J. A. Milne

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HILL FARMING RESEARCH ORGANISATION

ANNUAL REPORT FOR THE YEAR 1972

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ANIMAL NUTRITION AND PRODUCTION

REPRODUCTION

1. The effects of environmental stress on ovulation rate in sheep (J.M. Doney and R.G. Gunn)

Earlier work has shown that ovulation rate in Scottish Blackface ewes may be reduced by transfer from an accustomed environment into a subjectively 'stressful' environment before mating. In some cases a delay in onset of oestrus has been found. In one experiment where recently purchased ewes from a normal hill farm were used, the experimental 'control' environment appeared to have an adverse effect, suggesting that the environmental factors which may act as stresses could depend on the past habituation of the sheep and the degree of unfamiliarity.

Two experiments were carried out in the current year to study the relationship between environmental stress and delayed oestrus or ovulation rate and to ascertain whether the effects could be related to any specific aspect of the pituitary-adrenal response to environmental change. A pilot trial using exogenous A.C.T.H. had indicated a similar effect to that of severe environmental stress so it was decided to use adrenal stimulation by A.C.T.H. as the basis of experimental treatments.

I. The effects of exogenous A.C.T.H. administered from Day 13 to Day 16 of the oestrus cycle were compared with an untreated control in a group of Finnish Landrace x Dorset horn ewes. These were accustomed to the penning arrangements and adjusted to a uniform body condition over a period of two months. Oestrus was synchronised and the 35 ewes were allocated to two groups, one of which was given 40 I.U. of long-acting A.C.T.H. daily from Day 13 to Day 16 inclusive. Time of onset and duration of oestrus were recorded at 2-hourly intervals and ewes were killed after mating for counts of corpora lutea (C.L.). Mating commenced in the control group on Day 16 before the last injection was given to the treated group. These latter ewes did not show oestrus until a mean of 40 hours (18-58) after the last injection. Thus onset was significantly delayed by approximately two days. Mean duration of oestrus was slightly (non-significant) longer in the treated group (39 h) than in the control (35 h). The ovulatory response to treatment is shown in table 1 as the number of ewes in each group with 1 to 4 C.L.

Table 1

	Number of C.L.				Mean ovulation rate
	1	2	3	4	
A.C.T.H.	0	4	7	6	3.72
Control		10	8	0	2.44

The results show a significantly higher O.R. in the group treated with A.C.T.H. before mating. There were no apparent relationships within either group between O.R. and time of onset of mating (cycle length) or duration of oestrus.

II. The second experiment, carried out on Blackface ewes, was designed to test various aspects of pituitary/adrenal activity in relation to ovulation as compared with both control and subjectively stressful environments. After standard group feeding and adjustment of body condition the ewes were allocated into 5 basic groups and treatments were applied from Day 13 of the post-synchronisation oestrous cycle until the end of oestrus. The treatments were:

1. Control environment
2. Stress environment
3. Exogenous cortisol (100 g cortisol acetate/day in 3 doses)
4. Metopirone (3 g/day in 4 doses)
5. A.C.T.H. (60 I.U./day in single dose)
   a) discontinued on day 16,
   b) discontinued on day 17, recommenced at onset of oestrus.

Three ewes from each group except 4 were treated separately from the main groups and subjected to intensive programmes of blood sampling. These were to be used for determinations of plasma cortisol, progesterone and luteinising hormone (L.H.). Because of the requirements of the sampling programme the ewes of group 1 were more disturbed than those in the main experiment whereas the additional stresses in group 2 were probably less effective than in the main group.

Treatment with A.C.T.H. delayed the onset of oestrus by approximately one day beyond the last injection. The mean cycle length in all other groups was about 16 days. Ovulatory response in terms of the numbers of ewes with 0 - 3 C.L. are shown in table 2.

Table 2

	Number of C.L.				Mean ovulation rate
	0	1	2	3	
Group 1	0	5	18	2	1.88
2	0	10	14	1	1.64
3	0	5	14	2	1.86
4	0	3	7	0	1.70
5a	0	3	13	1	1.88
5b	6	4	11	2	1.39

From preliminary analysis the differences between pairs of treatments were not significant but, considering the trends at this stage, it appears that neither exogenous cortisol in the form given nor A.C.T.H. when stopped before mating depressed O.R. below the control level. However, in the stress environment, and in the groups treated with Metopirone or with A.C.T.H. during oestrus, the ovulation rate was reduced considerably. Plasma analyses of cortisol and progesterone are not completed but the preliminary analysis for LH showed that both groups 1 and 3 had a normal pattern whereas groups 2 and 5 had irregular and delayed peaks of LH release. One ewe in group 2 and one in group 5b showed no normal detectable peaks. Both ewes exhibited behavioural oestrus - of relatively short duration - and one (5b) failed to ovulate. It can be seen that there were five other ewes in the main experiment which did not ovulate after detection of oestrus by rams. Ovarian cysts or large follicles were fairly common in both the stress environment and the A.C.T.H. treated groups.

The tentative conclusion at present is that environmental conditions can influence reproduction by affecting onset or duration of oestrus, time of ovulation and number of ova released. These effects may be independent and may vary with the type and time of application of the environmental stress. Furthermore, it seems likely that the severity of the response to a given environmental factor may vary with genotype or previous habituation.

2. <u>Site of ovulation and implantation in relation to early embryonic mortality.</u>
(J.M. Doney and R.G. Gunn)

Observations on the location of corpora lutea and the site of development of the resulting embryos at 20-30 days post-mating were made in a number of previous experiments. These data were analysed to determine the extent of transuterine migration of embryos and its effect on mortality. Excluding the relatively small number of ewes with more than two corpora lutea (C.L.), three ovulation types were considered:-

A. unilateral twin ovulation (2 C.L. in one ovary)

B. bilateral twin ovulation (1 C.L. in each ovary)

C. unilateral single ovulation (1 C.L. in one ovary).

In this set of observations approximately 20% of ewes with a single C.L. returned to service after a normal cycle interval, indicating failure of the product of conception at some stage before embryonic migration is known to occur. Site of development in ewes which did not return could not be determined on slaughter in only 2% of the sample. In the case of ewes with 2 C.L. (types A and B) only 7% returned to service but the location of both embryos could not be determined in approximately 12% of cases. It could, therefore, be assumed that this latter category also represented, to a considerable extent, the pre-migratory failure of one of the shed ova.

Considering only those cases in which the number of identifiable development sites corresponded to the number of C.L., it was found that in type A ovulatory situations, migration of one embryo from the original uterine horn to the contralateral horn occurred in 87% of ewes. However, evidence of migration was found in only 1% of ewes with type B ovulation and 5% with type C. (Crossover migration in type B cannot be determined but this is considered unlikely and is irrelevant).

Excluding only the normal returns to service the wastage rate of embryos up to slaughter was 22%, 12% and 9% respectively in ovulation types A, B and C. Considering only those cases in which all development sites were identifiable, the corresponding mortality rates were 16.3%, 7.6% and 6.4% respectively. Thus higher wastage in twin-ovulating ewes was confined to those which shed both eggs from the same ovary (55% of total multiples).

The data were examined for mortality in relation to embryo location. In unilateral double ovulations, failure to migrate leaves two embryos in the original horn of the uterus, whereas dispersal of embryos by migration allows development of one embryo in the original horn and the second in the contralateral horn associated with an ovary without a C.L. Within type A it was found that 26.3% of embryos were not viable where no migration had occurred as compared with 14.6% when embryos were distributed. However, the mortality rate of the migrant embryos themselves was similar (22.6%) to that of the 'unspaced' embryos, whereas the non-migrants, remaining as sole occupants of the original horn, had only 6.6% mortality. This latter value was comparable to the 7.6% and 6.4% in ovulation types B and C where a single embryo was located in a uterine horn with C.L.

Significantly higher losses in unilateral twin-ovulating Cheviot ewes were found than in corresponding Scottish Blackface. In these data the high loss was entirely associated with a significant difference in the extent of embryo migration (72% as compared with 91%).

3. <u>The influence of body condition at mating on reproductive potential of North and South Country Cheviot ewes</u>
(R.G. Gunn and J.M. Doney)

This experiment, first carried out in 1971, was repeated in 1972 to give greater information on responses within these breeds. Out of 63 NCC and 62 SCC hill ewes (6.5 yr. old) managed between August and December in a similar manner to the previous year, 30 NCC and 31 SCC were, before mating, successfully brought into and maintained in body condition 3 ± 0.25, while 28 NCC and 26 SCC were brought into and maintained in condition 2 ± 0.25.

Ewes were killed either at return-to-service or after 29 ± 5 days for ovulation and viable embryo counts. The results and mean values of the two years' experiments are summarised in the following table:-

Live weight and potential reproductive performance of North and South Country Cheviot ewes in conditions 3 and 2 at mating

Breed		N.C.C.						S.C.C.					
Body condition at mating		3			2			3			2		
Year		1971	1972	Mean	1971	1972	Mean	1971	1972	Mean	1971	1972	Mean
LW at mating (kg)		63.4	66.1	65.1	53.5	52.2	52.8	54.6	55.1	54.8	47.0	44.3	45.3
No. of ewes with 1-3 ova	1	3	8	11	16	23	39	15	21	36	26	23	49
	2	15	20	35	5	4	9	20	10	30	6	3	9
	3	0	2	2	0	1	1	0	0	0	0	0	0
Mean ovulation rate		1.83	1.80	1.81	1.24	1.21	1.22	1.57	1.32	1.45	1.19	1.12	1.16
Ova not represented by viable embryos	No.	3	13	16	9	15	24	18	7	25	8	8	16
	%	9	24	18	35	44	40	33	17	26	18	28	24
Mean potential lambing rate to first mating only		1.67	1.37	1.48	0.81	0.68	0.73	1.06	1.10	1.08	0.94	0.81	0.88

The LW and ovulatory responses were similar in both years, with only the SCC ewes in condition 3 showing an apparent but non-significantly (χ^2 = 3.15) lower ovulation rate in 1972 than in 1971. This resulted in there being no significance (χ^2 = 2.37) between the two conditions of SCC ewe in the difference in ovulation in 1972, although when the years were pooled, the difference was significant (χ^2 = 11.40). A further consequence was that in 1972 the condition 3 NCC ewes had a significantly (χ^2 = 8.73) higher ovulation rate than the condition 3 SCC ewes and the pooled value for the two years was also significantly (χ^2 = 10.21) higher.

Embryo mortality was apparently higher in 1972 than in 1971 in three categories but lower in the condition 3 SCC ewes which had a lower than expected ovulation rate. Embryo mortality is, however, under the influence of factors over which we had little control in this experiment and only where the response has been consistent in both years can any comment be made. Although partly confounded by differences in the distributions and survival of single and twin shed ova, embryo mortality in the NCC breed over the two years was consistently and significantly (χ^2 = 7.32) higher in ewes in condition 2 than in ewes in condition 3. Furthermore, over both breeds and years, mortality of single shed ova was significantly higher in condition 2 than in condition 3 ewes (31% v. 13%, χ^2 = 4.40). In the SCC breed, one possibly important result was a consistently and significantly higher mortality of twin than single shed ova (33% v. 18%, χ^2 = 4.52). This was almost entirely due to the ewes in condition 3, in which mortality of twins was relatively high and mortality of singles relatively low (T = 37%, S = 8%).

The results of these two years experiments are to be prepared for publication in note form.

4. <u>The influence of the pattern of live weight and body condition recovery between weaning and mating on food consumption and reproductive performance of Scottish Blackface ewes</u>
(R.G. Gunn and J.M. Doney)

The effects of two patterns of live weight and body condition recovery on food consumption and subsequent reproductive performance were studied on 80 individually fed Blackface ewes in uniform initial body condition. Between July and November the two patterns were early recovery (E) followed by a maintenance period and late recovery (L) preceded by a maintenance period. During both recovery periods, body condition was raised from grade 2 to approximately grade 3 by <u>ad lib</u> feeding. Total food consumption was measured both during the recovery and maintenenace periods in each group. After a synchronised and recorded mating, all ewes were returned to the hill until lambing time when lamb production was recorded.

Differences in live weight between the groups at the start of the experiment, at the end of the recovery period and after mating were not significant and both groups can be said to have reached similar live weight and condition at mating by the two contrasting pathways. Voluntary intake during recovery varied widely from 1.47 - 3.05 kg/day and the time taken to rise to the required level of body condition ranged from 5 to 8 weeks.

The E ewes consumed significantly more food during maintenance than did the L ewes (66.9 kg v. 37.3 kg), averaging 1.19 kg/day or 20.9 g/kg LW/day compared with 0.61 kg/day or 14.2 g/kg LW/day. During recovery in August and September the E ewes consumed 2.45 kg/day for a LW gain of 322 g/day, compared with 2.14 kg/day for a gain of 298 g/day in the L ewes in October and November but these differences were not significant. Most of the greater quantity of food consumed was therefore required to maintain higher body condition.

There were no differences between the two groups in the distribution of number of lambs born per ewe nor in lambing percentage (E = 169%, L = 164%). Reproductive performance is therefore unlikely to be affected by the pattern of recovery to similar live weight and body condition at mating.

Although late recovery is a more economical pathway in terms of food consumed, there are other probably more important factors which must be considered in a grazing system.

These results have been prepared for publication.

LACTATION

1. The influence of intra-uterine nutrition on the post-natal growth of Blackface lambs.
(J.N. Peart)

In each of two years, two similar groups of multiparous Blackface ewes were fed either a high plane (HP) or low plane (LP) level of nutrition during late pregnancy. At parturition their mean liveweights were 70.1 and 54.0 kg and the mean birthweights of their lambs were 4.65 and 2.87 kg respectively. One lamb from each HP and from each LP ewe was fostered at birth to a nurse ewe for rearing. After four weeks of lactation either the HP or the LP lamb was removed from each nurse ewe and the remaining lambs reared as single-suckled. Milk and solid food intake of individual lambs were measured. A summary of milk intake and lamb growth rates is given in the following table:

	Weeks			
	0 - 4		5 - 10	
Group	LP	HP	LP	HP
Mean milk intake g/day	1275	1483	1137	1275
Mean milk intake (g) per g liveweight	0.211	0.165	0.075	0.064
Mean milk intake (g) per g liveweight gain	5.67	5.10	3.60	3.46
Mean live weight gain g/day	233	300	342	384

2. The influence of suckling cross-bred lambs on the milk production of Blackface ewes
(J.N. Peart and J.M. Doney)

In November 1971 approximately half of a hill flock of Blackface ewes was mated to Texel rams and the remainder to Blackface rams. The ewes remained on their hill grazing during gestation and were supplementary fed in late pregnancy. Within 7 days of parturition 10 ewes each with single-born lambs from each of the breeding groups were selected for milk production and lamb growth studies. The sex ratio of the lambs was made the same in each group. The selected groups of ewes and lambs were transferred from the hill and grazed on re-seeded pasture throughout lactation. Supplementary feeding of the ewes was continued but in diminishing quantities during the first 4 weeks of lactation. Milk production of the ewes was measured at weekly intervals during a 12-week period using a lamb-suckling weight-differential technique. The live weights of ewes and lambs were also recorded at weekly intervals. Mean ewe live weights of each suckling group were almost identical at parturition and both made consistent and similar gains during lactation. The results are summarised in the following table:-

Suckling Group	Mean live weight data of lambs birth-84 days			Mean total milk production of ewes
	Birth kg	84 days kg	daily gain g	84 day lactation kg
Texel cross	5.1	35.6	364	153.4
Pure BF	5.0	33.9	344	125.1

3. <u>The yield and composition of the milk of Finnish Landrace x Blackface ewes</u>
Pt. I Ewes and lambs maintained indoors
Pt. II Ewes and lambs maintained on pasture
(J.N. Peart)

These studies have been completed in colloboration with the Edinburgh College of Agriculture. The results of Part I have been published in J. Agric. Sci., Camb. (1972) 79, 303-313. In Part II the animals were maintained on pasture. Analysis of vegetation samples taken at weekly intervals gave DOMD values of 76 per cent in early lactation declining to 64 per cent at the end of lactation. Detailed analysis of the data are not yet complete but they indicate differences between years particularly in respect of milk composition and lamb growth. The shape of the lactation curves of each suckling group were similar in each year but mean total milk yields were lower when the ewes were on pasture.

	Mean total milk production kg		Mean fat content %		Mean lamb growth g/day	
	Indoors	Pasture	Indoors	Pasture	Indoors	Pasture
Single	134	114	6.6	9.1	320	259
Twin	202	176	7.1	8.9	302	238
Triplet	207	193	7.7	9.0	251	211

VOLUNTARY INTAKE

Factors affecting the long-term intake of roughage by sheep
Phase 1 - Non-pregnant, non-lactating ewes
(Janet Z. Foot and A.J.F. Russel)

This experiment, which was described in part in the last annual report (p.5), was terminated in July, 1972. During late April and early May there had been a sharp increase in intakes of dried grass (C) and the better quality hay (B). These appeared to decline before the experiment finished. In contrast, there was no such marked peak in the mean intake of the poorer hay (A) during the spring.

For the last eight weeks of the experiment, 5 of the 16 sheep in a dietary group were changed to each of the other two diets. In every case the sheep which had been on diet B had the highest intakes after the change, although those that had been on diet A were achieving similar intakes during the last three weeks. Sheep which had previously been offered diet C had substantially lower intakes of all three diets than had the sheep from the other two groups.

On turnout to pasture in July the mean live weights were as shown:-

Roughage diet during main experiment	Apparent DM digestibility %	Diet during last 8 weeks		
		A	B	C
		Mean liveweights at end of experiment (kg)		
A	59.5	53.0	54.0	63.5
B	61.5	57.5	61.5	73.0
C	81.5	68.5	70.5	82.5

At mating in November the mean liveweights of all groups were almost identical, ranging from 60 to 64 kg, with the exception of group BC which averaged 70 kg. Thus the substantial weight differences resulting from nine months <u>ad libitum</u> feeding on roughages differing widely in quality were almost nullified after four months at pasture.

The relationships in this experiment between intake, roughage quality and fatness of the sheep are being examined.

The majority of the ewes have been re-housed since December for Phase 2 of this experiment (see summary of New Work).

NUTRITION IN PREGNANCY

Studies on the nutritional physiology of pregnant gimmers
(A.J.F. Russel and Janet Z. Foot)

The reproductive performance of hill gimmers lambing for the first time at two years of age is generally not as good as that of ewes producing their second or subsequent lamb crops. The low birth weights and high incidence of mortality of gimmers' lambs are commonly attributed to inadequate nutrition during the final weeks of pregnancy. The results of an experiment outlined in a previous report (Annual Report 1971) indicated, however, that the disproportionately low birth weights of gimmers' lambs was more likely to be a result of inadequate nutrition, leading to excessive body weight loss, during the first three months of pregnancy. The results also showed clearly that the effects of severe under-nutrition during the first three months of pregnancy could not be overcome by supplying during late pregnancy levels of nutrition greater than those required to prevent a measurable degree of undernourishment.

Examination of field records suggests that the weight loss during the first three months of pregnancy is largely independent of mating weight. It is also probable that in poorly grown gimmers the partition of nutrients between uterine and maternal tissues may be different from that in animals which have more nearly achieved their mature size. For these reasons it is considered that weight and size at first mating may be of importance in respect to lamb birth weight in situations where substantial weight losses occur during the first three months of pregnancy.

An experiment to study the effects of weight and size at first mating on the birth weights of lambs from gimmers subjected to different nutritional treatments during the first three months of pregnancy is now in progress. The lower level of nutrition in early pregnancy is designed to produce a net weight loss of some 6 kg in three months, which is typical of that found in many field situations. The higher level of nutrition is designed to maintain net maternal weight during this period. Variation in weight and size of animal has been achieved by selecting gimmers from two widely different nutritional environments.

NUTRITION AND BODY COMPOSITION

1. The content, distribution and composition of body fat in different breeds of sheep
(A.J.F. Russel) (in collaboration with the Animal Breeding Research Organisation and the Edinburgh School of Agriculture).

An experiment in the Animal Breeding Research Organisation provided material with which to study the growth, efficiency of food utilization and carcass characteristics of Finnish Landrace, Southdown, Soay and Oxford Down sheep. H.F.R.O's contribution to this collaborative work was to undertake responsibility for the body composition part of the study, with particular reference to the content, distribution and composition of the body fat in these different breeds.

Two animals of each sex in each breed were slaughtered when they attained 40, 52, 64 and 76% of estimated mature weight. The Soays were first to reach the four stages of maturity and the Oxfords last. Differences between breeds in weekly live weight gain were highly significant, mean values being 0.60 kg for Soays and 2.00 kg for Oxfords. When growth rate was considered as a percentage of mature body weight all significant breed differences were removed. Efficiency of food utilisation did not differ between breeds over the range of maturity investigated.

At each stage of maturity the percentage fat in the fleece-free empty body (FFEB) was lowest in the Soay and greatest in the Oxford, with the Finnish Landrace and Southdowns having values near to that of the Oxford. The Soay showed the greatest increase in percentage chemical fat per unit increase in FFEB weight and the Oxford the lowest, but when FFEB weight was expressed as a percentage of mature weight the Soay was seen to have only half as much chemical fat as was found in the domesticated breeds.

Differences between breeds in rates of fat deposition in various sites were noted. In this respect the low rate of deposition of subcutaneous fat in the Soay and the high rate of deposition of omental and mesenteric fat in the Finnish Landrace were particularly noteworthy. Samples of fat from the different depots in a number of sheep of each breed have been kept for determination of fatty acid composition.

2. Changes in live weight and body condition of rams throughout the year
(A.J.F. Russel, A.J. Macdonald, C.D. Kerr and Brenda Rudd)

The patterns of change in live weight and body condition of hill ewes throughout the year are now relatively well defined for a number of situations, but no comparable information is available with respect to the male. Rams at Glensaugh, Lephinmore and Sourhope were weighed and condition scored at regular intervals from the autumn of 1970 until late 1972.

Preliminary analysis of the data indicates that, as in ewes under traditional systems of management, rams attain maximum live weight (approximately 90 to 100 kg in the Scottish Blackface) and condition (score 3.0 to 3.5) in October or early November. During the mating period from mid-November until the end of December there are substantial losses in weight (of some 12 to 15 kg) and condition (of about 1 condition score) which are greater than those noted in ewes over this relatively short time. Live weights and condition scores remain low and change little from January to early May, during which time ewes are generally experiencing a considerable loss of maternal weight and condition. Most of the recovery of weight and condition occurs during May and June, and changes from then until October or November are relatively small.

The general pattern of live weight and body condition of the hill ewe throughout the year is one of continual change, whereas that of the ram is characterised by long periods of relative constancy and only short periods of change. The data also suggest that the annual changes in body composition are less in the ram than in the ewe.

3. The use of dilution techniques to estimate body composition in hill sheep

In order to assess the feasibility of predicting body composition (in particular fatness) on a routine basis during nutrition experiments two trials have been carried out using tritiated water dilution. The first objective was to find out if the use of such a dilution technique contributed a degree of accuracy sufficiently greater than that achieved from liveweight and condition scoring alone to make it worthwhile. Secondly, we wished to see if extreme variation in feeding regimes altered the relationship between tritiated water space and total body water or between total body water and body fat.

Experiment 1. The use of tritiated water to predict body composition in Cheviot lambs.
(Janet Z. Foot, A.J.F. Russel and Richard H. Armstrong)

Tritiated water was infused into 58 cheviot lambs a few hours before they were slaughtered. The lambs were from a lamb growth study experiment (see Annual Report 1971 p. 10) and included 12 lambs in a preliminary slaughter group ranging from 14 to 21 kg and 46 lambs which had been on 4 different herbage feeds and weighed 17 to 34 kg. After slaughter the lambs were analysed for fat and water. The relationship between % fat and % water in the body was consistent for all treatment groups. The relationships between tritiated water space and body water or body fat are being examined.

Experiment 2. The estimation of body water in mature Blackface ewes by dilution techniques.
(Janet Z. Foot, E. Skedd and W. Smith)

The experiment was specifically designed to test the limitations of measuring body water, and subsequently estimating body fat, by tritiated water dilution. Indirect estimates of body water were compared with direct measurements after slaughter in 18 cast ewes which had been subjected to extreme dietary treatments over short periods of time (from half maintenance to ad libitum food allowances). In a limited number of cases deuterium oxide and Evans Blue (T1284) were used in parallel with the tritiated water infusions.

The laboratory analyses have now been completed; from the results of analyses of the slaughtered sheep an equation derived to predict body fat from body water and liveweight slightly overestimated fat in sheep fed ad libitum and underestimated it in sheep on half maintenance. The average deviation for each group was 0.6 percentage units for values ranging from 8 to 21% body fat. The deviations were all small so the extent of the error is predicting body fat from tritiated water space is likely to depend more on the differences between tritiated water space and total body water than on variation in the relationship between body fat and body water. Tritiated water spaces are currently being calculated.

NUTRITION - HEATHER

1. Seasonal changes in the nutritive value of heather (*Calluna vulgaris*) to sheep
(J.A. Milne)

The voluntary intake and digestibility of mechanically harvested heather, which contained 85 per cent of current season's shoots, were determined with six wether sheep per harvest. Harvests were taken in July, September, November and March, and the heather was cold-stored until offered to sheep. The sheep were offered heather ad libitum for a period of 4 weeks, the last 10 days of which were used as a measurement period. Some preliminary results have already been given (Annual Report 1971). Mean values of voluntary intake and digestibility or organic matter and apparent digestibility of nitrogen are given in the following table.

Seasonal changes in the nutritive value of heather

Time of harvest	O.M.I. ($g/kg\ W^{0.75}/day$)	O.M.D. (%)	Apparent N Digestibility (%)
July	37.0	56.8	42.2
September	32.8	47.5	14.3
November	34.6	47.2	25.1
March	28.0	42.7	26.7
S.E. of difference between means	± 3.74	± 2.26	± 4.62

As a consequence of the low voluntary intakes, only the sheep offered the July harvest of heather were in positive energy and nitrogen balance. At all harvests the amount of undigested dietary nitrogen in the faeces was high (mean 33%) but, although the apparent N digestibility of heather was negatively related to the quantity of tannin/g of protein ingested, estimates of true N digestibility were not similarly related.

2. The effect of age of stand on the nutritive value of heather, (*Calluna vulgaris*) to sheep
(J.A. Milne)

There have been several reports suggesting that the current season's growth of younger stands of heather was of a higher nutritive value than older aged stands. To examine these suggestions, an experiment was carried out in which pioneer, building and mature stands of heather were harvested in August 1972, and their nutritive value compared with six wether sheep per harvest. The sheep were offered heather, containing 90% current season's shoots, *ad libitum* for a period of 4 weeks, the last 10 days of which was used as a measurement period. The chemical composition of the harvests taken by the sheep was similar for all stands, except that the building stand had a higher crude protein content than the other stands. There were no significant differences between stands in the voluntary intake and digestibility of organic matter, but the apparent digestibility of nitrogen was significantly higher ($P<0.05$) in the building stand than in the other stands.

3. The effect of supplementation by grass on the voluntary intake of heather (*Calluna vulgaris*)
(J.A. Milne)

Results reported in this Annual Report above demonstrated that after flower initiation the nutritive value of heather was low, indicating that heather is likely to be supplemented with grass by the grazing animal in the autumn. An experiment was conducted to examine the effects of level of grass supplementation on the voluntary intake of heather. The levels of grass supplementation - 0, 12, 24, 36 and 48 g DM/kg $W^{0.75}$/day - were offered at 0900 and the heather offered *ad libitum* at 1300 to five wether sheep per level of supplementation for a period of one month; the last 10 days of which were used as a measurement period. The grass, a regrowth from a PRG sward and the current season's shoots of a building stand of heather were harvested and deep-frozen in September. The voluntary intakes of heather DM from the five levels of grass supplementation given above were 24.1, 29.2, 20.1, 13.7 and 7.3 g/kg $W^{0.75}$/day respectively. There was an increase in heather DM intake of 0.4 g per g addition of grass supplement from the heather *ad libitum* level to the lowest level of grass supplementation, but thereafter there was a decline in heather intake of 0.65 g per g addition of grass supplement. The DMD% of the heather and the grass were determined to be 44% and 68% respectively. There was no evidence of any associative effects of heather and grass on the digestibility of the total diets.

In collaboration with A.K. Martin (Hannah Research Institute, Ayr) an analysis of the simple phenols in heather and in the urine of the sheep on this experiment was carried out. This revealed that there was a significant ($P < 0.01$) linear relationship between the intake and excretion in the urine of a simple phenol, orcinol. Also the agreement between the slope of the regression line and the amount of the phenol in the heather offered to the sheep indicated that all the simple phenol ingested was excreted in the urine. Thus this phenol could be used as an inert marker in the measurement of intake of heather in the grazing situation, providing that total urine collection can be measured. This technique would be of particular use in situations where both the grass and heather intakes of grazing sheep were being measured.

4. The nutritive value of the diet selected by sheep offered plant material harvested from Vaccinium communities in the Spring
(J.A. Milne and L. Bagley)

The Blaeberry, Vaccinium myrtillus, is often found in the same plant communities as heather or in associated communities on heather hills. There have been several reports that Vaccinium communities are grazed by sheep, particularly in spring and early summer. To examine the sheep's preferences for Vaccinium and to measure the voluntary intake and digestibility of the diet selected, Vaccinium, from a Vaccinium-dominant area, was harvested in May and offered ad libitum to six wether sheep for a period of a month; the last 10 days of which were used as a measurement period. The harvested material contained 75% Vaccinium, 20% Agrostis/Festuca grasses and 5% mosses. The diet selected by the sheep contained 52% Vaccinium, 39% grasses and 9% mosses. Ninety-one per cent of the grass offered was selected, 68 per cent and 42 per cent of the moss and Vaccinium respectively were selected, and only 16 per cent of the Vaccinium leaf offered was selected. The mean DMD% of the diet selected was 51% and the mean voluntary intake of DM was 23 $g/kg\ W^{0.75}/day$. Considering the chemical composition of the Vaccinium leaf, the selection by the sheep against the leaf was surprising. The low voluntary intake and digestibility of the diet selected indicate that Vaccinium is unlikely to make a useful contribution to the sheep's diet in spring and early summer. These results also suggest that the sheep observed grazing Vaccinium communities in spring and early summer are selecting the grass species associated with Vaccinium communities rather than for Vaccinium myrtillus.

5. The prediction of dry matter digestibility from the in vitro digestibility technique and methods of chemical analysis of heather, (Calluna vulgaris)
(J.A. Milne, C.S. Lamb, D.R. Campbell and L. Bagley)

Previous work at HFRO (Annual Report 1970; p.77) indicated that the standard in vitro technique was unlikely to be suitable without modification for predicting the dry matter digestibility of heather samples. In a 2x2 factorial experiment using 10 samples of heather of known in vivo dry matter digestibility, two possible sources of variation within the technique were examined; namely, method of drying the sample and source of rumen liquor. The two methods of drying the sample were freeze-drying and oven-drying, and the two sources of liquor were from hay-fed and heather-fed sheep respectively. Freeze-drying gave in vitro digestibility values which were significantly higher ($P < 0.001$) than oven-drying, and liquor from heather-fed sheep produced in vitro digestibility values significantly higher ($P < 0.05$) than liquor from hay-fed sheep. However the mean in vitro digestibility values were 15 units lower than the in vivo digestibility values.

Predictions of dry matter digestibility from the in vitro digestibility methods and from determinations of nitrogen, neutral-detergent fibre and acid-detergent fibre were compared by comparing the residual standard deviations (RSD) of their regressions. The lowest RSD of ± 2.5 was obtained from relating in vivo DMD% to in vitro DMD%, when the samples were freeze-dried and when the source of liquor was from a hay-fed sheep. Larger RSD's were obtained from relating in vivo DMD% to measures of chemical composition, and multiple regression analysis failed to reduce the RSD significantly. The RSD obtained are still higher than those normally associated with the in vitro technique, and higher or similar to other reports with other plant species for the detergent analyses. Further experimentation is planned in an attempt to reduce the RSD with the in vitro technique to less than ± 2.

NUTRITION AND SUPPLEMENTATION

1. The effects on intake and digestibility by sheep of poor quality roughage diets supplemented with barley
(C.S. Lamb)

This experiment was a repeat of that reported in the Annual Report for 1971 as it was decided that progressive loss of appetite by the sheep (probably due to copper poisoning) invalidated the results. This study followed the same plan as that previously reported, except that supplements of barley and different wethers were used. The chemical composition of the feeds offered are shown in table 1.

Table 1

Chemical composition of feeds offered (means over 4 periods)

Feed	N (%)	CWC (%)	ADF (%)	Lignin (%)
Roughage 1	1.41	70.2	42.5	6.5
" 2	1.00	70.4	42.7	7.9
" 3	0.75	75.9	51.6	9.2
" 4	0.56	80.1	59.7	9.3
Barley	1.92	-	8.6	-

The fresh weights of barley fed were: level I, 275 g; level II, 550 g; level III 825 g. The intakes of roughage, total dry-matter and ration digestibility are shown in Table 2.

The intake of Roughage 1 was significantly reduced by feeding each level of supplement. The intake of Roughage 2 rose slightly when level I of supplement was fed while the feeding of greater amounts of barley resulted in roughage intakes that were significantly lower than those at level I. It would appear that the different response of these two roughages to supplementation may be related to their nitrogen content. Intakes of Roughages 3 and 4 were increased by feeding both level I and level II of supplement while feeding the highest level of barley led to roughage intakes that were similar to or less than intakes attained without supplements.

A notable feature of this experiment was that supplementation led to large increases in total dry-matter intake. The digestibility (organic matter) of the ration also increased considerably, with the largest increases being from level 0 to level I of supplement with all the roughages. These results would indicate that energy intake is increased considerably by supplementation of these poor roughages.

Table 2

Mean intakes of roughage, total DM and ration digestibilities

Roughage	Level of Supplement	Roughage DMI ($g/W^{0.73}$)	Total DMI ($g/W^{0.73}$)	Ration digestibility (%)
1.	0	68.8	68.8	56.0
	I	61.9	73.3	62.2
	II	58.9	81.5	64.0
	III	54.0	88.0	66.5
2.	0	66.0	66.0	52.0
	I	69.6	80.9	57.7
	II	62.1	84.7	59.5
	III	58.0	92.2	60.2
3.	0	49.9	49.9	43.8
	I	53.5	66.0	57.0
	II	54.1	78.7	59.8
	III	44.5	81.8	62.0
4.	0	49.1	49.1	47.3
	I	55.2	67.5	52.2
	II	51.0	75.3	56.4
	III	48.7	85.0	60.7

2. A study of the changes in intake and digestibility and of conditions within the rumen of sheep fed a poor quality hay supplemented with four levels of barley
(C.S. Lamb)

Four rumen fistulated sheep were fed poor quality hay (1.45%N, 75.5%C.W.C., 45.8%A.D.F.) ad lib with 0, 230, 460 or 690 g barley per day in a 4 x 4 Latin Square design. The supplements were fed in two equal portions at 9.00 and 17.00 hours prior to feeding the roughage. The results to date are shown in table 1.

Table 1

Mean intakes, digestibilities and blood and rumen characteristics

	Hay	Hay + 230 g barley	Hay + 460 g barley	Hay + 690 g barley
Hay DMI ($g/W^{0.73}$)	49.0	44.2	31.3	23.1
Total DMI ($g/W^{0.73}$)	49.0	55.8	54.7	57.6
OMD (%)	54.3	62.1	66.3	74.2
ADF.D (%)	49.8	51.2	48.3	50.7
DOMI ($g/W^{0.73}$)	24.6	33.6	34.4	39.2
Rumen pH	6.58	6.25	5.95	5.81
% disappearance of hay from Nylon Bags within rumen for 24 hours	17.9	14.9	12.5	8.9
Rumen Volume (l)	7.85	5.69	(5.1)	(5.1)
Plasma Glucose (mg/100ml)	49.7	51.8	54.0	56.5

Feeding increasing amounts of barley is seen to reduce the intake of hay, mean rumen pH, the rate of fibre digestion in the rumen and possibly rumen volume. Total DM intake was significantly increased by the low level of supplement while further amounts of supplements did not lead to further increases in intake. The OM digestibility of rations containing the supplement were all significantly greater than that of the all roughage ration. Energy (DOM) intake was significantly greater from rations containing supplement than without it. It is noteworthy that energy intake from the ration containing the low level of supplement was 37% greater than that from the all hay ration while two and three times this quantity of supplement did not yield multiple increases in energy intake.

NUTRITION - METABOLISM

Assessment of the protein status of hill ewes
(A.J.F. Russel (in collaboration with A.R. Sykes, ADRA))

It is generally believed that the principal nutritional limitation to production from hill sheep is an insufficient supply of dietary energy, and that protein intakes are adequate at most levels of energy intake. There is good evidence of response in production to increased supplies of energy, but most of the evidence regarding the adequacy of protein is indirect.

Results obtained from work at Glensaugh (RGG in collaboration with ADRA), considered in relation to evidence from experiments in ADRA, indicate that under the conditions prevailing there from November 1969 to May 1970 the protein status of hill ewes was not consistent with normal skeletal mineralization and foetal development. Although the supplementary feeding of these ewes did not follow normal practice, there was evidence of a protein deficiency before supplementary feeding was given. In a subsequent investigation in 1971-72 the apparent protein deficiency was less severe.

Work has now begun with ewes from the Cairn and Birnie flocks at Glensaugh, and the Mid Hill flock at Lephinmore to assess the adequacy of protein and energy intakes by the analysis of blood samples obtained at intervals throughout the year.

GROUP NUTRITION

Variation in intake among group-fed pregnant Scottish Blackface ewes given restricted amounts of food.
(Janet Z. Foot, A.J.F. Russel, T.J. Maxwell and P. Morris)

Previous work on group-feeding of non-pregnant ewes (Foot and Russel, 1973 and Annual Report 1970) has indicated that there may be a two-fold difference in the intake of pelleted food by individual animals in the same group. An experiment was carried out at Castlelaw to measure the intake of food by individual sheep housed in groups during late pregnancy when they were fed according to commercial practice on a basic diet of hay with a rising plane of concentrate food.

Three groups of animals were used: (1) 16 mature ewes, (2) 16 2-year-old ewes and (3) 8 mature and 8 2-year-old ewes. The daily hay allowance was constant but the concentrate was increased from an equivalent of 96 g DM/sheep at the beginning of the experiment, about seven weeks before the ewes were due to lamb, to 435 g when the ewes were turned out about a week before they were due to lamb. The intake of concentrates and hay by each individual was measured three times at three-weekly intervals using total faecal output. A chromic oxide marker was incorporated in the concentrate so that the intake of that portion of the diet could be estimated.

Individual concentrate intakes were most variable when the group allowance was small (CV over 50% in the mixed group) but variation decreased when amounts of concentrates were increased to contribute up to 47% of the total DDMI. The CV for the total DDMI ranged from 13 to 24%.

The younger sheep were at no disadvantage when penned with mature ewes. Intakes by individual ewes were compared with their calculated requirements (Russel, Doney and Reid, 1967) and several twin-bearing ewes appeared to have a substantial energy deficit during the last collection period. This was confirmed by the elevated plasma ketone concentrations.

This work has been submitted for publication.

CATTLE

1. The characterization of nutritional state in beef cows
(A.J.F. Russel, Janet Z. Foot and T.J. Maxwell)

Regular measurements of the nutritional states of cows in three commercially owned and managed beef herds were made during the period from October 1971 to September 1972. Blood samples were collected every six weeks from approximately 24 cows in each of the following herds: a spring calving Luing herd (Herd A), an autumn calving Friesian x Hereford herd (Herd B) and an autumn calving mixed Blue Grey and Hereford x Friesian herd (Herd C).

Live weights were recorded in Herds A and B at each blood sampling and less frequently in Herd C. In Herds A and B the amplitude of the annual live weight curve was of the order of 100 kg, and it was estimated that approximately half of this was attributable to changes in uterine weight, the remainder reflecting changes in maternal tissues. The patterns of live weight gain and loss in relation to physiological state and level of nutrition were examined.

Plasma concentrations of glucose, non-esterified fatty acids, ketone bodies, urea nitrogen and protein-bound iodine were determined in the blood samples collected. The most useful single parameter was plasma ketone concentration. In Herds A and C mean ketone concentrations were generally maintained between 2 and 3 mg%; individual values of between 3 and 5 mg% were recorded in less than 20% of animals in each herd during the winter months. Such values indicate a moderate degree of undernourishment. In Herd B mean ketone concentrations increased from 2.4 mg% in October to 5.9 mg% in early March, some six months after calving. This latter figure is considered to be high for a mean value and might be considered to indicate a potentially dangerous situation. The range around the mean was, however, relatively small, being 3.2 to 10.4 mg%; excluding these two extreme values the remainder fell within the range 4.3 to 8.1 mg%. This relatively narrow range suggests that although the animals were being forced to draw on body reserves to a considerable extent, the degree of control of nutrition of individual cows was of a very high standard. By the middle of April the mean ketone concentration had fallen to 4.0 mg%, and was maintained below 3.0 mg% during the summer months.

Plasma urea nitrogen concentrations showed marked seasonal changes with minimum values of between 8 and 10 mg% in March and maximum values of 22 to 26 mg% in July. Differences between herds were generally small and there was no evidence of a deficiency of dietary protein in any of the herds.

The performance of the cows in all three herds was high, and it is clear from the results of the blood analyses that their nutrition was generally satisfactory. It can be tentatively suggested that in Herd C, and to a lesser extent in Herd A, the cows could, at times, have been made to use body reserves to a greater extent without any undue effect on performance, but it is difficult with the knowledge available to date to indicate the extent to which feed savings might have been possible. Herd B is noted for its high productivity, yet the severity of undernourishment recorded was at times considerable and could not have been increased without serious consequences. The results indicate that the management of this herd was of an exceptionally high standard and that the nutrition of the animals was under close control.

2. Assessment of the nutritional state of beef cows throughout the annual cycle
(A.J.F. Russel, Janet Z. Foot and T.J. Maxwell)

The programme of weighing and blood sampling the Hereford x Shorthorn cows in the Hairney Law - Auchope Year Round Grazing System continued during the year to provide information on the nutritional state of breeding cows within a system of controlled grazing designed primarily to intensify production from sheep. The cows in this development project are used mainly as an aid to pasture management and thus their nutrition during the grazing season is of secondary consideration to that of the sheep stock.

The cows calved during February and March and, as in previous years, were grazed on the Hairney Law - Auchope area from 1st May to the end of the year. All cows lost weight during the early months of lactation but regained their mean prepartum (January) weight by the end of July. The contribution of uterine contents to gross weight would be much less in July than in January and thus the net weight gain must have been appreciable during June and July when the cows were grazing the hill area. During the period when the cows were used to 'clean up' the production areas after grazing by lactating ewes they lost some 35 kg live weight, but this was more than regained during the subsequent months, and the cows attained a maximum mean weight of 610 kg in November. The amplitude of the annual live weight curve was considerably greater than in the previous year, being some 130 kg or more than 20% of maximum live weight. Although this suggests a substantial dependence on body reserves at certain periods of the year, the fact that the maximum weight was about 30 kg greater than that recorded the previous year indicates a very satisfactory level of year-round nutrition, and a further continued increase in live weight since the animals' introduction as heifers in 1969.

The results of the blood analysis confirmed that the cows were never more than moderately undernourished at any time. Plasma ketone concentrations were highest during late August when the cows were grazing the herbage left by the ewe stock in the production areas, but the mean value of 3.2 mg% (range 2.1 to 4.0) at this time indicates that this did not entail any serious nutritional penalty. Plasma concentrations of glucose, non-esterified fatty acids, urea and protein-bound iodine were all within their respective normal ranges and indicative of highly satisfactory levels of nutrition throughout the year.

3. The use of tritiated water in the measurement of milk intake by calves
(E. Skedd, I.R. White, J.N. Peart and A.J.F. Russel)

The literature contains reports of the use of tritiated water to measure milk intake by young ruminants kept indoors. This technique is based on the fact that the daily water intake by an animal is directly related to its rate of water turnover, corrected for any changes in total body water due to growth. Daily water turnover and total body water can both be conveniently determined by measuring the dilution and rate of disappearance of a marker substance, such as tritiated water, which equilibrates readily with total body water.

In the autumn of 1972 a trial was carried out to assess the usefulness and practicability of this technique to measure lactation in future experiments with beef cows. Ten individually penned Ayrshire calves, weighing between 30 and 45 kg at the beginning of the trial, were given fixed daily amounts of milk substitute ranging from 3 to 7 kg in two feeds. Fresh water was offered to the calves each day, and concentrate feed and dried grass were available at all times. The water contents of the milk substitute and feeding stuffs were measured and daily intakes of water by individual calves were calculated over a four-week period.

Estimates of daily water turnover and total body water were made using the tritium dilution technique. Each calf was intravenously infused with 3 ml tritiated water (66.7 µci/ml) on the 1st, 15th and 29th days of the trial. Rates of disappearance of tritiated water (and hence daily turnover rates) were calculated from measurements made by liquid scintillation techniques of the activity of blood samples collected on three days in each week. Total body water estimates were also obtained from these data by calculating, from extrapolations, the dilution of tritiated water at the time of infusion, making allowance for residual activity from any previous infusions.

Measured water intakes by individual calves varied from 2.7 to 6.6 l/day. Regressions of measured daily water intake on estimated daily water turnover rates were computed separately for the first two and last two weeks of the trial, and were found not to be significantly different. The overall relationship covering both periods was:

$$y = 1.12\ (\pm\ 0.07)x - 0.69$$

where y = measured water intake (l/day) and x = estimated water turnover rate (l/day). The correlation coefficient was 0.97 and the standard error of the mean predicted water intake (Sy.x) was ± 0.08 l (i.e. ± 1.71%).

The relationship between measured water intake and that estimated indirectly from water turnover rate is sufficiently strong to allow the regression to be used with some confidence for predictive purposes. It should be borne in mind that these data represent the situation at its worst in that the direct measurement of water intake in the trial cannot be assumed to be without error.

No attempt was made in the trial to calculate the contribution of metabolic water to total water turnover. The negative regression constant in the above equation presumably reflects this omission, and although inclusion of this component might make the regression pass through the origin it would in no way affect the correlation between the variates or the accuracy of prediction afforded by the regression.

The results of this trial indicate that tritiated water offers a useful and practicable means of measuring the intake of water by calves kept indoors and, from this, the lactation of beef cows. The principal merits of the technique are its ease of use and the fact that it gives integrated measurements over periods of some 10 to 20 days as opposed to most conventional methods which rely on occasional intermittent sampling.

4. <u>Veterinary aspects</u>
(A.S. Whitelaw)

The accommodation facilities in the cattle shed for housing the cows which are to be used in the project were not completed in 1972.

However they were sufficiently advanced to enable the cows and calves to be housed in December. After the initial difficulties encountered with animals unused to being secured they rapidly settled down in the house. A total of 82 cows in approximately equal proportions of breed - Blue Greys and Hereford-Friesian crosses constitute the herd from which the experimental animals will be chosen.

To assist in the detection of oestrus, an Aberdeen Angus bull was vasectomised and prior to housing was fitted with a chin-ball marker to obtain dates of oestrus in the cows.

On entry into the shed the bull was put in daily for periods with each of four groups and the dates of oestrus noted. A schedule for the aspects of oestrus detection was drawn up, including recording and the use of forward planning charts.

A schedule of the veterinary implications of the cattle project was also drawn up and monitoring of ill-health was instituted.

It is hoped that mating will commence in January 1973 and it is hoped to get the animals in calf with a minimum spread of calving date.

Nutrition has been such that prior to mating the cows are on an ascending plane.

No health problems attributable to housing in cubicles have emerged to date.

PLANTS AND SOILS

MINERALISATION

1. The effects of added calcium and aluminium upon the distribution of aluminium in soils
(A.G. Lowe and M.J.S. Floate)

Brown earth soil of the Sourhope series was tested in a 4 x 4 factorial experiment design with 12.5, 25 and 50% of the cation exchange capacity of calcium (as calcium carbonate) and aluminium (as aluminium sulphate). The treated soils were allowed to stand for 3 weeks with no disturbance other than watering. After this period samples were taken, dried and analysed for water-soluble and neutral salt solution (in potassium chloride) extractable aluminium and for the pH in water.

In most of the cases the water soluble aluminium was less than the potassium chloride extractable. This may mean that the water soluble fraction is an estimate of the aluminium bound very loosely (if at all) in the soil. The potassium chloride extractable aluminium is the water soluble aluminium plus a factor which exchanges with the potassium. Thus

$$Al_{ka} = Al_{H_2O} + Al_{Exch.}$$

Thus an estimate of the aluminium available for displacement from the exchange complex by neutral salts may be obtained by taking the water soluble value away from the potassium chloride extractable value. The resultant values were then plotted against the pH values and two straight lines were found to exist, the steeper intersecting the pH axis at 5.28 (correlative coefficient = .982).

Above pH 5.28 the amount of aluminium in either fraction is not sufficient to impair plant growth and in a recent paper by MacLean et al it has been proposed that liming to a pH of about 5.3 eliminates or reduces the soluble aluminium. This method may thus be used to predict the level to which to lime in order to reduce the aluminium in soil solution and improve plant production. This value may vary with soils. Using the organic soil from Sourhope in a similar way a value of 4.60 was obtained.

Reference

MACLEAN, A.J., HALSTEAD, R.L. and FINN, B.J. Effects of lime on extractable aluminium and other soil properties and on barley and alfalfa grown in pot tests. Can. J. Soil Sci. 52, 427-438 (1972).

2. The effect of calcium and aluminium on plant composition
(A.G. Lowe and M.J.S. Floate)

A brown forest soil of the Sourhope series was treated with three levels of Ca^{++} (as calcium carbonate) and Al^{+++} (as aluminium sulphate) in a 4 x 4 factorial experiment. These were added at rates equivalent to 12.5, 25 and 50 per cent saturation of the cation exchange capacity. Herbage from *Agrostis tenuis* grown on the treated soils was cut three times during the year, dried, milled and analysed for Al and Ca by X.R.F.

There was no significant correlation between the level of aluminium in the soil (as estimated by extracting with water, or with I.N. KCl solution) and Al concentration in the plant material. This was because of wide variations in herbage -Al between replicates as well as between treatments. Some observations must be emphasised and require further investigation. Those soils treated with the highest levels of aluminium were the most acid, with highest levels of water soluble Al and KCl extractable Al, and those below pH 3.8 failed to support plant growth. At this threshold of growth some treatments resulted in high concentrations of aluminium in the herbage. It is possible that under other treatments in which soil Al was high, high concentrations of aluminium may be in the plant roots, and this possibility is being investigated. The lack of variation and relation between soil aluminium and the aluminium in the herbage at higher pH 4.5-5.0 may be due to the low availability of Al in soil under these conditions. There were significant differences for the amounts of aluminium in the herbage between harvests, the first harvest having significantly higher concentrations of aluminium than the subsequent two harvests. This suggests a different rate of aluminium uptake at different stages of plant growth which could be due to more vigorous growth in the early stages or blockage of absorption sites as the plant ages.

These possibilities may need further study: an investigation of plant root aluminium content is in progress.

3. The effects of plant aluminium content on decomposition rate (A.G. Lowe and M.J.S. Floate)

Agrostis tenuis was grown on a Sourhope series soil treated in a 4 x 4 factorial design with calcium (as calcium carbonate) and aluminium (as aluminium sulphate). The grass was harvested and dried, and analysed for aluminium and calcium by X-ray analysis, which showed that there was a range of aluminium contents of 190-750 ppm in the material.

It is proposed that comparisons between material 200, 400 and 600 ppm aluminium should be made. Comparisons are also being made between aluminium within the plant and its effect on the decomposition, and aluminium added, outside the plant, as aluminium sulphate. Thus the 200 ppm-content material was used with addition of aluminium equivalent to 0, 200 and 400 ppm (to give similar amounts of aluminium to those mentioned for plant composition above). The plant material plus treatments was marbated at 30°C with an inoculum from decomposing grass. Sufficient results are not yet available.

GERMINATION

The effect of varying the time of fertiliser application on the subsequent germination of certain species on peat (J.A. Rogers)

There appears to be no general agreement on the best time to apply N P K fertiliser in relation to the time at which the seed is sown. The unpredictable outcome of sowing operations at Lephinmore indicates that more information is required on the germination and emergence of seeds on peat.

In a pilot trial the effects on germination of applying N P K fertiliser before, simultaneously with and after sowing were examined. Peat cores 15 cm in diameter were cut from the blanket bog at Lephinmore and transferred to a trough of water in Edinburgh. All the cores were given a top dressing equivalent to 5 tonnes per hectare of ground lime-stone and basic slag containing the equivalent of 57 kg per hectare of phosphorus. After a period of 14 days the experimental treatments were commenced. These consisted of a top dressing of SAI No. 1 compound fertiliser at rates equivalent to 136 kg per hectare and potassium sulphate also equivalent to 126 kg per hectare. In treatment 1 (T 1), the fertiliser was applied 7 days prior to sowing, in Treatment 2 (T 2), it was applied at the same time of sowing and in Treatment 3 (T 3), the fertiliser was applied 7 days after sowing. Two seed species were sown, S24 Perennial Ryegrass and Huia White Clover. 100 seeds were sown on each core using a vacuum seed counting device; there were three replicates.

Throughout the experiment the water table was kept at 5 cm below the surface of the peat cores and additional artificial rain was given equivalent to the difference in average rainfall between that at Edinburgh and Lephinmore.

The number of seeds emerging was recorded three times per week. For perennial ryegrass T 2 (simultaneous application of fertiliser) gave the highest rate of emergence from 10 days after sowing until 31 days after sowing. After this time both T 1 and T 2 levelled out at just below 80% while the maximum germination in T 3 did not exceed 70%. For white clover the pattern of emergence was similar but T 1 and T 2 both emerged more rapidly than T 3; there was no difference between T 1 and T 2.

While the results of this trial were statistically significant an obvious biological explanation does not immediately present itself. It is, therefore, worth confirming that this is in fact a real effect. In postulating a biological explanation for this effect the following facts should be borne in mind. The seeds of both species were shown on filter paper culture to be non-dormant; germination percentages for perennial ryegrass in the high nineties were obtained within seven days on filter paper whereas in the experiment, germination was slower than this, only reaching fifty per cent after nine to twenty days from sowing. This may be due to the lower temperatures occurring in the experiment which was conducted in the open air or from some partially inhibiting factor in the peat. If the latter, it would seem that the application of fertiliser concurrently with sowing did, in some way, oppose this partial inhibition, or alternatively it did actually enhance germination. Further experimentation is therefore required to confirm this effect and to further elucidate its nature.

PLANT NUTRITION

1. Assessment of the availability of phosphate to plants
(P. Newbould and Mrs. M. Pimplaskar)

Non-completion of the glasshouse at Bush has delayed work on this project. However, several preliminary experiments have been carried out with soils from Glensaugh, House of Muir, Lephinmore and Sourhope to establish the levels of phosphate which will be needed both in the equilibration solutions for phosphate isotopic exchange measurements and in the soils for growth of plants. Meanwhile, the experiments have provided interesting comparative information on the soils and an assessment of the likely relative order in which their phosphate will be available to plants. It is hoped to test these assessments in subsequent pot experiments with plants grown in soils labelled with radioactive phosphate.

Replicate 5 g aliquots of soil were shaken with 60 ml $kH_2 PO_4$ solution containing either 3, 9 or 15 mg P for seven days under standard conditions. After the equilibration period the quantity of phosphate remaining in the soil solution was assessed using the molybdenum blue method of Truog and Meyer (1929) with stannous chloride as reducing agent. The quantity of phosphate sorbed(S) by the soils at the highest concentration level (15 mg P/60 ml) and the reciprocal of this value (1/S) is given in Table 1. Values of the latter type have been shown to be related to the availability of phosphate to plants (Russell et al 1957). The pH of the soils in 0.01 M $Ca Cl_2$ with a 1: 2.5 and a 1:5 ratio of soil to solution for mineral and peat soils respectively is given. In addition the total phosphate of the soils determined by Jacksons (1958) method and the quantity of phosphate extractable by 2.5% acetic acid as described by Reith and Robertson (1971) are shown.

The slopes of the phosphate sorption curves (P sorbed by soil v. P initially in solution) differed significantly between the soil types; that for Lephinmore (Peat) was least while that for House of Muir (Brown earth) and the Glensaugh (Podzol 5-5 cm layer) mineral soils were greatest with Sourhope (Brown earth) being intermediate. These differences in slope probably reflect the number of exchange sites for phosphate which are available under these conditions on the peaty and mineral soils. The work will be continued next year when it is hoped that all the necessary facilities will be to hand.

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TABLE 1. The pH, total phosphate, acetic acid extractable phosphate and quantity of phosphate sorbed from $kH_2 PO_4$ solutions by different hill soils

Soil		pH in M/10 $Ca Cl_2$	Total 'P'		'P' extractable by 2.5% acetic acid mg/100g soil	S Sorbed 'P' mg/5g soil	$\frac{1}{S}$	Likely relative availability of 'P' to plants
Place	Type		mg/100 g soil	kg/ha				
Glensaugh	Podzol 5-15 cm layer	3.5	27.5	151	0.16	9.7	0.10	Low
House of Muir	Brown earth 'A' horizon	4.6	101.9	560	0.21	9.4	0.11	Low
Glensaugh	Podzol 0-5 cm layer	3.0	58.0	116	2.68	3.8	0.26	Medium
Sourhope (Dod site)	Brown earth 'A' horizon	3.9	97.8	538	3.05	3.8	0.26	Medium
Lephinmore	Peat 0-15 cm layer	3.1	50.0	100	2.69	1.5	0.65	High

2. Field studies of the optimum conditions required to establish clover rich pastures on hill soils
Experiment on blanket peat at Lephinmore
(P. Newbould, W. McDermott and G.R. Bolton (in collaboration with Drs. J. Holding and J.F. Lowe of the Microbiology Department, Edinburgh School of Agriculture))

An area of indigenous vegetation (mainly Eriophorium vaginatum, Calluna vulgaris and Erica tetralix) was burned in April 1972. Lime at 2.5, 5.0 and 7.5 tonnes per ha (1, 2 3 ton/ac) and phosphate (as slag) at 52 and 85 kg/ha was then applied. Two levels of potassium (56 and 112 kg/ha) and a starter dressing of nitrogen (20 kg/ha) were added immediately prior to sowing the seeds (S23 and S24 perennial ryegrass, S184 and NZ Huia white clover) in June. Trace elements, extra nitrogen (20 kg/ha) and inoculation of the clover seed with rhizobia were applied to some of the plots; it was not possible to completely randomise all the treatments. Replication was four fold.

The number of plants established per unit area was recorded at weekly intervals and samples of herbage were taken in September. Chemical and statistical analyses are still in progress. However a striking result which was obviously highly significant without statistical analysis was the big boost given to establishment of clover by inoculation of the seed with effective rhizobia. The increases in ground cover with clover at the low (2.5 tonnes lime, 52 kg P and 56 kg K) and high (7.5 tonnes lime, 85 kg P and 182 kg K) nutrient levels per hectare were from 2 to 27 and from 3 to 34 per cent respectively The effect of the inoculation treatment on fixation of nitrogen and the subsequent growth of both the clover and grass plants will be assessed in the first full growing season.

Experiment on a peaty podzol at Glensaugh
(P. Newbould, W. McDermott and L. Fairlie)

An experiment of similar design to that described above will be carried out at Glensaugh. The heather was burned in April 1973 and the lime and slag applied shortly afterwards. It is intended to sow the seeds in late July.

Experiment on a poorly drained brown earth soil at Sourhope
(P. Newbould, W. McDermott and R.H. Armstrong)

The comparative effectiveness of New Zealand and Edinburgh strains of rhizobia for white clover and the effect of Gaffsa rock phosphate coated on to the surface of white clover seeds will be examined in an experiment to be started at Sourhope in 1973. The site which had been limed and slagged in early 1972 was burnt in May. It is hoped to sow the seeds in late June.

The nutritional requirements of clover on blanket peat
(W. McDermott)

The availability of the major nutrients (N, P K and Ca) to clover plants grown on blanket peat together with the response of the plants to additions of fertiliser will be studied in a series of pot experiments. This work will complement the small plot field experiment now in progress on blanket peat at Lephinmore.

After preliminary trials it has been decided to use pots filled with chopped and uniformly mixed peat rather than undisturbed cores as the medium for growing the plants.

3. The effect of earthworms on pasture production from hill soils
(P. Newbould, W. McDermott, E.G. Hallsworth (C.S.I.R.O. Australia) and W. Guild (E.S.A.))

Specimens of three species of Australian earthworms - Notoscolex montokoscuisko a sub-soil feeder, Vesiculodrilus frenchii and Cryptodrilus fastigatus, both surface litter feeders will be introduced into plots 4 x 4 m on three contrasted sites at Lephinmore. For comparison, similar numbers of one of the major indigenous earthworms, lumbricus terrestris will also be introduced. Sheets of polythene have been placed around the plots to a depth of 60 cm and with a projection above the peat surface of 15 cm to prevent the earthworms spreading.

A trial batch of Australian earthworms arrived in December but attempts to keep them alive for introduction at Lephinmore in the Spring were not very successful. It is proposed to take the next batch straight to Lephinmore for immediate introduction.

4. <u>The calcium nutrition of white clover and grasses in hill soils</u>
(P. Newbould and Miss D.M. Vernon)

The quantity of lime needed to establish and maintain clover rich pastures on hill soils, particularly deep peats and soils with a surface mat of organic matter, is uncertain. Recommendations vary from 1.25 to 12.5 tonnes lime per hectare. To judge the level of lime which best suits the biological and economic constraints of a site requires knowledge of the effect of added lime on soil properties and the growth of the plants, and the length of time for which it is effective. A series of experiments has been started on all three aspects but preliminary results are as yet available only for the last subject.

The residual value of dressings of lime (approximately 7.5 tonnes/hectare) and the need for maintenance applications was investigated by taking samples of soil from the sites of two experiments set up 16 years ago at Lephinmore (Hughes and Nicholson, 1961) and at Glensaugh (Hughes and Nicholson, 1962). It should be noted that the fences around both sets of plots fell into disrepair about five years ago and the herbage has since been heavily grazed by sheep.

Samples of soil taken both from the treated and the surrounding untreated areas were analysed for their content of readily extractable calcium, phosphate and potassium. Five gram aliquots of dry soil were shaken with 200 ml of acetic acid solution (2.5 per cent by volume) for two hours. The content of calcium and potassium in the supernatant was measured by flame photometer and the content of phosphate by the Molybdenum blue technique with Stannous Chloride as the reducing agent.

The quantity of the nutrients added per unit weight of air-dried soil was estimated from the amounts of lime, slag and compound fertiliser applied and estimates of the likely water content of the soil at the time of the application. Since the latter can vary within very wide limits these figures may be in error by quite large factors especially for the deep peat at Lephinmore.

The results shown in Table 1 indicate that a considerable proportion of the calcium added at the start of the experiment was still present at both sites but especially at Glensaugh. This difference between the sites is also reflected in the pH values.

The higher relative retention of calcium at Glensaugh could be due to the larger number of exchange sites on the mineral fraction of the soil than on peat or to the lack of downward percolation of rain water; the slope and surface mat of organic matter together with the iron pan below the podsolized layer at this site may have resulted in considerable surface run-off of water.

At Lephinmore, by contrast, the site of the experiment is in a hollow and surface run-off is unlikely to have occurred to any great extent. The considerable loss of calcium from this site must be due to removal in grazed herbage and to the small number of exchange sites on the peat and the significant downward leaching of rain water. No samples were taken from below 15 cm and it is possible that some of the calcium may still be present lower down the profile. By contrast, although not statistically significant, the quantities of both phosphate and potassium extracted from the treated areas were less than those present in the surrounding untreated areas. Either these elements have become unavailable to the extractant used, been leached faster than calcium or considerable amounts have been removed in the herbage grazed by sheep.

From the point of view of establishing and growing clover at both these sites it is encouraging that the single dressing of lime made 16 years ago continues to provide conditions in which clover would be able to grow and fix nitrogen although it is apparent that a further dressing of lime would now be needed at Lephinmore to maintain this situation. More information is needed on phosphate and potassium but it would appear that further dressings of both elements would now be required to grow clover satisfactorily at both these sites.

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<u>Table 1.</u> Nutrients extracted from soil at Lephinmore and Glensaugh to which lime and fertilisers were added 16 years previously (Treated) and from soil adjacent to these treated areas (Untreated)

	Lephinmore (Deep peat 0-15 cm)		Glensaugh (Humus layer 0-7.5 cm)		Glensaugh (Mineral layer 7.5-15 cm)		LSD (P=0.05)
	Untreated	Treated	Untreated	Treated	Untreated	Treated	
pH (in H_2O)	3.7	4.6	3.5	5.4	3.8	4.3	0.3
Nutrients (mg/100 g air-dried soil)							
Added to soil in 1957							
Ca		1800		800			
P		100		20			
K		40		15			
Extracted* from soil in 1973							
Ca	36.2	283.0	37.8	649.5	1.8	70.3	33.0
P	2.7	0.8	3.5	2.4	0.4	0.3	NS
K	33.1	21.7	40.7	26.8	13.2	11.0	NS

* Extraction with solution of acetic acid (2.5% by volume) (5 g air-dry soil + 200 ml extractant)

PASTURE FORMATION - HERBICIDES

The effect of a reduction in bracken density on the production of underlying grasses.
(G.E. Davies)

The herbicide, Asulam, has been widely tested by various scientific organisations throughout the country and there is little doubt that the results obtained in the reduction of bracken-frond cover make it one of the most promising herbicides so far used in the control of bracken. It has given fairly consistent results together with a high degree of control which lasts at least until the third year after treatment. Up to the present, however, workers have concentrated their efforts on achieving the best 'kill' of bracken and little attention has been given to quantifying the effect of the removal of bracken on the underlying grass sward so that an assessment can be made, in terms of animal production, of the possible economic benefits of bracken removal. It is therefore proposed to set up, in 1973, a joint project with the Agronomy Department to answer some of the questions posed. The work will include botanical as well as animal intake studies.

HEATHER - MOORLAND MANAGEMENT

1. The effects of grazing on blanket bog
(Sheila A. Grant, W.I.C. Lamb, C.D. Kerr and G.R. Bolton)

The aims and design of this group of experiments together with site descriptions were detailed in last year's annual report. In brief, wet and dry variants of bog communities were subjected to three different grazing pressures, the pattern of grazing being related to various sheep systems currently under test at Lephinmore farm.

The effects of season of the year and grazing pressure on grazing behaviour of the sheep are being followed both by direct observation of the vegetation and by examination of cuticle fragments in the faeces of the sheep. The interest lies in establishing the utilisation levels to which the various species in the sward are subjected so that, any changes in floristic composition of the sward may be interpreted in the light of this information, and inferences drawn as to correct management of such areas. By examining utilisation levels of the species in relation to their cover or weight per area it is possible to calculate their percentage contribution to the diet of the sheep. These results are then compared with percentage cuticle fragments of the different species in the faeces.

The experiments were begun in the summer of 1971 and results are now available after a complete year of grazing. As expected there were marked changes in species preference with season. In the May-July period, where sufficient cover obtained, grazing was more or less confined to Trichophorum caespitosum, Molinia caerulea, and the few Carex and grass plants of other species which were present. Small amounts of Calluna or the two Eriophorum species were taken. Trichophorum caespitosum, a species dismissed by Gimingham (1972) as having low palatability and poor nutritive value, was very heavily utilised and samples collected in May for analyses of chemical composition had an in vitro digestibility of 68%, nitrogen content of 2.2%, cell wall constituents 46%, acid detergent fibre 27% and lignin 4%. Where Trichophorum and Molinia were absent, Calluna and the two Eriophorum species were more heavily grazed. In August-October utilisation of Trichophorum and Molinia declined; both species die back and are unavailable over the winter period. During August-October Calluna and the two Eriophorum species are increasingly heavily utilised with Calluna being the most preferred of the three. Over the January to March period Calluna is the most heavily utilised species and apparent grazing of the Eriophorum species is less than in the autumn, though the young flowers in their sheaths are drawn at this time of year.

Grazing pressure affects utilisation in three ways. If a preferred species is plentiful, utilisation increases proportionately to grazing pressure. If the preferred species is in short supply, where pressure is highest one of two possibilities occurs; either the preferred species is harder grazed (i.e. longer portions of the leaf or shoot are removed rather than merely a higher percentage of plants grazed) or the surplus pressure falls on a species lower down the order of preference ranking. There is some evidence that the latter occurs with Calluna and Eriophorum. Eriophorum receives scant attention in the lowest and middle grazing pressure plots but is subject to a fair degree of utilisation in the heaviest grazed plots.

Comparisons of percentage cuticle fragments in the faeces of different sheep grazing the same plots show significant differences. This could be interpreted either as meaning that animals differ in diet selection or that they vary in their ability to digest the different species. The degree of confidence in the ability to distinguish related groups of species with certainty is less than that reported by earlier workers (Martin 1955). In 1973 it is intended to collect samples of the main species, serially throughout the year, and to run in vitro digestions on these samples, one on dried and ground material to provide digestibility data and the other on chopped, fresh material to provide reference samples of cuticle fragments.

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2. Heather Moorland Management: grazing and burning experiment
(Sheila A. Grant and W.I.C. Lamb)

The third and final phase of the Glensaugh experiment investigating the effects of grazing and burning on heather moors is now completed. In this third phase, the range of stand types resultant on previous burning and grazing patterns were burned in one and the same fire. Dry matter percentages of the fuel, climate while burning, fire temperatures etc., were all recorded and observations made post burning of the quantities of unburned material, lengths of old heather stick remaining and rates of regeneration of the vegetation. A report of this phase of the study is currently being prepared for publication.

3. Heather utilization: reaction of the heather plant to various levels of cutting at different times within the growing season
(Sheila A. Grant and W.I.C. Lamb)

This is the second year of this experiment, the aims and design of which were described in last year's report. Briefly, 0, 40% or 80% of the length of current season's shoots were removed at each of three phases of the annual growth cycle, all permutations of level of utilization with time of year being employed. Dry weights of clippings were recorded at all harvests and the harvested material was analysed for nitrogen content, percentage cell wall constituents (C.W.C.) acid detergent fibre (A.D.F.) and lignin content.

At the start of the experiment each box contained nine heather plants. Serial destructive harvests, removing whole plants as thinnings, are planned. This will enable the effect of the various cutting treatments on dry matter output as affected by time to be followed. The first such destructive harvest took place in August 1972. The plants removed in this harvest had been cut according to schedule in 1971 but were rested in 1972. Total dry matter output (harvested weight per box plus clippings) varied from 114.97 g for undefoliated plants to 45.62 g for plants where 80% of the current season's growth had been removed in May, July and September of 1971. The yield of plants where 40% of the current season's growth had been removed once or twice was not significantly different from that of the control group (i.e. in May and July, May and September or July and September 1971). The proportion by weight accounted for by current season's growth of plants harvested in 1972 was increased in plants which had been cut in 1971. This indicates that cutting stimulates growth. The balance between reduced photosynthetic tissue and this stimulation to growth rate will determine whether dry matter output will be reduced, remain the same or be increased.

The current season's material from the destructive harvest was analysed for nitrogen, phosphorus, potassium, calcium and magnesium. At this very early stage in the experiment, though differences in morphological type were significant, the range was fairly small with the bulk of the plants having between 60-75% of their total above ground weight accounted for by current season's shoots. The proportion of current season's growth accounted for by flowers, however, showed a fairly wide variation, being lowest in plants which had been heavily defoliated in the previous autumn. Separate analyses were done on green shoots and flowers. Significant differences occasioned by the 1971 cutting treatments occurred for nitrogen content, the latest and heaviest cut plants having some 15-20% more nitrogen than plants uncut in the previous autumn. Potassium and calcium showed significant interactions though main treatment effects were non significant. Phosphorus and magnesium showed no significant variation. Flowers (in August) had similar nitrogen contents to shoots, 1.01 compared with 1.02, less phosphorus, 0.210 compared with 0.288, less calcium, 0.417 compared with 0.482 but more potassium, 0.954 compared with 0.866 and more magnesium, 0.172 compared with 0.159.

Clippings from plants continuing in the experiment underwent the usual van Soest analysis of chemical composition. This indicated a much larger than usual within season fall in nitrogen content, perhaps as a consequence of the prolonged drought. (The boxes were watered regularly; nevertheless, water deficits may still have developed). Nitrogen content (average overall treatments) was 2.40 in May, 1.85 in July and 1.16 in September. In May, when shoot length was only 1-2 cm. the gradient of N content within the shoot was significant and treatments significantly affected both nitrogen and lignin contents. Cell wall constituents and acid detergent fibre showed no significant variation. In July both gradients along the shoot and treatment effects were significant for all the constituents analysed, i.e. nitrogen, C.W.C., A.D.F. and lignin. In September differential flowering masked gradients within the shoot so that differences were non-significant but variation due to treatment was significant for all constituents.

4. Heather utilisation by the grazing animal
(J.A. Milne and Sheila A. Grant)

The aim of this experiment is to investigate the effects of different levels and patterns of utilisation on the morphology and floristics of a heather community, on the annual dry matter production of the heather and on the quality and quantity of the diet selected by grazing sheep. In earlier cutting and grazing experiments summer utilisation was compared with winter and in the grazing experiment, levels of utilisation were not pre-determined. Heather was found to be more sensitive to utilisation in summer than in winter. No information is available on the effects of autumn utilisation. In the current experiment the effects of three different grazing pressures (0, 40 and 80% utilisation of current season's growth) during June-July and/or September-October will be studied.

The experimental site was chosen in 1970, burned in February 1971 and a perimeter sheep-proof fence erected the same spring. A hare netting was added in the autumn as there was evidence of heavy grazing by hares.

In August 1972 the annual dry matter production was measured and found to be 2477 Kg/Ha indicating exceptionally good regeneration. The site was grazed by some 60 sheep for three weeks. Internal fences were erected in October 1972 and provision for watering stock will be made early in 1973. Grazing treatments will begin in June-July of 1973.

To examine the potential for any change in floristic composition consequent on heavy grazing pressure, soil samples had been collected in October 1971 to investigate the viable seeds population. This exercise indicated a real poverty of alternative species to heather. 92.7% of the seeds germinating were *Calluna vulgaris*, 6.1% were *Rumex acetosella* and only 1.2% was accounted for by other species (e.g. *Carex*, *Galium*, *Juncus*, *Agrostis* etc.).

5. The utilisation of grass and heather by the grazing sheep
(J.A. Milne, Sheila A. Grant and T.J. Maxwell)

A site was chosen for a pilot experiment investigating the effect of various grazing pressures on swards containing different proportions of grass and heather. The interest lies in the grazing behaviour of the sheep, how their utilisation of the two components of the pasture will vary with time of year and grazing pressure, and the effects of the utilisation patterns on sheep nutrition and productivity of the swards. In this pilot experiment plots will be 15, 30 and 45% grass and grazing will take place during the complete months of May, July and October to simulate the use of grass/heather areas as production areas integrated with the hill resource. There will be three grazing pressures at the 30% grass level with the middle grazing pressure only at the 15% and 45% grass levels.

The scale of the pilot experiment was determined by the available area of a suitably aged heather sward and minimum plot size for collecting animal performance data. Site preparation began in August 1972 when an area of older heather (about one acre in extent) lying adjacent to the younger heather was treated with a flail harvester. Two tons of ground limestone and half a ton of 15% basic slag were then applied and the area harrowed. A ryegrass seeds mixture consisting of 20 lbs of Borenza and 20 lb of S24 was sown on August 16th. Three cwts of 10, 24, 24 compound fertiliser were then applied and the area rolled. A perimeter fence was erected round the site in late autumn 1972 and site preparation will be finalised during early 1973. It is hoped to begin the grazing treatments in the summer of 1973.

Pasture regrowth
(J. King)

Work started in this field in 1972. The main interest lies in the effect of defoliation on subsequent regrowth. In the past defoliation/regrowth relationships have been explained in terms of a simple model usually involving only one principal factor, leaf area index though leaf age and canopy structure have also been taken into account. This seems inadequate to account for all the effects of defoliation and it is more probable that at least two major factors are involved. The present working hypothesis is that, while leaf area index and canopy structure are likely to have a controlling influence in the later stages of regrowth, another factor may be more important in the early stages. This factor may be the concentration of labile reserves in the stubble or something correlated with this. If this is so, labile reserves are likely to be relatively important on pastures subjected to heavy grazing pressure and it is this aspect which is at present being investigated. Three types of experiment are in progress or planned. First, experiments in which defoliation is by clipping at frequencies and intensities spanning the range which has been reported to occur in grazed swards. The effect of such treatments is measured on regrowth, leaf area index and stubble reserve levels. The reserve levels are measured in terms of total soluble carbohydrates or of dark regrowth which is the capacity of a sward sample to produce new growth in total darkness when other factors are non-limiting. Such experiments do not imply any causal relationship between regrowth and the other factors measured. Accordingly, a second type of experiment is being started in which stubble reserve levels and leaf area index are controlled independently and their effects on regrowth measured. It remains to be seen whether the method used to control the independent variables will be successful.

The third type of experiment involves defoliation by grazing animals directly. The growth is measured at intervals throughout the season on samples of sward from paddocks grazed at various intensities. It is hoped to measure regrowth in terms of net photosynthesis using an Infra-red Gas Analyser.

So far, the only experiments that have been completed are pilot trials which have yielded much information on methods but only a little data on defoliation effects. Defoliation frequencies in the range that might be expected to occur on heavily grazed swards have not always had the expected effect, although, owing to the small number of replicates, it is not possible to draw any conclusions from this. For example, twice weekly defoliation, which is very severe, was found to depress the level of stubble reserves and of regrowth for at least three weeks afterwards. Weekly defoliation, on the other hand, reduced regrowth over the first three days after defoliation but not over a longer period, despite a considerable depression of both stubble reserve levels and stubble leaf area. These results simply point the need for more measurements.

An experiment started in 1972 to measure autumn defoliation effects on regrowth of an Agrostis/Festuca pasture has not been successful. Owing to drought and lack of growth only low defoliation frequencies could be used, so that treatment effects on spring growth are likely to be negligible. A difficulty associated with natural pastures is the effect of the high content of dead herbage in the stubble on soluble carbohydrate measurements. Litter contains only 3-4% soluble carbohydrates against values of from 7-25% for green stubble material. Since more than 50% of a stubble sample may be litter it is necessary to separate fresh green material from the litter for analysis. This is not practicable for more than a very small number of samples and imposes a serious limitation on experiments with Agrostis-Fescue swards. It may be necessary as a result to rely on dark regrowth measurements.

NUTRIENT CYCLING

1. Nutrient cycling in Grazing Expt. I
(M.J.S.Floate and A.G. Lowe)

Data from Experiment I of the Improvement-Response series has been re-calculated to assess the extent of nutrient re-circulation via excreta in the final year of this experiment.

The total amounts of N and P returned in excreta form under 4 treatments are shown in the table. These amounts are expressed as percent of the total soil pod of these elements and the results show that, with increasing intensity of improvement from treatment 1 to 4, increasing proportions of the soil nutrient pod are involved in the cycle.

	Excreta-N re-cycled kg/ha	Soil-N kg/ha	re-cycled-N as % of Soil-N	Excreta-P re-cycled kg/ha	Soil-P kg/ha	Excreta-P as % of Soil-P
1. Low-intensity grazing	16	3220	0.48	2.4	616	0.39
2. Control grazing	38	3510	1.08	5.8	649	0.90
3. Control grazing & N	108	2970	3.64	12.6	702	1.80
4. Control grazing & NPK & lime & re-seeding	179	3440	5.21	21.5	879	2.45

It may be concluded that under more intensive grazing use the reserves of soil fertility are more efficiently used.

2. Soil nutrient levels after 3 years under the excreta return experiment
(M.J.S.Floate, J.S. Black and A.G. Lowe)

After three years treatment under the faeces and urine return experiment, soil samples were taken from each plot and from control areas. Analyses are now complete for pH, C, N, C/N ratio, Total-P, Available-P and -K: treatment differences have been compared statistically. In general these differences were remarkably small and were only significant for Total-P. Increases were recorded where faeces or P were returned at the higher rates. Other trends were for pH to be higher than control where urine had been applied, and for C/N ratio to be lower than control under all treatments. It may be concluded that increased herbage DM production has been achieved at no expense to soil fertility because of nutrient re-cycling in excreta or inorganic forms.

The similarity in soil-N and -P levels, despite wide variations in nutrient uptake and return rates is remarkable and requires explanation. The amounts of these nutrients taken up in plant growth, and returned in excreta or inorganic treatments are precisely known for three years and if the net gain or loss amount is applied to the control soil level, the predicted amounts in treated soils are in some cases too high and in other cases too low. Mineralisation of re-cycled nutrients would not affect the overall nutrient status of the system, and other explanations (e.g. loss of N, or gains in rainfall) would affect the predictions in either a positive or negative way, but not both simultaneously.

If multiple re-circulation of nutrients occurred within one season (i.e. N in the first cut herbage, returned as urine re-appeared as N in the second and third cut herbage) the magnitude of predicted gains (or losses) would be too great. As a first approximation it may be assumed that 50% re-circulation occurs and the predicted soil-N and -P levels can be re-calculated. The results of such a re-calculation are much closer to the measured values so that it seems likely that significant re-circulation of these nutrients does occur within the season. If this is the case it has far reaching consequences on the efficiency of soil nutrient utilization, on maintenance requirements and on the overall biological efficiency of intensively grazed systems. In order to quantify this effect any more precisely tracer techniques are required.

INPUT-OUTPUT

1. Improvement-Response Studies

A series of long term experiments have been established on a range of soil/pasture types at Sourhope and Lephinmore to examine the response to progressively more comprehensive improvement treatments. These include grazing control, lime basic slag and surface seeding with white clover and improved grasses. The experiments are continuing and ultimately it is the objective to select the most appropriate treatment for each site: such assessment will be based on production and cost-effectiveness criteria. Interim results are presented here for certain aspects of 5 sites.

Experiment I - Nardus-Agrostis/Peaty Podzol
(M.J.S. Floate, J. Eadie and J.S. Black)

This experiment was brought to a close in 1971 and the final conclusions were published in a paper by M.J.S. Floate, J. Eadie, J.S. Black and I.A. Nicholson "The improvement of Nardus dominant hill pasture by grazing control and surface treatment, and its economic assessment" presented at the Potassium Institute Colloquium, Edinburgh 1972.

Sourhope F_2 - Experiment II
(M.J.S. Floate, J.S. Black and A.G. Lowe)

Pre-treatment soil samples were taken in 1969 and the results of the analysis of these were published in the Annual Report 1970. Treatments were applied in 1970 and an interim sapling of the top 0.5 cm soil was undertaken in 1972.

A summary of results is presented in the Table and, although statistical significances have not yet been calculated, some treatment differences can be readily detected.

At this site the original soil and vegetation were Brown Forest and Festuca Agrostis and the litter layer, post treatment, has remained constant at about 1.0 cm on all plots.

0-5 cm	1. Control 69	72	2. Lime 69	72	3. Lime & P 69	72	4. Lime & P & Clover 69	72	5. Lime & P & Clover & Grass 69	72
pH	5.5	5.4	5.9	6.2	5.2	6.5	5.7	5.8	5.9	6.4
Avail-P g/m^2	0.21	0.25	0.20	0.38	0.15	0.88	0.18	0.74	0.20	0.96
Avail-K g/m^2	9.1	8.9	9.6	8.7	9.2	9.4	10.3	10.1	10.5	8.3

pH has dropped slightly on the control grazing plot but under all other treatments which have involved lime application increases in soil pH have resulted.

Available-P has increased at least 4 fold under treatments which included P application, and lime alone has almost doubled the available-P level since 1969.

Available-K has remained more or less constant under all treatments except 5 where there is some suggestion that soil K level may be decreasing. It is also possible that more K may have been taken up by vegetative growth on 5.

Sourhope G3 - Experiment III
(M.J.S. Floate, J.S. Black and A.G. Lowe)

This experimental site was characterised by Nardus-Molinia dominant pasture on a Peaty Podzol before treatment in 1970. The results of some pre-treatment soil analysis were published in the Annual Report, 1970 and the remaining results together with those for an interim sampling conducted in 1972 are summarised below.

	1. Control		2. Lime		3. Lime & P		4. Lime & P & Clover		5. Lime & P & Clover & Grass	
	70	72	70	72	70	72	70	72	70	72
depth A_o cm	4.4	1.6	4.7	1.6	3.8	1.7	3.8	1.8	3.7	1.6
pH A_o	3.7	4.4	3.9	6.2	4.1	5.8	4.1	5.8	4.0	6.3
0-5	3.6	4.1	3.6	4.6	3.8	5.0	4.0	4.9	3.8	4.9
Avail-P (mg/100g)										
A_o	29.7	23.9	29.3	23.2	31.0	32.3	37.7	40.6	29.9	34.1
0-5	9.3	7.2	12.8	8.8	14.7	8.6	19.6	13.5	18.4	9.8
Avail-K (mg/100g)										
A_o	117.3	144.1	122.3	246.5	147.8	237.0	120.5	205.5	143.7	256.7
0-5	88.8	71.2	81.9	90.2	98.2	81.3	90.5	93.4	93.3	85.6

The litter layer appears to have been markedly reduced on all plots since 1970 but this may be due in part to sampling techniques.

pH of all plots receiving lime has increased by about 1.5 units in the surface samples, and the values indicate that free lime is probably still present. The pH of the 0-5 cm layer has also increased above the starting level in all lime-treated plots.

Available-P has not markedly changed in the surface layers under treatments 1, 2 or 3 but has increased under 4 and 5. On all plots there is an indication that the concentration of P may have dropped since the start of the experiments. Results for weight/volume of Available-P are awaited before this observation can be confirmed.

Similarly weight/volume data will be required to confirm the observation that available-K appears to have increased in the A_o layers under all treatments. The amounts of available-K in the 0.5 cm layer show little change either between treatments or between years.

<u>Experiment III - Expt. in Progress</u>

<u>Effect of lime treatment on herbage composition</u>
(M.J.S. Floate, J.S. Black and C.C. Evans)

Samples were taken from the first cut in the first grazing period in 1972, from control and lime treated plots of Experiment III to compare herbage composition. In the whole samples, the lime treatment increased the per cent of Ca, P and K and reduced the per cent of Al. Increases in Ca content were consistent through all fractions (i.e. broad-leaved and fine-leaved, dead and green and moss) and the overall increase was from 0.07 to 0.24% Ca. P and K content increased most in the green fractions and a notable feature was the ten-fold difference in K content between green and dead fractions. Al content was slightly reduced in the whole sample mainly due to the reduction from 0.78 to 0.27% in the broad-leaf green fraction. A curious observation was the overall increase in Si from 1.50% to 2.96% which was consistent in all fractions except moss.

<u>Sourhope F4 - Experiment IV</u>
(M.J.S. Floate, J.S. Black and A.G. Lowe)

This experiment is situated on a similar and adjacent site to the discontinued Experiment I. Following the conclusion that it is not practicable to reduce <u>Nardus</u> by grazing control, a herbicide treatment was applied to all plots at the outset. Prior to any treatments being applied soil samples were taken and the final results from the analysis of these samples are not yet available.

Lephinmore Le1 - Experiment I
(M.J.S. Floate, J. Eadie and G.R. Bolton)

The experiment at this site differs from the Sourhope Experiments in the Improvement-Response series in that the objectives here are as much concerned with assessing long-term maintenance requirements as with responses to initial improvement treatments. Indeed this latter is the objective of a more detailed experiment (Project 03D).

0-5cm	D		F		E		A		C		B	
	1 Ca_1P_{20} +		2 Ca_1P_{20}		3 Ca_1P_{40}		4 Ca_2P_{20}		5 Ca_2P_{20} +		6 Ca_2P_{40}	
	71	72	71	72	71	72	71	72	71	72	71	72
pH	3.5	4.1	3.5	3.9	3.5	4.1	3.4	4.2	3.5	4.4	3.5	4.3
mean:	(3.5)	(Ca_1=4.0) (Ca_2=4.3)										
Avail P g/m^2	0.36	0.32	0.35	0.50	0.30	0.60	0.51	0.56	0.46	0.42	0.38	0.60
mean:	(.39)	(P_{20}=.45) (P_{40}=.60)										
Avail K g/m^2	2.07	3.40	2.48	3.77	2.24	3.72	2.45	5.23	2.52	3.89	2.03	4.53
mean:	(2.30)	(4.09)										

The site was established by burning and re-seeding in 1972 after pre-treatment soil samples were taken in 1971. All plots received an initial treatment of K = 100 kg/ha, $CuSo_4$ = 20 kg/ha, $CoSO_4$ 2.0 kg/ha, Sodium Molybolate = 70 g/ha and 125 kg/ha SAI No. 1 compound fertilizer. Treatment differences consisted of 2 rates of Lime (1,2 ton/ac) and 2 rates of P (20,40 kg/ha) as indicated in the Table.

Soil samples were again taken post-treatment in 1972 and the results of analysis for the 0.5 cm layer for 1971 and 1972 are given. These show that the pre-treatment pH (3.5) was very low and that an average Ca_1 treatment increased this to 4.0 and Ca_2 to 4.3.

The pre-treatment soil levels of P and K were also very low. On average P_{20} treatments have increased soil P to 0.45 g/m^2 but 2 of the results show lower values in 1972 than in 1971. P_{40} treatment has increased soil P values on all plots (mean = 0.60 g/m^2). Soil K levels have nearly doubled as a result of treatment.

Soil sampling and analysis will be repeated in 1973 and, pending the results, it appears that supplementary P treatment may be required sooner than originally planned.

2. Pasture composition in Input/Output trials
(J. King)

Pasture records have been made from all the Input/Output trials at Sourhope. A summary of records completed and projected for the future is as follows:-

Trial	Started	Pasture Records Completed	Pasture Records Projected
Fasset Agrostis/Fescue			
Plots ABC_1DE	1969	1970)	1973
Plot C_2 *	1972	1972)	
Gairs Molinia	1970	1971 & 72	1975?
Fasset Molinia	1971	1971 & 72	1975?

* Plot C_2 is an additional control added to the trial in 1972.

The composition of the swards in the plots to which the various treatments have been applied are given in Tables 1, 2 and 3.

Fasset A/F site (Table 1).

The data for all plots except plot C_2 were collected before the treatments had had time to have a measurable effect and it will be seen that the initial variation between plots was considerable. Plots A, B and E contained a higher quality of Agrostis/Fescue pasture than did plots D and C. The highest quality of all occurred in B where the sward contained quite large amounts of Trifolium, Festuca rubra and Poa pratensis. It is possible that, owing to the initial quality of this sward, the treatment (Lime only) will have only a small effect on the composition.

Plot D and the control C_1 contained only a very little Trifolium, Festuca rubra or Poa pratensis and this, combined with the presence of Deschampsia flexuosa in the plots suggests that these swards were inferior to those in the other treatments.

The additional control plot C_2 by 1972 is already a high grade Agrostis/Fescue pasture with abundant Trifolium, Festuca rubra and Poa. Its composition suggests that in the period 1969/72 it has undergone some improvement as a result of heavy deposition of dung and urine. Whether this standard of sward will be maintained by the Control treatment remains to be seen.

Gairs Molinia (Table 2).

The data for this site show that Molinia is still present in significant amounts although there has been a reduction since 1971 when the Molinia cover ranged from 36% to 54%. Nardus also is abundant and it will be interesting to see for how long it persists. The species characteristic of low quality Agrostis/Fescue pastures are present but the absence of Festuca rubra and Poa pratensis from all but plot B where the former has been sown along with Lolium, may limit the degree of pasture improvement that can take place unless these species can establish themselves naturally.

Fasset Molinia site (Table 3).

This site was sprayed with Dalapon to eliminate Nardus and the data show that both Nardus and Molinia have been almost eliminated by this treatment. Both were formerly quite as abundant as on the Gairs Molinia site. Most of the species necessary to form a good Agrostis/Fescue sward are present, F. rubra being the chief absentee. Where they have been sown, both Lolium and Trifolium have established but the seedling density is not high. Since Lolium is not a stoloniferous species, it remains to be seen the extent to which this species can dominate the sward starting from a rather low initial establishment density.

TABLE 1

Input/Output Trial: Pasture Composition

Fasset Agrostis/Fescue Site: % Ground Cover of Species 1970

	Treatment					
	A	B	C_1	D	E	C_2(1972)
	LP+LpTr	L	Control	LP	LP+Tr	Control
Species						
Agrostis canina	2.4	3.3	5.6	3.9	5.0	1.1
Agrostis tenuis	29.1	37.8	25.9	28.2	28.5	45.7
Anthoxanthum odoratum	4.3	9.8	5.9	4.3	4.2	4.8
Cyanosaurus cristatus	0	0.9	0	0	0	0.4
Deschampsia caespitosa	2.6	3.7	0.9	0.9	0.2	1.1
Deschampsia flexuosa	0	0	2.2	2.4	0.4	0
Festuca ovina	30.8	21.4	31.9	31.2	30.8	9.4
Festuca rubra	3.7	25.2	2.9	1.5	17.4	40.1
Helictotrichon pratense	1.1	1.1	0.9	0.2	0.2	0.6
Helictotrichon pubescens	1.1	0.6	0.6	0.2	0.4	1.7
Holcus lanatus	3.9	10.9	2.2	0.6	2.0	7.6
Holcus mollis	0	0.7	0	0	0	0
Nardus stricta	4.1	3.5	12.1	5.0	3.0	4.4
Poa pratensis	7.4	18.7	6.5	7.1	8.5	25.7
Carex spp.	6.7	7.0	5.0	7.2	6.1	6.1
Luzula spp.	2.0	2.6	0.9	4.6	3.3	6.1
Achillea millefolium	0	0	0.4	0.4	1.5	0
Campanula rotundifolia	0.4	0.4	1.3	3.9	0.6	3.0
Cirsium palustre	0	2.8	0	0	1.3	0
Galium saxatile	0.2	0.2	2.4	4.8	1.1	0
Lathyrus montana	4.1	0.7	4.6	3.5	4.4	1.5
Lathyrus pratensis	0.2	0.9	0.2	0	0.6	3.7
Lotus corniculatus	0.4	1.3	0	0	1.7	1.1
Potentilla erecta	4.6	3.0	7.8	6.7	1.9	2.4
Ranunculus acris	0	0.2	0	0	0	0.2
Ranunculus repens	0	0.2	0	0	0	0
Rumex acetosa	0	0.2	0.4	0.2	0.2	0
Trifolium repens	15.4	17.8	0.4	0.6	10.0	17.6
Moss spp.	24.8	24.1	13.5	10.6	10.1	43.7

TABLE 2

Input/Output Trial: Pasture Composition

Gairs Molinia Site: % Ground Cover of Species 1972

Species	A LP+Tr	B LP+LpTr	C Control	D LP	E L
Vaccinium myrtillus	1.5	0.9	7.8	4.1	4.1
Agrostis canina	11.8	7.8	5.4	8.1	8.7
Agrostis tenuis	1.8	2.2	0.7	1.5	0.7
Anthoxanthum odoratum	8.7	6.5	0.9	3.9	10.2
Deschampsia flexuosa	6.5	3.3	24.2	10.7	14.6
Festuca ovina	47.4	32.9	40.5	37.6	42.7
Lolium perenne	0	27.8	0	0	0
Molinia caerulea	18.5	20.5	36.3	35.2	24.0
Nardus stricta	22.8	15.9	18.7	15.4	28.3
Carex spp.	1.5	0.4	1.1	3.3	1.3
Luzula spp.	0.4	1.1	2.6	2.0	6.7
Juncus squarrosus	0.6	2.2	2.4	3.5	3.1
Trichophorum caespitosum	0.4	1.1	0.9	1.1	0.9
Galium saxatile	0.2	0	1.3	0.2	0.7
Potentilla erecta	0.6	0.6	0	0.6	0.7
Trifolium repens	43.3	52.0	0	0	0
Moss spp.	4.3	5.4	27.6	10.4	15.9

TABLE 3

Input/Output Trial: Pasture Composition

Fasset Molinia Site: % Ground Cover of Species 1972

Species	A LP+Tr	B L	C Control	D LP	E LP+LpTr
Vaccinium myrtillus	0	0	0	0.4	2.0
Agrostis canina	4.8	5.0	2.0	6.8	7.6
Agrostis tenuis	6.3	7.2	8.1	5.2	3.0
Anthoxanthum odoratum	4.3	7.0	5.0	6.5	3.1
Deschampsia flexuosa	7.0	8.1	4.4	7.0	3.1
Festuca ovina	47.7	42.4	33.3	52.7	49.0
Holcus mollis	3.1	0	0	0	0
Lolium perenne	0	0	0	0	20.9
Molinia Caerulea	1.1	1.3	0.2	0.2	0.6
Nardus stricta	0.2	0.4	0.7	0.4	0.2
Poa annua	0.6	0	0	0.4	0
Poa pratensis	0.4	0.6	0.6	0	0.7
Carex spp.	14.2	4.4	0.2	6.7	5.4
Luzula spp.	0.6	0.9	1.5	3.0	3.0
Cirsium spp.	0	0	0	0	0.4
Galium saxatile	15.9	17.2	34.0	34.8	21.5
Potentilla erecta	3.7	4.4	3.1	4.4	11.7
Stellaria media	0	0	0	0	0.2
Trifolium repens	9.1	0	0	0	6.7
Moss spp.	23.1	20.7	33.5	21.5	14.6

X-ray Fluorescence Spectrometry
(C.C. Evans and M.J.S. Floate)

Routine analysis of plant, soil and faecal samples has continued.

A requirement during the past year has been the development of methods for solution analysis. Due to absorption of X-rays by air in the spectrometer light element analysis has to be performed under vacuum conditions. This condition is not necessary for higher atomic number elements and consequently it is these elements which may be directly analysed in solution.

Liquids requiring analysis included blood plasma and digesta fluids of sheep. Protein precipitation was necessary for the plasma samples before analysis. Unless this precaution was taken poor reproducibility would be caused by proteins precipitated in the sample when irradiated with X-rays. Using this solution technique Br was determined in blood plasma and rumen fluid at the 2-10 ppm level (LLD 1 ppm).

Experimental sheep have been fed added Cn and Ru and these elements have been determined in digesta fluids in the range 1-100 ppm Cn and 3-100 ppm Ru.

Evacuation of the spectrometer between samples was necessary when analysing digesta fluids to prevent the build up of volatile fatty acids in the sample and chrystal chambers. Poor reproducibility would otherwise result due to variable and increasing X-ray absorption.

Gas Flow Proportional Counter

A recurring problem has been the contamination of the counter by impurities in the gas mixture. This was reduced by scrubbing the gas. This problem has been reduced still further by the acquisition of stainless steel wire to replace the conventionally used tungsten wire as the anode element. While this stainless steel wire has not yet been fully evaluated, it is anticipated that an increase in 'anode-life' of at least 10 times will result. This is presumably due to the inert chemical reaction of stainless steel to contaminants of the gas supply.

Copper in Blood
(C.C. Evans)

Due to the possibility of Cu toxity in restrained housed sheep, a method for the analysis of blood Cu has been developed as a diagnostic aid. Cu is bound to protein in normal blood but is released on acidification. This is achieved on a blood sample by the addition of trichloro acetic acid (TCA) which also precipitates protein at a final TCA concentration of 20% (v/v). The protein free plasma is freeze dried and dissolved in a small volume of H_2O for analysis. Cu is thus effectively concentrated and the final concentration is dependent upon the original blood volume and the final analysed volume. The instrumental sensitivity is 26 counts sec^{-1} ppm^{-1} with an LLD of 0.04 ppm in the original blood.

SYSTEMS DEVELOPMENT

(J. Eadie and T.J. Maxwell)

Introduction

For a detailed discussion and outline of the work carried out under Systems Development reference should be made to the Fifth Report 1967-70, p. 70 (Hill Sheep Production Systems Development).

1. YEAR ROUND GRAZING SYSTEMS

A. Sourhope - Hairney Law/Auchope (Y.R.G.S. 1)
(R.H. Armstrong, Miss B. Rudd and P. Watchorn)

This resource consists of 283 hectares of mainly grassy pasture which has been subdivided in such a way as to enclose some 81 hectares of Agrostis-fescue pasture. It is stocked with North Country and South Country Cheviot ewes and from the 1st May to 31st December with 25 suckler cows.

Ewe numbers have increased by 43% since the study began in 1969, with 398 ewes and gimmers. The combined effect of increased stock numbers and improvement in individual performance in terms of weaning percentage and weaning weight of lambs has given rise to an increase in the total weight of lamb weaned of almost 100% since 1969. Ewe body weight at mating has continued to increase from 54.8 kg in 1969 to 60.3 kg in 1972 for the NCC and 47.8 kg in 1969 to 58.2 kg in 1972 for the SCC x NCC.

Production Data

	1969	1970	1971	1972	1973
Stock numbers (ewes and gimmers)	398	451	518	529	573
Weaning percentage	84.7	86.5	103.3	104.7	
Total weight of lamb weaned (kg)	7359	8893	14700	13953	
Total weight of wool (kg)	787	1005	1273	1369	

B. Lephinmore (Mid-Hill) (Y.R.G.S. 2)
(D.C. Currie and C.D. Kerr)

The resource consists of 405 hectares of blanket bog. Improved pasture falls into two categories, some 18 hectares of grassy pasture, eight of which were reseeded several years ago, and two larger areas totalling 69 hectares of improved Calluna Eriophorum moorland within which some 20% of the area has been surface seeded to give a mosaic of improved grazing pasture throughout the whole. The remaining 324 hectares is open hill. It is stocked with 384 Blackface ewes, slightly more than prior to the initiation of this phase of the study.

There has been a substantial improvement in the weaning percentage during the four years this phase of the study has been in progress. This has resulted in a 42% increase in total weight of lamb weaned since 1969.

A new phase is being initiated in 1973 and, in anticipation of this, stock numbers were increased to 422 in November, 1972.

Ewe body weights at mating have increased from 44.9 kg in 1968 to 49.9 kg in 1972. Much of this improvement can be attributed to the substantial improvement in the weight of gimmers at mating and the consequences of this on body weight in later life.

Production Data

	1969	1970	1971	1972	1973
Stock numbers (ewes and gimmers)	339	361	373	384	422
Weaning percentage	85.0	92.5	103.5	103.6	
Total weight of lamb weaned (kg)	7207	8500	10268	9924	
Total weight of wool (kg)	652	772	772	814	

2. OFFWINTERING (INWINTERING) SYSTEMS

A. Sourhope (Rigg and Gairs) (I.W.S. No. 1)
(R.H. Armstrong, Miss B. Rudd and P. Watchorn)

This is a grassy pasture environment consisting of two similar units, the Rigg and Gairs, each of 101 hectares, the traditional stocking of which has been in the region of 130-140 ewes and gimmers. Both sheep stocks, which are South Country Cheviots, are inwintered for the same length of time (from January up to lambing) in the same wintering house, and the difference between the units is that in the Gairs a pasture improvement programme has begun. Fifteen hectares of Agrostis-festuca pasture has been enclosed, limed, slagged and oversown with clover. Further, 10 hectares of what was previously Molinia/nardus grass heath has been limed, slagged, sprayed with granoxone, rotovated and direct reseeded.

Twenty-four suckler cows were grazed in such a way as to equate the number of grazing days spent on the Gairs with the number of days on the Rigg from the 1st May to 31st December.

Stocking rate increases have been made equally on the two units.

Winter feed has been based on hay, sugar beet pulp and a proprietary concentrate. Total feed cost per ewe in 1972 was £2.29. Total feed cost per hogg housed in 1972 was £1.30.

There has been a progressive improvement in the premating body weights of both the Rigg and Gairs.

Production Data

	1970	1971	1972	1973
Rigg				
Stock number	205	205	238	278
Weaning Percentage	83.0	87.0	100.8	
Total weight of lamb weaned (kg)	3706	4432	5712	
Total weight of wool (kg)	402	534	641	
Gairs				
Stock number	209	207	233	260
Weaning percentage	83.0	96.0	91.4	
Total weight of lamb weaned (kg)	3581	5146	5176	
Total weight of wool (kg)	461	524	634	

B. Lephinmore (Low End) (I.W.S. No. 2)
(D.C. Currie and C.D. Kerr)

This is an area of Calluna Eriophorum moorland, consisting of two similar units, each of 162 hectares, traditionally carrying 100 Blackface ewes and gimmers both units having use of 14 hectares of 'common' enclosed grassy pasture. Both sheep stocks are inwintered in the same house for the same length of time, from January up to lambing. One of the units has a pasture improvement programme referred to as 'inwintering + land improvement'. Eight hectares of blanket bog has been enclosed and an oversown grass/clover pasture established. A further seven hectares were established during 1971/72.

Stocking rate increases have been made equally on the 'inwintering' and 'inwintering + land improvement' sides.

Winter feed has been based on hay and a proprietary concentrate. Total feed cost per ewe in 1972 was £1.78 and total feed cost per hogg housed was £1.91.

There has been a reduction in the premating ewe body weight of 2.0 kg from 1970 to 1972 on the 'inwintering' unit.

	Production Data			
	1970	1971	1972	1973
Inwintered				
Stock number	107	115	143	166
Weaning Percentage	80.0	93.0	103.5	
Total weight of lamb weaned (kg)	2279	2857	3775	
Total weight of wool (kg)	205	257	282	
Inwintering + Land Improvement				
Stock Number	102	112	137	160
Weaning Percentage	71.0	104.5	97.1	
Total weight of lamb weaned (kg)	2015	3324	3511	
Total weight of wool (kg)	179	246	274	

3. RECORDS AND STATISTICS
(A.R. Sibbald and J.M. Brown)

The programme of maintenance, checking and analysis of sheep records from each of the projects has continued. During the year records from Glensaugh projects were added.

Appropriate methods of statistical analysis of the data are being developed in consultation with Miss Phillips of the ARC Unit of Statistics and with the Edinburgh Regional Computing Centre. These methods will include the use of GENSTAT, a suite of programmes for data-handling and statistical analysis, developed by the Statistics Department of ARC's, Rothamsted Experimental Station.

4. ECONOMIC APPRAISAL
(A.R. Sibbald)

Methods of economic appraisal have been developed.

Firstly, it has been possible to further develop the method of Harkins (1968) to obtain an initial guide to the increases in output necessary to break even on a given level of capital investment. It can also be used in assessing the current results of systems studies in HFRO and in planning their future development.

Secondly, methods of cash flow and 'liquidity' analysis have been developed. These enable a detailed and comprehensive study to be made of the effects of rate of flock expansion and rate of improvement in flock performance relative to the proportion of capital invested at any one time. A computer programme which can deal with these alternatives has been written. It has been designed for use on the multi-access system at the Edinburgh Regional Computing Centre using an I.C.I. 4/75 computer. Access is by teletype. This allows an operator to make judgements about his results, change input data and instantly compute a further set of results.

Finally, when alternative policies for a given hill unit have been formulated that which makes the best use of capital can be established by calculating the net present value (NPV) of the capital invested in each. This too is a part of the computer programme already referred to.

5. BOTANICAL MONITORING

Pasture composition in Hairney Law and Auchope paddocks (YRGS. 1) and Gairs paddock (IWS. 1) at Sourhope
(Dr. J. King)

Hairney Law and Auchope paddocks

The paddocks in Hairney Law and Auchope were first recorded in 1969 respectively by 25 and 20 permanently marked sample plots. In 1970 and 1971 about half of these plots were recorded for a second and third time. At each recording 100 point quadrat observations per plot were made, the species present at each point being listed. The mean values for percentage cover for the more common vascular species is given in Tables 1 and 2. If the 1969 data (20 and 25 plots) is taken as being representative of the initial composition of these pastures, comparison of the means for 10 or 12 plots in 1969, 1970 and 1971 gives no indication that any marked change has taken place, except perhaps a modest increase by White Clover (Trifolium repens) on the Auchope paddock. This reflects a marked increase on only two or three plots where clover was already present. The species has not spread to plots where it was absent in 1969, nor would one expect it to do so without further treatment such as the application of lime and phosphate accompanied by seeding.

Gairs paddock

This was recorded first in 1970 after which about half the area received an application of lime and slag and was surface seeded with S184 White Clover. The soils on about one quarter of the paddock area are gleyed and before liming had pH values of over 5.2. These soils supported a good quality wet Agrostis-Fescue pasture and the average quality of the pasture as represented by the sample plots is consequently better than that of the Hairney Law and Auchope paddocks. Festuca rubra, Poa pratensis and Trifolium are relatively abundant while F. ovina is less so. On the best parts of this paddock it should be possible to produce a very high grade Agrostis/Fescue sward, but on the poorer soils which are densely covered by bracken, the sward will be more difficult to improve.

Bracken density on systems trial paddocks.

The bracken areas in the paddocks on Hairney Law, Auchope and Gairs have been sampled respectively by 30, 25 and 10 permanent sample plots. On these, frond counts have been made annually since the paddocks were enclosed and the mean values are summarised in the following table.

Mean frond density/m^2 on sample plots

	1968	1969	1970	1971	1972
Hairney Law paddock	17.3	17.7	15.4	17.9	18.8
Auchope paddock	19.0	21.9	18.6	22.2	23.4
Gairs paddock	-	-	30.5	34.3	29.9

The sample plots cannot be taken as giving a wholly representative sample of the bracken density of each paddock so that comparisons between paddocks are not informative. Comparisons between years are valid and it is apparent that there is no tendency for the bracken to decrease. Statistical analysis may show that some of the differences between years are significant but this will be attributable to seasonal effects such as the incidence of early frosts.

TABLE 1

YRGS. 1 - Hairney Law Paddock: Pasture Composition

% ground cover (vascular spp. only)

Species	1969 (25 sites)	1969 (12 sites)	1970 (12 sites)	1971 (12 sites)
Vaccinium myrtillus	0.1	0.2	0.5	0.6
Agrostis canina	4.0	2.4	3.3	3.0
A. tenuis	47.6	54.4	41.4	46.7
Anthoxanthum odoratum	4.7	4.8	6.3	8.4
Deschampsia caespitosa	6.7	9.8	9.0	9.6
D. flexuosa	1.8	0.9	1.1	-
Festuca ovina	24.6	22.4	23.1	26.6
F. rubra	7.9	9.0	8.6	7.7
Holcus lanatus	2.4	2.2	1.6	2.1
H. mollis	0.5	1.1	0.4	0.5
Nardus stricta	0.8	0.2	0.4	0.5
Poa pratensis	13.5	14.9	13.8	16.2
P. trivialis	2.4	0.3	0.4	1.0
Carex spp.	1.9	0.9	1.0	2.2
Luzula spp.	2.1	1.5	2.7	4.4
Achillea millefolium	0.6	0.3	0.4	0.5
Campanula rotundifolia	0.4	0.5	0.5	1.0
Conopodium majus	0.2	0.4	0.4	0.3
Galium saxatile	4.9	4.3	8.8	11.1
Lathyrus montana	1.2	0.3	0.6	0.3
L. pratensis	0.1	0.1	0.1	0.2
Potentilla erecta	3.7	4.7	2.1	3.8
Rumex acetosa	0.2	0.3	0.2	0.2
Stellaria graminea	0.1	0.1	0.1	0.3
Trifolium repens	2.0	1.7	1.0	0.8
Veronica chamaedrys	0.5	0.4	0.5	0.2

TABLE 2

YRGS. 1 - Auchope Paddock: Pasture Composition

% ground cover (vascular spp. only)

Species	1969 (20 sites)	1969 (10 sites)	1970 (10 sites)	1971 (10 sites)
Vaccinium myrtillus	0.4	0.2	0.7	0.7
Agrostis canina	5.2	6.4	4.1	4.2
A. tenuis	41.2	46.4	32.2	39.3
Anthoxanthum odoratum	6.8	7.3	6.7	9.0
Deschampsia caespitosa	11.2	10.5	9.1	11.1
D. flexuosa	5.2	5.2	2.9	8.0
Festuca ovina	23.0	26.7	24.3	28.0
F. rubra	8.5	6.4	5.8	8.3
Holcus lanatus	5.0	5.6	3.5	7.4
H. mollis	0.4	0.9	0.1	-
Nardus stricta	1.4	0.2	0.5	-
Poa pratensis	10.1	6.7	8.6	10.8
Trisetum flavescens	0.6	0.2	0.2	0.2
Carex spp.	4.7	4.5	3.9	6.8
Luzula spp.	6.0	5.8	3.4	7.9
Campanula rotundifolia	0.5	0.5	0.4	0.7
Galium saxatile	11.7	13.0	13.4	18.7
Lathyrus montana	11.1	1.1	-	0.1
L. pratensis	1.0	0.2	0.4	0.6
Potentilla erecta	5.8	6.2	2.5	5.1
Ranunculus acris	0.2	0.1	-	0.7
R. repens	1.5	1.2	0.9	1.2
Rumex acetosa	0.3	0.1	0.1	0.3
Trifolium repens	3.0	4.6	5.1	8.7
Viola spp.	0.2	-	0.1	-

TABLE 3

IWS. 1 - Gairs Paddock: Pasture Composition

% ground cover (principal vascular spp. only)

Species	1970 (17 sites)	1971 (19 sites)	1972 (18 sites)
Agrostis canina	2.3	2.3	2.9
A. tenuis	27.4	33.2	35.8
Anthoxanthum odoratum	6.1	10.5	8.3
Cynosurus cristatus	0.2	1.5	1.3
Deschampsia caespitosa	11.5	13.6	5.8
D. flexuosa	3.1	3.2	1.6
Festuca ovina	19.9	15.7	21.2
F. rubra	11.8	13.5	23.9
Helictotrichon pratense	0.1	0.1	0.4
H. pubescens	0.2	0.9	0.9
Holcus lanatus	6.4	6.3	3.6
H. mollis	-	0.2	2.8
Nardus stricta	6.8	7.0	3.1
Poa pratensis	9.7	16.8	13.9
Trisetum flavescens	0.9	1.8	0.6
Carex spp.	4.8	5.4	4.1
Luzula spp.	2.0	3.5	4.1
Juncus spp.	1.3	3.6	1.8
Campanula rotundifolia	0.4	0.9	0.2
Cirsium arvense	0.6	1.2	0.6
C. palustre	0.5	0.6	0.5
Galium saxatile	5.2	10.8	8.0
Lathyrus montanus	0.1	0.4	0.6
L. pratensis	0.2	0.5	0.2
Potentilla erecta	1.9	2.3	2.4
Ranunculas acris	0.2	0.7	0.4
R. repens	1.0	0.1	0.9
Rumex acetosa	0.1	0.4	0.3
Trifolium repens	4.1	17.9	12.3
Veronica chamaedrys	0.7	1.2	0.7
Vicia spp.	-	0.2	0.2

YRGS.2 - Lephinmore: Pasture Composition
(J. Rogers)

Two sets of quantitative botanical data have now been collected from PII, using point quadrats. These are for the years 1970 and 1972. While long term changes in the composition of the vegetation, in response to increased grazing pressure, cannot be reliably interpreted from only two years' observation, it is nevertheless interesting to compare the two sets of results.

In 1969, qualitative data from 290 sites, distributed uniformly over the whole of PI and PII were used as a basis for classifying the vegetation into a number of types. Five sites from each of five such types, or 'clusters' were, thereafter, selected for a more intensive, quantitative study over a number of years, the object of which was to discover any changes in the botanical composition concomitant with a more intensive grazing regime.

The cover percentage of the more important species in 'cluster 2b' grassy sites presumed to be reseeded areas, is given in Table 1.

TABLE 1

Percentage cover of species in Cluster 2b (Reseeds) on PII

	1970	1972	Change	P	Significance
(A - Sown species)					
Trifolium repens	37.8	13.6	- 24.2	< 0.1%	***
Lolium perenne	11.8	6.0	- 5.8	< 1.0%	**
Festuca rubra	5.6	8.2	+ 2.1	> 5.0%	N.S.
Poa pratensis	6.4	11.4	+ 5.0	> 5.0%	N.S.
(B -'Weed' species)					
Sagina procumbens	12.8	11.0	- 1.8	> 5.0%	N.S.
Juncus effusus	1.0	2.6	+ 1.6	> 5.0%	N.S.
Nardus stricta	9.8	8.2	- 1.6	> 5.0%	N.S.
(C - Native species)					
Carex echinata	5.6	9.4	+ 3.8	< 5.0%	*
Festuca ovina	9.8	5.4	- 4.4	< 5.0%	*
Agrostis tenuis	13.0	10.0	- 3.0	< 5.0%	N.S.
Anthoxanthum odoratum	9.4	7.6	- 1.8	< 5.0%	N.S.
Holcus lanatus	5.2	3.4	- 1.8	< 5.0%	N.S.

The biggest changes are the reduction in cover percentage for clover and perrenial ryegrass. These figures represent a reduction, over a period of two years, of 63.5% and 49.2% of the 1970 cover respectively; it is not possible to say whether this is due to a decline in the clover and ryegrass population or to more intensive grazing immediately prior to the 1972 sampling resulting in a depletion of sampled aerial organs. The slight, but not significant, increase in the cover of red fescue and smooth stalked meadow grass - two species which are much grazed by sheep - may suggest the former alternative to be the case.

Juncus effusus and Nardus stricta, two species which often increase in moist pastures do not show any significant increase; although Juncus effusus has more than doubled its cover percentage, the total amount present is still too small to register as a statistically significant increase. Sagina procumbens, which has a percentage cover similar to that of perennial ryegrass, may prove to be a serious weed, by preventing establishment and spread of more useful and productive species. On the other hand, it may merely occupy what would, in its absence, be bare ground. The significant increase shown by Carex echinata, may be due to an increase in soil fertility and differential grazing.

Three blanket bog types were distinguished in the original cluster analysis. These differ from one another in the proportion of the principal species within each, possibly as a result of hydrological difference. Cluster 1, for example, is drier than Cluster 3 and Cluster 5, with a relatively high cover percentage of Scirpus cespitosus, and Juncus squarrosus. A comparison of the three blanket bog types is given in Table 2.

TABLE 2

Species	% cover in 1970 (data from Point Quadrat sites)			Difference in Cover % between 1970 and 1972		
	Cluster 1	Cluster 3	Cluster 5	Cluster 1	Cluster 3	Cluster 5
Calluna vulgaris	51	53	58	-8.0 NS	-14.0**	- 6.4 NS
Erica tetralix	20	9	18	-8.8 *	- 2.0 NS	- 2.0 NS
Eriophorum vaginatum	16	34	39	-6.4	-14.6**	-20.2 **
E. angustifolium	15	25	19	-4.0 NS	- 7.6 NS	0.0
Scirpus cespitosus	20	3	21	-8.6 **	- 1.0 NS	-11.0
Juncus squarrosus	10	.7	1	-0.4 NS	-	-
Carex nigra	0.2	2.4	0	-	-	-
Molinia caerulea	25	16	2	-8.8	- 7.6 NS	-
Deschampsia flexuosa	0	12	0	-	- 7.0*	-
% all sites in PII containing the species (1969)						
Sphagnum rubellum	38	8	38			
S. capillaceum	15	13	6			
S. plumulosum	6	2	3			
S. cuspidatum	9	0	6			
S. recurvum	9	33	3			
S. subsecundum	0	2	0			
S. palustris	6	8	3			
S. papillosum	44	21	15			
S. magellanicum	3	2	0			

The occurrence of Sphagnum spp. is included in Table 2 as these are believed to be sensitive indicators of hydrological and chemical conditions; S. rubellum is characteristic of drier parts of the bog, notably the summit of hummocks. S. plumulosum, S. capillaceum and S. papillosum are three of the more important peat forming species and are tolerant of a fairly wide moisture range, whilst S. recurvum, S. cuspidatum and S. subsecundum occur in the wetter areas, including pools in the hollows.

All the recorded changes in the percentage cover for these three types are negative; in many cases, there was no significant change. If these changes are due to increased grazing pressure, it should be noted that, while they all show a decrease, there is no corresponding increase in the percentage cover of any other species. Although the sum of these cover percentages exceeded 150% in 1970, by 1972 they were reduced to 107-118% (for those species shown in Table 2). Thus, if this trend were to be continued over many years, it may be expected that a significant proportion of the area would become bare ground, or (in the wetter areas in particular), moss covered.

Thus, while it is accepted that these figures are inadequate, in the sense that they represent only two recording dates spanning a period of two years, it is suggested that this type of blanket bog community is not able to sustain prolonged grazing pressures such as those which have been applied in PII of the Lephinmore Year Round Grazing System.

6. SOILS
(M.J.S. Floate and A.G. Lowe)

Sourhope

The year land systems were established using paddocks on Hairney Law and Auchope in 1968. Soil samples were taken from these paddocks in 1968 to monitor conditions at the start of the project and interim samples were taken in 1970. Results of these analyses have been reported in previous annual reports (1969 and 1970). At the end of the fifth grazing season the original sampling programme was repeated and samples were taken from the same sites. These samples are currently being analysed and not all results are yet available. However results for the thickness of the litter layers and for pH are presented in the table and may be compared with previous years.

		1968	1970	1972
Hairney Law	Ao	2.8 ± 0.1 cm	2.7 ± 0.2 cm	2.0 ± 0.1 cm
pH	Ao	4.8 ± 0.4	4.1 ± 0.1	4.5
	0-5	4.5 ± 0.4		4.3
	5-10	4.7 ± 0.4		4.4
Auchope	Ao	2.4 ± 0.1 cm	2.3 ± 0.2 cm	1.3 ± 0.1 cm
pH	Ao	4.7 ± 0.6	4.4 ± 0.1	4.8
	0-5	5.0 ± 0.7		4.8
	5-10	5.0 ± 0.6		4.9

These results indicate that there has been a substantial reduction in the thickness of the mat layer as a result of intensified grazing management for five years. Although the pH is still below 5.0 and benefits would undoubtedly be derived from liming, the increasing acidity reported in 1970 has not been sustained. In fact it appears that pH levels have improved towards the levels at the outset, probably as a result of improved biological cycling of bases and nutrients.

Lephinmore
(M.J.S. Floate, G.R. Bolton and A.G. Lowe)

Patches of improved pasture were originally established by surface seeding, lime and fertiliser treatments in 1958/59 with a maintenance treatment in 1968. In 1964 and in 1972 pairs of samples were taken at adjacent sites inside and outside the improved patches to monitor soil fertility and to examine the long-term effects of treatments.

Interpretation of the data is complicated because (a) no pre-treatment soil data are available although the soils outside the improved areas have probably changed little: (b) different analytical methods were employed in 1964 and 1972: (c) no density data are available for the 1964 samples so that only concentration comparison can be made: (d) samples were taken from different depths and (e) the vegetation and nutrient uptake differ as between improved and unimproved areas.

However, the pH data show that residual effects of lime were present in 1964 and were still present in 1972:

			Unimproved	Improved
PI	1964	0-3"	4.5	5.1
		3-6"	4.3	4.7
PI	1972	0-5 cm	4.1	5.0
		5-10 cm	4.4	4.7
PII	1963	0-3"	4.6	pre-treatment
PII	1972	0-5 cm	4.3	4.9
		5-10 cm	4.2	5.0

Although the improved areas in 1972 still supported grass-clover pasture (cf. *Calluna*, *Deschampsia*, *Eriophorum* etc. on unimproved areas) the data for soil-P and -K were inconsistent. It is believed that this may be due to gross differences in nutrient uptake between the contrasting vegetation types. Work is in progress to devise improved techniques.

7. THE ASSESSMENT OF SUPPLEMENTARY FEEDING REQUIREMENTS OF GRAZING AND HOUSED EWES DURING LATE PREGNANCY
(A.J.F. Russel, Janet Z. Foot and T.J. Maxwell)

The technique of regulating inputs of supplementary feeding during late pregnancy according to the biochemical assessment of nutritional state was continued in four development projects in 1972.

Groups of 40 early lambing ewes and gimmers from the Sourhope Year Round Grazing System and from Sourhope, Lephinmore and Boghall In-Wintering Systems were blood sampled at regular intervals during late pregnancy. Samples were collected prior to feeding and were analysed for plasma ketone concentrations, this being the most useful single index of nutritional state in large scale studies of this type. Feed inputs were adjusted to maintain mean plasma ketone concentrations around 3 mg %; consideration was also given to the range in concentrations within any group and to the change in mean concentration resulting from the previous feed adjustment. In the Sourhope and Lephinmore In-Wintering systems mean ketone concentrations were generally low, indicating very satisfactory nutritional states throughout late pregnancy. Mean values tended to be higher than the prescribed 3 mg % on occasion in the Sourhope Year Round Grazing System and in the Boghall In-Wintering system, but at no time was the degree of undernourishment of a severity likely to prejudice performance.

Full details of quantities of feeding given and of the changes made in response to the results of the blood analyses are contained in the section on Systems Development. The results, in terms of reproductive performance, confirmed the usefulness of the technique in providing an objective basis for determining inputs of concentrate feeding in both the grazing and housed situations. A fuller account of this work over the years 1969 to 1972 is given in the Organisation's Sixth Report.

8. THE INFLUENCE OF CHANGES IN MANAGEMENT ASSOCIATED WITH THE DEVELOPMENT OF NEW SYSTEMS ON THE OCCURRENCE OF PREMATURE BROKEN MOUTH. (R.G. Gunn)

Annual examination of the incisor dentition of the draft ewe age on each of the YRG and IW Systems at Sourhope and Lephinmore has now been carried out for two years. The use of such an imprecise parameter over a relatively short time scale makes the data of limited value but certain trends can be identified.

In the Sourhope YRGS, approximately 25% of 6½-year-old ewes were broken-mouthed compared with <10% in the Lephinmore YRGS. Neither of these has shown much change over the two years but the incidence is still higher (particularly at Sourhope) than was the case some 15 years ago when no broken mouth was observed.

In the Sourhope IWS, the incidence has increased on both Rigg and Gairs, with the Rigg showing the greater increase to over 60% broken-mouthed at 6½ years. A similar dramatic increase has been apparent in the Lephinmore IWS, with a present value of 55% broken-mouthed at 6½ years.

It seems fairly clear that although the inwintering of ewes in the IW Systems has been in operation for only 3 - 4 years, the effect on the teeth is considerable and presumably could get worse. This may be largely due to physical stresses associated with obtaining food, particularly hay, from racks with metal mesh covers but it is suggested that this is still only a secondary effect super-imposed on a basic condition. The condition itself is presumably one related to animal exploitation and the breakdown of alveolar bone brought about by some limitation in bone-salt metabolism.

In the short term, attempts are being made to reduce the physical stresses and all future trends will be carefully observed.

RED DEER

The Husbanding of Red Deer

(J.M.M. Cunningham and W.H. Hamilton in collaboration with Dr. K.L. Blaxter)

The farm was further subdivided, three of the large paddocks being split, so that the herd can be split into two parts for experimental purposes. Thirty-eight acres of forest were leased and fenced.

As in the previous year calves were obtained from several estates in Scotland, 54 being acquired. Forty-one of these were reared on two experimental milk diets, one based on cow milk substitute (CSM) and the other ewe milk substitute (ESM), both prepared to contain 25% dry matter. The 20 calves on the high lactose CSM diet failed to thrive developing diarrhoea and inappetance and the milk was withdrawn after 11 days. Nine animals of this group died from a variety of causes; whereas only 2 in the EMS group were lost.

The calves were housed until release on to the farm on 16th August, approximately one month earlier than 1971. During the rearing period all calves average 12 kg liveweight gain (22.6 to 15.8) with an efficiency of conversion of 1 kg gain per 2.37 kg on dry feed.

All animals have been gathered monthly for routine weighing, body measurements (two monthly) and studies of haematology, parasitology, blood calcitonin, hair growth and faecal-N concentrations. For safety antlers were sawn off stags in September.

Mr. Hamilton designed a restraining crate which makes it possible to dispense with manual restraint during sampling procedures.

The 1971 catch (56) were fed throughout their first winter receiving 2.0 lb in September and October 1971 and 1.0 lb daily from November 1971 to March 1972. Little growth occurred from December to March but rapid growth commenced in May and by September stags weighed 78 kg and hinds 66 kg.

The yearling hinds were mated at various hind/stag ratios.

The four hinds born in 1970 had reached 79 kg by September and stags of the same age 98 kg; these being typical of ferals at 3 to 4 years old. The four hinds calved successfully, their calves averaging 7.5 kg at birth and gained 18.0 kg in their first two months.

These calves were weaned in December. The stag calves weighed 48 kg and the hind calves weighed 41 kg. So far all stock remain manageable but the calves born on the farm are much more timid and great care has to be exercised in handling adult stags.

Health has remained excellent, mortality on the farm being zero. Internal parasites so far are of minimal importance and although warble larvae (Hypoderma diana) were found on 22 animals treatment in February and March with an organo-phosphorus insecticide was successful. The head fly (Hydrataea irritans) has proved troublesome to stags while in velvet and studies were made.

Basic research continues at the RRI, results being published in Ann. Rept. 28.

Observations on Red deer teeth

(R.G. Gunn and W.J. Hamilton, HFRO, with R.N.B. Kay and G.A.M. Sharman, RRI)

A start has been made to the routine recording of the type, number, looseness, appearance and presence of abnormalities of the incisor teeth in the Red deer herd at Glensaugh. The effects of sex, age and type of rearing will be assessed in the long term. Molar tooth development, wear and loss will be studied superficially from examination of jaws retained from all animals dying or being killed for commercial purposes.

SUMMARY OF NEW WORK

ANIMAL NUTRITION AND PRODUCTION

Milk production of ewes and its relation to lamb growth
(J.N. Peart and J.M. Doney)

The shape of the lactation curve of ewes can have a considerable effect on lamb growth. The evidence indicates that for mutton breeds the comparatively rapid decline in milk production during mid lactation is partly a genetic characteristic but is also influenced by ewe nutrition and appetite for milk by the suckling lambs. The appetite for milk by lambs in later lactation may be inherent in the breed or cross and is influenced by the quantity and quality of solid food available to the lambs. The possibility of obtaining a sustained lactation to improve lamb growth as influenced by solid food is being investigated.

1. The effect and utilisation of sustained laction on the growth of lambs of different genotypes when offered solid food of different qualities.

2. The milk production of Westphalian milch sheep when suckling lambs and maintained indoors.

3. The milk production and composition of the milk of Swaledale ewes suckling lambs on high quality pasture (in collaboration with the Edinburgh College of Agriculture).

4. The lactation performance of Blackface ewes rearing single and twin lambs when offered grass and grass/heather diets (in collaboration with J. Milne).

5. The nutritive intake of lactating ewes grazing high quality pasture (in collaboration with J. Eadie and Edinburgh College of Agriculture).

Apart from the lack of information on the grazing intake of lactating ewes, information is required on the effects on milk production of the techniques employed. The objectives are:

(a) An estimation of the herbage intake of lactating ewes grazing high quality pasture.

(b) An estimation of the effects on milk production of the application of techniques involved in the measurement of grazing intake.

(c) A comparison of the chromium sesquioxide and total faecal collection methods of assessing intake.

The voluntary intake and lactation performance of Blackface ewes rearing single and twin lambs, when offered grass and grass/heather diets
(J.A. Milne and J.N. Peart)

In grazing experiments to be carried out at Glensaugh, wethers grazing grass and grass/heather swards will be used to measure the voluntary intake of the diet consumed in early summer. It is known that the ewe has an expanded appetite in early lactation and a knowledge of the degree of expansion and the factors affecting it is desirable in the interpretation of the data from the grazing experiments. To do this adequately requires the use of diets similar to those likely to be eaten by the grazing animal. These diets are likely to consist of mainly grass in early lactation, and grass and heather in later lactation. An experiment is being conducted to compare the voluntary intake of lactating ewes, nursing single and twin lambs in the first four weeks of lactation, with the voluntary intake of mature wethers offered the same diet; the diet being freshly harvested improved species grasses. The same animals will be used subsequently to measure the substitution rates of grass for heather and to determine the lactation response of ewes offered grass and heather.

Factors affecting long-term intake of roughage by sheep
Phase 2 - pregnancy and lactation
(Janet Z. Foot and A.J.F. Russel)

In December 1972 48 mated Blackface ewes were brought into the sheephouse and individually fed *ad libitum* on one of two roughage diets: a medium quality hay and dried grass. Food intake is to be measured throughout pregnancy. At parturition all animals will be offered a second dried grass and the effects of previous feeding on their voluntary food intake during lactation will be measured.

The majority of ewes (38) were on Phase 1 of this experiment and as in Phase 1 total body water will be measured at intervals using tritiated water dilution. The relationships between body composition of the animals and their intake of roughage food will be investigated.

The partition of digestion in sheep given heather (*Calluna vulgaris*)
(J.C. MacRae and J.A. Milne)

Appreciable quantities of 'tannins' have been found in heather, and 'tannins' are known to bind readily with proteins under certain conditions. *In vitro* evidence from other sources of 'tannin' has suggested that 'tannin'-bound protein is protected from rumen fermentation, and may subsequently be digested in the post-ruminal tract. It is possible, therefore, that apparent digestibility is not a good index of apparent absorption of utilisable nitrogen in heather. Sheep surgically prepared with a rumen cannula or with a rumen cannula plus T-shaped cannulae at the proximal duodenum and terminal ileum are being used to study the partition of digestion of nitrogen and energy contained in current season's shoots of heather harvested in July and November.

Preliminary technique - development studies required for a programme of investigation into the digestive physiology of supplementary feeding
(J.C. MacRae)

Before any long term study of the nutritive value of hill herbage, and the effects of this N.V. of supplementary feeding, can be undertaken several preliminary methodological studies need to be carried out. Those under investigation at the present include:-

(a) Evaluation of different forms of surgical preparation of sheep on their subsequent performance on poorer quality diets (J.C. MacRae and A. Whitelaw).

(b) Development of a satisfactory, non-radioactive, liquid and solid phase marker system for use with surgically-prepared sheep (J.C. MacRae and C.C. Evans).

(c) Development of a method for measuring rates of fermentation in the rumen and the caecum of sheep (J.C. MacRae and S. Wilson).

(d) Examination of the effects of freeze-storage of hill herbage on the chemical composition of subsequent experimental rations. (J.C. MacRae, D.R. Campbell and J. Eadie).

Input/Output Studies - Lephinmore
(J. Eadie and G.R. Bolton)

The input/output series has now been extended to include work on blanket peat at Lephinmore. The treatments, however, differ since in contrast to the grassy vegetation at Sourhope where soils improvement without the introduction of new plant material through reseeding may be expected to produce results of interest and value, no such possibility exists on blanket peat. Both soils upgrading and sown seeds are essential and interest centres on both the short and long term effects of the size of the initial dressings of lime and slag.

(The site, on blanket bog on Low End Hill, had vegetation consisting of *Calluna vulgaris* and *Eriophorum vaginatum* co-dominant with some *Erica tetralix* and *Eriophorum augustifolium* and scattered patches of *Tricophorum caespitosum*.

The treatments have been arranged to allow for repeat dressings of lime and slag when and as the early results indicate.

Veterinary Section
(A. Whitelaw)

There has been no veterinary member of staff in the interval between Dr. Foster's departure in 1970 and the appointment of his successor in September, 1972.

A re-appraisal of the preventative medicine programme and investigation of new monitoring techniques has been commenced.

Improved recording of mortality and disease has been instituted.

Investigations into aspects of Cobalt deficiency are being planned.

All experimental animals were subject to routine inspections.

It is visualised that when the staffing of the section is complete, the work and involvement will expand.

PLANTS AND SOILS

The effect of time of sowing on the germination of grasses and clovers in hill soils (J.A. Rogers)

In addition to the controversy on the optimum time to apply fertilisers in relation to the sowing of seeds described in the progress report (p.19), there is no general agreement on which is the best season of the year for sowing seeds on hill soils. To investigate this question, an experiment has been set up to compare the germination of four perennial ryegrass strains (S23, S24. Belgian Melle and Dutch Gremie). When sown in pots of John Innes compost in late Autumn and in early Spring.

Interactions between lime and aluminium in hill soils and their effect on the growth and composition of introduced herbage plants (M.J.S. Floate, A.G. Lowe and P. Newbould).

The quantity of lime required by acid mineral soils to establish introduced grasses and clover appears to be much greater than that required by acid organic soils. The difference between the two types of soils may be related to the quantity of aluminium in the soil solution as well as other factors. Previous laboratory work as described in the progress report (p.18) has investigated the effects of added calcium and aluminium on the quantity of soluble aluminium in soil solutions. The provision of glasshouse facilities at the Bush Estate will enable the effect of variations in soluble aluminium on the growth of introduced grasses and clovers and their composition to be investigated in a range of hill soils. A series of experiments with plants growing in pots of hill soils has been planned and it is hoped to start them later in the year.

Soil and botanical monitoring in systems under development (M.J.S. Floate, J. King and J.A. Rogers)

The programme of soil and vegetation monitoring will continue as planned at Sourhope. However, at Lephinmore the schedule of vegetation monitoring for the Mid-hill (Y.R.G.S. 2) project is being modified to take account of the increased area of pasture which will be improved this year.

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