingly low in view of lamb growth rates for example which are achieved on heather pastures. The values obtained for the early June cut, when current seasons shoots varied between just under 6 mm - 18 mm long (spring was very late), ranged from 43 to 56% digestible (omitting data from plots 5-8 which were more coarsely ground and gave lower values). A trend worth further investigation was indicated, for current seasons growth of 'young' stands to have a digestibility a few units higher than that of 'old' stands on the same plot ('young' mean digestibility 50.3%, 'old' mean digestibility 47.0%, $t = 2.661$, $P < .05$).

'In vitro' digestibility measurements were made on dried and ground material. The drying process itself may influence digestibility. Certainly dried and ground heather is more difficult to wet than dried and ground grass. Work is in progress in co-operation with Mr. Eadie to prepare an area of heather to allow current seasons growth to be harvested on a scale sufficiently large for 'In vivo' digestibility trials to be undertaken on fresh heather. It is also intended to compare the digestibility of heather fed alone with that of heather when fed in mixture with grass.

Another aspect of the heather problem is that in the 'In vitro' measurements rumen liquor was taken from sheep fed on grass. It is possible that adjustments in the rumen flora may occur when sheep are fed on a heather diet and in future it is hoped to measure digestibilities of heather samples when incubated with rumen liquor of a grass fed compared with that of a heather fed sheep.

Plant growth in relation to soil aeration and moisture regimes in the field (J. A. Rogers)

As described in previous reports, this experiment is conducted in two phases. In phase one, the twenty-nine sites on the Gairs and Rigg at Sourhope are characterized in terms of soil moisture and aeration parameters in relation to the existing vegetation, while in phase two, ten of the sites are selected, and the performance of four introduced herbage species is evaluated in relation to those parameters.

The four species, Dactylis glomerata (Cocksfoot), Phleum pratense (Timothy), Festuca arundinacea (Tall Fescue) and Lolium perenne (Perennial Rye-grass) were planted in 1967 and serial harvests were taken during the following year, when samples of the herbage were retained for chemical analysis. During 1969, three harvests were taken, some material again being retained for chemical analysis, and additional information on soil aeration, was obtained from all the sites for use in phase one.

Whilst all the data collected in 1968 for phase 2 have not been fully analysed statistically, it has been shown that when soil moisture tension, carbon dioxide and oxygen concentrations are regressed against yield, it is the latter parameter which plays the most significant role in accounting for differences (dry matter production) in yield between sites. The generally lower correlation with tension is probably due to considerable fluctuations in moisture tension following weather variations, particularly in the dry and intermediate sites. In these sites the oxygen content (and yield) remained at relatively high levels.

Chemical analyses on herbage material from five harvests have now been completed for total Potassium, Magnesium, Calcium, Nitrogen and Phosphorus. From a preliminary examination, it would appear that there is a positive correlation between soil oxygen level and the Potassium, Magnesium and Nitrogen content of the herbage and possibly a negative correlation with Calcium. An examination of the Potassium balance of the soil/plant system indicates that there is an overall increase of Potassium in the dry, well aerated sites and a decrease in the wetter sites. The increase could be explained if the roots in such dry sites were obtaining this element from lower soil horizons than those which were analysed. Many explanations for losses can be postulated, by leaching, removal by weeds, or by locking away in storage tissues which were not analysed.

During the current (1969) growing season, three crops were taken and soil moisture and aeration measurements made. Although no strict comparison in absolute terms with the previous season can be made, owing to different cutting regimes, comparisons between sites were possible. The season proved to be much drier than 1968 (see Table), and at the last harvest, in October, soil moisture deficit limited growth in the drier sites whereas in the wetter ones the soils dried out sufficiently to improve aeration, but not enough to result in high moisture tensions. Thus, the yield in these sites surpassed that in many drier ones. The Table shows the marked differences in soil moisture tension between the years 1968 and 1969.

Mean of weekly soil tensiometer readings (cms of Mercury) for 1968 and 1969 (May 27th - September 30th)

Site No.	Soil	Drainage	1968	1969
1	Brown Earth	Very good	11.4	23.9
6	Gleyed Brown Earth	Good	7.4	23.5
7	Gley	Poor	0.5	6.8
8	Brown Earth	Very good	9.6	26.8
9	Flushed Gley	Fairly good Intermittent waterlogging	3.7	12.3
14	Flushed Gley	Very Poor	0.4	1.1
19	Brown Earth	Very good	15.6	29.7
23	Gley	Moderate	4.2	9.6
24	Flushed Gley	Fairly good Intermittent waterlogging	4.9	12.8
27	Gley	Very poor	0.5	6.3

The soil aeration parameters, which were recorded from all the (phase one) sites were:- oxygen and carbon dioxide concentrations, oxydation - reduction potential and oxygen diffusion rates. The values obtained correlated well with soil moisture tensions.

Next year, it is proposed to examine the vertical distribution of root activity using radio-active tracers, in a number of the planted sites.

SYSTEMS DEVELOPMENT

Introduction

The Organisation's research programme now includes systems development projects. The purpose of this work is to test the principles which determine the integration of resources in improved systems of sheep production from hill land.

The ultimate test of the worthwhileness of any animal production system must be an economic one, and since system changes require capital investments an assessment of the returns to such marginal capital investments is an important part of the evaluation process. At the same time, however, since only a small number of development studies can ever be undertaken, in order to make extrapolation of the findings to other situations with any degree of certainty possible, an adequate monitoring of the biology of these systems is essential.

Year-round Grazing Systems

So far, two exercises have been started, one at Sourhope and one at Lephinmore. Both are year-round grazing systems and both are centred round the idea that pasture improvement is the key to economically sound improvements in hill sheep production systems.

Common to both studies is the integration of improved pasture with the open hill, in such a way as to ensure, in so far as present knowledge allows, the maximum impact of improved pasture on sheep performance. This means that, as far as possible, improved pasture is used for ewes from the time of lambing up to weaning, (mid-August) and again, following a mid season rest, during the pretupping and tupping period. During the remainder of the year the sheep-stock is kept on the open hill.

The major difference between the two studies derives from the major differences in their soil and vegetational resources. Initially at any rate, pasture improvement at Sourhope has depended simply upon the enclosure of some of the better Agrostis-festuca pastures. Pasture improvement at Lephinmore has required soils improvement and surface-seeding.

Associated with the pastoral management changes have been changes in husbandry. Any attempt to improve sheep performance will exacerbate under-nutrition in late pregnancy, and an essential accompaniment to pasture improvement is the provision of adequate supplementary feed in late pregnancy. There are good arguments within existing systems of production for more control over lambing; these arguments are enhanced where intensification is sought. Both the efficiency with which supplementary feed is used in late pregnancy and a controlled lambing are improved by identifying early and late lambers and this is a more practicable operation where tupping takes place in enclosures. Tups are therefore harnessed and crayon blocks used at mating.

Year round grazing systems

I. SOURHOPE (Hairney Law - Auchope)

Land Resources

An area of some 700 acres (Near and Far-End Hairney Law and Auchope) is being used in this work. Two areas, each of around 45 acres, of Agrostis-festuca pasture were enclosed in June 1968. These were grazed to some extent by sheep and to a greater extent by cattle during June and July 1968, and both areas were shut up in early August to allow of pasture accumulation for use in November/December.

These two areas have subsequently been used as briefly described in the introduction.

A further "production" paddock of some 50 acres was enclosed in 1969. As yet this area has only been grazed by cattle in an attempt to reduce the fund of overgrown neglected herbage.

Two small fields were used as lambing paddocks in 1969 and thus far ewes with twins have been run on inbye land on the farm.

Sheep Stocks

Two sheep stocks, one of North Country Cheviots bred pure, and one of South Country Cheviots being crossed with North Country Cheviot tups are run on the area. These will be progressively merged into one flock. Numbers in 1968 and 1969 are shown in the livestock reconciliation table below.

Table 1

Livestock Reconciliation (1968/69)

	Ewes and Gimmers Nov.1968	Cast	Deaths	Gimmers brought into flock	Hoggs born 1969	Ewes and Gimmers Nov. 1969
N.C.C.	175	18	9	62	58	210
S.C.C.	223	34	5	57	58	241

The ewe stock (ewes + gimmers) has been increased from 398 to 451 for the sheep year 1969-70.

The results of a number of post mortem examinations by the Veterinary Investigation Centre, St. Boswells, suggest that deaths in adult stock were attributable to a number of different diseases with enterotoxaemia (3) and and pasteurella septicaemia (3) predominating. Other deaths, or removal from the flock, were due to nephritis, suppurative mastitis, chronic fascioliasis, prolapse of the uterus, fractured limbs and asphyxia (couping).

Cattle

Cattle have two roles to perform in a sheep-oriented development study of the kind described here. Initially they have an important part to play in pasture improvement by helping to effect the vegetational morphological changes which are the key to Agrostis-festuca grassland improvement. Ultimately they will play an important part in helping to maintain improved pastures.

It is likely that the pace of improvement will depend to an important extent on the number of cattle employed, so that it is necessary to restrict cattle numbers to a level which is realistic, recognising that cattle numbers on hill farms bear little relation to the area of hill land which would benefit from their presence, and are determined, in the main, by the area of inbye land available for the provision of their bulk winter feed.

It was decided therefore to restrict cattle numbers at what is considered to be a realistic level, and, from May 1969, 24 hill cows (in 1969 as bulling heifers) will be carried each year from 1st May to 31st December.

Sheep year 1968-9

(a) Mating

The sheep (including hoggs) were put into the enclosures on 30th and 31st October. The hoggs were removed from the enclosures on 21st November prior to the tups going out. The ewes were removed from the Auchope enclosure on 6th December and from the Hairney Law enclosure on 17th December and tupping was completed on the hill. The tups were raddled.

The hoggs were brought into an inbye field in December where they were fed to accustom them to hand feeding. This will become an annual practice.

(b) Winter Feeding

Traditional practice at Sourhope (as on other Cheviot farms) has been to feed hay in storm. This practice is continued in the present work. In addition it has become the practice to supplement the diet in late pregnancy with a concentrate. This practice too has been continued, but as a consequence of work in the Organisation, which has suggested that a better matching of feed supply and demand will be made by feeding on a sliding scale, the food input was increased towards the end of pregnancy.

Two feeding points were established and the flock fed in two groups (N.C.C. and S.C.C.).

Concentrate feeding started on 13th March, and the quantities supplied were as follows:-

13/3 to 27/3	-	½ lb./hd./day
28/3 to 10/4	-	¾ lb./hd./day
10/4 to lambing	-	1 lb./hd./day

At the beginning of the feeding period 30 ewes, half of them early and half late lambers were selected in as balanced a fashion as possible throughout the age groups, from each sub-flock. These were blood sampled at weekly intervals on five occasions, and the results of plasma ketone and plasma N.E.F.A. analyses used as a guide in controlling feed inputs to maintain a moderate degree of undernourishment. This was successful (see below).

Some 33 lb. hay/head was fed, roughly ⅔ of which was storm feeding before late pregnancy supplementation began. Up to lambing 22 lb. concentrate/each was fed.

The spring of 1969 was the poorest and latest for many years and it was decided to continue feeding after lambing. Ewes with twins were given 1½ lb. conc./hd./day and ewes with singles ¾ lbs./hd./day and this was continued with single-bearing ewes until 6th May and with twin-bearing ewes until 21st May. Feeding from the start of lambing added 25 lb. conc./head to the feed input.

Feed costs were as follows.

Up to lambing - Hay - 7 tons 4 cwt. at £16/ton	=	£115: 4: -
Conc. - 3 tons 17 cwt. at £36/ton	=	138:12: -
After the beginning of lambing - Conc. - 4 tons 9 cwt. at £36/ton	=	160:14: -
Total Cost	=	£414:10: -

The cost per ewe was 20/10d.

The hoggs traditionally are wintered on the hill. There are, however, advantages, particularly in snow storms in running ewes and hoggs separately in winter. For the 1969-70 winter a hogg paddock of some 40 acres has been established, but during the winter of 1969-70 the hoggs were run on inbye fields from 20th November to 28th March when they were returned to the hill. One hundred and nineteen hoggs were fed a total of 1 ton 4 cwt. hay (cost £19) and 2 tons 9 cwt. grass cubes (cost at £28/ton - £68 - 10). The total hogg feeding cost was thus £87:19:-d.

(c) Lambing Performance

Lambing performance data is given in Table 2 for each of the sub-flocks.

Table 2

Lambing Performance 1969

Sub-Flock	Ewes to tup	Tup Eild	Keb.	Ewe losses to lambing	Total lambs born	Lambs marked	Lambs weaned	Lambs lost
						42	8	50
N.C.C.	175	15	-	2 + 1*	198 (113%)	156 (89.1%)	148 (84%)	25%
S.C.C.	223	22	1	1 + 2*	224 (100%)	193 (86.5%)	189 (84.8%)	16%
						31	4	35

* Cast

Total lamb losses (birth to weaning) were 20.6% of which more than 80% occurred before marking and over half of which took place in the first week of life, reflecting the cold wet conditions prevailing at lambing.

Lamb birth, marking and weaning weights are given in Table 3.

Table 3

Lamb weights (Kg)

Sub Flock	Birth Wts.		Marking Wts.		Weaning Wts.	
	Singles	Twins	Singles	Twins	Singles	Twins
N.C.C.	3.77	3.14	11.45	10.20	24.5	25.0
S.C.C. (+ N.C.C.)	3.91	3.09	10.30	7.95	22.1	21.0

(d) Wool Production

Fleece weights were as follows (Table 4)

Table 4

Fleece Weights 1969 (Kg)

Sub Flock	Ewes	Hoggs
N.C.C.	1.62	1.80
S.C.C.	1.58	1.76

(e) Ewe Bodyweight Changes

A comprehensive sheep-weighing programme began in October 1968. Some selected bodyweight data, representative of the more critical periods during the sheep year are given in Table 5.

Table 5

Selected Bodyweight data (Kg) Sourhope 1968-69

Age	Nos.	Premating '68 21/11/68	Prefeeding 6/3/69	Prelambing 10/4/69	Marking 30/5/69	Weaning 7/8/69	Premating '69 20/11/69
N.C.C.							
Average		57.6	50.4	55.9	50.7	53.8	-
4 crop		57.7	50.4	53.4	50.4	54.6	62.3
3 crop		62.4	53.4	58.0	54.8	58.5	64.1
2 crop		60.6	52.6	56.4	54.2	59.9	61.5
1 crop		56.5	46.8	50.6	49.0	55.5	54.0
Maidens		49.0	39.8	42.6	42.8	48.4	49.9
All ewes		54.8	45.8	49.3	47.9	53.4	56.1
Hoggs		33.8	30.4	-	34.8	43.5	35.4
S.C.C.							
		21/11/68	6/3/69	8/4/69	29/5/69	7/8/69	20/11/69
4 crop		51.5	44.5	50.2	43.8	47.5	52.1
3 crop		49.4	42.7	48.2	42.0	46.1	51.3
2 crop		46.9	40.9	46.8	41.1	45.3	53.4
1 crop		47.7	40.9	45.9	41.2	46.2	52.1
Maiden		44.8	38.4	40.5	38.9	45.4	45.8
All ewes		47.8	41.2	45.8	41.2	46.0	50.7
Hoggs		30.2	27.6	-	32.2	39.8	32.3

Pretupping (Nov.) weights have increased by 1.3 Kg in the N.C.C. stock and by 3.1 Kg in the S.C.C. stock.

II. LEPHINMORE (Mid-Hill)

Land Resources

The land resources used in this study are those used in a previous large scale investigation the results of which we published in the 1968 summer issue of Scottish Agriculture.

The 1000-acre Mid-Hill hirsel now comprises

(a) Open Hill - 800 acres
(b) Two enclosures P1 and P2 (respectively 71 and 104 acres) within which some 15% of the total area had been reseeded to make a mosaic of improved patches
(c) Enclosed moderately productive grassland amounting to 24 acres hereafter referred to as the "production paddocks" and
(d) Two enclosures of poor quality grassland used mainly for management purposes, (e.g. as lambing paddocks) amounting to 21 acres.

This is essentially the resource as it was the end of the previous study.

In August 1969 an area of 10 acres from within P1 was fenced. The intention is to reseed this area in 1970, but it will not be employed in the development study until 1971.

Sheep Stock

The Mid Hill Blackface stock had been built up from 205 ewes and gimmers in 1956 to 372 ewes and gimmers in 1968. By the time of the pre-mating count in 1968, however, the numbers had fallen again to 339 and it was decided to re-establish the flock at around 370 ewes and gimmers as quickly as possible.

The livestock reconciliation table for 1968-69 is given below.

Table 1

Livestock Reconciliation 1968/9 Mid-Hill

Ewes and Gimmers Nov.1968	Cast	Deaths	Gimmers brought in	Older ewes brought in	Hoggs born 1969	Ewes and Gimmers Nov.1969
339	63	12	90	7	97	361

The intention is to maintain flock size at around its current level and to measure the effects of the pasture management changes in terms of responses in individual sheep performance.

Sheep Year 1968-9

(a) Mating 1968

This study began officially in January 1969. The ewes, however, were tupped on the better grassland and the tups were raddled at mating.

At the end of tupping ewes and gimmers were returned to the open hill where they remained until mid-March. At that time the gimmers were removed to P2. Ewes and gimmers were thus run separately during the pre-lambing supplementary feeding period.

The sheep remained there until immediately pre-lambing when the early lambers were moved into the lambing paddocks. The mature ewe stock was lambed in the lambing paddocks and the gimmers were lambed mainly in P2.

(b) Winter Feeding

Concentrates only were fed as a supplement in this study. The procedure here was similar to that at Sourhope in that feed inputs were increased as lambing approached.

Feeding started on 11th March and the quantities given were as follows:-

12th - 18th March	-	$\frac{1}{2}$ lb./hd./day
19th - 25th March	-	$\frac{3}{4}$ lb./hd./day
26th - 1st April	-	1 lb./hd./day
2nd - 9th April	-	$1\frac{1}{4}$ lb./hd./day
10th - 16th April	-	$1\frac{1}{2}$ lb./hd./day

Thereafter all grit ewes were fed $1\frac{1}{2}$ lbs./hd./day and lambed ewes were fed for a maximum of 3 days after lambing.

The total quantity fed was 40 lbs./hd., giving a total feed input of 6 tons 1 cwt. The cost per head was 12/10d and the total cost £217:16:0d.

(c) Post-Lambing Management

The available land resources differ from those at Sourhope in that the area of best quality grassland (the production paddocks) is limited in relation to ewe numbers. This requires the setting up of priorities for this better land in terms of the sheep which merit preference; ewes with twins are the highest priority class followed by gimmers over older ewes with singles.

After lambs were footed in the lambing paddocks, they were therefore allocated on that basis. In the event all the gimmers could be accommodated in the production paddocks and 60 older ewes with single lambs were brought in to increase the grazing pressure on these paddocks on 5th June.

The remaining ewes with lambs at foot were run on P1 and P2 until weaning. The open hill carried the hoggs, (which were returned to the hill on 2/5/69) and the dry sheep until weaning.

(d) Lambing Performance

The relevant data is given in Table 2.

Table 2

Lambing Performance (Mid-Hill 1969)

Ewes to tup	Tup Eild	Keb.	Ewe losses to lambing	Singles Born	Pairs Born	Total Lambs born	Lambs Marked	Lambs Weaned
339	33	19	5	228	48	324 (96%)	297 (87%)	289 (85%)

Total lamb losses amounted to 11.4% of which roughly 75% took place before marking and slightly under 50% within a day or two of birth.

Lamb birth, marking and weaning weights are given in Table 3.

Table 3

Lamb Weights (Kg.) Mid Hill

Birth		Marking		Weaning	
Singles	Twins	Singles	Twins	Singles	Twins
3.85	2.73	9.91	8.21	25.99	20.74

(e) Wool Production

Fleece weights were as follows:-

1963 age - 1.43 Kg;
1964 - 1.55;
1965 - 1.47;
1966 - 1.50;
Gimmers - 1.73;
Hoggs - 1.61.

(f) Summer Management

After weaning (12/8/69) the whole stock (ewes, gimmers and hoggs) were returned to the open hill area, where they remained until 9th October, during which time P1, P2 and the production areas were free of stock. The hoggs remained on the open hill until early November, but the ewe stock began to utilise the improved pasture areas from 9th October.

(g) Ewe Bodyweight change

A comprehensive programme of sheep-weighing began in November 1968 and in Table 4, some of this data, representative of the more critical periods during the sheep year are presented.

Table 4

Bodyweight Data (Kg) Mid-Hill (1968-9)

Age	Nos.	Premating 1968 19/11	Postmating 1968 27/12	Prefeeding 11/3	Prelambing 17/4	Marking 27/5	Weaning 12/8	Premating 1969 17/11
4 crop		46.7	47.8	42.4	45.4	45.3	49.0	52.0
3 crop		47.8	49.5	43.5	46.3	45.6	48.5	51.5
2 crop		46.1	47.8	41.4	43.9	44.0	48.1	50.0
1 crop		43.8	44.9	39.0	40.4	41.1	46.4	49.6
Gimmers		42.4	44.2	37.0	41.0	42.3	47.3	45.1
All ewes		46.1	47.5	41.6	44.0	44.0	48.0	50.8

There has therefore been an increase in pretupping weight from 46.1 Kg in 1968 to 50.8 Kg in 1969.

III SYSTEMS DEVELOPMENT MONITORING

A. Preventive Medicine (W. N. M. Foster)

Unless disease entities can be adequately controlled, or the losses due to them quantified, an accurate analysis of the benefit, expressed in terms of increased production, accruing from agronomic practices is precluded.

With the inception of the development projects at Sourhope in the autumn of 1968 and at Lephinmore in the spring of 1969 studies were, therefore, initiated to investigate the effect of certain diseases on the productivity of the sheep stock on the project hirsels.

In determining the priority of the investigations cognizance was given to (a) a knowledge of diseases known to be endemic in the area; (b) the current prophylactic veterinary routines employed on the farm and their effectiveness and (c) the possible effect of intensification on existing or potential diseases. Consideration of these criteria suggested that the diseases meriting attention were primarily parasitic with particular emphasis on the debilitating diseases such as helminth and liver fluke infestation which, if subclinical, may cause an occult loss. It was also felt that a study of the influence of the tapeworm Moniezia on lamb growth was justified since its ubiquity contrasts markedly with the paucity of information concerning its pathogenicity. A continuation of subsidiary studies into tick-borne fever was also envisaged since this disease is known to be endemic at Sourhope and Lephinmore.

(a) The Effect of Helminth and Liver Fluke infestation on Productivity

In seeking an assessment of the influence of helminths or liver fluke on productivity little is to be gained by routine worm or fluke egg counts. Parameters such as weight gain and lamb production must be used as the ultimate criteria. It thus seemed that the most effective method for determining the influence of these diseases would be a comparison of productivity in a 'worm and fluke free' group of sheep with the productivity in a strategically dosed 'flock' group. Not only would this show the maximum production obtainable under any given conditions if these two diseases were minimised, but it would also provide information on the effectiveness of the present strategic prophylactic measures. The latter are currently based on experience and custom, but in a dynamic situation, particularly where stocking rates are being increased, it is clear that new routines may have to be devised to suit changing conditions.

A number of pilot studies utilising the above method have been initiated during the past year. The results of completed studies are itemised below. Progress in other studies which are of longer duration is noted. When the trials were initiated it was believed that liver fluke only occurred at Lephinmore. The parasite free groups of sheep on this farm were, therefore, dosed monthly with Nilverm and also injected with Trodax. Only the monthly Nilverm dosing has been employed at Sourhope.

(i) Cheviot Lambs, Sourhope

On both the Hairney Law and Auchope hirsels 25 single lambs were maintained worm "free" by monthly dosing from May 30th until weaning on August 8th. The live weight gain of these lambs was not significantly different from that of an equivalent group of undozed flock lambs (Table 1).

Table 1

Sourhope Lambs

	Initial wt.(lbs) May 30th	Final wt. Aug 8th	Total wt. Gain	Wt. gain /day
Hairney Law (North country Cheviot)				
Monthly dosed group	24.2	52.4	28.2	0.40
Flock group	23.9	55.0	31.1	0.44
Auchope (South country Cheviot)				
Monthly dosed group	21.0	46.2	25.2	0.35
Flock group	22.7	49.0	26.3	0.37

(ii) Blackface lambs, Lephinmore

Thirty single lambs were maintained worm and fluke free by monthly treatment with Nilverm and Trodax from May 27th until weaning on August 12th. Live weight gain over this period did not differ significantly from that of the undosed flock lambs (Table 2). In this and in the previous investigations at Sourhope, the live weight gain over the study period was approximately 0.4 lb/day.

Table 2

Lephinmore Lambs

	Initial wt.(lbs) May 27th	Final wt. Aug.12th	Total wt. Gain	Wt. gain /day
Mid-Hill (Blackface)				
Monthly dosed group	24.3	58.9	34.6	0.45
Flock group	23.5	58.0	34.5	0.45

(b) Studies on the Effect of Helminths and Liver Fluke on the Growth and development of hoggs

Routine monthly treatment of 25 hoggs on each of the Hairney Law, Auchope and Mid-Hill hirsels was commenced shortly after weaning in September 1969. This is essentially a long term study and should continue until April 1971.

(c) Studies on the Effect of Helminths and Liver Fluke on the Production of Ewes

Monthly treatment of 25 ewes on the three aforementioned hirsels was commenced in November 1968. Due to the exigencies of management practice some modifications were made to the composition of the groups after lambing in April 1969. Seasonal weight changes have been similar in both the dosed and flock groups and although the dosed groups at Sourhope have maintained a slightly higher body weight the differences are not marked. This study which will be terminated in 1970 is indicative rather than definitive since the number of ewes which can currently be utilised is insufficient to permit an assessment of overall productivity.

This illustrates one of the limitations inherent in the monitoring system outlined above at the present time. Routine monthly dosing can be shown to keep the sheep relatively worm and fluke free, but since infestation depends largely on the ingestion of contaminated herbage it is clearly impossible to dose more than a small proportion (approximately 10%) of the total number of animals without vitiating the problem under investigation. This is less important if the total population, and hence the dosed sample, is large, but it obviously creates analytical difficulties if the total population is small. It seems, however, that this problem will be resolved as stock numbers increase on the experimental hirsels.

In summary it would appear that in 1969 helminths alone or helminths and liver fluke (Lephinmore) were not instrumental in retarding the growth rate of single lambs, maintained initially in enclosures and later on the hill, between the time of marking and weaning. Moreover, the live weight gain of approximately 0.4 lbs/day in the different experiments does not suggest that an unknown entity was causing an overall depression of growth and hence masking the effect of the treatments. There is also little evidence to date that helminth and liver fluke infestation has markedly affected the live weight of ewes nursing single lambs. These comments, however, can only apply to the year of study since helminthiasis and fascioliasis will depend, inter alia, on the nutritional status of the animal and climatic conditions.

Single lambs have been employed exclusively in the 1969 studies. It may, however, be argued with justification that more attention should be given to ewes with twin lambs maintained at higher stocking rates on improved pastures. The number of twin lambs is, however, relatively small for experimental studies. It is, moreover, known that under these intensive conditions helminthiasis is probable rather than possible and strategic drenching is, therefore, a necessity.

B. The assessment of supplementary feeding requirements in free-grazing ewes during late pregnancy (A. J. F. Russel and J. Z. Foot)

The nutritional status of the Hairney Law - Auchope ewe flock was assessed at weekly intervals during the later stages of pregnancy by means of biochemical measurements made on blood samples collected from 60 ewes. These samples were analysed for plasma free fatty acid and ketone concentrations, and this information was used to assess the adequacy of the supplementary feeding, the objective being to ensure that undernourishment was kept within acceptable limits. Levels of supplementary feeding were adjusted according to the analytical results within 48 hr. of sampling.

Plasma ketone concentration appeared to be a more reliable index of the severity of undernourishment than plasma free fatty acid concentration. It is considered that, in spite of the precautions taken to minimize disturbance of the animals before sampling, plasma free fatty acid concentration was affected by gathering and penning. These results add support to the belief stated in previous reports that although plasma free fatty acid concentration is a particularly valuable index of nutritional state in closely controlled experimental situations, it is in certain respects too sensitive, and consequently less useful, in field studies.

The results showed clearly that undernourishment was measurably greater in ewes on Auchope than in those on Hairney Law. Within these groups, and particularly in the Auchope ewes, animals in their first pregnancy and those carrying twins experienced a greater degree of undernourishment than older ewes with single foetuses; earlier lambing ewes were also at a slight disadvantage compared with those lambing later. Although these differences were apparent they were generally quite small, and no animals experienced a degree of undernourishment which was likely to materially affect lamb production. Nevertheless, the fact that differences were evident suggests that more efficient use of the supplementary feeding could be achieved by separating the gimmer age group from the main flock, and giving them preferential nutritional treatment. Similarly, it would appear advantageous to divide the main flock according to expected date of lambing, and, if possible, into single- and twin-bearing ewes.

This particular work constitutes the first attempt on a field scale to regulate the input of supplementary feeding during late pregnancy according to biochemical assessments of nutritional state. The results indicate that the technique was successful, and that the objective of keeping undernourishment within prescribed limits was achieved. The use of this approach will be extended to other flocks and situations in the next pregnancy period.

C. Ingested pasture quality (J. Eadie)

Using faeces nitrogen content as an indicator and predicting from the general regression equation relating faeces nitrogen concentration and digestibility established in previous work, a monitoring of the quality of the herbage ingested by the sheep stock on the Hairney Law - Auchope project at Sourhope on a number of occasions during the sheep year 1968-9 has been carried out. A background for comparative purposes are the data from the Gairs annual cycle of nutrient intake study.

This work has so far been confined to periods when the sheep are in the enclosures and the faecal collections are made by walking quietly through the sheep and picking up material recently defaecated. On each day some 30-40 samples are aggregated from flocks totalling 120-200 sheep. Collections are usually made on 3-4 successive days.

In Nov./Dec. 1968 this procedure was carried out on 5 separate occasions during the autumn grazing period on each of the two enclosures. The results indicate that ingested pasture quality throughout the grazing period was slightly better on the Hairney Law paddock than on the Auchope paddock, and initially some 4-5 units better than that recorded at the same time of year on the open hill (Gairs study). As the grazing of the enclosures proceeded, however, this advantage declined, and at the end of the period in mid-December the difference was around 2 units of digestibility. The data were found to be useful in aiding decisions about when to remove the sheep from the paddocks.

The continuation of supplementary feeding after lambing, together with the consequences of the late spring on pasture growth and availability on the enclosures, combined to limit the measurements in the early summer of 1968 to the month of June. Again, however, ingested pasture quality was rather better, by 2-3 unit of digestibility in early June than the figures obtained during the Gairs study on the open hill at the same time of year.

The work has been continued into the sheep year 1969-70.

D. Vegetation changes (J. King and J. A. Rogers)

The paddocks associated with the year-round grazing systems established on Mid-Hill at Lephinmore and Hairney Law/Auchope at Sourhope have been subjected to fairly intensive botanical recording. The problems presented by the two farms are somewhat different causing different methods to be adopted.

(a) Sourhope

Here the two paddocks, each of about 45 acres are comparatively uniform botanically consisting mainly of low grade Agrostis/Festuca grassland, and the closely related Festuca/Deschampsia grass-heath, both associated with moderately dense bracken. The soils are quite variable but are mainly acid Brown Earths and skeletals. As a consequence of the grazing management it is expected that the bracken cover will diminish and pasture changes will occur leading towards an Agrostis/Festuca/Poa community. Interest lies in the completeness and rapidity with which the change takes place on different soil types and in different parts of the paddock. Each paddock therefore has been sampled by two sets of relocatable plots, randomised within strata based on soil type and topography. One set is used for bracken frond counts and height measurements, the other for quantitative recording of the pasture composition. This is supplemented by fixed point photography. The intensity of recording has been high, to provide a good base line for future comparisons. It is probable that future annual recording can be at a lower intensity without loss of information.

(b) Lephinmore

Here there are two sorts of paddock, the high-grade Agrostis/Festuca grassland area below the forest road and the larger (190 acres) area of Calluna and Trichophorum moorland above this. Attention this year has been given almost entirely to the latter as it presented the most urgent problem, but both areas will be recorded in 1970. The whole 190 acre area has been sampled by nearly 300 $1m^2$ marked plots located at the intersections of a 50m x 50m grid. Data collected includes species lists, cover estimates of species, records of height and growth form of heather and depth of peat. It is proposed to classify the vegetation of the sample plots using a numerical multivariate procedure. On the basis of the vegetation types so obtained a smaller representative sample of each will be selected on which quantitative measurements can be made annually.

E. SOILS (M. J. S. Floate)

In October 1968 soil samples were taken from the paddocks on Hairney Law and Auchope. These samples were taken from sites on a grid pattern and were adjacent to the sites used by the Botany Department for permanent vegetation recording. Five sites were distributed along each of 5 (Auchope) and 6 (Hairney Law) surveyed transects which were marked by pegs. In most cases the samples were taken from the upper right hand quadrant from the centre leg at each site.

The layers (Ao soil horizon) were sampled by cutting 2 of 20x15 cm blocks from the mat which had been stripped from the mineral soil surface using a sharp knife. The thickness of each block was recorded and the volume of each sample was calculated. From bare soil areas 12 cores were taken at depths 0-5 cm, and 5-10 cm using a cylindrical auger. Samples in which stones interfered with the penetration of the auger were rejected.

After collection the samples were bulked for each depth and stored in deep freeze. After the shortest possible time the samples were removed from storage for sub sampling, dyring and analysis.

Immediately after thawing out, moist 5 g sub-samples were taken for the determination of NH_4^+-N and NO_3^- -N extractable in 50 ml 2M. KCl and for the determination of moisture content and pH.

When dry, the bulk of each sample was sieved and the weight of the soil fraction (< 2mm), including the soil from sub-samples, was recorded. The bulk density of each sample was calculated:-

$$BD = \frac{\text{weight of air dry soil } (< 2mm)\ (g)}{\text{field volume (ccs)}}$$

This takes account of the dilution effect of stones. Bulk density in g/cc x 10^4 = weight of soil per square metre to 1 cm depth.

The following analyses were carried out on the dry soil samples: Organic - C by hot acid dichromate digestion, total - N by the Kjeldahl method and extractable P and K using a modified Morgan's procedure. The mean analytical results (with standard deviations) and the calculated weights of each constituent per square metre per horizon are presented in Table 1.

Table 1

Soils Data
Auchope and Hairney Law Paddocks

Median Thickness of mat (cm)	Soil and depth (cm)	Number of samples	pH	NH_4^+-N (ppm)	NO_3^--N (ppm)	C (%)	Total-N (%)	Extractable P (mg/100g)	Extractable K (mg/100g)	C/N Ratio
Auchope 2.5-3.0	Auchope Ao	23	4.7 ± 0.6			25.5 ± 6.4	1.32 ± 0.29	15.41 ± 8.18	146.0 ± 31.47	19.6 ± 4.2
	0-5	25	5.0 ± 0.7	34.0 ± 8.3	3.2 ± 2.5	9.1 ± 4.2	0.70 ± 0.22	0.58 ± 0.39	39.3 ± 14.01	12.7 ± 1.7
	5-10	25	5.0 ± 0.6	23.3 ± 6.4	3.0 ± 2.3	6.8 ± 3.0	0.55 ± 0.24	0.36 ± 0.25	30.3 ± 13.19	12.4 ± 2.0
							(mg/m^2)*	(mg/m^2)*	(g/m^2)*	
	Auchope Ao	23					*45.5 ± 13.3	*505.3 ± 239.8	*5.0 ± 1.2	
	0-5	25					*179.4 ± 41.5	*141.9 ± 71.8	*10.6 ± 4.5	
	5-10	25					*179.9 ± 30.8	*115.3 ± 60.9	*10.6 ± 5.2	
Hairney Law 2.5	Hairney Law Ao	28	4.8 ± 0.4			24.8 ± 3.9	1.40 ± 0.20	15.40 ± 10.32	153.3 ± 22.34	17.4 ± 2.2
	0-5	30	4.5 ± 0.4	27.9 ± 6.9	3.9 ± 2.5	11.9 ± 7.3	0.85 ± 0.39	1.30 ± 2.43	50.4 ± 12.21	13.6 ± 2.7
	5-10	30	4.7 ± 0.4	19.8 ± 5.0	3.7 ± 2.3	8.6 ± 5.9	0.65 ± 0.33	0.49 ± 0.41	38.2 ± 10.89	12.8 ± 2.6
	Hairney Law Ao	25**						12.70 ± 7.71		
	0-5	28**						0.66 ± 0.36		
	5-10	29**						0.45 ± 0.30		
							(mg/m^2)*	(mg/m^2)*	(g/m^2)*	
	Hairney Law Ao	28					*58.4 ± 14.8	*704.8 ± 456.4	*6.4 ± 1.5	
	0-5	30					*162.2 ± 50.1	*213.6 ± 314.7	*9.8 ± 2.3	
	5-10	30					*171.5 ± 49.2	*126.6 ± 79.2	*10.4 ± 3.1	
	Hairney Law Ao	25**						*588.9 ± 296.7		
	0-5	28**						*133.2 ± 67.0		
	5-10	29**						*120.4 ± 72.9		

* calculated weight per horizon
** excluding few widely divergent P results

The thickness of the mat layer (Ao) is likely to be one of the first characteristics of these soils to change as a result of the management treatments. It is intended to record thickness and pH for Ao samples again in 1970. The distribution of mat layer thickness at the time of the initial sampling is given in Table 2.

Table 2

Distribution of Mat Layer (Ao) thickness (1968)

Thickness cm	No. of sites Auchope	H. Lay
0	2	2
0.5	1	2
1.0	3	-
1.5	4	-
2.0	10	6
2.5	11	23
3.0	12	17
3.5	5	9
4.0	2	1

Integration of reseeded pasture with unimproved heather-dominant hill
(R. G. Gunn, A. L. Fairlie and J. M. Doney)

(a) Forestry Park The surviving original ewes in this experiment (born 1963) have now been drafted. It is proposed to continue the present uncontrolled grazing at the existing stocking rate on a self-replenishing basis. Control of grazing may be introduced as information regarding its desirability in such situations is derived from other sources. Regular monitoring of production parameters will continue.

(b) Mid-Finella The main objective has been to examine the effects of the integration in a system of animal production based on a subjectively assessed stocking rate designed to achieve as high a level of per capita ewe performance within sensible animal limits as can reasonably be achieved from the pasture resource components with minimum recourse to supplementary feeding.

Ewe numbers and management have now been stabilised and the monitoring of production parameters stepped up. Lamb production at birth was this year at an acceptable level of about 150% but as no decision had at that time been taken to buffer adverse seasonal effects such as occurred, the levels of supplementary feeding in late pregnancy and early lactation were insufficient to reduce a 20% lamb mortality to marking and a further 7% to weaning.

A start has been made to determine any differential grazing behaviour, consequent upon limited imposed management, on the utilisation of the two resource components and of the different pasture communities on the unimproved hill by routine observation and plotting of ewe positions. An attempt has also been made to identify and record individual ewes but the technique requires improvement before this can be satisfactorily carried out.

Changes in pasture morphology consequent upon this system of animal production are being studied by the Botany Department.

(c) Vegetation survey (Sheila A. Grant)

A number of transects were set up on the hill to follow up possible changes in the botanical composition of the various sward types composing the hill. There were eight transects - each transect consisting of a base line marked at either end by a six foot stob. Within each transect ten groups of five one metre square quadrats are located at varying distances along and to the left and right of the base line. Yearly records of presence/absence are collected for all species in all quadrats. In addition, cover estimates are made for the main species. In transects where grasses predominate point quadrats will also be recorded though not every year.

Gross botanical changes, e.g. changes in the border between heather dominated and grass dominated communities, the extent and density of bracken patches, etc. are perhaps best seen in photographs and an annual panoramic photograph is being taken every September from a fixed point.

Vegetation records were first collected in the summer of 1969 and the first annual photograph taken in September 1968.

Controlled grazing - Park Law (J. N. Peart)

A study was initiated on Park Law hill in 1954 to observe firstly, the effects of progressively increasing sheep stocking rate of unimproved hill pasture, and secondly, the influence of a minimal change in grazing management on sheep production and performance. These observations were made during the period 1954-65 and the results have been written up and accepted for publication. The evidence confirmed previous findings that the type of hill pasture being studied has a considerable potential for increased animal production. The evidence also indicated that this potential cannot be attained by traditional management practises.

Since 1965 the objective on Park Law has been to integrate and apply existing knowledge in an attempt to further increase sheep production above the level already achieved. Substantial changes in management of sheep and pastures have been made to provide for:

1. Continued improvement of selected areas of hill pasture by grazing control and limited application of fertilisers
2. A rising plane of nutrition of ewes before and during mating
3. Improved nutrition during late pregnancy and early lactation by supplementary feeding as a standard practise.

Recurrent annual expenditure on food and fertiliser has been 32/- per ewe compared with 6/3d per ewe which was previously expended.

Sheep numbers during 1968-69 were similar to those of previous years and additional summer grazing was again provided by 25 bullocks. Though the ewes were in very good condition at mating they lost weight rapidly during the mid-pregnancy period. Substantial quantities of supplementary food (dried grass/barley cubes) were fed in late pregnancy and early lactation. The quantities fed were progressively increased from $\frac{1}{2}$ lb./hd. at 4 weeks pre-partum to $2\frac{1}{2}$ lbs./hd./day during the last 1-2 weeks of pregnancy. Feeding was continued around this level for 2-3 weeks in early lactation. Despite the generous supplementary feeding in late pregnancy the average lamb birth weights were 1.5 lbs. below the average of the previous 3 years. The numbers of lambs born and weaned were also below previous years.

The reduction was particularly great in the North Country Cheviot flock due to increased numbers of barren and aborted ewes and a reduced number of twin lambs born and reared. Nearly all lamb deaths occurred near to birth and about half the mortality was recorded as due to inclement weather around the time of birth associated with lack of milk. The average birth weight of lambs in the latter category was approximately 0.7 kg less than the flock average. Lamb growth rates were lower than in past years and a anthelminthic dosing trial indicated that worm infestation had had little effect on lamb growth. (See section on preventive medicine for details).

	N.C.C.	S.C.C.
Ewes to ram	115	115
Av. ewe weight (kg): Nov. 1968	58	53
Nov. 1969	60	54
Ewes barren and aborted	15	18
Ewes producing twins	19	15
Lambs born alive	115	108
% lamb death (birth-wean)	21.0	13.0
Av. birth weight (kg) single lambs	3.8	3.5
twin lambs	3.0	2.7
Av.weaning wt. (kg) single lambs	22.0	22.2
twin lambs	22.6	19.7
Weight of weaned lamb plus wool (lb.) per ewe mated	38.6	40.9
per acre	50.8	

Animal Production - 1968-69

	lb.
Weaned lambs	8174
Wool	972
Live weight increment of cattle	4260
Total	13406
Output per acre	74.5

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