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HILL FARMING RESEARCH ORGANISATION

ANNUAL REPORT FOR THE YEAR 1973

Headquarters

Bush Estate, Penicuik, Midlothian EH26 0PH.

Research Stations

Glensaugh, Laurencekirk, Kincardineshire

Lephinmore, Strathlachlan, Argyll

Sourhope, Yetholm, Kelso, Roxburghshire

House o' Muir, Midlothian.

STAFF

(as at 1st January 1974)

Director

J.M.M. Cunningham, B.Sc. (Agr), Ph.D., F.R.S.E., F.I. Biol.

Animal Production and Nutrition Department

J. Eadie, B.Sc. (Agr)

A. Whitelaw, B.Sc., F.R.C.V.S.

J.M. Doney, B.Sc., Ph.D.

R.G. Gunn, B.Sc. (Agr), Ph. D.

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Miss J.Z. Foot, B.Sc. (Agr), M.Agric.Sc., Ph.D.

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G.R. Bolton, B.Sc. (Agr)

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M. Cowie

Plants and Soils Department

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Miss L. Torvell, B.Sc.

G.K. Kinnaird

Information Officer/Librarian

Miss A. Ramsden, B.Sc., M.Sc.

Research Stations

Glensaugh

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A.J. Macdonald, N.D.A.

S. Buschman

M. Begg

Red Deer Project

W.J. Hamilton, B.A. (Open), N.D.A., N.D.D. M.I.Biol.

Lephinmore

D.C. Currie, N.D.A., N.D.D.

Sourhope

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House o' Muir and Animal House, Bush

A.J. Senior, S.D.A.

N.W. Mortimer

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J. Leary

Lab. - General Services

Mrs. C. Thompson

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A. ANIMAL NUTRITION AND PRODUCTION

REPRODUCTION (01A)

1. Repeatability of ovulation rate in Blackface ewes
(J.M. Doney, A. Whitelaw and R.G. Gunn)

This project was designed to test surgical techniques of laparoscopy or endoscopy in relation to repeated intervention to study ovulation rate throughout the breeding season in relation to body condition. Twelve draft Blackface ewes were penned in the Bush Animal House and individually fed to produce two groups in thin or fat condition. Once ewes were in either the condition range 1½-2 or 2½-3 they were fed to maintain them in these conditions. Teaser rams were used to test for onset of oestrus from September onwards but no ewe came into overt oestrus until 23rd October. At the first recorded oestrus, ewes were examined surgically to count the number of corpora lutea relating to both the previous silent oestrus and the present overt one. Thereafter, as ewes came into oestrus they were examined by endoscopy to count new corpora lutea. With the ewes in fat condition, considerable difficulty was experienced in relation to repeated intervention, on account of adhesions. Certain of the fat ewes had therefore to be removed from the study before its conclusion. Adhesions were not a problem in the thin ewes. At the end of February, one fat ewe had ceased to exhibit overt oestrus and the remaining two others had to be killed to enable the current and previous corpora lutea to be counted. All thin ewes were still exhibiting overt oestrus in early March but with no comparison with fat ewes, it was decided to conclude the study at that time.

Ovulation rate in the two groups was much as expected for the levels of condition the ewes were in (mean condition scores of 2.75 and 1.75), with the fat ewes averaging approximately two ova/cycle and the thin ewes averaging slightly more than one ovum/cycle. Although the recorded silent oestrus produced slightly more ovulations than the subsequent overt cycles there was little sign of variation in number or change in pattern of ovulations with time throughout the oestrus season in these ewes maintained in two levels of body condition.

2. The effect of body condition on ovulation rate in Swaledale ewes
(R.G. Gunn, J.M. Doney and W.F. Smith)

The body condition of 36 Swaledale ewes was manipulated by group management in grass paddocks at Bush to produce two groups of ewes in conditions 1½ and 3 by November. Considerable difficulty was experienced in getting the low group to lose condition and 5 animals in condition 2½ or above had to be penned in the Animal House and fed a restricted diet. Although they were fed 500 g feed/day for 4 weeks and 300 g/day for a further 2 weeks, these animals remained at or above condition 2½ at mating. As a result, at the time of the synchronised mating in mid-December, there were ewes distributed throughout the condition range 1½-3. All ewes were killed for ovulation counts 2-3 days after mating. Since the numbers available in any one condition were limited, the data for condition score (CS) are presented in such a manner that the ewes in quarter grades on each side of the main half grades are combined both with the grade above and with the grade below. This gives the following pattern:-

CS	LW (kg)	No. of ewes with 1 or 2 CL		OR
		1	2	
3 ± ¼	56.2	6	9	1.60
2½ ± ¼	52.2	8	5	1.38
2 ± ¼	45.0	8	3	1.27
1½ ± ¼	42.9	6	1	1.14

These results suggest that the Swaledale breed will give an ovulatory response to increasing body condition and that the degree of response is not unlike that of the Cheviot breeds but is less than that of the Blackface.

3. Short-duration nutritional effects on ovulation rate in lean ewes
(J.M. Doney, R.G. Gunn and W.F. Smith)

Studies on Blackface ewes have shown a strong effect of increasing body condition on ovulation rate but little apparent effect of increasing nutrition which did not produce an increase in body condition prior to mating. At a low level of body condition, however, there was a possibility that increasing nutrition might have an effect. Since at this level of condition there is the problem of silent oestrus in very lean ewes even when they are being well fed to raise them in condition, it was considered desirable to examine the effect of a short-duration nutritional boost which did not increase body condition in ewes previously being maintained in such a condition at which silent oestrus was unlikely.

The body condition of 88 Blackface ewes was adjusted between August and October by manipulation of group management in grass paddocks. The intended condition was in the range 1½-2. When this was achieved, feeding was introduced to maintain body condition. Oestrus was then synchronised and the ewes split by body condition and live weight into two equal groups in mid-November. During the last 8 days of the oestrous cycle after synchronisation, one group was fed at twice maintenance (treatment = T) and the other at maintenance (control = C). After mating at this oestrus, all ewes were fed at maintenance for 4 weeks and returns to service were recorded and killed. Feed level was then increased and remaining ewes were killed as they reached a marketable level of finish. Ovulation and viable embryo counts were then made.

Mean live weight (LW) and condition scores (CS) before and after treatment, ovulation rate (OR), percentage returns to service (RTS), percentage embryo mortality (EM) and potential lambing rate (PLR) to first mating (M) are shown in the following table:-

Group	LW(kg) & CS at M-8 days		LW(kg) & CS at M		OR	% RTS	% EM	PLR
T	48.1	1.82	46.0	1.75	1.28	34	30	0.82
C	48.3	1.83	43.2	1.77	1.28	33	32	0.81

No attempt has been made in the above LWs to correct for differences in gut fill and it is apparent that the maintenance level of feeding have been low, although approximately 1200 g feed/head were being fed (50% dried grass pellets, 50% SAI Summermax). Twice maintenance feeding for 8 days only checked the apparent LW loss shown by the control group and had no effect on body condition or on any of the reproductive parameters studied. It can therefore be concluded that a short-duration nutritional boost for 8 days just prior to mating will produce no additional ovulatory response in lean Blackface ewes.

01A/080 UPLAND

4. The effects of time of mating and body condition on ovulation rate, early embryo mortality and lamb production of Greyface ewes.
(R.G. Gunn, J.M. Doney, T.J. Maxwell, J. Eadie, J.D. Macdonald and W.F. Smith)

In a sheep-production systems-study in the uplands, with Greyface ewes at Glensaugh, information is required on the effects of time of mating and body condition on various aspects of reproduction. Two mating times were proposed, early October and early November, and two distinct but complementary studies were carried out. One was a field study, monitoring the responses of

the systems flock split and mated at the two times but with no other imposed treatment. The other study was on purchased ewes, managed in an identical way to the main flock but with the additional treatments of synchronising oestrus and reducing the spread of body condition at the times of mating. From the former study, information has been and will be obtained on the spread of body condition at the times of mating, on the pattern of mating response and on the resultant lambing performance. From the latter study, information has been obtained on ovulation rate and early embryo mortality at the two mating times of ewes in mainly high body condition.

(a) In the main experiment, 229 Greyface ewes of mixed age were allocated to two groups by age, origin, live weight and body condition in late September. One group was put to the ram from 8th October (early) and the other from 5th November (late). Mean live weights (kg) and condition scores were as follows:-

	26th Sept.	↓M. 8th Oct.	18th Oct.	↓M. 5th Nov.	15th Nov.	5th Dec.
Early	68.8	70.9	70.8	70.1		
	3.08	3.05	3.10	3.08		
Late	67.9		72.1	69.2	69.3	70.4
	3.04		3.14	3.06	3.17	2.93

The pattern of mating was as follows:-

	Early		Late	
Marked in 1st 10 days	22/113	19%	97/116	84%
" " next 7 "	36/113	32%	18/116	15%
" " 1st cycle	58/113	51%	115/116	99%
" " 2nd "	52/113	46%	0/116	0%
Unmarked	3/113	3%	1/116	1%
Returns to service after 1st cycle	15/58	26%	10/115	9%

Lamb production is at present being recorded but will not be available in time for this Report.

(b) In the supplementary experiment, 58 draft Greyface ewes were purchased in early August and by group management in grass paddocks were brought into as uniform body condition as possible by early October.

Half the ewes were oestrous synchronised for mating at the second synchronised oestrus starting on 8th October (early). All ewes were fed at a maintenance level from early October and the second half of the ewes were oestrous synchronised for mating to start on 5th November (late). First mating and returns to service were recorded. Ewes that returned were then killed and the remainder were killed for ovulation and viable embryo counts at between 4 and 7 weeks after mating.

Unfortunately, a viable ram got among the late ewes at the first synchronised oestrus and 13 held to this mating. The data have therefore been examined over three times of mating and results are shown in the following table:-

Start of mating	No. of ewes	LW & CS at mating		OR	% EM	PLR
8th October	29	67.8	2.80	2.31	21	1.83
21st "	13	68.1	2.83	2.00	19	1.62
5th November	16	70.7	2.80	1.88	23	1.44

Although mean condition scores (CS) remained similar there was an apparent decline in ovulation rate (OR) with time. With little difference in embryo-mortality (EM), potential lambing rate (PLR) to first mating therefore showed a similar decline with time.

5. The effect of nutrition on ovulation rate in South Country Cheviot ewes

(R.G. Gunn, J.M. Doney and W.F. Smith)

Ovulation rate in South-Country Cheviot (SCC) ewes has been shown to respond less to achieved body condition when it is being maintained than is the case in Blackface ewes. No information is, however, yet available on any dynamic effects of nutrition on ovulation rate in the former breed.

In mid-September, 120 SCC ewes were group penned in the Sourhope sheephouse and randomly allocated to different feeding regimes designed to manipulate body condition and produce groups of ewes in conditions $1\frac{1}{2}$–2, $2\frac{1}{2}$–3 and $3\frac{1}{2}$–4. Great difficulty was experienced in getting ewes any fatter than condition 3, possibly on account of feed quality, consequently the experimental design had to be changed. In early November, 60 ewes were in condition $3 \pm \frac{1}{4}$, 42 ewes were $2 \pm \frac{1}{4}$ and 18 were $2\frac{1}{2}$. Half the ewes in condition 3 and all in condition 2 were then fed at $1\frac{1}{2}$ maintenance for 5 weeks while the other half of the condition 3 ewes were fed at $\frac{1}{2}$ maintenance. The condition $2\frac{1}{2}$ ewes were fed at maintenance. Oestrus was synchronised and mating took place in early December. After mating, all ewes were fed at maintenance and returns to service were recorded and killed. At 4–5 weeks after mating all remaining ewes were killed for ovulation and viable embryo counts.

Mean live weights (LW) and condition scores (CS) before and after treatment, ovulation rate (OR), percentage embryo mortality (EM) and potential lambing rate (PLR) to first mating (M) are shown in the following table:-

Condition and treatment group	LW (kg) and CS at M–5 weeks		LW (kg) and CS at M		OR	%EM	PLR
$1\frac{1}{2}$M 3H	58.7	2.88	60.2	2.99	1.72	28	1.24
$\frac{1}{2}$M 3L	58.2	2.88	49.1*	2.50	1.21	15	1.04
M $2\frac{1}{2}$M	50.8	2.48	51.6*	2.46	1.44	16	1.24
$1\frac{1}{2}$M 2H	47.8	2.00	55.4*	2.48	1.62	18	1.32

* If an allowance is made for differences in gut fill related to level of feeding these three values would tend to equalise at about 52 kg.

The difficulty, described above, of getting ewes above condition 3, remained. Group 3H ewes certainly ate their $1\frac{1}{2}$ maintenance ration but showed little or no response in LW or CS. In the other three groups, the feeding regimes successfully brought them together into condition $2\frac{1}{2}$ at mating. In terms of ovulation rate it can be concluded that the dynamic effect of nutrition prior to mating of ewes rising in condition to $2\frac{1}{2}$ has produced a significant response in this breed. In terms of potential lambing rate this was still the case, but in the ewes in condition 3 being well fed, the greater embryo mortality destroyed any advantage of their higher ovulation rate and they were unable to improve on the PLR of ewes in condition $2\frac{1}{2}$ which had been well fed or maintained.

LACTATION (02A)

1. Lactation and grazing intake studies with Swaledale ewes and lambs (J.N. Peart, W.F. Smith, J.M. Doney and Richard H. Armstrong, in collaboration with Dr. A.E. Edwards and Miss E. Donaldson, Edinburgh College of Agriculture)

Objectives

1. To determine the yield and composition of the milk of Swaledale ewes when grazing high quality pasture.
2. To measure the herbage intake of lactating ewes.
3. To compare total faecal collection with the chromic sesquioxide method of assessing grazing intake.
4. To assess the physical influence, if any, of measuring herbage intake on the milk production of grazing ewes.

Thirty-eight cast for age Swaledale ewes and two Swaledale rams were purchased in Autumn 1972. The ewes were synchronised for oestrus and the lambing period was further reduced by induction of parturition using Dexamethasone The ewes were maintained in good body condition (score 2 to 3) throughout pregnancy. Supplementary feeding was discontinued soon after lambing and the ewes and lambs transferred onto a reseeded pasture (3-year old sward) where they remained for the duration of the study. Fourteen ewes with twin and 12 ewes with single lambs were selected for the study. They were divided into two similar groups, one of which was milk recorded at weekly intervals and their milks analysed ("lactation" group). The other group ("intake" group) was also milk recorded at weekly intervals but in addition were used for estimations of herbage intake. Total faecal collections of the intake group were made daily during a 4-day period at 2-week intervals throughout lactation and were also dosed with chromic sesquioxide pellets twice per day during a 14-day period in mid-lactation and again in late lactation.

To avoid disturbance to the lactation group which may have resulted from the faecal collection and chromic sesquioxide dosing of the intake group, each group was grazed separately. The grazing area was, therefore, divided into 3 small paddocks each of approximately 2.5 acres and each group was rotationally grazed between paddocks. Flock movements were made daily. Sward uniformity throughout the paddocks was improved by trimming with a flail mower as deemed necessary. Grass samples were cut at 3-tier levels at weekly intervals and removed for both general analyses and in vitro digestibility estimations. Further grass samples were cut in bulk for in vitro herbage digestibility estimations using wether sheep. Some of the chemical analyses have yet to be completed and the data processed.

The initial mean milk yield of each of the single- and twin-suckled ewes of the intake group was higher than that of the lactation group. However, from lactation week 2, the situation was reversed and the yield of the lactation group remained greater during the remainder of lactation. Maximum differences of approximately 200 g/day were recorded in weeks 3 and 4. Thereafter the yields of both groups steadily declined to around 1.1 kg/day in week 12. The data show that Swaledale ewes have a high potential for milk production and the values are approximately 25% higher than those expected from Blackface ewes in a similar situation.

Milk production and liveweight of Swaledale ewes and lambs

	Suckling Group	Intake Group	Lactation Group
Max. daily milk yield (kg)	Twin	2.95	3.11
	Single	2.00	2.12
Mean total yield (kg) 87 day lactation	Twin	173.1	179.5
	Single	139.9	143.2
Liveweight gain of lambs (g/day)	Twin	217	236
	Single	268	287
Liveweight gain (kg) of ewes during lactation	Twin	1.8	2.9
	Single	0.4	6.3

2. Milk Production of Westphalian Milch Sheep

The milk production of Westphalian ewes was recorded in early 1973. The ewes were the property of Glendevon Farms Ltd. which retained control of all feeding and flock management. The ewes were maintained indoors and were well fed during pregnancy. After parturition and throughout lactation the ewes were fed both concentrates and hay *ad libitum*. Records of food intake were not obtained but the mean daily intake of concentrates was around 3 kg per head.

The milk recorded flock comprised 12 ewes ranging from 3 to 10 years of age and contained single-, twin-, and triplet-suckled ewes in equal numbers. Milk production was estimated at weekly intervals using an oxytocin technique. The milk from each ewe was analysed for principal constituents by Dr. A. Edwards and Miss E. Donaldson of E.S.C. Agric.

As expected milk yields in early lactation ranked in order of suckling intensity but later estimations suggested abnormalities. Dissatisfaction with the physical nature of the concentrate food was expressed by Glendevon staff and the source of food was changed on two occasions. Various animal health problems were evident and from about six weeks post-partum several ewes and lambs were clearly affected by ill-health. One cause of ill-health was identified as copper poisoning and the lactation study was discontinued. One ewe and three lambs died during the study and several more died later owing to excessive copper in the diet.

Despite the adverse conditions, the data demonstrate that ewes of this breed have a capacity for high and sustained milk yields.

Milk production of Westphalian ewes

Suckling Group	Total Yield 0-7 weeks kg	Mean daily Yield during week 7 kg
Single	96.8	1.74
Twin	173.8	3.48
Triplet	135.5	1.93

Liveweight and growth rates of Westphalian lambs

	Birth kg	Wt. at 7 weeks kg	Av. daily gain 0-7 weeks g
Single	4.7	14.0	285
Twin	4.6	12.3	251
Triplet	4.1	11.4	232

3. The effect and utilisation of sustained lactation on the growth of lambs of different genotype when offered high quality food ad libitum (02A/04A)
(J.N. Peart, A.J. Macdonald and J.M. Doney)

A flock of Blackface ewes were synchronised for oestrus in Autumn 1972 and subsequently mated to either Blackface or Texel rams (first lambing group). A second flock were given similar treatment 3 weeks later but were all mated to Blackface rams. The ewes were diagnosed for pregnancy and only ewes of the first group bearing single lambs, and only ewes of the second group bearing twin lambs, were retained. The selected ewes were put in individual pens about 8 weeks prepartum and fed a high quality pelleted food in quantities exceeding theoretical requirements. After parturition all ewes were fed similar food ad libitum. The lambing period was further reduced by the induction of parturition using Dexamethasone. The ewes were milk recorded at weekly intervals using a lamb-suckling technique.

The lambs from the second lambing group of ewes were removed at birth and discarded, and one lamb (3 weeks old) was fostered from half of each sub-group of the early lambing ewes. Lamb fostering was almost 100% successful. This process resulted in four groups of single-suckled lambs as follows:-

10 Pure B.F. lambs not fostered and reared normally
10 Texel x B.F. " " " " " "
10 Pure B.F. " fostered at 3 weeks to newly lambed ewes
10 Texel x B.F. " " " " " " " " "

The fostering of lambs at 3 weeks of age to newly lambed ewes gave these lambs an opportunity to exploit the milk production of ewes which had a potentially daily yield of approximately 3 kg at a time when the fostered lambs were 6 to 7 weeks old. Therefore, the recorded milk intakes of these lambs was a consequence of appetite for milk and not limited by the quantity of milk produced by their foster mothers.

At four weeks of age all lambs were placed in individual pens and joined with their dams for suckling at fixed intervals each day. Solid food was offered to the lambs ad libitum and individual intakes recorded daily.

The results clearly show that the cross-bred lambs have a much greater appetite for milk than the pure bred Blackface, and the similarity of the intakes of the groups of non-fostered lambs indicate that their intakes reflect the milking capacity of the ewes. The 30% greater milk intake by the fostered cross-bred lambs was associated with a similar reduction in solid food intake. This was also apparent with the pure bred lambs but the differences were only 13%. The similarity of lamb growth rates indicate that the substitution of milk with solid food and vice versa had little influence on lamb growth. This result is not unexpected in a situation where lambs had ready access to unlimited high quality solid food.

	Texel x B.F.		Pure B.F.	
	fostered	not fostered	fostered	not fostered
Milk intake				
Mean intake g/day 5-10 weeks	1735	1328	1525	1348
Mean intake g/kg wt. of lambs	76.5	59.6	73.0	64.0
Solid Food intake				
Mean daily intake (g) 5-10 weeks	624	810	682	682
Mean intake g/kg wt of lambs	24.3	31.9	28.6	29.2

	Texel x B.F.		Pure B.F.	
	fostered	not fostered	fostered	not fostered
Lamb liveweight				
Birth (kg)	5.1	5.0	4.8	5.0
Wt at 3 weeks (kg)	11.5	11.2	10.8	10.9
Wt at 10 weeks (kg)	30.4	31.3	28.9	28.8
Mean daily gain (g)				
5-10 weeks	370	394	360	355

VOLUNTARY INTAKE (01B)

Factors affecting the long term intake of roughage by sheep
Phase I Pregnancy and lactation.
(Janet Z. Foot and A.J.F. Russel)

Forty-eight mated Blackface ewes were individually fed ad libitum for 14 weeks of pregnancy on one of two roughage diets: a hay (apparent dry matter digestibility 51.5%) and a dried grass (apparent dry matter digestibility 65.3%). During the week before they were due to lamb all the animals were offered dried grass (apparent dry matter digestibility 74.4%) and continued on this diet ad libitum until the lambs were weaned at 10 weeks of age.

Food intake was measured throughout the experiment. The ewes and lambs were weighed regularly and body compositional changes in the ewes were studied using tritiated water dilution.

During pregnancy there was little difference in the mean intakes of the same diet by ewes carrying single lambs (S) and by those carrying twins (T). However ewes eating hay (H) consumed on average less than half the digestible dry matter consumed by those eating dried grass (DG) (455 and 956 g/day respectively). This difference resulted in lighter post-partum ewe weights and lamb birth weights.

Diet in pregnancy	Ewe post-partum weight (kg)		Lamb birth weight (kg)	
	S	T	S	T
DG	65.7	66.5	4.7	4.2
H	54.6	52.9	4.2	3.5

Intakes by SH ewes in lactation were similar to those of ewes suckling twins; SDG ewes had lower intakes. The previous diet of the ewes had no effect on the growth rates of lambs to six weeks: 260 g/day for twins, 300 g/day for singles. Differences between previous dietary treatments were manifest in the weight changes of ewes during lactation; these were significantly higher in H ewes, such that after 12 weeks of lactation their weights were 95% of those of DG ewes.

Group	SDG	TDG	SH	TH
Mean daily dm intake during 12 weeks lactation (g)	2312	2611	2605	2716
Peak dm intake (g)	2649	3128	3052	3243
Liveweight gain (kg)	6.4	1.7	15.8	9.8

Results from tritiated water dilution are still being calculated.

Phase II. Weaning to mating.
(Janet Z. Foot)

The intakes and changes in liveweight and body composition were studied in four groups of Blackface ewes offered dried grass ad libitum from weaning to mating.

Ewes which had weaned twin lambs (Groups TH and TDG) tended to gain more weight than those which had weaned single lambs (Groups SH and SDG). Those which had been offered hay during pregnancy (SH and TH) tended to gain more weight than those which had been offered dried grass during pregnancy (SDG and TDG). By mating time mean weights of all groups were similar.

Dry matter intakes and changes in body composition are still being calculated.

NUTRITION IN PREGNANCY (02B)

1. The effect of undernourishment during mid-pregnancy on foetal and placental development in hill sheep
(A.J.F. Russel, J.M. Doney and R.G. Gunn)

At this point in time we have some understanding of the role of nutrition during the first four and last six weeks of pregnancy as it affects the reproductive performance of hill sheep. It has generally been assumed from results of work on lowground sheep that the level of nutrition between these times (i.e. during mid-pregnancy) has relatively little effect on production provided that the level of nutrition during late pregnancy is not unduly low.

In the Organisation's development studies ewe numbers have in most cases increased substantially. This, together with the fact that during January and February the ewe stock is excluded from the areas of better pasture, has led to considerably increased grazing pressures on the areas of poorer quality pasture during mid-pregnancy. This has in turn resulted, in some instances, in greater weight losses during mid-pregnancy than formerly. In all cases late pregnancy nutrition has been closely controlled and nutritional states maintained within what are regarded as acceptable limits. Although there is no direct evidence from the development studies of any adverse effects of large body weight losses during mid-pregnancy on lamb birth weights it is nevertheless considered prudent to examine more closely the relationships between the severity of undernourishment during this period and subsequent production.

In practical terms the question being examined can be stated as follows: in a system of management in which ewes are subjected to a moderate degree of undernourishment during late pregnancy, what is the greatest severity of undernourishment which can be imposed for a prolonged period between the 30th and 100th days of pregnancy without incurring an unacceptable post-natal production penalty? This question is being tackled in two stages: (1) the quantification of the effects of undernourishment during the period from 30th to 100th days of pregnancy on foetal and placental weight and development at 100 days, and (2) a study of the effects of a moderate degree of undernourishment during late pregnancy on foetuses of different weights and stages of development at 100 days.

An experiment relating to (1) above was set up in December 1973. Seventy Scottish Blackface ewes mated at the second oestrus following synchronisation were allocated to a wide range of levels of feeding (9.5 to 30.5 g feed/kg live weight/day) from the 30th to 100th days of pregnancy, during which period changes in body weight and nutritional status were monitored at regular intervals. All ewes were slaughtered 100 days

after mating. Data collected at slaughter included foetal and placental weights, numbers and weights of cotyledons, and weights of foetal brains, livers, hearts, spleens, pituitaries, thyroids and adrenals. Foetal glands and skin samples were prepared for histological examination.

The data from this experiment are currently being analysed. The only evidence of an effect of the mid-pregnancy nutritional treatments which is available at this time is an indication that the higher levels of mid-pregnancy nutrition resulted in greater embryonic or foetal wastage.

2. The assessment of supplementary feeding requirements of grazing and housed ewes during late pregnancy.
(A.J.F. Russel and T.J. Maxwell)

The technique of regulating inputs of supplementary feeding during late pregnancy according to the biochemical assessment of nutritional status was extended to eight development project flocks in 1973.

Groups, generally of 40 early lambing ewes and gimmers from each of the three In-Wintering Systems (Rigg and Gairs, Low End and Boghall), from four Year Round Grazing Systems (Hairney Law and Auchope, Mid Hill, Cairn and Birnie, and Alderhope) and from the Greyface Upland Sheep project at Glensaugh, 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/100 ml; 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, as in previous years, generally low, indicating that the technique of progressively increasing the amount of supplementary feeding to match the pattern of foetal growth during late pregnancy was successfully maintaining a very satisfactory nutritional state throughout this period. The nutritional stat of the Boghall ewes was more rigorously controlled than in previous years when it had been found difficult to maintain plasma ketone concentrations within the prescribed limits.

In the Year Round Grazing Systems, and particularly in the Mid Hill and Cairn and Birnie flocks the very considerable ewe body weight losses during mid-pregnancy, and the poor body condition of the ewes in early March, gave some cause for concern. In late pregnancy the quantities of feeding found necessary to maintain acceptable nutritional states were generally greater than in previous years and were effective, in as far as the performance of these flocks at lambing was judged to be satisfactory.

In the Glensaugh Greyface flock, where there was no experience of either the level of production which might be expected or of feed inputs in previous years, the technique was particularly useful in providing an objective means of controlling the nutritional management of these ewes.

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 relevant sections of this report. The results, in terms of reproductive performances confirmed the usefulness of the technique in providing an objective basis for determining inputs of concentrate feeding in both the grazing and housed situations.

3. Studies on the nutritional physiology of pregnant gimmers

(A.J.F. Russel and Janet Z. Foot)

In a previous report (Annual Report 1972) it was suggested that in poorly grown gimmers the partition of nutrients between uterine and maternal tissues may be different from that in animals which had more nearly achieved their mature size. For these reasons it was 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 earlier stages of pregnancy.

An experiment designed to study the effect of weight, size and condition at first mating on the birth weight of lambs from gimmers subjected to different nutritional treatments during the second and third months of pregnancy was conducted in 1973. Thirty well-grown Scottish Blackface gimmers from House O' Muir and 30 smaller gimmers from Lephinmore were individually fed from the fourth week of pregnancy until lambing. The levels of feeding of half the animals from each source were adjusted individually from weeks 4 to 14 of gestation with the object of producing a net maternal weight loss of 6 kg over this period (low plane). The feeding of the remaining 30 gimmers (high plane) was designed to maintain mat maternal weight during the same period. All animals received an adequate level of feeding during the final seven weeks of pregnancy.

Full analysis of the results are not yet complete, but some points of interest are contained in the following table of birth weights of single lambs.

Mean birth weights of single lambs (kg)

Source	Low plane		High plane		Mean
	♂	♀	♂	♀	
Lephinmore	3.66	3.26	3.69	3.73	3.58
House O' Muir	5.07	4.90	4.34	4.14	4.55
Mean	4.22	4.08	4.08	3.92	
Mean	4.14		3.98		

Perhaps the most interesting feature is the higher birth weight of lambs from gimmers on the low plane of nutrition during mid-pregnancy. This appears to result from a decrease in the birth weight of lambs from the larger and better grown (House O' Muir) high plane animals; no such effect is evident in the lambs from the more poorly grown (Lephinmore) animals. Although this finding is apparently at variance with what would be expected, it has been corroborated in personal communication with other workers.

The results also indicate that in a situation where nutrition is not a limiting factor (high plane group) lamb birth weight is not correlated with the weight, condition or size of the gimmer at mating. However, in the low plane animals (both sources pooled), where a nutritional limitation was imposed from weeks 4 to 14 after mating, correlations with single lamb birth weights were as follows: weight at mating, $r = 0.87$; size at mating, $r = 0.79$; condition at mating, $r = 0.68$; food intake within the limits of the low plane treatment, $r = 0.87$. Measurements of weight are, of course, quite closely correlated with size and condition, and in this experiment food intakes were adjusted on a body weight basis. The multiple regression incorporating these variables, and making correction for sex of lamb accounted for 80% of the variances in the birth weight of lambs from low plane gimmers, and for virtually none of the variance in the high plane animals.

The results indicate that in the hill environment where some nutritional restriction during pregnancy is almost inevitable, there is considerable advantage to be gained in terms of lamb birth weight by ensuring that gimmers are well grown and in good condition at first mating. Given this, such animals can withstand an appreciable body weight loss during mid-pregnancy without detriment to lamb birth weight, and indeed such a management system would appear to give better results than one which aims to prevent body weight loss in gimmers during pregnancy.

NUTRITION AND BODY CONDITION (03B)

A study of some biological consequences of increasing fatness of sheep (A.J.F. Russel)

One of the consequences of the new systems of management being studied in the Organisation's development programme is an increase in the fatness of the sheep, at least at certain times of the year. To some extent this increased fatness, particularly in the autumn, is an aim rather than a consequence of the new systems being tested.

Evidence from the development studies indicates that the increased fatness of the ewe stock has resulted in increased lambing percentages and it is assumed, although good evidence is not available, that the increased body reserves of the ewe stock are serving as a buffer against poor winter nutrition from pasture. Although experience suggests that the increased fatness of the ewe stock has been generally beneficial, the full biological consequences of this change are not known. In particular, there is no knowledge of the effect of increased fatness on the ewe's food requirements or on the ability of the ewe to use her enhanced body reserves during periods of undernourishment.

Reports in the literature and results of preliminary work in HFRO (Russel, Annual Report 1969) indicate that maintenance requirements are markedly increased in fatter animals, and it is submitted that quantitative estimates of this effect are required. This type of information has an important bearing on questions such as whether increased output from a particular resource should be sought from an increase in stocking rate (more ewes with low requirements) or from an increase in individual animal performance (fewer ewes with higher requirements).

There is also evidence that very fat ewes are unable to utilize readily this reserve of energy. (This is supported by recent Scandinavian work on the inhibition of fat mobilization in pigs). Although it is unlikely that levels of fatness achieved in some experiments with housed sheep will be encountered in any of the pastorally-based systems of management with which HFRO is concerned, this effect also merits investigation.

An experiment, similar in design to that reported by Russel & Doney (J. agric. Sci., Camb. 1969, 72:59) and using 48 non-pregnant non-lactating Scottish Blackface ewes, was conducted in late 1973 to provide information on the effects of level of fatness of sheep on (1) their food requirements for maintenance and gain, and (2) their ability to catabolize body fat and protein during periods of undernourishment.

The results are currently being analysed.

HEATHER (04B)

1. Partition of digestion in sheep given heather (Calluna vulgaris) diets
(J.C. MacRae, S. Wilson and J. A. Milne)

Data represented in the Annual Report 1972 (pp 9-10) suggested that when heather was given to sheep, the digestibility of the N component (14-42%) was low compared with other constituents (OM, 42-57%). An experiment has been conducted to examine the hypothesis that these low N-digestibilities were a direct result of the complexing properties of the tannin components of heather, (see Annual Report 1972, p 50).

Blackface wethers, each surgically-prepared with either a rumen cannula (6 sheep, group (a)) or with a rumen cannula plus duodenal and ileal T-shaped cannulae (7 sheep, group (b)) were given diets of frozen July harvested and November harvested heathers at intakes ranging from 250-500 g DM/day. Group (b) sheep each received ruminal infusions of the dual-phase markers ^{103}Ru-phenanthroline and ^{51}Cr-EDTA in order to calculate 24 h duodenal and ileal digesta flow rates from spot-samplings of digesta (6 x 4 hourly) taken from the respective cannulae. Over the same period faeces, urine and rumen liquor samples were obtained from group (a) animals.

Limited data available to date suggested significant relationships ($P < 0.01$) between duodenal, ileal and faecal OM flow rates and the corresponding OM intakes on both diets. Analyses of the intestinal samples are now being undertaken. Rumen ammonia levels tended to be higher in sheep consuming July heather (8-12 mg NH_3/100 ml) than those eating November heather (3-5 mg NH_3/100 ml), but all values were extremely low compared with those reported for other diets, (good quality hays, approx. 20 mg NH_3/100 ml; Winter-quality Agrostis-Festuca 25-40 mg/100 ml; fresh pasture 35-130 mg/100 ml). Tannin may have had a considerable influence on the amount of dietary protein available for microbial digestion.

2. The development of a method for the measurement of urinary output in the grazing sheep
(A.R.M. Chambers, A.J.F. Russel and J. A. Milne)

The proposed use of a marker phenol in the urine to measure the D.M. intake of heather in diets of heather and grass selected by the grazing sheep requires inter alia the accurate measurement of daily urine output and the taking of a sample for subsequent analysis. An apparatus which collects a representative sample of a given proportion of the daily urine output of grazing ewes, fitted with in-dwelling bladder catheters, has been developed.

The principle of the design of the apparatus is that the urine from the catheter fills two reservoirs; one reservoir being a given proportion of the other. When both the reservoirs are full, the contents of the smaller reservoir are stored on the apparatus and the contents of the larger reservoir are voided from the apparatus. This mechanism operates automatically and is controlled electronically. The aliquot collected is measured every 24 h, total urine volume is calculated from the proportionality by volume of the two reservoirs and a sample is taken for analysis. Dry batteries are used as a power source. The apparatus, together with power source, is attached to a harness fitted to the sheep and the total weight attached to the sheep is approximately 3 kg.

A prototype was tested successfully under penned conditions, and 8 automatic urine collectors have been built by NIAE (Scottish Station). One of the collectors has been tested successfully under unrestricted grazing conditions. Further testing of the automatic urine collector is in progress prior to their use during the Summer of 1974 in grazing experiments. It is envisaged that the automatic urine collector could be used for a variety of other measurements on the grazing ruminant, e.g. in the measurement of energy expenditure, in nitrogen metabolism studies and to test for certain trace element deficiencies.

3. An examination of a phenol marker method of predicting intake of heather in mixed diets
(J.A. Milne)

1972

Results reported in last year's Annual Report (p 10) indicated a significant ($P < 0.01$) linear relationship between the intake of heather and the 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. Further experimentation has shown that over 90% of orcinol given intraruminally was excreted in the urine. Thus, this phenol could be used as an inert marker in the measurement of the intake of heather when sheep are grazing grass and heather communities. Daily dry matter intakes (DMI) of grass and heathers are estimated as:-

$$\text{Daily DMI of heather} = \frac{\text{Urine output/24 h x orcinol conc. in urine}}{\text{Orcinol conc. in heather ingested}}$$

$$\text{Daily DMI of grass} = \frac{\text{DM faecal output/24h} - \frac{\text{DMI of heather/24 h}}{(100 - \text{DM digestibility of heather})}}{(100 - \text{DM digestibility of grass})}$$

The orcinol concentration in heather ingested and the DM digestibility of grass and heather are determined on extrusa samples from oesophageal-fistulated sheep.

The use of this prediction method will depend upon the following factors:-

a) the presence of simple phenols in the current season's shoots of heather in quantities that are measurable,

b) the absence of simple phenols from other plants likely to be grazed and from the urine of sheep when other plants are grazed,

c) the measurement of daily urine volume of the grazing sheep,

d) the absence of bias and large random errors.

Further experimentation has shown that orcinol is present in the urine of heather-fed sheep both in summer and winter, but in smaller, although still measurable, quantities in summer. Similar highly significant linear relationships between heather intake and orcinol excretion in urine have been found. Orcinol has been found in the urine of sheep offered Vaccinium, but the characteristic phenol pattern found in the urine of Vaccinium-fed sheep will allow for a correction to be made, if necessary, for Vaccinium intake. An apparatus for the measurement of daily urine volume of the grazing animal has been developed (see 08S, Tracer Chemistry, in Annual Report). An experiment to examine sources of bias and size of the random errors is in progress. It may prove possible to extend the use of phenolic substances to measure clover intakes in mixed clover and grass swards.

4. The utilisation of grass and heather by the grazing sheep (04B/05D)
(J.A. Milne, L. Bagley and S.A. Grant)

A site for a preliminary experiment to investigate the intake and digestibility of the diet selected by sheep, grazing areas with different proportions of grass and heather at different grazing pressures was prepared in 1972 and 1973, prior to the start of the experiment in May 1974. The proportions of grass to heather chosen for the treatment plots were 15, 30 and 45%. The opportunity was taken in August 1973, to graze the treatment plots

for a period of a month with castrated male sheep under experimental management conditions. The aim was to observe the grazing behaviour of the sheep over the period of a month and to establish at what time during the day samples from oesophageal-fistulated sheep should be taken.

Behavioural observations were made on one day per week from dawn to dusk with observations being made four times each hour. Sheep numbers were adjusted so that 40% of the DM of current season's shoots of heather would be removed. However the sheep were removed after 3 weeks to avoid possible damage to the recently established grass. The mean levels of heather utilisation achieved were 15-25%. The results of the behavioural observations are given in the following table:-

Behavioural observations of sheep grazing grass and heather communities (mean of 20 sheep)

	Week 1	2	3
Total time spent grazing (h)	5.0	4.0	6.2
% total time spent grazing	28	25	39
Time spent grazing heather (h)	1.1	1.6	1.9
% grazing time on heather	22	40	30

Total time, % time spent grazing and time spent grazing heather increased over the period of 3 weeks. The high % time spent grazing heather in week 2 was probably associated with lack of available grass. The time spent grazing heather increased as proportion of grass to heather decreased. The daily pattern of grazing was similar for both grass and heather with principal times of grazing in early morning and before dusk. However there was a small peak of grazing of grass and heather after the sheep had been penned for administration of Chromic Oxide. The presence of this grazing peak will be used to facilitate the collection of representative grass and heather samples from oesophageal-fistulated sheep.

5. The effect of levels and patterns of utilisation of heather on the quantity and quality of the diet selected by the grazing sheep (04B/05D) (J.A. Milne and L. Bagley)

The aim of this long-term experiment is to investigate the effects of levels and patterns of utilisation on the growth form and dry matter production of heather, and on the quality and quantity of the diet selected by the grazing sheep. Two periods of grazing, viz. June-July and September-October and 3 utilisation levels, viz. 0, 40 and 80% removal of the current season's dry matter, are being examined. All combinations of time of year and level of utilisation are included so that there are 9 treatments. The first year of the experiment when treatments were imposed was 1973. Levels of utilisation, proportion of the plant grazed and species selected are given elsewhere in this Annual Report, (p 44).

Levels of utilisation were achieved using 1, 2 and 3 year old castrated male sheep (mean liveweight 50 kg). Measurements of faecal output and digestibility were made in weeks 2 and 5 of each 5 week grazing period. Faecal output was measured with Chromic Oxide as an indigestible marker on 4 sheep/treatment and 4 oesophageal-fistulated sheep/treatment were used to provide extrusa samples, on which in vitro DM digestibility determinations were made. A summary of the results obtained from the first year of the experiment are given in the following table. DM digestibility fell from 54% in June to 50% at the end of July, but there was no further decline in September and October. Effect of previous grazing did not significantly change DM digestibility. There was a small decline in DM intake from June to October and higher utilisation levels in October caused a reduction in

intake. In general the DM intakes and digestibilities found in this experiment are in accord with those found previously with harvested heather fed under controlled conditions.

Dry matter intake (DMI) and digestibility (DMD%) of heather selected by the grazing sheep
(Mean of 4 sheep/treatment)

			Level of utilisation of current season's shoots (June-July/Sept/Oct)(%)							
			0/40	0/80	40/0	40/40	40/80	80/0	80/40	80/80
DMI ($g/kgW^{0.75}$/day)	June-July	Wk 2	-	-	44.0	36.0	N.D.	40.0	39.0	N.D.
		Wk 5	-	-	38.0	34.0	N.D.	38.0	48.0	N.D.
	Sept-Oct	Wk 2	44.0	37.0	-	35.0	33.0	-	58.0	39.0
		Wk 5	38.0	32.0	-	41.0	29.0	-	46.0	30.0
DMD (%)	June-July	Wk 2	-	-	53.9	53.9	N.D.	53.3	53.3	N.D.
		Wk 5	-	-	52.5	49.4	N.D.	48.5	49.7	N.D.
	Sept-Oct	Wk 2	51.1	49.2	-	49.5	47.6	-	50.6	51.6
		Wk 5	51.5	50.9	-	52.0	45.7	-	52.6	47.5

6. The use of the in vitro technique to predict the dry matter digestibility (DMD%) of heather in extrusa samples from oesophageal-fistulated sheep

(J.A. Milne)

Previous work at HFRO (Annual Report 1972; p11) showed that the in vitro DMD% of heather was considerably lower than in vivo DMD%, and that predictions of DMD% could be made with some accuracy from in vitro DMD%. Further experiments were carried out in an attempt to increase the in vitro DMD% of heather and to reduce the residual standard deviation (RSD) of the prediction of DMD% from in vitro DMD%. Increasing first stage fermentation time from 48 to 72 h increased in vitro DMD% significantly ($P < 0.01$), but increasing the level of nitrogen or increasing the concentration of rumen liquor did not improve in vitro DMD%. The addition of nitrogen reduced the RSD of the prediction of DMD% from in vitro DMD% by 8% but none of the other treatments decreased the RSD. It was concluded that the standard in vitro procedure was adequate for the prediction of digestibility, provided that a set of heather standards is used.

To test the validity of the use of the in vitro technique to predict DMD% of heather in extrusa samples from oesophageal-fistulated sheep, a comparison was made between the in vitro DMD% of 9 heathers of known in vivo DMD% and the in vitro DMD% of extrusa samples of the same heathers fed to oesophageal-fistulated sheep. There was no significant difference between the in vitro DMD% of heather and the extrusa samples of heather; nor were there any changes in the RSD of the prediction of DMD% from in vitro DMD%. Thus the in vitro technique can be used to predict the digestibility of heather in extrusa samples from oesophageal-fistulated sheep.

NUTRITION SUPPLEMENTATION/PASTURE UTILISATION (05B/03C)

Investigations into the digestive physiology of supplementary feeding

A 3-phase study involving grazing trials, indoor feeding and metabolism experiments is now underway into the nutritive value of Agrostis fescue pasture herbage and the effects of supplementing this ration with concentrate additives. However before any long-term study could be undertaken several preliminary methodological investigations had to be carried out:-

1. Evaluation of different surgical preparations in sheep on the subsequent performance of the animal on poorer quality diets (J.C. MacRae, S. Wilson and A. Whitelaw)

There are two basically different methods of obtaining data on partitions of digestion in ruminants. In one method animals are prepared with re-entrant cannulae, in the other with simple (T-shaped) cannulae. From the former, 24 h data are obtained by collection of total amounts of digesta passing through the cannulae, while from the latter isolated spot-samples are taken and 24 h flow data are calculated relative to concentrations of indigestible markers present in the sample. Until comparatively recently lack of adequate markers made the latter method less accurate, but now these inadequacies have been overcome and so other considerations can be taken into account.

Re-entrant cannulated sheep are arguably under "chronic stress" to a greater degree than animals with T-shaped cannulae. It was suspected that the low nutritional status of experimental animals given hill pasture herbage might exacerbate any chronic stress and for this reason it was decided initially to prepare sheep with T-shaped cannulae for use in the heather experiments, (detailed elsewhere in this Report). However, with a longer-term view, an objective evaluation of the post-operative normality of re-entrant and T-shaped cannulated sheep has been undertaken.

The experiment was only recently concluded, and not yet fully analysed, however data so far available suggests that voluntary feed intake (VFI), digestibility and rate of passage of digesta were not significantly affected by establishment of either preparation. Briefly the experiment was carried out as follows:- 24 Scottish Blackface wethers of similar age (18 months) and origin and ranging in live weight from 35-47 kg were housed in metabolism crates and given a ration of chopped hay.

After 4 weeks acclimatisation to the ad lib feeding on this ration, faeces and urine were collected for 14 days (Period 1). On the basis of VFI ($g/kg\ BW^{0.75}$) the sheep were allocated to one of three groups in a randomised block design. Group A animals were kept as controls (i.e. no surgery) throughout the subsequent investigation. Animals in Groups B and C were each prepared with a rumen cannula and then all groups were again fed ad lib on the diet used previously (Period 2). Group B animals were then each prepared with duodenal and ileal re-entrant cannulae while Group C animals were each prepared with duodenal and ileal simple (T-shaped) cannulae. All groups were again fed ad lib on the chopped hay diet (Period 3). Data on VFI and digestibility are summarised in the following table:-

Voluntary feed intake (VFI) and digestibility of the chopped hay ration

Groups:	VFI ($g/kg\ BW^{0.75}$)				Digestibility coefficients			
	A	B	C	SEM	A	B	C	SEM
Period 1 (March 73)	48	48	48	±0.9	61	61	62	±1.1
Period 2 (July 73)	64	64	55	±2.2	59	62	61	±0.9
Period 3 (Nov. 73)	56	49	43	±2.9	58	60	62	±0.8

Although the mean VFI of sheep prepared with simple (T-shaped) cannulae (Group C, Period 3) was significantly lower ($P < 0.05$) than that of the control sheep, the only significant effect on VFI that could be directly attributed to surgical preparation was the reduction consequent upon rumen cannulation of Group C sheep. No reason can be offered for this finding, because Group B sheep had the same rumen surgery yet their mean VFI in Period 2 was identical to the control animals. Indeed the mean VFI of all 16 sheep prepared with rumen cannulae (59.5 ± 2.2 g/kg $BW^{0.75}$) was not significantly different from the control group. It would have been desirable from the biological point of view to have re-randomised Groups B and C rumen cannulated animals prior to intestinal surgery. However, this was not statistically possible because all sheep had previously been randomised on a block design relation to their VFI in Period 1. Intake changes consequent upon intestinal surgery were not significantly different from changes in the control group. (Group A, -8; B, -13; C, -13 g/kg $BW^{0.75}$, SEM ±3.1) and indeed when co-variance analysis was used to adjust VFI of Period 3 relative to equalised intakes in Period 2, the adjusted intakes were not significantly different (Group A, 55; B, 49; C, 43 g/kg $BW^{0.75}$, SEM ±3.6).

The ability of the sheep to digest the hay ration did not appear to be affected by the surgical preparation (see table).

Faecal excretion of the digesta particulate and liquid phase markers, non-radioactive Ru-phenanthroline and Cr-EDTA (see section 2) were also examined in Periods 1-3 but the range of VFI's made it difficult to compare operated and intact sheep. A fourth feeding period was therefore carried out in which all sheep were given the same intake of a dried grass diet (900 g/24 h). Limited data available to date (duplicate measurement on 3 sheep per group) suggest that the cannulations had little effect on digesta retention times. The times (h) taken for 50% faecal excretion of intraruminally-administered Ru-phenanthroline were Group A, 59.6±2.40; B, 59.2 ±1.66; C, 56.2±1; and of Cr-EDTA were Group A, 51.1±2.64; B, 52.2±0.95; C, 50.6±1.73 indicating more rapid excretion of liquid phase marker, but no between-group differences.

Certain blood parameters were monitored throughout the experiments. Cortico-steroids, serum glutamic-oxalacetic transaminase, protein-bound iodine, glucose and urea levels, erythrocyte and leucocyte counts and haemoglobin estimations, all failed to show any difference due to surgery, but plasma caeruloplasmin levels showed a marked elevation 1-2 weeks after surgery in all sheep other than when Group B animals received re-entrant cannulae and acetyl promazine was administered. It took 2-3 months for these levels to return to normal; the latter findings are being investigated further. The nature of the results from this experiment and especially the VFI data are such that small difference consequent upon surgical establishment of gastro-intestinal cannulae cannot be discounted. However the data failed to demonstrate large effects.

2. Development of non-radioactive ruthenium-phenanthroline as a digesta-particulate marker

(J.C. MacRae and C.C. Evans)

Ru-labelled tris (1,10-phenanthroline) ruthenium (II) chloride has been shown to be a satisfactory solid-phase marker in several experiments on ruminant nutrition but its general use as an intestinal marker could be somewhat limited by its radioactive properties (0.42-0.60 McV gamma emission). A method has been developed which can now accurately determine Ruthenium by X-ray fluorescence spectrometry and this has facilitated the evaluation of inert ruthenium-phenanthroline (Ru-P) as a solid-phase marker.

For a substance to perform satisfactorily as a particulate phase marker it must (a) be completely indigestible and (b) associate itself closely with the digesta particulate phase. Faecal recoveries of Ru, measured in two sheep given continuous intraruminal 9 day infusions of the complex, were 96.6% and 101.1%. In subsequent experiments, on which pulse-doses of marker were administered intraruminally to 24 sheep, to measure transit time of digesta, mean faecal recovery of Ru was 101 ±2.5%. Adherence of Ru to the solid phase of the digesta was examined in the 9 d infusion experiment and also in in vitro experiments. In these, Ru-P solution was incubated with rumen liquors at 37° for consecutive 2 h periods during which the pH was adjusted to 6, 3 and 8 respectively to represent conditions pertaining in the rumen, in the abomasum-duodenum and in the ileum-caecum. When samples of rumen liquor were centrifuged at 3000 g for 20 min in all instances less than 2% of the Ru was detected in the supernatant fraction. When samples of faeces excreted on days 8-10 of the 9 d infusion were homogenized with 4 vol water and centrifuged at 300 g, the solid phase contained 58.4 ±3.81 mg/kg Ru and the supernatant fraction contained only 1.3 ±0.19 mg/kg.

Chromium can also be estimated by X-ray fluorescence, and infusions of Ru-P plus Cr-EDTA have already been used to study the relative transit times of the solid and liquid phases of digesta (see Section 1).

3. Examination of the effects of freeze-storage of hill pasture on its physio-chemical composition

(J.C. MacRae, D.R. Campbell and J. Eadie)

Changes occurring in the physio-chemical composition of ryegrass and clover upon freezing and thawing can alter the potential utilisation of such material by ruminant. However cutting poorer-quality hill pasture herbage daily throughout the winter months would present unsurmountable difficulties and so freeze-storage had to be considered.

An experiment was carried out at Sourhope to investigate changes in the physio-chemical composition of hill pasture herbage when subjected to freezing and subsequent thawing. Two winter-quality hill pastures (a species - poor Agrostis-Festuca and a Nardus-Molinia grass heath, both on "Fasset" face) were sampled before the onset of spring growth. The Agrostis-Festuca pasture was later sampled prior to and after ear emergence and two further higher quality pastures, a perennial ryegrass from Park Low Meadow and a white clover at Bush Estate were sampled for comparative purposes. The soluble carbohydrate and nitrogen contents, the cell-wall carbohydrate contents and the in vitro digestibilities of all samples were measured in (a) the fresh sample; (b) the frozen sample and (c) at 3 h, 6 h, 12 h and 24 h after removal from cold storage.

Changes occurred in the soluble carbohydrate content upon freezing and thawing of all herbages, invertase activity causing an increase in both glucose and total reducing sugar concentrations. All samples other than the Winter quality herbages showed a marked fall (up to 50%) in total soluble-N content upon freezing and thawing, this change almost entirely resulting from reductions in soluble protein.

Breakdown of di- to monosaccharide is unlikely to alter utilisation of the herbage by ruminants, and fortunately the more serious changes in physical composition of the N constituents were negligible for the Winter quality herbages. The study would therefore suggest that freeze-storage of Winter quality hill pasture is unlikely to significantly alter the nutritive value of the herbage when subsequently fed, as experimental rations, to ruminants.

Investigations into the effect of supplementation on the nutritive value of winter hill herbages

1. The supplementation of winter hill herbage with cereal and cereal and protein supplements

(C.S. Lamb, J.C. MacRae and J. Eadie)

The major aims of this experiment are to quantify the effects of responses in terms of intake of gross and total energy to a range of supplements given to sheep grazing Agrostis-Festuca hill pasture in winter. A parallel indoors experiment using cut herbage of similar origin is also being carried out.

Thirteen acres of an Agrostis-Festuca sward at House o' Muir was enclosed on September 27th, 1973. The area was sub-divided into three 2 acre plots for the grazing study; a 7 acre block was cut to provide herbage for the indoor study - 15½ tons fresh wt. - 5.7 tons D.M. were harvested on December, 5th, 6th, 7th, packed into polybags and stored in deep freeze.

The grazing experiment was carried out in three consecutive phases:

1. A covariance trial of 5 weeks.
2. The main trial when supplements were fed for 5 weeks.
3. A covariance trial of 5 weeks.

The sheep grazed a different plot in each of these phases.

Forty-eight 2½ year old B.F. wethers were used in the experiment which began on December 17th, 1973. They grazed together a different plot in each phase of the study. The sheep were bagged for faeces collection during the final 2 weeks of each phase of the experiment. Liveweights were recorded weekly and quadrat counts were taken four times during the collection period to determine the amount and composition of the herbage available. Faecal D.M. output per unit of liveweight was determined for each sheep for the first covariance trial and the sheep were then allocated to eight treatment groups for the main trial by random allocation from six faecal output classes.

The supplements fed during the main trial were 0, 100, 200, 300, 400 and 500 g of rolled barley (1.45% N) and 100 and 300 g of an 85% barley + 15% soya bean meal mixture (2.32%N). The sheep were penned individually each day to receive the supplement. Blood samples were taken from each sheep during the faeces collection period. The sheep in each of the groups receiving supplements were fitted with coloured plastic straps and their grazing behaviour observed for 3 days in each of the final 2 weeks of the main trial.

The only results available at this time are the weight changes of the sheep throughout the grazing study and are given in the following table:-

TABLE I

Liveweights (kg) of sheep throughout the grazing study

Treat-ament Group	Level of Supplement	Pre-Expt. Wt. 10/12/73	Covariance (1) Mean Wt. 11-18/1/74	Main Trial Mean Wt. 1-8/3/74	Co-variance (2) Mean Wt. 5-12/4/74
1	0 g	52.8	45.9	41.3	43.2
2	100 g	49.8	43.1	39.6	41.7
3	100 N*g	52.6	44.5	41.3	42.2
4	200 g	51.8	44.9	43.1	43.7
5	300 g	52.8	45.6	43.5	44.9
6	300 N*g	52.2	43.7	42.7	43.8
7	400 g	55.3	46.8	44.6	45.1
8	500 g	50.5	43.2	43.5	44.6
	Overall Mean	52.2(2.5)+	44.7(2.2)+	42.7(1.9)+	43.7(2.0)+

* Barley + soya bean meal supplement

\+ Mean body condition score.

NUTRITION - METABOLISM (06B)

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. Evidence is now accumulating, however, to suggest that this assumption may not be valid in all cases, and in particular that it may not be true in cases where heather forms a major constituent of the diet.

During 1973, 70 Scottish Blackface ewes from the Birnie and Cairn flocks at Glensaugh and a further 70 from the Mid Hill flock at Lephinmore were blood sampled at intervals throughout the year to assess the protein status of the ewe flocks in these heather-dominant situations.

Total serum protein concentrations showed a markedly seasonal pattern in all three flocks, being lowest during March and April, increasing relatively slowly throughout the summer months to maximum values in August, and thereafter declining only very slightly during the remainder of the year. In general, the Glensaugh flocks appeared to have a more satisfactory protein status (although absolute values were still low) during late pregnancy and early lactation than did the Lephinmore ewes. The serum protein concentrations of the Lephinmore ewes were exceptionally low during March (5.6 - 5.8 g/100 ml) and April (62 g/100 ml); values for the Glensaugh ewes were around 6.6 g/100 ml during this period. Of the two Glensaugh flocks, the Birnie ewes had a somewhat better protein status than those in the Cairn flock during lactation (8.2 v 7.0 g/100 ml in June and 8.1 v 7.6 g/100 ml in July). By August the mean serum protein concentrations in all three flocks were similar at about 8.8 g/100 ml.

Further analyses indicated that most of the changes in serum protein concentration were attributable to changes in the globulin fraction; serum albumin concentrations remained relatively more constant throughout the year.

Blood urea nitrogen concentrations also exhibited a characteristic annual pattern, increasing markedly following the introduction of late pregnancy feeding and thereafter showing a pattern similar to that of changes in pasture quality. Concentrations in early March were again low, particularly in the Mid Hill (5.0 mg/100 ml) and Cairn (6.0 mg/100 ml) flocks. The comparable value for the Birnie ewes was 14.5 mg/100 ml.

Differences within flocks between ewes suckling twin lambs and grazing on production area, and those on the hill areas with single lambs, were evident in all parameters at the appropriate times.

These results refer to only one year and at this stage must be treated with caution. They suggest, however, that in 1973 the protein status during late pregnancy of the Mid Hill ewes was such as to give cause for concern. It is probable that the situation was exacerbated by the feeding of sugar-beet pulp which contains very little protein; this practice has now been discontinued. The apparent superiority of the Birnie ewes' protein status, relative to that of those on Cairn, is tentatively attributed to a greater availability of grass on the Birnie hill.

A limited analysis of blood samples collected from the Hairney Law and Auchope ewes at Sourhope during late pregnancy indicated that inadequate protein intakes are unlikely to be a problem in ewes grazing on grass-covered hills.

This study is continuing.

CATTLE (08B)

1. The effect of nutritional state during late pregnancy on the production of suckler cows
(A.J.F. Russel, A. Whitelaw, J.N. Peart, A.J. Macdonald and W.F. Smith)

An experiment designed to measure the effects of nutritional state during late pregnancy on the production of suckler cows, as measured in terms of calf birth weights, milk production and live-weight responses of cows and calves during lactation, commenced at Glensaugh in mid-1973 and is still in progress. The effects of nutritional state during late pregnancy and of genotype on immunoglobulin production and absorption in beef cattle are also being studied.

I. Effects on calf birth weight
(A.J.F. Russel, A. Whitelaw, J.N. Peart and A.J. Macdonald)

A total of 63 cows (32 Blue Grey and 31 Hereford x Friesian) were brought into the Glensaugh cattle shed as required some 15 weeks before their expected dates of calving, which ranged from mid-October to mid-January. A complete non-pelleted diet comprising ground barley, chopped barley straw, molasses and protein concentrate (including mineral and vitamin supplements) in the proportions 6:3:1:1:5 was used throughout the experiment. The calculated energy and protein contents, on a dry matter basis, were 2.65 Mcal ME/kg and 14.0% CP.

All cows were individually fed according to body weight at a level designed to provide maintenance + 20% (13 Mcal ME/day for a 500 kg cow) for an initial 3 week pre-experimental period.

During the final 12 weeks of pregnancy cows were randomly allocated to one of eight levels of feeding ranging in equal increments from 75% of the maintenance requirements of a non-pregnant non-lactating cow to somewhat more than the full requirements of a pregnant cow at term (i.e. from 8.2 to 18.7 Mcal ME/day for a 500 kg cow).

These levels of feeding were designed to provide a wide variation in nutritional state, as estimated by analysis of weekly blood samples, during late pregnancy. Nutritional state, being a measure of the extent to which an animal's food requirements are met by its food intake, is considered to be a more useful parameter to which performance may be related than either food requirements (which will vary according to foetal burden, whether the animal is housed or grazing, and to prevailing climatic conditions, and which cannot yet be easily measured) or food intake (which cannot be easily measured in the grazing situation). In the current experiment variations in performance (i.e. calf birth weight, level of lactation and cow and calf live-weight changes during lactation) will be related to the variations measured in nutritional state during late pregnancy.

Data relating to the effect of nutritional state in late pregnancy on calf birth weight are currently being analysed statistically.

II. Studies on lactation and calf growth
(J.N. Peart, A.J.F. Russel, A. Whitelaw and A.J. Macdonald)

Groups of Hereford x Friesian and Galloway x Shorthorn cows had been inseminated with the semen of one Hereford bull, and subjected to different levels of nutrition in late pregnancy.

After parturition 48 cows and calves representing low, medium and high planes of nutrition in late pregnancy were selected in equal numbers for study during lactation. Initially all cows were fed ad libitum a complete diet of similar composition to that fed in late pregnancy. The calves were

offered similar food but their daily intake was restricted to 2.5 kg per head. The daily food consumption of cows and calves was recorded. Severe and re-occurring scour was observed in most calves. This was attributed to an excess intake of milk. Consequently the food intake of later calving cows was restricted to provide maintenance plus 6.8 kg of milk per day for a period of 3 weeks after which they also were fed ad libitum. The diet restriction did not prevent calf scours which re-occurred regardless of age of calf. A further restriction in cow food intake was made at approximately 16 weeks post partum and whilst it did not eliminate calf scour, the calves were noticeably more active. Details of veterinary problems are contained in the section concerned with animal health (p 25).

A slight reduction in cow liveweight was recorded during the period of restricted feeding in early lactation but all cows made substantial live-weight gains when fed ad libitum. Cow food intakes increased to 25-30 kg per head per day around lactation week 8 then steadily declined to around 18 kg in week 16.

The daily milk production of 24 cows was measured at 2-week intervals using a calf-suckling weight-differential technique. Observations made to determine the frequency of calf suckling showed that some suckling activity took place in each hour of the day. However, distinct peaks of suckling activity occurred around 0700 h, 1300 h and 2000 h in each 24 h period.

There was little difference in milk production between pregnancy nutrition groups but during the first 8 weeks of lactation the daily milk intake of calves suckling Hereford x Friesian cows was approximately 1.2 kg greater than that of calves suckling Galloway x Shorthorn cows. Subsequent data indicate that milk intake of the two groups were becoming similar. Maximum milk yields were recorded in lactation week 8.

In addition to measuring milk production by calf-suckling, estimations of the daily production of 8 cows were made using an oxytocin technique with machine milking followed by hand stripping. These estimations were made on the day following calf-suckling recordings thus permitting a comparison to be made between the two methods. Oxytocin estimations in early lactation were approximately 25% less than the recorded milk intake of calves. In mid lactation the values were nearly equal but in later lactation the discrepancy re-appeared and the oxytocin method gave an underestimate of around 20% in lactation week 16. The reason for these discrepancies is not clear. A stage of lactation effect may be implicated but the effect of disturbance due to the oxytocin method is a probable cause. Other observations suggest that the milk yield of beef cows is readily depressed by disturbance factors.

This lactation study is still in progress and therefore the data are provisional.

	Hereford x Friesian	Galloway x Shorthorn
Milk production (kg/day)		
Week 2	9.2	8.0
Week 8	10.7	9.4
Week 14	8.5	8.5
Calf liveweights (kg)		
Birth	38½4	37.8
Week 2	46.8	46.1
Week 8	93.9	93.0
Week 14	138.3	140.9

III. Effects on immunoglobulin production and absorption
(A.J.F. Russel (in collaboration with R. Halliday, ABRO and A.J. Macdonald))

The production of immunoglobulins in the colostrum of suckler cows and the absorption of these by new-born calves may be affected by the nutritional state of the cow during late pregnancy. Differences between genotypes, such as have been shown to exist in sheep, may also be important with respect of immunoglobulin production and absorption. These factors are being examined in the suckler cow experiment which commenced at Glensaugh in mid-1973.

Samples of colostrum were collected twice daily for four consecutive days after parturition. Calves were blood sampled before suckling and twice more on each of the first two days after birth. The analyses of these samples for immunoglobulin concentration is in progress.

VETERINARY
(A. Whitelaw)

GLENSAUGH
Cattle (08B)
Reproduction

Insemination of the cows commenced on 10.1.73. Oestrus detection was by Teaser bull and visual examination.

Animals were housed in cubicles.

The same Hereford bull was used and 83 cows were involved.

One cow (13) was culled because of cystic ovaries, treatment being unsuccessful. Cow 44 had a persistent metritis which had not cleared up by the end of the breeding period.

Thirteen cows did not settle in calf by the end of the breeding period. Four of these had been yeld in 1972 and were culled. No abnormalities were found in the genitalia of the others.

Cow No. 33 aborted. Laboratory examination was negative for abortion agents.

Forty-seven cows settled to the first service and 18 cows settled to the second service.

Calving commenced on the 16th October and on the 31st December 5 had still to calve. Calvings were uneventful.

In 1974 synchronisation of oestrus by the use of Prostaglandin $F_{2\alpha}$ is planned to narrow down the calving interval.

The problem of oestrus identification in the suckler herd in cubicles is one in which a teaser bull is of limited value. Similarly oestrus identification by visual examination is found to be difficult in the cubicles. Synchronisation of oestrus may provide the answer.

Health
Summer mastitis: Several cases occurred in the cows in August with subsequent loss of quarters. The difficulties of keeping flies away from the cows' udders at this time of year were only partly solved by spraying.

Cows and Calves : Scouring: The use of an ad lib diet of a home-mix type to the cows post calving led to excessive intakes in most of the herd. This produced persistent soft faeces in the cows making cleaning difficult.

The problem of digestive scour in calves has been a real one, and can be attributed to the large intake of the dams on ad lib feeding and possibly to some of the constituents of the diet, e.g. molasses.

There has been little evidence of infectious scour but the labour requirements in treating scouring calves has been unacceptable.

LAMB GROWTH (01C)

Lamb growth studies
(Richard Armstrong and John Eadie)

Previous work in this programme showed that ryegrass was superior to Agrostis-Festuca for the promotion of live-weight gain. Subsequent work showed that white clover enhanced lamb growth rate when mixed with grass of hill or lowland origin. In addition to this, work with milk substitute has demonstrated the significance of modest levels of milk during the latter half of the growth period to weaning. Further information therefore was required on the responses to milk and the inter-relationships of milk supply, herbage intake and herbage feed quality.

Two experiments were carried out using milk substitute in 1972, one indoors and one with grazing lambs. These were S.C.C. lambs which had been weaned at 9 weeks of age.

1. Indoors Experiment

Three groups of seven lambs were individually fed ryegrass/clover (Rg/Cl) herbage to 20 per cent excess for nine weeks. One group was fed 160 g milk dry matter per head per day; one group was fed 80 g per head per day. Organic matter digestibility of herbage and milk were measured during a nine-day period. Herbage organic matter intakes were recorded daily and liveweights once weekly.

Results (g/head/day : 2.7.72 - 2.9.72)

	OMD	OM Intake		DOMI	LWG
	Herbage	Herbage	Milk	Total	
Rg/Cl + High milk	-	603	150	618	182
Rg/Cl + Low milk	-	625	75	577	154
Rg/Cl	81.8	681	-	557	139
LSD at 5% level		52	1.8	-	55

The increment of live-weight gain with the high level of milk was less than that reported in 1970. This increment is very largely due to higher total intakes of digested organic matter.

The performance of the low milk group in terms of total DOMI and LWG was intermediate between that of the other two groups.

2. Grazing lambs

Three groups of lambs were subjected to the same milk treatments as Experiment 1.

After four weeks indoors they were allowed to graze a clover plot for six weeks. Faecal collections were made on all lambs on four consecutive days each week. The amount and digestibility of herbage ingested by non-milk fed lambs was predicted using an intake factor-faeces nitrogen regression derived in 1969, together with faecal outputs.

Herbage intakes of milk-fed lambs were predicted by correction of faecal output for undigested milk and assuming that the quality of ingested herbage was similar to that of the non-milk fed lambs.

Results: (g/head/day : 8.8.72-8.9.72)

	OMD	OM Intake		DOMI	LWG	*FOM/kg.$^{.73}$
	Herbage	Herbage	Milk	Total		
160 g milk	-	770	150	694	308	17.2
80 g milk	-	724	75	596	263	17.7
No milk	73.5 **(70.4)	776	-	569	230	20.0
LSD			1.8		42	1.8

* Corrected for undigested milk
** In vitro dry matter digestibility of cut sample
LSD= Least significant difference at the 5 per cent level

The growth rates of the non-milk fed lambs were twice as high as those of suckling lambs on the hill at this age. This was largely, but not entirely, due to the high levels of herbage DOMI achieved.

The live-weight gain increments due to the high level of milk feeding was only slightly lower than that reported in 1969 with lower quality Agrostis-Festuca herbage.

Further work is indicated in the grazing situation to calculate the nature of the relationships between the quality of the pasture ingested by the lamb, the amount of herbage which it ingests and its consumption of milk. Critical work on these aspects is dependent on the development of more accurate techniques for the prediction of the quantity and quality of herbage ingested by the lamb. To this end limited experimentation was carried out in 1973 as part of an investigation into the lactation performance of hill ewes at pasture and the growth of their lambs (project 02A).

The results of this experiment are as yet incomplete.

INPUT/OUTPUT STUDIES (02C/07D)

Sourhope
(J. Eadie, R.H. Hetherington and T.G. Common)

This series of experiments, designed to quantify responses to a range of inputs in the improvement of varying types and qualities of hill land, was continued during 1973. The background and basic aims of this work were set out at its inception in the Annual Report 1969. Three sites, of differing soil and pasture type, were under investigation. The range of treatments to these sites was as follows:-

A - control grazed (fencing only)
B - lime applied
C - lime and slag applied
D - lime and slag applied with clover sown
E - lime and slag applied with clover and ryegrass sown

rates: lime - 2.5 tons/acre
slag - 10 cwt/acre
clover - 2 lb/acre
ryegrass - 20 lb/acre

Experiment 1 was carried out on an Agrostis Festuca pasture with a brown earth soil to which treatments were applied in 1969. An additional plot (F) similar in size to the treatment plots has been included in the comparison for 1972. This plot has had no fertiliser or seed. Carrying capacity of all plots in terms of grazing days per acre is given in Table 1.

Table 1 - Grazing days/acre

Treatment:	A	B	C	D	E	F
Grazing days/ acre	960	1232	1024	1332	1572	1308

This represents an increase of about 64% in the carrying capacity of the highest input plot over the control. The mean weight changes of all sheep remaining on plots throughout each grazing period were as follows:-

Table 2 - Liveweight change (kg)

Treatment:	A	B	C	D	E	F
1st Period 15/5-12/6/73	-1.0	+5.2	-0.7	-1.9	+3.8	+2.8
2nd Period 19/7-16/8/73	+4.7	+5.0	+6.1	+5.4	+6.0	+6.1
3rd Period 12/10-2/11/73	+4.5	+2.0	+3.3	0	+2.5	+2.7

With the exception of Treatment B (lime only) the amount of herbage dry matter available at the beginning of the grazing period rose as the level of inputs was raised (Table 3).

Table 3 - Dry matter availability at start of grazing period

Treatment:	A	B	C	D	E	Acclimatization
DM available (lb/ac)						
1st grazing (15/5)	749	826	815	982	1019	919
2nd grazing (19/7)	1158	1657	1415	1580	11659	1382
3rd grazing (12/10)	868	1526	1038	1414	1802	1338

Experiment 2: This site was set up on an area of Molinia dominant pasture on a peaty podzol.

Table 1 - Carrying capacity

Treatment:	A	B	C	D	E
Grazing days/Ac	762	878	910	1222	1148

Outputs for treatments D and E were greater than that of the control plot by 60% and 50% respectively.

Liveweight gains during the grazing periods were also higher on the higher treatment levels.

Table 2 - Liveweight changes (kg)

Treatment:	A	B	C	D	E
1st Period					
1st Part 11-25/5/73	+1.9	+4.0	+3.2	+3.9	+4.3
2nd Part 12/6-3/7/73	+2.3	+2.9	+3.0	+1.4	+2.1
2nd Period 16/7-15/8/73	+0.9	+0.7	+0.5	+1.4	+6.0
3rd Period 16/10-6/11/73	-0.5	-1.5	-2.0	+0.6	+2.2

Table 3 - Dry matter availability at start of grazing period

Treatment:	A	B	C	D	E
DM available (lb/ac)					
8/5/73)	592	620	490	700	670
13/6/73)	764	1358	918	1248	796
12/7/73	765	998	1234	1097	634
15/10/73	884	1084	1119	1410	1426

Available dry matter was greater than that of the control in all plots over the year as a whole, although there was more in the low input treatments (lime and lime + slag) than in the high input plots.

Experiment 3: This area is Nardus dominated on a peaty podsol.

Table 1 - Carrying capacity

Treatment:	A	B	C	D	E
Grazing Days/Acre	882	1022	964	1118	1128

Table 2 - Liveweight changes (kg)

Treatment:	A	B	C	D	E
1st Period 21/5-18/6/73	+2.5	+2.0	+0.5	+3.1	+6.1
2nd Period 23/7-20/8/73	+2.2	+0.3	+1.6	+3.1	+4.9
3rd Period 15/10-5/11/73	+2.0	+0.8	+4.1	+1.9	+3.8

In this case, grazing days have risen as the level of treatment has increased. Although grazing day totals of plots D and E were almost the same, the liveweight gains over the year as a whole were substantially larger on plot E than on plot D though both were greater than the control plot values.

Table 3 - Dry matter availability at start of grazing period

Treatment:	A	B	C	D	E
DM available (lb/ac)					
16/5/73	963	737	841	675	1027
19/7/73	1149	1620	1455	1668	1382
12/10/73	1019	1068	964	1257	1217

The total herbage dry matter available on the plots at the beginning of the grazing periods was greater on the clover and grass and clover plots than on control or the low input plots.

B. PLANTS AND SOILS

NUTRIENT INTERACTIONS (01D)

1. The influence of aluminium on the decomposition of herbage
(A.G. Lowe and M.J.S. Floate)

The herbage from the pot experiment described earlier (HFRO 196) was separated into groups with different aluminium contents and this material was used in decomposition studies.

During decomposition it was found that the pH of the herbage increased and a buffer was introduced to maintain the pH at 4.2, the pH of the untreated soil. Different amounts of aluminium were added (200 and 400 ppm) to material with an aluminium content of 200 ppm and this was incubated in duplicate for two weeks. The carbon dioxide released during the experiment was absorbed in 5N sodium hydroxide and titrated against standard acid.

No differences were found between the different treatments. Material containing 200, 400 and 600 ppm was incubated in a similar manner but results were equivocal. It is suggested that work of a similar nature would be profitable on the root samples from the pot experiment as the magnitude of the aluminium content in the shoots may not have been great enough to affect the decomposition whereas the roots may well be more effective.

2. The effect of calcium and aluminium on plant composition (01D/03D)
(A.G. Lowe and M.J.S. Floate)

In a pot experiment Agrostis tenuis was grown on a Sourhope series soil in a 4 x 4 factorial design with calcium (as calcium carbonate) and aluminium (as aluminium sulphate) as variants. The herbage and roots were harvested and analysed for aluminium, calcium and phosphorus.

The results were compared with the aluminium fractions in the soils (see 1972 Report) and some trends were identified. No statistical analysis has yet been carried out. The aluminium content in the shoots seems to be constant with some high contents on soils with high aluminium values, the calcium and phosphorus seen to be related to the aluminium in the soils. The aluminium in the roots was related to the phosphorus in a ratio of 3:1 aluminium:phosphorus by weight implying that there is more aluminium in the roots than may be assumed by Al PO_4 precipitation in the roots. The aluminium in the roots was one order higher than in the shoots and was related to the soil aluminium. To assess the uptake mechanisms for Al the total plant content was compared with $pH-\frac{1}{3}pAl$ and $(aluminium)^{\frac{1}{3}}$, and there seems to be a good relationship between plant Al and the cube root of the aluminium in water which is not improved by the inclusion of pH considerations.

3. Review of data on soil-Al and organic matter in relation to lime requirement (01D/03D)
(M.J.S. Floate)

During the course of experiments with Ca and Al additions to Sourhope (Brown Forest soil) and Cowie (Peaty Podzol) soils, data has been collected on the pH response to 3 rates of lime. $CaCO_3$ was added in amounts related to the CEC of the soils up to about 3 tonne/ha.

In the absence of added Al the pH of Sourhope soil increased 1.4 units per ton $CaCO_3$ compared with 0.5 units per tonne $CaCO_3$ on Cowie peat. Increasing amounts of Al (also added in relation to CEC) progressively reduced the unit response to lime.

Although organic soils usually give larger unit responses than mineral soils, these results may be due to widely differing density, CEC and Exchangeable Al. Further investigation is planned.

A survey has been made of exchange data for soils collected from sites where soil and vegetation data had been studied in relation to differential grazing management. These soils were from hill areas in S. Scotland where there was no previous record of lime or fertilizer treatment. (Annual Reports 1967, 1968 and 1969).

Exchangeable cations, H and CEC were determined by the Macaulay Institute (neutral N.BaOAC) and exchangeable Al was determined using N.KCl. CEC is largely dependent on soil organic matter content and is greatest in the surface organic horizons and decreases with depth. Low bulk density of highly organic soils results in exaggerated values expressed as meq/100g. In mineral soil horizons exchangeable Al was inversely related to pH but the amounts in organic layers were lower than would be expected for mineral soils in the same pH range (see following table).

Relationship between pH and Exchangeable Al in mineral and organic soils

Soil	pH	Exch. Al meq/100g	Exch. Al meq/100cc
Mineral	4.0–4.5	12.0–20.0	7.0–15.0
	4.5–5.0	6.0–15.0	4.0–10.0
	5.0–5.5	0 - 9.0	2.0– 8.0
Organic Layers	4.0–4.5	2.0–13.0	0.5– 6.0

In surface organic layers CEC and exchange acidity (H) are high but exch. Al is relatively low. In the mineral horizons of the same soils, the apparent discrepancy between exchange acidity and exchangeable Al decreases with depth.

The results suggest that there is a large discrepancy between exchange acidity and exchangeable Al especially for surface organic horizons which could be an artefact of technique or a real observation which requires explanation. Further experimental work is in progress.

PASTURE ESTABLISHMENT (02D)

Determination of conditions for optimum germination of selected grasses and white clover on hill soils

1. Assessment of the effects of different sowing dates on the germination and establishment of perennial ryegrass (Lolium perenne) (J.A. Rogers)

One of the most frequent causes of failure in pasture establishment is the occurrence of a period of drought soon after sowing, when the seeds have just commenced germination. One way of circumventing this is to sow at a time when such droughts are less likely to be a problem. However, in attempting to avoid this problem, another that of frost and low temperature, is likely to be encountered. It was, therefore, decided to study the effects of sowing in the late Autumn and early in Spring.

In a box trial, four cultivars of Perennial Ryegrass, representing early and late flowering types, were sown at two dates in November and March. The early heading varieties were Grenie and S24 while the late ones were S23 and Belgian Melle.

Sowing in November resulted in the early varieties germinating more rapidly than the late ones. Similar differences were recorded between the dry matter yields in July, when Grenie and S23 gave heavier crops than the other two. By October, the late flowering varieties gave the higher DM, nevertheless the early varieties gave the greater total yields. Following the March sowing, on the other hand, there was no difference between the phenological types, although Grenie emerged more slowly than the others. Dry matter yields, which were always lower than those of the November sown plants, again showed no relationship with the phenological type. These results are summarised in the following table:-

	"Final" Emergence		DM yield in June (g per 100 seeds)		DM yield in October (g per 100 seeds)	
Sowing date	November	March	November	March	November	March
Variety	%	%	g	g	g	g
Early flowering						
Grenie	93.6	57.5	59.8	25.4	17.0	15.1
S24	81.5	72.0	52.2	23.3	17.2	12.6
Late flowering						
Melle	58.0	75.5	34.3	27.4	23.9	15.9
S23	62.0	68.5	39.7	26.1	22.1	12.4
l.s.d. P<0.1%	19.12%		10.5 g		4.2 g	
P<1.0%	14.48%		7.4 g		3.1 g	
P<5.0%	10.57%		5.6 g		2.3 g	

It would appear, therefore, that sowing Perennial Ryegrass, particularly the early varieties, but also the late ones, in late Autumn has some advantage over Spring sowing, at least in the first year. By the time that the droughts characteristic of early Summer manifest themselves, it is probable that the plants have developed adequate root systems.

2. Germination of Perennial Ryegrass varieties at different temperatures (J.A. Rogers)

The same four varieties of Perennial Ryegrass that were used in the experiment described above were sown in filter paper culture at temperatures ranging from 5°C to 20°C. At 5°C no germination was recorded for any variety. At 10°C the two early varieties, Grenie and S24, germinated more rapidly than the two late ones. At higher temperatures this intervarietal difference was reduced to a non-significant level. This fits in well with the time of sowing experiment where, following the November sowing, Grenie and S24 emerged more rapidly than the late varieties at the lower temperatures of winter, while at the higher spring temperatures, there was no difference between the phenological types.

PLANT NUTRITION (03D)

Improved Production of White Clover

1. Major nutrient requirements on blanket peat

P. Newbould, W.G. McDermott and G.R. Bolton (in collaboration with Drs. Holding and J. Lowe, MD-ESA)

i) Field experiment

Work on the experiment at Lephinmore described in the Annual Report for 1972 (HFRO 196) has continued. Chemical and statistical analysis is still in progress on many of the samples but the striking benefit of inoculating white clover seeds with rhizobia is shown by the data which are available (see following table). Inoculation at both levels of lime and other fertilisers initially affected establishment by preventing death of germinated seedlings. Subsequently it enhanced the production of dry matter by both the white clover plants and the companion grass. This beneficial effect was enhanced at the higher level of lime, phosphate and potassium. A further advantage of inoculation is shown by the figures for loss of white clover plants over the winter of 1972/73; a much smaller proportion of plants disappeared from the inoculated plots than from those which were not so treated.

The method of inoculating the seeds with rhizobium used in this experiment involved the application of a dilute solution of plant nutrients including trace elements as well as the micro-organisms. A similar solution without micro-organisms was not added to the inoculated seeds. Thus, it is possible that one or other of the added nutrients may have affected the germination, establishment and growth of the clover plants; experiments to examine this possibility are in progress at both HFRO and MD-ESA.

The effect of inoculation of white clover seed with effective rhizobia and level of lime and other fertilisers on the establishment and growth of the plants and the companion grasses on blanket peat (sown 28/6/72).

Lime (tonnes/ha)		2.5		7.5	
Phosphate as slag (kg/ha)		52		85	
Potassium (kg/ha)		56		112	
Inoculation		0	+	0	+
Emergence of white clover (N^o/m^2)					
20/7/72		500	456	543	558
26/9/72		104	431	221	498
23/3/73		25	229	65	323
Loss over first winter (%) (26/9/72-23/3/73)		76	47	71	35
Yield of Dry Matter (kg/ha)					
10/10/72	Clover	4.4	23.1	6.5	36.1
	PRG	5.2	13.1	8.3	9.9
10-12/ 6/73	Clover	9.5	143.7	7.6	207.8
	PRG	43.8	61.4	43.0	100.8

(ii) pot experiments
W.G. McDermott

To complement the field experiment at Lephinmore described elsewhere in this Report (p 33), a series of small pot experiments with white clover growing in the glasshouse has been planned. The pots will be filled with chopped and uniformly mixed peat from Lephinmore. The aim of the experiments is to study the response of white clover plants to additions of fertiliser over a wider range of levels than can be studied in the field.

The first experiment was to determine the ideal level and type of nitrogen fertiliser to establish the plants in blanket peat. Two varieties of white clover, S184 and NZ Huia, were grown with four levels of nitrogen - 0, 20, 40 and 80 kg/ha in both the NH_4^+ and NO_3^- forms. Lime, phosphorus and potassium were added to all the pots at rates equivalent to 5 tonnes, 85 kg and 112 kg/ha respectively. There were five replicates of each treatment.

Statistical and chemical analyses of the samples are still in progress but the results suggest that neither the form of nitrogen nor the amount has had any large effect on shoot production as measured by yield of dry matter. However, the form of the roots and the number of and distribution of nodules appears to differ according to the form in which the nitrogen fertiliser was applied. This experiment will be completed and the work extended to study the responses of white clover to additions of phosphorus, potassium and calcium.

2. Major nutrient requirements on a peaty podzol
(P. Newbould, W.G. McDermott and A.L. Fairlie in collaboration with Drs. J. Holding and J. Lowe, MD-ESA.)

An experiment of similar design to that in progress at Lephinmore was started at Glensaugh in 1973. The heather was burned in February/March 1973 and lime and slag were applied in June 1973. The seeds were sown in August 1973 and although they germinated, the majority were not able to establish because of the onset of a very dry period. The few plants which survived the drought from inoculated seed had an average 9-10 nodules per plant while those from untreated seed had only 1-2 nodules per plant. If insufficient plants remain in Spring 1974 the experiment will be restarted.

3. Coated seeds : experiment on a poorly drained brown earth soil at Sourhope
(P. Newbould, W.G. McDermott and R.H. Armstrong)

A small plot field experiment to investigate the benefit of coating seeds with Gafsa rock phosphate and inoculating them with rhizobia of New Zealand or British origin on establishment and growth of white clover was started in 1973. The site was on the Fasset hill at Sourhope and consisted of a Nardus dominant grass heath overlying a poorly drained brown earth soil. Lime at 3 ton/acre and slag at 15 cwt/acre was applied in September 1971. An attempt to burn the surface vegetation in May 1973 was not wholly successful so paraquat (1 lb/acre) was sprayed on 1st June. The area was rotavated three times and the seeds were sown on 15th June followed by hand-rolling.

There were six treatments in 4-fold replication: bare or coated seed, each with none, New Zealand or British rhizobium from Dr. Holding at Edinburgh. Three lb/acre of Huia white clover or the same weight of coated seed was applied with 20 lb/acre of S23 Perennial Ryegrass as the companion grass. With the coated white clover seed the ratio of seed to coat weight was 4:3, giving a lower sowing rate than the bare seed. The manufacturers claim that this disadvantage is more than offset by the greater establishment of coated

than bare seed. The number of clover plants which germinated and emerged was recorded at weekly intervals and after assessing plant cover by a point quadrat technique samples of the vegetation were taken on 5-7th September for weighing and chemical analysis. Further samples were taken during 1973 so that the winter survival and subsequent growth of the plants could be followed.

Preliminary results for the first harvest only are shown in the following table; the results of the chemical analysis and statistical analysis of the data are still in progress. However, even without the confirmation of statistics it is apparent that the uninoculated seeds, whether coated or not, germinated and established best on this site; the clover plants in both these treatments were well nodulated indicating that indigenous organisms had successfully infected the plants. The inoculum from Edinburgh contained an effective strain previously isolated from Sourhope which should have performed well; its apparent failure is under investigation by the microbiologist at the Edinburgh School of Agriculture. The most successful treatment from the point of view of yield of clover and companion grass in the first year was the bare seed with New Zealand rhizobia. Although the experiment is still in progress it has raised questions about the relatively poor performance of coated seeds which requires further investigation.

The effect of coating and rhizobial inoculation on germination and growth of white clover (Ibdin) in a poorly drained brown earth soil at Sourhope

SEED	COATED			BARE		
Rhizobia	0	New Zealand	Edinburgh	0	New Zealand	Edinburgh
Germination as at 18th July (% of all seeds sown)	36	24	21	37	27	15
Harvest 1 (5-7th Sept.)						
Ground cover (%)						
Clover	28	22	19	38	44	23
PEG	67	56	63	73	72	67
Yield (kg DM/ha)						
Clover	141	145	171	266	396	166
PEG	504	391	564	639	817	224

4. Factors which affect nitrogen fixation
(A. Haystead and A.G. Lowe)

(a) A series of investigations is planned to determine the amount of nitrogen fixed in the hill situation and the conditions required for maximal nitrogen input (fixation) into the hill pasture ecosystem. The initial stage of this programme is the development of a reliable and quantitative technique for the in situ determination of nitrogen-fixing activity. The instrumentation required for the assay of nitrogenase by acetylene reduction is operational and that for the measurement of nitrogen transformations in air/plant/soil systems using ^{15}N is under construction.

(b) The inoculation procedure used in the clover establishment trial at Lephinmore (see 03D pg33) has rendered the apparent beneficial effect of inoculation equivocal. A small scale trial conducted under microbiologically defined conditions on undisturbed peat cores in in progress. The experiment is designed to separate the effects of seed inoculation and nutrient application on the establishment, nodulation and nitrogen fixing capacity of white clover.

Assessment of the availability of P to plants from hill soils

1. Comparison of extraction methods
(M.J.S. Floate)

It was reported in the HFRO Annual Report 1972, No. 196, that inconsistent results were obtained for P extracted from the soils of improved and indigenous areas of pasture on Lephinmore PI development area.

These and other soils, known to be P-treated and untreated, have been the subject of a series of comparisons of methods using extractants and sorption methods: this section describes the results of the extraction studies.

Four extraction methods, likely to be applicable to acid soils, were employed to extract P in solution from four pairs of soil samples. Three of these pairs consisted of soils known to have received P fertilizer within the previous three years, and adjacent untreated soils and the remaining pair were contrasting horizons from a peaty podzol of the Ettrick Association in which P-fixation is reputed to be high.

Analyses were carried out on (+ P) and (- P) soils simultaneously in 3 batches of 10 replicates for each sample. Results for the mean and extreme range for each batch, for each method, for 2 of the soil pairs are presented in Table 1.

The suitability of the method can be assessed from the reproducability of results both within and between batches, and by the magnitude of differentiation between (+ P) and (- P) soils expressed either as the difference or ratio of means.

Table 1. (03D) "Available" P extracted by different extractants (mg/100g)

	Morgan (NH_4OAc)		Bray (NH_4F)		Truog (H_2SO_4)		Olsen ($NaHCO_3$)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Lophinmore + P	21.05	20.50 - 21.75	7.14	5.22 - 8.95	17.62	17.00 - 18.20	20.50	19.20 - 23.04
	19.88	19.00 - 20.50	8.64	7.75 - 9.59	18.38	17.80 - 18.80	18.96	18.16 - 19.88
	18.80	18.50 - 19.00	7.81	7.33 - 8.33	17.62	17.00 - 18.20	19.86	17.88 - 20.08
Lophinmore - P	8.75	8.25 - 9.25	2.73	2.46 - 2.94	6.21	5.90 - 6.30	10.08	9.88 - 10.48
	8.00	7.00 - 9.00	3.20	2.63 - 3.83	5.32	5.10 - 5.80	7.88	7.56 - 8.80
	6.75	6.25 - 7.00	3.17	2.43 - 3.74	6.21	5.90 - 6.30	13.62	12.84 - 15.32
Linhope + P	0.62	0.51 - 0.93	0.88	0.80 - 1.02	0.90	0.73 - 1.18	0.72	0.62 - 0.84
	0.52	0.47 - 0.57	0.96	0.90 - 1.18	0.66	0.36 - 0.76	0.38	0.22 - 0.50
	0.53	0.46 - 0.62	1.33	1.12 - 1.50	1.07	0.92 - 1.26	0.88	0.81 - 0.98
Linhope - P	0.58	0.48 - 0.70	0.42	0.36 - 0.49	0.49	0.38 - 0.73	0.50	0.46 - 0.56
	0.63	0.60 - 0.70	0.38	0.27 - 0.48	0.27	0.14 - 0.54	0.35	0.30 - 0.42
	0.55	0.49 - 0.66	0.67	0.46 - 0.89	0.56	0.46 - 0.64	0.62	0.50 - 0.76
Lophinmore difference (+P) - (-P)		12.08		4.83		11.96		9.24
ratio (+P):(-P)		2.56		2.59		3.04		1.97
Linhope difference (+P) - (-P)		-0.03		0.57		0.44		0.49
ratio (+P):(-P)		0.95		2.15		2.00		1.34

2. Sorption studies and phosphate potential

(M. Pinplaskar, M.J.S. Floate and P. Newbould)

(a) Organic soils

The procedure for measuring P-sorption described in Annual Report 1972 was employed in a comparison of soils from untreated indigenous and P-treated improved pasture patches from the Lephinmore PI development area.

Four pairs of samples were selected in two of which Morgan Extractable P was higher in the untreated soil, and in the other two pairs Morgan Extractable P was higher in the treated soil.

The results are presented in Table 2 and are as difficult to interpret as the data for Morgan Extractable P. The results for desorption from Zero P added give the same ranking of soils as the Morgan procedure. With increasing additions of P, all treated soils (+) show decreasing desorption and, with the exception of (3+), show positive sorption at the highest level of addition. One untreated soil (6+) behaves similarly but the remaining untreated soils are abnormal in that increasing desorption appears to occur with increased P addition. This may be due to enhanced organic matter extraction with increasing P concentration in the surrounding solution.

"F" values facilitate comparisons between soils. "F" value is defined as "Free"-P in solution after equilibration expressed as % of added P. Because all these soils either desorb P or only give small adsorption, "F" values are near to or greater than 100. When the added-P is 3 mg/5 g soil "F" values give the same ranking as Morgan extractant; at higher rates of P additions, the untreated soils give higher "F" values.

Two features are common to the results: the first is that all samples give low or negative values for sorption which might indicate high availability of added P, and the second is that in all pairs of samples the $\frac{1}{S}$ values would suggest higher availability of P in the untreated soils.

The indications are that this is unlikely to be a reliable method for assessing the P-status of organic soils.

Table 2. (03D) P-Sorption studies of P-treated (+) and untreated (-) Lephinmore peat

Sample + or - added P	Morgan -P (mg/100g)	P sorbed from solution by soil (S) (mgP/5g soil) (1)				$\frac{1}{S}$ (at Z = 15)
		P added in solution (Z) (mgP/5g soil) (2)				
		0	3 "F" value in brackets(3)	9	15 "F" value in brackets	
2 +	10.13	- 1.37	- 0.96 (132)	- 0.33	+ 0.12 (99)	8.33
2 -	15.10 *	- 1.50 *	- 1.59 (153) *	- 1.51	- 1.68 (111) *	- 0.60 *
3 +	2.27 *	- 1.45 *	- 1.09 (136) *	- 1.42	- 0.24 (102)	- 4.17
3 -	0.75	- 0.66	- 0.93 (131)	- 1.28	- 1.70 (111) *	- 0.59 *
4 +	5.65	- 1.42	- 0.96 (132)	- 0.42	+ 0.02 (100)	50.00
4 -	15.12 *	- 1.55 *	- 2.16 (172) *	- 2.87	- 4.18 (128) *	- 0.24 *
6 +	7.10 *	- 1.09 *	- 0.51 (117) *	+ 0.58	+ 0.96 (94)	1.04
6 -	5.56	- 0.70	- 0.41 (114)	+ 0.12	+ 0.62 (96) *	1.61 *

See footnote on Table 3

(b) Mineral soils

The technique has also been used in comparing untreated and P-treated soils from Sourhope and Linhope series of Brown Forest soils (Table 3).

These soils all behaved normally in that sorbed-P increased with increasing increments of P added.

Morgan extraction ranks the Sourhope and Linhope soils:- S + P > S - P > L + P ≃ L - P and this ranking is confirmed by sorption values. It is interesting to note that the P status of Sourhope soils is higher than Linhope, that surface layers are higher than lower layers, and P-treated soils are higher than untreated soils. The higher sorbed-P values for Linhope provide experimental evidence for the higher fixation capacity of soils of the Ettrick Association.

The "F" values indicate the proportion of added P which remains "Free" in solution and these values for P-treated soils of both Sourhope and Linhope (at 3 mg/5 g soil) are double the values for untreated soils. The values suggest that some 30% of added P may remain available in the P-treated Sourhope soil compared with less than 5% in the untreated Linhope soil.

For comparison two horizons from Minchmoor peaty podzol (Ettrick Association) were included. The A horizon ranks between Sourhope and Linhope, while the B horizon has a very low P status, and higher P-sorption than any other soil examined.

The results suggest that "F" values derived from sorption from 3 mgl/5g soil may be a useful index of P status for mineral soils.

(c) Phosphate potential

Schofield (1955) proposed the use of phosphate potential ($\frac{1}{2}$pCa + pH_2O_4) as an index of the availability of soil phosphate and attempts have been made to measure the phosphate potential of hill soils. 10 g samples of soil were shaken for 0.5 mins with 50 ml 0.01 M $CaCl_2$ and P was determined in the filtered solution. Very low concentrations (10^{-5} - 10^{-6}M) were found and the errors in measuring these low concentrations were large. This procedure is thought unlikely to prove useful in assessing P in hill soils.

Reference:- Schofield, R.K. (1955) Soils & Fertilizers 18, No. 5.

Table 3. (03D)

P-Sorption studies of P-treated Brown Forest Soils

Soil Sample	Morgan P (mg/100g)	P sorbed from solution by soil (S) (mgP/5 g soil) (1)						$\frac{1}{S}$ (at Z = 15)
		P added in solution (Z) (mgP/5 g soil) (2)						
		0	3		9	15		
			"F" value in brackets (3)			"F" value in brackets		
Sourhope (+P) 0-5 cm	1.01	0.03	2.03	(32)	3.57	4.96	(67)	0.202
5-10 "	0.72	0.01	2.19	(27)	4.30	4.82	(68)	0.208
Sourhope (-P) 0-5 cm	0.79	0.02	2.52	(16)	5.47	7.42	(51)	0.135
5-10 "	0.78	0.00	2.73	(9)	6.46	8.50	(43)	0.118
Linhope (+P) 0-5 cm	0.56	0.01	2.77	(8)	6.51	8.30	(45)	0.120
5-10 "	-	0.00	2.84	(5)	6.72	8.94	(40)	0.112
Linhope (-P) 0-5 cm	0.59	0.00	2.88	(4)	6.44	8.56	(43)	0.117
5-10 "	-	0.00	2.90	(3)	6.92	8.86	(41)	0.113
Minchmoor A	0.30	0.00	2.28	(24)	4.74	6.30	(58)	0.159
Minchmoor B	0.14	0.00	2.95	(2)	8.62	12.80	(15)	0.078

Footnotes for Tables 03D-2 and 03D-3

1. Negative values indicate desorption of P from soil to solution
2. Equivalent rates for (Z) : 3 mgP/5 g Soil ≡ 60 kgP/ha
3. "F" value is "Free"-P in solution after equilibration, i.e. "F" = $\left(\frac{Z - 5}{Z}\right)100$

* Asterisks indicate higher index of availability in each pair (applies to Table 03D-2 only)

3. Assessment of tracer techniques - "L" value experiments

(M. Pimplaskar, P. Newbould and M.J.S. Floate)

Lephinmore, Glensaugh, Sourhope and House o' Muir soils were assessed in likely relative order of P-availability by sorption studies (Annual Report 1972, No. 196). Although Lephinmore was assessed high by this means it was thought possible that the total soil-P pool might be limiting. In order to test these suggestions, and to evaluate the "L" value assessment of availability of P in hill soils a pot experiment was undertaken in the glasshouse.

Labile soil phosphate "L", (Larsen, 1952) was measured for 4 soils, with 2 test crops - ryegrass S.24 and white clover S.184, at 2 levels of P addition - 1 ngP/5 g soil and 5 ngP/5 g soil.

Standard volumes of each soil were mixed with N(30 kg/ha), K(80 kg/ha) as KNO_3, and $CaCO_3$ (2.5 tonne/ha), Tracer P-32 was added at the rate of 6.4 μCi per pot together with carrier P-31 at 1 and 5 ngP/5 g soil. Soils were uniformly mixed, packed into 4" pots, wetted to field capacity, and planted with 100 seeds per pot. These were arranged in a "Balanced Latin square design" with 5 replicates. For comparison, a small experimental control with no added P, using 2 replicates of the same soils and crops, was carried out simultaneously. Germination was uneven in P_2 treatments and clovers failed altogether possibly due to high salt concentrations in the soil surface. Pots were re-seeded and kept wet from above. All pots were maintained at 60% field capacity. Ryegrass was cut twice, after 6 and 11 weeks and clover cut once only after 10 weeks. Clover tops and roots were separated. Total DM production, Total P uptake and Tracer P-32 uptake were determined and "L" values were calculated by the following formula.

$$\text{"L"} = \frac{32 - \text{P added}}{32 - \text{P in plant}} (\text{stable P in plant} - \text{P in seed}) - \text{Stable P added to soil}$$

A complete analysis of the results has yet to be completed but the following preliminary comments can be made.

(a) In the absence of added P, DM production increased in sequence:-
Lephinmore (L) < Glensaugh (G) < Sourhope (S) < House o' Muir (H) for clover but for ryegrass S > H. Poor growth in H was believed to be due to N deficiency in the latter stages.

(b) Both crops, in all the soils responded to added P with increased DM production. The greatest response was to P_1 and P_2 gave little extra response except for ryegrass second cut on Sourhope. Response was greatest on Lephinmore and least on House o' Muir soils.

(c) P-uptake at P_0 and P_1 levels was broadly related to DM production but P_2 produced notably higher P uptake, in all soils but especially Lephinmore.

(d) There was little difference in DM production or P uptake between the 2 crops on different soils except for lower ryegrass production on House o' Muir.

(e) The calculation of "L" values for ryegrass P_2 treatments gave negative values; best agreement between replicates was obtained from clover tops at the P_1 level and for ryegrass at the same level at the second harvest.

(f) These results give "L" values between 0.2 and 0.6 ngP/5 g soil in order L < G < S < H.

This ranking of the soils is broadly the same as that for DM production, and P-uptake for both crops but does not coincide with the ranking predicted from sorption studies or from Morgan extractable P assessments.

The results suggest that this may be a useful technique for assessing the P-status of hill soils, and that it warrants further investigation. A comparison with estimates of soil P by isotopic exchange ("E" values) will be measured in future laboratory equilibration experiments.

Improvement of the growth and nutrition of herbage plants by the use of earthworms
P. Newbould, W.G. McDermott, E.G. Hallsworth (CSIRO, Australia) and W. Guild (ZD-ESA)

No further progress has been made. The second batch of earthworms from Australia is expected shortly; the first batch died during attempts to multiply their numbers in Edinburgh. New methods of collecting specimens from soil are to be tried by our Australian collaborators who found manual digging extremely laborious. It is hoped to use either an electrical shock or chemical method to bring the earthworms to the surface where they can be easily collected.

PASTURE ESTABLISHMENT (04D)

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

The experiment is sited on one of the production paddocks (P2) of the 'Hairney Law-Auchope Project' (Year Round Grazing System) and consists of two areas, each of 60 m x 60 m, which vary in bracken density. The underlying vegetation is composed mainly of Agrostis and Festuca species on brown earth soil. During 1973 plots were marked and the herbicide "Asulox" applied in late July at the recommended rate of 6.4 kg a.i./ha and at a volume rate of 450 litres/ha. No deleterious effect on the grass cover was observed after treatment and only a slight scorching of the growing tip of the bracken fronds occurred. All plots were later sampled for bracken frond counts and height measurements.

Area 1 gave a mean count of 33 fronds per sq m and a mean height of 75 cm whilst Area 2 gave a mean frond count of 27 and a mean height of 58 cm per sq m. The data also showed that although the sampling method used was adequate, large experimental errors occurred and though the variation in grass growth is as yet unknown it was considered necessary to change slightly the experimental layout. This has now been done and the areas to be recorded in 1974 fenced.

Records to be taken in 1974 and 1975 will be concerned mainly with detecting possible changes in dry matter production and species composition of the underlying vegetation following treatment. In addition it is hoped to collect information on the effect of the bracken canopy on soil temperature and moisture.

EFFECTS OF UTILISATION : MOORLAND (05D)

The effects of utilisation by grazing hill sheep
(Sheila A. Grant, W.I.C. Lamb, C.D. Kerr and G.R. Bolton)

1. On stability and productivity of blanket bog, Lephinmore.

Plots were established on wet and dry variants of blanket bog in the summer of 1971. Patterns of grazing on these plots are related to periods of use of the hill component of the two pasture systems currently being developed at Lephinmore. For each pattern and site type, the effects of three grazing pressures are being examined.

In the initial phases of the study detailed records were collected on the seasonal patterns and levels of use of the various bog species. Two methods were used (a) observation of permanently sited quadrats to estimate utilisation using a scoring technique and (b) the examination of cuticle fragments in faeces obtained by grab sampling as the sheep were taken off the plots. The results were broadly similar from year to year. The reader is referred to the 1972 Report where seasonal patterns of use and grazing pressure effects were described. Little can be added to that report at this time other than to say that in the second year there was evidence of a March peak for the utilisation of Eriophorum vaginatum. Results for the third year are not yet available. It is hoped to write up this phase of the study during 1974/75. The intensity of monitoring the experiment will be scaled down during the next two years with grazing pressures continuing as initially set. Floristic analyses will be made each July and in the event of species composition remaining unaffected by current grazing pressures the treatments will be reviewed in 1975.

Subsidiary projects:-

(a) Serial sampling of bog species to determine seasonal patterns of in vitro dry matter digestibility and chemical composition as measured by the van Soest chemical techniques. Species sampled Trichophorum caespitosum, Molinia caerulea, Eriophorum vaginatum, E. angustifolium, Juncus squarrosus, J. articulatus and mixed Carices with Carex panicea and Carex echinata predominating. The separated green material of Trichophorum, Molinia and Carex spp gave in vitro d.m.d. values of 66-68 per cent in May falling to 64 per cent in June. Thereafter the Carex spp. maintained the highest digestibility returning values of 57.50-61.0 through to December. Trichophorum fell very slowly until August after which values as low as 38-40% were returned. Molinia dropped more steadily falling to 52.5 in July and 49.3 in August but remained in the upper 40's until December when very low values indeed were returned by the now dead Molinia 'hay'. The two Eriophorum spp. gave values of 62-66% in May but fell to values of 36-40 by July. Low values were returned for samples collected in August, September and October but a substantial improvement was shown by the December samples. For Eriophorum vaginatum green material was 56.05, drawn leaf bases were 65.2 and the young flowers were 76% digestible. The two Juncus species responded very differently to in vitro analysis. The technique clearly fails with J. squarrosus which returned meaningless values between 15 and 28%. J. articulatus gave values in the mid 60's until July, falling to 59 in August and to the 40's by September and October.

Using the Van Soest analyses data and the equation DDM = 0.98S + W(14 - 78.9 Log L) - 12.9 the DDM's were calculated to see how the results compared with the in vitro analyses. For the May-June period values in the upper 60's were returned for Carex spp. Molinia and Trichophorum. For the latter two species however the fall in quality with season was less than that indicated by the in vitro analyses. The results of Eriophorum vaginatum showed excellent agreement with the in vitro

analyses while those for E. angustifolium were poor returning values of 51-55% DOM and showing no seasonal trends. The results for Juncus squarrosus seemed reasonably sensible - a value of 60% being indicated for May, falling through the 50's in June and July to the mid 40's by August. Thereafter values remained low until and including October but climbed to 54 in December - a pattern very similar to that exhibited by E. vaginatum. Juncus articulatus has very low lignin levels so that the equation returned unrealistically high DDM's.

(b) Cuticle Identification in Faeces. Because of doubts as to the ability to distinguish between the cuticle fragments of certain species with any degree of confidence, collections of species were made at intervals throughout the year. To date samples of fresh material from June and September have been chopped with scissors and subjected to the in vitro digestion procedure before preparing reference slides for cuticle identification. The degree of variation in cell size and shape within species was found to be quite wide and certainly greater than that reported by Martin (1955). Indeed some species, e.g. Eriophorum vaginatum, differed in the description of average cell size and shape and others, e.g. Trichophorum caespitosum, which Martin suggests may not survive the action of the digestive juices, did survive the in vitro process. Though Trichophorum cannot be distinguished with any degree of confidence from E. vaginatum cuticle fragments with cells of the Trichophorum type predominated at times of the year when Trichophorum was the main dietary constituent. Samples for 1973-74 are currently being examined.

(c) Selective grazing behaviour of sheep as between Calluna and E. vaginatum:- crated grazing animal trials.
Analyses indicate that the green material of Eriophorum is superior in quality to Calluna during the January to March period and yet grazing records from the main experiment suggest Calluna is grazed in preference to Eriophorum. This could be due to a poor availability of green Eriophorum (most leaf tips are dead) and/or failure to detect drawn leaves of Eriophorum, the grazing of which is thus underestimated. To study sheep behaviour as between these two species in the January-March period in more detail, crates were designed for grazing animals so that their grazing could be restricted to pre-recorded selected sites and their grazing behaviour closely observed. Pilot trials have been carried out during February and March. The results are only just to hand and have yet to be analysed.

2. On carbohydrate reserves and re-growth of heather (05D/04B)
(W.I.C. Lamb)

Initial results using the anthrone method for detecting water-soluble carbohydrates were inconsistent. Tests showed the method to be sensitive to a number of factors difficult to control when using manual procedures. For this reason, and to speed up sample flow, the method was adapted to suit automated analysis with the help of Mr. E. Skedd. Results from the cutting experiment at Bush suggest that it will be worthwhile investigating further the relationships between water-soluble carbohydrate levels, defoliation and re-growth. Levels ranged from 1-4% for wood and 3-7% for green tissue.

The difficulty of separating heather roots from organic rooting media has ruled out investigations of root carbohydrate levels. Recent investigations of sand as a rooting medium have been promising. Of six different nutrient solutions tested, the one which produced the best results had low nutrient levels and a high ratio of NH_4^+ to NO_3^-.

3. On growth form and productivity of heather moor (05D/04B)

(a) Cutting experiment at Bush. (Sheila a Grant and W.I.C. Lamb)

In this experiment heather plants growing in boxes are being subjected to different seasonal patterns and levels of clipping to determine the effect of utilisation on both quantity and quality of the dry matter produced. The plants are now four years old and the experimental treatments have been applied for three years.

Plants which had been clipped for two years but which were rested in 1973 were removed as thinnings in August. The fresh and dry weights of the thinnings were recorded. Material from two blocks was kept for the measurement of carbohydrate reserves while that from the third block was separated into the various plant fractions flowers and current season's green shoots, older green material, dead shoots and wood. The proportion by weight of these fractions was recorded and the material was then ground and is currently being analysed for nitrogen, phosphorus, potassium, calcium and magnesium content.

Undefoliated and lightly defoliated plants were already becoming quite tall and open in habit with only 30% by weight of the above ground biomass accounted for by current season's shoots. Growth forms became increasingly compact as defoliation became more severe with a tight cushion like habit being assumed by plants undergoing the most frequent and the heavier defoliation. With such growth forms current season's growth accounted for 60% of the above ground weight. Total dry matter output to date has yet to be analysed

Plants remaining in the boxes were clipped according to schedule during 1973. Though the plants were a year older, the average weight of clippings harvestable per plant was scarcely more than for 1972. The onset of growth was unusually late in 1973, the mid-May harvest having to be delayed until late May-early June. Regrowth following clipping was not evident until some four weeks after cutting and it is thought that, though the boxes were watered regularly, the summer drought could have caused internal water deficits which depressed growth rates (note: growth was also poor after July in 1972 again in association with a prolonged drought).

The clippings were analysed for nitrogen and cell wall constituents. The results are summarised in the table below:-

Chemical composition of heather clippings
(Results expressed as a percentage of DM)

	May		July		September	
	N_2	C.W.C.	N_2	C.W.C.	N_2	C.W.C.
Means						
Half shoots	2.44	32.30	1.63	35.56	1.50	39.87
Whole shoots	2.44	31.00	1.59	38.00	1.52	38.59
Treatment at immediately preceding harvest						
0 (no cutting)	1.94	32.66	1.41	37.65	1.29	40.32
½ (40% length)	2.41	32.29	1.65	35.85	1.50	39.47
1 (80% length)	2.79	30.00	1.77	36.85	1.78	37.78

(b) Grazing experiment - Big Hill, Glensaugh
(Sheila A. Grant, J.A. Milne and W.I.C. Lamb)

The aim of this experiment, which is a joint enterprise with Dr. J.A. Milne, is to investigate the effects of different levels and patterns of utilisation on the growth form and dry matter production of heather and on the quality and quantity of the diet selected by grazing sheep. There were two periods of grazing, viz. June-July and September-October. Available current season's growth was measured prior to each grazing period, with allowance being made for growth during the June-July period, and stock numbers were adjusted to achieve utilisation levels of 0, 40% and 80% of current season's dry matter. All permutations of time of year and level of utilisation were provided thus there were nine plots.

At the close of each grazing period levels of utilisation were assessed using a scoring technique which estimated the percentage of heather cover within sample quadrats showing signs of grazing. In addition, the proportion of the grazing falling into three classes as detailed below was noted, viz. 'A' less than half current season's long shoots removed, 'B' more than half current season's long shoots grazed, and 'C' all current season's long shoot grazed, shoot eaten down to previous season's wood. Shoots (all cut at ground level) were also sampled from grazed and ungrazed plants within each plot at the close of the grazing periods for the measurement of water soluble carbohydrate reserves.

Oesophageal fistulated sheep were used towards the beginning and close of each grazing period to collect samples which were used to establish both the nature and quality of the material being ingested by the sheep. Four samples per plot, using separate sheep on consecutive days, were collected during each of the sampling periods. The samples were stored in the deep freeze until analysis was possible.

Results of the first year's run with respect to animal performance, intake and digestibility of the heather are reported by J.A. Milne under project 04B.

Results for which the 05D team are responsible are summarised below.

(i) Productivity of heather

The mean yields of current season's shoots on ungrazed areas of heather amounted to 510 kg/ha on 12th June, 1635 kg/ha on 18th July and 2800 kg/ha on 11th September. Yields on grazed areas on 11th September averaged 1500 kg/ha. Available current season's growth for the first grazing period was taken as the amount available at the beginning of the grazing period plus the yield estimated for the close of the grazing period, the 30th July (1935 kg/ha, found by extrapolating from the growth curve) divided by 2, i.e. 1200 kg/ha. For the second grazing period amounts were calculated on the basis of the amounts available on grazed versus ungrazed areas of the plots, the percentage of the area grazed having been assessed at the close of the June-July grazing period. Amounts available varied from 2800 kg/ha on previously ungrazed plots to just over 2000 kg/ha on plots hard grazed in June-July. These data plus grazing days per unit area, estimates of the percentage of the area grazed, a breakdown of this grazing into percentage accounted for by each class and mean height of stand are summarised in the following table.

TABLE I

Plot No.	2	4	5	6	7	8	9	10
Treatment	0 1	1 0	½ ½	½ 1	½ 0	1 ½	1 1	0 ½
Available Calluna June/July	-	1200	1200	1200	1200	1200	1200	-
Available Calluna September/October	2800	-	2206	2224	-	2103	2032	2800
Grazing days unit area								
June/July	-	1031	523	558	540	732	927	-
September/October	3295	-	775	2072	-	702	1472	1009
% grazed at close								
June/July	-	52.5	45.7	44.3	39.2	53.6	59.1	-
September/October	54.8	(51.2)	49.0	67.0	(38.9)	53.4	74.7	32.1
Class of grazing as a percentage of								
total 'A'	11.7	19.8	17.4	5.1	24.1	16.4	9.9	18.3
'B'	43.8	57.2	61.4	32.7	56.2	48.9	33.5	43.8
'C'	44.5	23.0	21.2	62.2	20.7	34.7	56.6	37.9
Estimate % utilisation	50.1	38.5	37.7	69.3	28.4	44.9	73.5	27.3
Height stand (cm)								
ungrazed	14.4	13.0	12.7	13.3	13.7	13.9	13.6	14.6
grazed	4.8	8.5	6.2	6.1	7.6	7.7	5.7	6.8

* 'A' weighted x .25; 'B' x .75; 'C' x 1.25

(ii) Utilisation

The grazing behaviour of the sheep was influenced by several factors, e.g. the presence of small patches of grass, rushes, bare ground, the siting of water troughs, topography, presence or absence of sheep in neighbouring plots, etc. so that grazing tended to be uneven with heavily utilised and ungrazed areas. The heavier the grazing pressure, the more evenly distributed was the grazing. Grass and rush patches, though only accounting for between 0.1 and 2% of the cover, were selectively grazed so that in the early part of the June-July grazing period heather averaged less than 60% of the dietary intake. On all plots there were signs of class 'C' grazing, i.e. all the current season's long shoot plus some of the previous season's wood. Sometimes this was only 1-2 mm old wood and sometimes well down the stem. The incidence of class 'C' grazing increased as grazing pressure increased but so did the incidence of broken and torn off heather shoots - these usually having a fair amount of second year wood. Thus the grazing and utilisation estimates reflect the penalty incurred by the sward but not necessarily the nature of the ingested material.

(iii) Nature of diet selected

Samples of ingesta from oesophageal fistulated sheep were preserved in Formalin-aceto-alcohol. After stirring, thin suspensions of the samples were placed in shallow dishes and examined under desk lamp magnifiers. Counts were made of the various species present using a series of line transects and for heather, leafy shoots were distinguished from wood. Differences due to ageing within the season and between individual sheep existed. There were no consistent differences occasioned by treatment but it should be borne in mind that this was the first year of grazing and that the sward was uniform at the outset.

Percentage Calluna in the June samples was highly variable ranging from 3-100%, the average over all plots and sheep being 59.5%. By July Calluna accounted for 96.8% of the diet (the grass and rush patches having been grazed to the ground). In September Calluna accounted for 90% of the diet and by October almost 98%. The percentage of woody shoots was 13.6, 19.2, 25.9 and 32% in June, July, September and October respectively. Longest shoots per sample examined averaged 1.9 cm in June and increased to 2.96 cm by July. In September the mean was 2.68 cm rising to 2.89 cm by October. Most shoots however fell within the range 0.5-1.5 cm. Occasionally shoots of 5-6 cm were found. Differences between sheep suggested that some animals may be able to select a more leafy, less woody diet than others. For example Sheep D57 selected heather averaging 18.8% wood in September and 29.1% in October. Sheep NT on the other hand selected heather containing 29.9% wood in September and 39.8% in October.

4. On the production and utilisation of grass and heather in mixed swards

A joint report will be found under 04E/05D - "The utilisation of grass and heather by the grazing sheep".

EFFECTS OF UTILISATION : PASTURE (06D)

1. Effects of defoliation on pasture regrowth
(J. King)

From time to time various mechanisms have been suggested to account for the effects of defoliation on pasture regrowth. There is evidence for example that regrowth can be affected by the level of labile carbohydrate reserves. Similarly growth has been related to leaf area index and an optimum leaf area has been postulated at which growth is maximised. It seems probable in the grazing situation that both these mechanisms are involved, their relative importance changing according to the nature of the defoliation regime.

An experiment was carried out in 1973 to examine this possibility. The object was to relate regrowth and sward characteristics to defoliation and to identify the conditions under which different sward characteristics such as leaf area index and soluble carbohydrate level might each have a controlling influence.

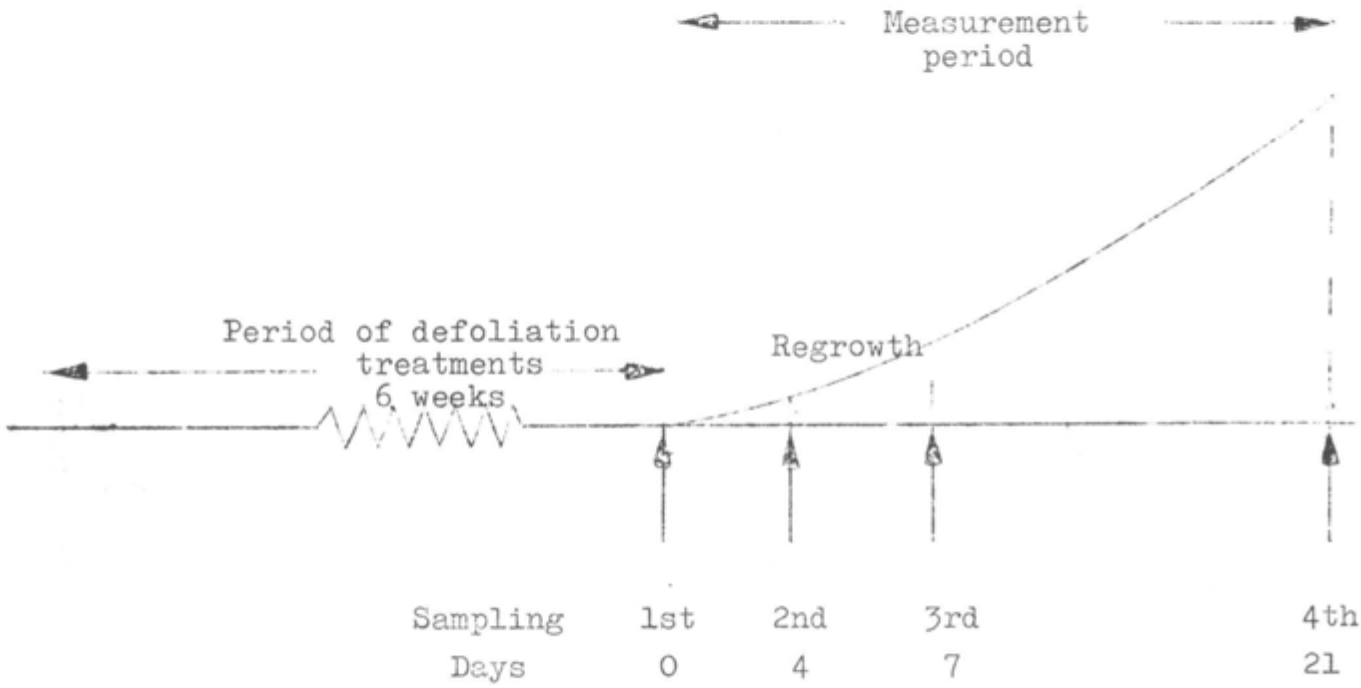
The experiment was carried out on small swards of Ryegrass (S.23) growing in large plant pots. These were sown in spring 1973. Defoliation treatments were as shown below, giving nine factoral combinations of frequency and intensity of cutting. The range of frequency and intensity was intended to cover that found in continuously grazed swards.

Frequency	Intensity	Sampling Dates	Replications
Cut every 7 days	Cutting height 2 cm		
" " 10 "	" " 3 cm	4	6
" " 21 "	" " 4 cm		

After the swards were fully established the differential cutting treatments were applied for six weeks. At the end of this time all treatments were sampled by withdrawing pots from the experiment, the remainder being allowed to regrow without further defoliation treatment.

Further sets of samples were withdrawn after 4 days, 7 days and 21 days regrowth (Fig 1).

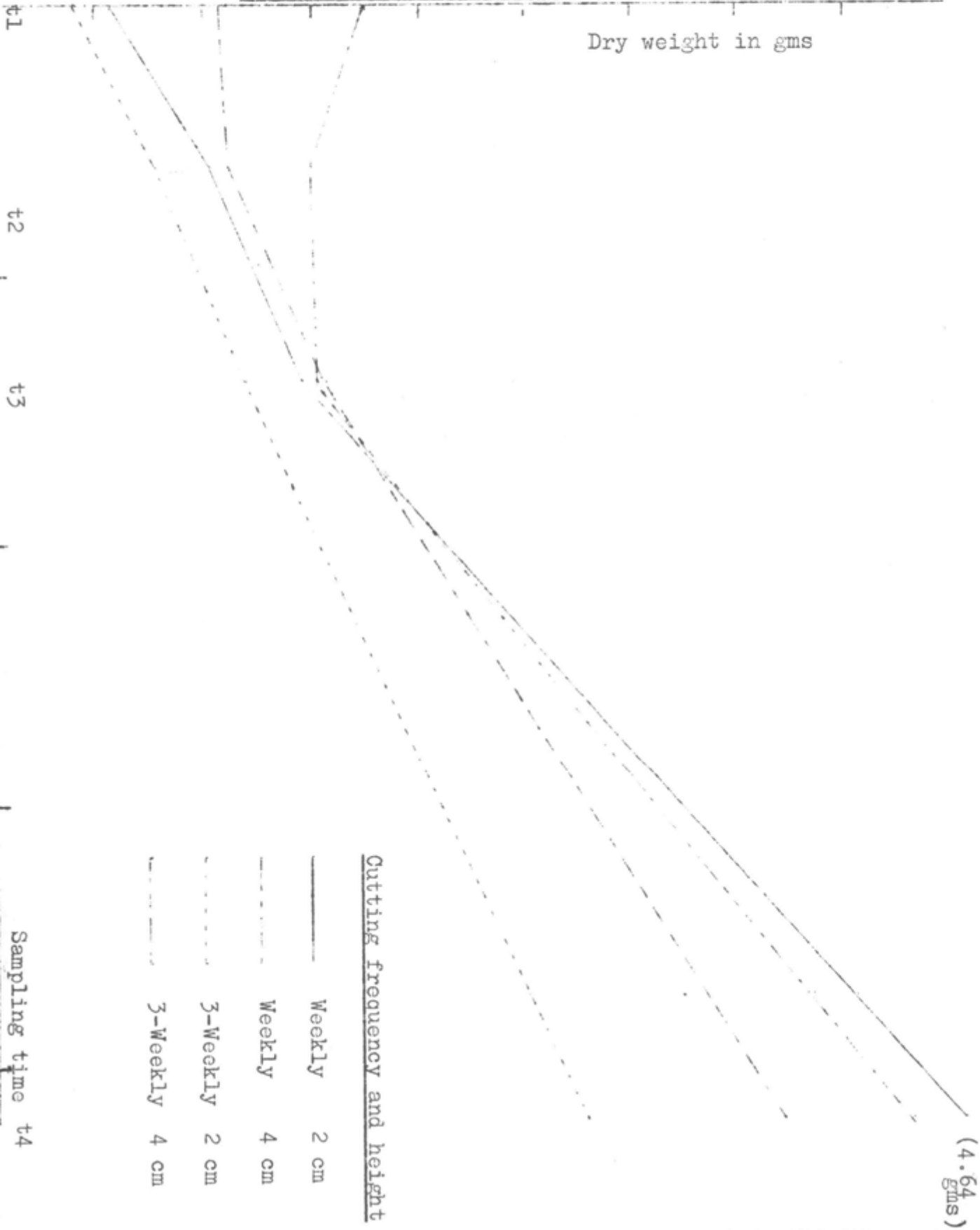
Fig. 1. Experimental procedure



Results

The effect of the defoliation treatments was to produce nine swards differing in growth form and ranging from dense and prostrate to open and erect. The essential characteristics of the swards produced by the four contrasting treatments are given in Table 1. The regrowth of these swards in terms of production of new leaf is given in Fig. 2.

Fig. 2. Regrowth of young leaf/unit area ground for swards of S 23 defoliated at different frequencies and intervals.



It is worth noting in Table 1 that the proportion of the crop removed by a single defoliation is much lower on the weekly as opposed to the 3 weekly cut swards. A high frequency - close cutting regime - therefore need not inpose high stresses on the plants.

Fig. 1 shows that the regrowth over 0-7 days was greatest on the weekly cut treatments. Indeed the 3 weekly cut swards scarcely produced any new growth at all in this period. The reason appears to be connected with a high rate of senescence of older leaves in such swards. The high regrowth rate of the weekly cut swards may be due in part to the high levels of soluble carbohydrates that occurred, but, in the case of the weekly cut 2 cm swards, a low rate of leaf senescence and an adequate leaf area index may also be responsible.

Regrowth rate from 7-21 days was poor only in the 3 weekly cut 2 cm sward. This seemed to be related to the very low leaf area achieved by this sward at 7 days.

In general the results of this experiment show that high frequency, close defoliation need not depress regrowth and indeed may inpose only a moderate stress on the plants. Senescence or high respiration losses appear to be important and may prove to be a major cause of low regrowth rates. The role of carbohydrate level is still unclear but the results are consistent with the notion that high carbohydrate levels are necessary if leaf area is inadequate, but not otherwise. Defoliation frequencies of once in 7-10 days are reported to occur where grazing is heavy (Hodgson & Ollerenshaw, J Brit. Grass. Soc. 24, 1969) and it will be of interest to learn whether or not such frequencies lead to a reduction in regrowth capacity. The present results suggest that they need not do so.

TABLE 1. Sward characteristics produced by four defoliation regimes

Defoliation frequency height	Cut weekly		Cut 3 weekly	
	2 cm	4 cm	2 cm	4 cm
Leaf Area Index	2.4	5.0	1.0	3.6
Tiller No. per dm^2	302	288	254	272
% Total soluble carbohydrates in stems	22.0	23.7	24.9	30.4
% Crop removed by a single cut	20.0	11.0	60.0	35.0
Growth form	prostrate		erect	

2. Measurement of growth rate of continuously grazed pastures (J. King)

The method commonly used to measure pasture growth in the presence of grazing animals involves the determination of the difference between the yield of crop on caged and uncaged sample areas. This is unsatisfactory for a number of reasons. It is usually necessary to use measurement periods of at least two weeks and on hill pastures even longer periods may be needed. The result is that growth within the cages becomes dissimilar to that outside. In addition the loss of leaves by senescence is appreciable and cannot readily be measured.

Measurement of net photosynthesis by means of Infra-Red Gas Analyser (IRG offers a possible alternative method of assessing pasture growth. This has the advantage that senescence losses can be allowed for, and that no protectiv cages are necessary the measurements being made directly on turf samples taken from the grazed sward.

It is proposed during 1974 to test the method by attempting to measure the relative growth rates of pastures grazed at contrasting grazing intensities.

An apparatus has been constructed to allow the method to be evaluated. If successful, a large apparatus will be needed to handle the number of samples likely to be required and this will be most conveniently used in conjunction with the proposed controlled environment facility.

The method involves the measurement of the net photosynthetic rate (P net) of different swards in terms of CO_2 consumption under standard conditions of temperature and light intensity.

Turf samples (each 5 dm^2) are taken from the pasture and placed in a Perspex chamber through which air is circulated at the desired temperature and which is exposed to artificial light of standard intensity. The air stream is sampled at appropriate points and the apparent net consumption of CO_2 by the growing sward and (P app) is determined by measuring the depletion of CO_2 in the air stream by means of the IRGA.

Production of CO_2 by combined soil and plant respiration (R_d) is also determined by measuring the degree of CO_2 enrichment of the air by the whole turf (R_d), and by the soil + roots alone (R_{s+r}) in the absence of light after the herbage has been cut off. From these measurements net canopy photosynthesis (P_{nc}) gross photosynthesis and canopy respiration (R_c) can be determined.

Two questions remain to be resolved before the method can be used extensively. These are, firstly, the rate at which samples can be processed. With the present apparatus this is unlikely to exceed 6-9 samples per day, and this will limit the application of the method. Secondly, sampling errors: with such small samples this may be large and a suitable way must be found to overcome this.

It is proposed to test the method first on a grazing experiment carried out at House o' Muir on a pure sward of S.23 Ryegrass.

Treatments

Stocking rate adjusted to produce and maintain pastures in the following states:

1. Very short approximately 2 cm deep
2. Short " $3\frac{1}{2}$ " "
3. Moderately short " 5 " "

Sward length is monitored and stock numbers adjusted weekly.

The treatments are applied for at least six weeks and may be continuous. In the sixth week the paddocks are sampled for measurement of photosynthetic rate. This can be repeated at intervals over the season.

During 1974 it is hoped to obtain data for at least one and possibly two measurement periods.

NUTRIENT CYCLING (07D)

1. Redistribution of phosphorus in hill soils

a) Fence line soil data
(M.J.S. Floate and I.A. Nicholson)

Data collected between 1966-1968, and subsequent analytical data from soil samples, have been re-assessed and is currently being prepared for publication.

b) Sheep intake and output of P and the effects of faecal P content on water solubility
(M.J.S. Floate and A.J.F. Russel)

Previous studies showed that the inorganic P of dried and milled faeces was almost 100% water soluble but that solubility was reduced when whole pellets were dried. It was planned to examine the effects of wide variation in P intake upon faecal-P content, and upon the water solubility of P in whole pellets but suitable material has not come available yet.

2. Mineralization of nutrients from plant materials and sheep faeces (07D/01D)
(M.J.S. Floate)

Plant materials and sheep faeces from control and lime-treated plots of 2 Input-Output experimental areas (Expts. 2 and 3) were collected in 1971 (Annual Report 1971). These materials have been used in incubation experiments to assess the effects of 3 levels of lime addition upon the mineralization of N and P and upon the production of CO_2 throughout 12 weeks at 10°C.

Data are given in Table 1 for materials used, amounts of lime added and for amounts of CO_2, N and P mineralised at the end of 12 weeks. The results indicate that lime addition may have stimulated CO_2 production but odd results were obtained for N and P mineralization.

It was believed that these odd results may be due to the inoculum which had been obtained from dried and stored soil samples. Accordingly the experiment is being repeated using a freshly prepared inoculum: to date results for F_2 herbage at 4 levels of lime addition are available and these are presented in Table 2.

The trends indicated for this one material will need to be confirmed but the first indications are that lime has not greatly stimulated mineralization. A series of pH measurements were made during incubation (Table 3) and it was found that in all treatments (including L_0) pH rose to near 7.0 by 6 weeks. This could account for similarity of mineralization between treatments and may be due to dissolved ammonia in the moist substrate: further investigation is in progress.

Table 07D 1

Effects of lime on mineralization of nutrients from plant and faecal materials (stored soil inoculum)

Material and Treatment	Amount of lime added ($CaCO_3$ mg/g)	C as CO_2 mg/100g	NH_3 mg/100g	NH_4 mg/100g	Inorg. P mg/100g
Festuca-Agrostis herbage (Expt. 2)					
L_0	-	5438	1.3	26.2	138
L_1	10 mg/g	5937	8.3	1.5	380
L_2	100 mg/g (2.5 ton/ac)	7281	4.1	0.0	256
Molinia-Nardus herbage (Expt. 3)					
L_0	-	3090	1.6	12.9	38
L_1	10 mg/g	4830	2.7	2.4	40
L_2	100 mg/g (2.5 ton/ac)	5188	0.5	2.5	23
Sheep faeces (Expt. 2)					
L_0	-	1949	32.6	5.7	319
L_1	30 mg/g	1919	62.6	9.0	310
L_2	60 mg/g (2.5 ton/ac)	2649	41.7	5.2	279
Sheep faeces (Expt. 3)					
L_0	-	1998	29.4	31.1	331
L_1	30 mg/g	2120	30.2	10.5	315
L_2	60 mg/g (2.5 ton/ac)	2060	12.2	16.1	292

Table 07D 2

Effects of lime on mineralization of nutrients from plant and faecal materials (fresh inoculum)

Material and Treatment	Amount of lime added $CaCO_3$ mg/g	C as CO_2 mg/100 g	NH_3 mg/100 g	NH_4 mg/100 g	Inorg.P mg/100 g
Festuca-Agrostis herbage (Expt. 2)					
L_0	-	3632	11.5	92.6	28
L_1	10 mg/g	5121	27.3	16.8	29
L_2	100 mg/g	5627	31.1	6.0	27
L_3	200 mg/g	4168	27.9	57.1	37

Table 07D. 3

Effects of line and length of incubation period on pH of substrate during incubation at 10°C

Material and Treatment	pH				
	at start	3 weeks	6 weeks	9 weeks	12 weeks
Festuca-Agrostis herbage (Expt. 2)					
L_0	4.7	5.3	6.5	6.1	5.9
L_1	4.8	5.8	7.3	6.3	5.8
L_2	5.2	6.6	7.1	7.1	6.6
L_3	5.3	6.9	7.4	6.8	6.9

3. Maintenance of improved pastures on peat
(M.J.S. Floate, G.R. Bolton and J. Eadie)

The objectives and design of the improvement-response experiment (Le1) on peat were given in Annual Reports 1971, 1972 together with data on soil changes in the first 2 years. Soil samples were collected again in 1973 with a view to assessing maintenance needs but two problems have arisen. The first concerns the interpretation of "Available-P" measured by the Morgan method, and the second concerns small areas on Ca_1 P_{20} (D) and Ca_1 P_{40}(E) plots where introduced herbage species have died out.

Because of the first problem "Available-P" measurements have not yet been carried out pending the results of the investigation into "Assessment of availability of P" (03D). pH was measured on the samples collected in 1973 and the results are given in Table 4. These results indicate that the mean pH on Ca_1P_{20}, and Ca_1P_{40} plots is lower than on other treatments but that the minimum values on these plots are no lower than on other treatments. On average Ca_1 treatments are 0.2 units lower than Ca_2 treatments.

Soil and plant material samples were collected from normal and abnormal areas within plots (D) and (E) and these were analysed in an attempt to diagnose the cause of failure in the abnormal areas. The results are given in Table 5: these indicate marked differences in soil and water pH between normal and abnormal areas on plot D, but only small differences on plot E. Si, Al and Mg showed little difference between normal and abnormal areas for either plant or soil on both plots. Mg levels are low. There was some indication that Ca levels were lower in soil and plant from abnormal areas but these differences were more marked for K.

Table 07D. 4

pH data for soils in the Improvement-Response Experiment on Peat (Le 1)

Treatment	Ca_1P_{20} (D)	Ca_1P_{20} (F)	Ca_1P_{40} (E)	Ca_2P_{20} (A)	Ca_2P_{20} (C)	Ca_2P_{40} (B)
pH 1971 (0-5 cm)	3.5 (3.32-3.70)	3.5 (3.34-3.69)	3.5 (3.28-4.22)	3.4 (3.04-3.60)	3.5 (3.28-4.09)	3.5 (3.21-3.61)
1972	4.1 (3.36-4.49)	3.9 (3.78-4.15)	4.1 (3.86-4.19)	4.2 (3.97-4.60)	4.4 (4.12-4.63)	4.3 (3.91-4.72)
1973	4.1 (3.80-4.48)	4.3 (3.90-4.95)	4.1 (3.91-4.35)	4.5 (3.80-5.30)	4.3 (4.00-4.56)	4.3 (4.04-4.53)

Table 07D. 5

Analysis of soil and plant materials from normal and abnormal areas from plots (D) and (E)

Treatment and Material		pH Soil	pH Water	Si. %	Al. %	K %	Ca %	Mg %	Mo ppm	Ash %
Peat (0-5 cm)										
D	N	5.1	6.0	.58	.15	.16	1.18	.13	0.86	5.84
	A	4.5	5.3	.55	.14	.12	.74	.13	0.99	4.46
E	N	5.2	6.0	.44	.13	.15	1.37	.16	0.82	6.30
	A	5.0	5.9	.46	.14	.12	1.43	.15	0.74	6.01
Herbage										
D	N			.25	.02	.73	.41	.14	.79	3.58
	A			.25	.02	.57	.37	.14	.62	3.02
E	N			.23	.02	1.05	.41	.13	.64	4.59
	A			.23	.02	.54	.38	.11	.59	2.95

N = Normal; A = Abnormal

These results are difficult to interpret as all the field circumstancial evidence indicates the uneven spreading of lime on two plots at 1 ton/ac rate as the probable cause. This is confirmed by pH and Ca results but differences are not so great as might be expected, and the K results were entirely unexpected. Work is being urgently continued to solve this problem.

4. Maintenance of improved pastures on mineral soils
(M.J.S. Floate, R.B. Hetherington and J. Eadie)

Details of treatments and soil changes in Improvement-Response experiments at 4 sites at Sourhope have been presented in previous Annual Reports. No soil samples were collected from these sites in 1973. All available data from the start of each experiment is being evaluated to give estimated DM production, plant nutrient uptake, and plant nutrient return in excreta per annum. This data is required to assess the efficiency with which soil nutrient sources are being utilized and to assess possible future maintenance needs, for each treatment at each site.

C. SYSTEMS DEVELOPMENT

YEAR ROUND GRAZING SYSTEMS (04C)

Introduction

An introduction to the work covered by Systems Development was given for the year-round grazing systems in the Annual Report, 1969 and for the Inwintering Systems in the Annual Report, 1970. Below are the results of each of these studies during 1973 with a brief summary of total production data for all the years.

For a brief discussion and outline of the work carried out under Development, reference should be made to the Fifth Report, 1969-50, p 70 (Hill Sheep Production Systems Development).

YRGS I: Low Capital input on a grassy hill - Hairney Law/Auchope
(R.H. Armstrong, J. Eadie, T.J. Maxwell and P. Watchorn)

Land Resources

There are 283 hectares of mainly grassy pasture which has been subdivided in such a way as to enclose some 100 hectares of Agrostis-Festuca pasture. There are now five Agrostis-Festuca enclosures which are fully integrated into the grazing system, one of them being primarily used as a hogg wintering paddock. The lambing paddocks are now allocated on an all-the-year round basis to the system and during lactation are primarily used for twin nursing ewes.

Cattle

As in previous years, the hill cows were carried from 1st May to the end of December.

Sheep Stocks

Two sheep stocks, one of North Country Cheviots (NCC) bred pure, and one of South Country Cheviots (SCC) crossed with North Country Cheviot tups are run on the area.

Livestock Reconciliation 1971/72

	Ewes & gimmers	Cast	Deaths	Gimmers brought into flock	Hoggs born 1973	Ewes & gimmers 1973
NCC	300	75	10	80	70	295
SCC	273	43	11	86	77	305

Total Stock Numbers 1968-1973

	1968	1969	1970	1971	1972	1973
NCC	175	210	260	269	300	295
SCC	223	241	254	260	273	305
TOTAL	398	451	514	528	573	600

Ewes and gimmers have increased in number by over 50% since the study began. Ewe mortality continued at a low level at 3.9% in the NCC and 4.0% in the SCC.

Sheep Year 1972/73

(a) Winter Feeding

During January the ewes and ginners were given sugar beet pulp nuts at 227 g per head per day. At the end of February (28th) the ginners from Hairney Law and Auchope were stocked on P5 and continued to get 227 g SBP per head per day. During March feed was given as follows:-

8th March	
NCC ewes : 340 g SBP	SCC ewes:227 g SBP
NCC ginners : 227 g SBP	SCC ginners : 227 g SBP
27th March	
NCC ewes : 340 g SBP + 114 g Conc.	SCC ewes : 227 g SBP + 114 g Conc.
NCC ginners : 227 g SBP + 157 g Conc.	SCC ginners : 227 g SBP + 157 g Conc.
30th March	
NCC ewes : 454 g Conc.	SCC ewes: 326 g Conc.
NCC ginners : 397 g Conc.	SCC ginners : 397 g Conc.
7th April	
NCC ewes : 568 g Conc.	SCC ewes : 397 g Conc.
NCC ginners : 397 g Conc.	NCC ginners : 397 g Conc.

Total feed consumption per ewe was as follows:-

NCC	
Hay	4.72 kg
Sugar beet pulp	18.14 kg
Protein concentrate (14% CP)	15.4 kg
Total cost per head	£1.37

SCC x NCC	
Hay	4.54 kg
Sugar beet pulp	16.91 kg
Protein concentrates (14% CP)	12.6 kg
Total cost per head	£1.91

The hoggs were wintered on a hill paddock and given a total per head of 2.14 kg hay, 14.2 kg sugar beet pulp and 14.2 kg protein concentrate at a cost of £0.94 per head.

The feeding pattern for the ewes and ginners was designed to maintain blood ketone levels below 3 mg%.

(b) Lambing performance in 1973

	NCC	SCC x NCC
Ewes to tup	300	273
Tup eild Kebs	33	14
Ewe losses to lambing	2	4
Total lambs born	336 (112.0%)	319 (116.8%)
Lambs marked	292 (97.3%)	299 (109.5%)
Lambs weaned	278 (92.7%)	292 (107.0%)

(c) Lamb weights (kg)

	NCC 1973	SCC x NCC 1973
Birth weights, singles	4.3	4.3
twins	3.5	3.6
Marking weights, singles	10.2	11.5
twins	8.9	9.1
Weaning weights, singles	23.7	24.3
twins	25.7	26.0

(d) Wool production (kg/ewe)

		NCC	SCC x NCC
Age	4 Crop	1.8	2.1
	3 Crop	1.9	2.1
	2 Crop	2.2	2.3
	1 Crop	2.0	2.2
	Ginmers	2.5	2.3
	All ages	2.1	2.2

(e) Ewe body weight changes 1972/73 (kg)

	Nos.	Pre-mating Nov. 1972	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov. 1973	Nos.
4 Crop	61	63.7	61.8	64.5	54.5	57.5	60.3	47
3 Crop	57	64.6	60.0	63.2	53.7	57.8	59.6	46
2 Crop	52	62.2	58.4	62.4	53.6	56.1	58.4	47
1 Crop	50	57.9	53.3	55.9	49.7	54.9	54.9	75
Ginmers	80	54.8	45.0	53.8	44.9	50.4	46.4	80
All ages	300	60.3	55.0	59.6	50.9	55.0	54.7	295

Ewe bodyweight changes 1972/73 (kg) - SCC

4 Crop	41	63.5	61.8	64.4	53.7	56.1	57.4	47
3 Crop	53	61.2	59.1	62.5	52.3	55.2	57.0	46
2 Crop	49	61.0	57.0	60.1	51.9	55.0	54.3	54
1 Crop	55	55.5	52.3	55.5	47.8	51.2	52.8	72
Ginmers	75	53.2	48.3	52.6	44.3	47.3	47.0	86
All ages	273	58.2	54.8	58.2	49.3	52.3	52.8	305

Prenating Ewe bodyweight (kg)

	1968	1969	1970	1971	1972	1973
NCC	54.8	56.1	58.9	59.5	60.3	54.7
SCC x NCC	47.8	50.2	53.2	55.8	58.2	52.8

It will be noted that for the first time ewe bodyweight at mating has not increased. There was a much greater loss in weight between pre-lambing and marking than has occurred in previous years and there was no evidence to suggest that the ewes regained this loss later in the year.

Production data

	1969	1970	1971	1972	1973	1974
Stock numbers	398	451	518	529	573	600
Weaning percentage	84.7	86.5	103.3	104.7	99.5	
Total weight of lamb weaned (kg)	7359	8893	14700	13953	14202	
Total weight of wool	787	1005	1273	1369	1560	

The total production of lamb and wool has continued to increase as a result of a further increase in ewe numbers. Individual animal performance was reduced.

YRGS II. On Blanket Bog - Lephinmore/Midhill
(T.J. Maxwell, J. Eadie and D.C. Currie)

Land Resources

The resource consists of 444 hectares mainly of blanket bog. Improved pasture falls into two categories, some 22 hectares of grassy pasture, 14.3 of which was reseeded several years ago, and two larger areas (PI and PII) totalling 69 hectares of unimproved Calluna and Eriophorum moorland, within which some 35% of the area has been surface seeded to give a mosaic of improved grassy pasture throughout the whole. Ten per cent of this area was created during 1973, 4.5 hectares being established in PII and 5.5 hectares in PI. The remaining 340 hectares is 'open hill'. Further division fences in PI will be erected to increase the capacity to graze twin nursing ewes and gimmers separately during lactation on improved pasture.

Sheep stock

There has been a further increase in stock numbers to a total of 433 Blackface ewes.

Livestock reconciliation

Ewes and gimmers Nov. 1972	Cast	Deaths	Gimmers bought in	Hoggs born 1973	Ewes and gimmers Nov. 1973
384	62	10 (2.6%)	110	124	422

Sheep year 1972/73

(a) Winter feeding

At the commencement of supplementary feeding the gimmers were moved into PII, the ewes remaining on the hill. The gimmers were also lambed separately.

Supplementary feeding was started earlier than usual owing to a period of snow cover. Initially sugar beet pulp cubes were used and then a 14% CP concentrate. Sugar beet pulp cubes were given during the end of February and early March and again as an additional supplement to concentrates in April.

	Ewes	Ginners
March 1	280 g SBP	230 g Conc.
March 11	239 g Conc.	340 g Conc.
March 26	400 g Conc.	450 g Conc.
April 7	450 g Conc. 170 g SBP	566 g Conc.
April 19	450 g Conc. 170 g SBP	450 g Conc.

Feeding continued into lactation.

Average concentrate consumption was 17 kg/hd. Cost per head @ £50/ton = £0.83.

Average sugar beet pulp consumption was 10 kg/hd. Cost per head @ £30/ton = £0.13.

Total cost per head amounted to £0.96.

The hoggs were wintered inbye and given S.B.P., hay and concentrates. Total cost per hogg was £2.24.

(b) Lambing performance

	1973	
Ewes to tup	422	
Tup eild)	34	
Kebs)		
Ewe losses to lambing	12	
Total lambs born	469	(111.1%)
Total lambs marked	439	(104.0%)
Total lambs weaned	436	(103.3%)

(c) Lamb weights (kg)

Birth weights, singles		3.9
	twins	2.9
Marking weights, singles		11.3
	twins	10.8
Weaning weights, singles		23.7
	twins	23.0

(d) Wool production (kg/ewe)

Age	4 Crop	1.5
	3 Crop	1.7
	2 Crop	1.6
	1 Crop	1.6
	Ginners	1.6
	All ages	1.6

(e) Ewe body weight change (kg)

Age	Nos.	Pre-nating Nov. 1972	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-nating Nov. 1973	Nos.
4 Crop	68	55.1	47.4	47.9	46.6	50.5	51.7	65
3 Crop	74	52.8	46.6	47.1	46.1	50.2	50.2	70
2 Crop	79	51.3	44.7	45.2	44.3	48.6	49.4	80
1 Crop	91	48.7	40.4	41.5	42.7	48.1	49.4	105
Ginners	110	44.2	37.8	39.8	39.5	44.1	43.2	113
All ages	422	49.9	42.7	43.7	43.4	47.9	48.3	433

Prenating Ewe Body Weight 1968-73

1968	1969	1970	1971	1972	1973
44.9	49.3	49.4	51.2	49.9	48.3

Production Data

	1969	1970	1971	1972	1973	1974
Stock numbers (ewes & ginners)	339	361	373	384	422	433
Weaning percentage	85.0	92.5	103.5	103.6	103.3	
Total weight of lamb weaned (kg)	7207	8500	10268	9924	10218	
Total weight of wool (kg)	652	772	772	814	815	

YRGS. III. High Capital Input on a Grassy Hill - Sourhope/Alderhope.

Introduction

The Systems Development Programme has been extended at Sourhope to incorporate a system which is dependent for its improved pasture component on a high input of capital in a complete reseeding operation. The principles which have already been enunciated and applied with regard to the use of improved pasture in relation to the open hill in year-round grazing systems, e.g. Hairney Law/Auchope YRGS I, are also being applied in this system. Stock numbers will be increased.

Land Resources

The resource consists of 130 hectares of mainly grassy pasture dominated by Molinia heath and Nardus heath, the latter being interspersed with Festuca. Agrostis-Festuca is present, but is species poor and represents a smaller proportion of the total area than the other sheep resources at Sourhope. During 1972, 3.0 hectares of reseed were established and in 1973 a further 6.2 hectares were sown (see Farm Reports 1972 and 1973).

Stock

The resource is stocked with Scottish Blackface ewes.

Livestock Reconciliation
1972/73

Ewes & ginners Nov. 1972	Cast	Deaths	Ginners brought into flock	Hoggs born 1973	Ewes & ginne Nov. 1973
217	39	13	56	65	222

Sheep Year 1972/73

(a) Winter feeding

The total feed given was as follows:-

Hay	2.6 kg
Sugar Beet Pulp Nuts	7.04 kg
Concentrate	11.84 kg
Total cost per head	£0.83

(b) Lanbing performance

Ewes to tup	217	
Tup eild Keb	10	
Ewe losses to lanbing	2	
Total lanbs born	270	(124.4%)
Total lanbs narked	246	(113.4%)
Total lanbs weaned	245	(112.9%)

(c) Lanb weights (kg)

Birth weights,	singles	4.2
	twins	3.4
Marking weights,	singles	12.7
	twins	8.6
Weaning weights,	singles	28.1
	twins	25.8

(d) Wool production (kg)

Age	4 Crop	1.7
	3 Crop	1.7
	2 Crop	1.8
	1 Crop	1.8
	Ginners	2.0
	All ages	1.8

(e) Ewe Body Weight Changes (kg)

Age	Nos.	Pre-Mating Nov. 72	Pre-feeding	Pre-lanbing	Marking	Weaning	Pre-nating Nov. 73	Nos.
4 Crop	42	57.6	53.3	60.5	53.1	53.1	53.1	33
3 Crop	37	57.3	52.5	58.8	50.5	50.8	56.0	37
2 Crop	41	56.4	52.4	58.9	51.0	51.6	53.3	41
1 Crop	42	51.8	47.9	53.6	45.9	48.3	51.4	54
Ginners	55	50.5	45.3	49.9	43.5	46.4	47.8	57
All ages	217	54.4	50.0	55.8	48.3	49.7	51.8	222

YRGS IV. On Heather Moor, Glensaugh/Birnie and Cairn.
(T.J. Maxwell, J. Eadie, A.L. Fairlie and C.D. Kerr)

Introduction

The immediate objective is to create two self-contained and similar resources in terms of acreage, vegetation and stock numbers. Management procedures on each of the resources will be the same.

The establishment of two such units is a necessary prelude to the testing on a practical scale of the ideas which emerge from the current heather research programme. Because of the needs of the experimental programme for sheep neither of these areas had the established flock size and performance base line required of a development unit.

Land Resources

The area is situated at the north-eastern end of Glensaugh on land rising from 190 to 460 m with a fence dividing it into two 200 hectare hirsels, the Cairn and the Birnie. Associated with each of these predominantly heather resources is an area of enclosed hill (12-14 hectares) which will be used as a lambing paddock. Further, included with each unit, there is initially an area of seven hectares of improved pasture on land which has been limed, slagged and sown with grass and clover seeds. Both of the required areas have been established for some time.

The improved pasture was grazed as far as possible in accordance with the principles outlined for the other year-round grazing systems.

Stock

On each of the hirsels there were approximately 225 Scottish Blackface ewes.

Livestock Reconciliation

	Ewes & Gimmers Nov. 72	Cast	Deaths	Gimmers brought into flock	Hoggs born 1973	Ewes & Gimmers Nov. 73
Cairn	234	82	19	46	57	187
Birnie	219	60	15	58	62	202

Sheep Year 1972/73

(a) Winter Feeding

Feeding commenced on 14th February and continued as follows; the gimmers were separated on 25th February.

	Ewes	Gimmers
14 February	227 g SBP	227 g SBP
25 February	227 g SBP	227 g SBP
29 February	227 g SBP	227 g SBP + 114 g Concentrate
15 March	227 g SBP + 114 g Conc	227 g SBP + 227 g Concentrate
23 March	227 g SBP + 343 g Conc	227 g SBP + 454 g Concentrate
31 March	511 g Conc	681 g Concentrate

The total feed given per head was as follows:-

Sugar Beet Pulp Nuts	8.68 kg
Concentrate	17.89 kg
Total cost per head	£1.17

The hoggs were wintered in-bye and given 171 g + 227 g of a mixture of bruised oats and protein pellets.

Feeding continued throughout lambing and also during the early part of lactation.

(b) Lambing performance

	Cairn	Birnie
Ewes to tup	234	219
Tup eild / Keb	32	19
Ewe losses to lambing	8	4
Total lambs born	249 (106.4%)	225 (102.7%)
Total lambs marked	229 (97.9%)	217 (99.1%)
Total lambs weaned	229 (97.9%)	217 (99.1%)

(c) Lamb weights (kg)

	Cairn	Birnie
Birth weights, singles	3.9	4.0
twins	3.2	3.2
Marking weights, singles	11.8	14.1
twins	13.1	12.7
Weaning weights, singles	21.9	25.4
twins	22.4	22.1

(d) Wool production (kg)

No data is available for this year.

(e) Ewe body weight changes (kg) - Cairn

Age	Nos.	Pre-mating Nov. 72	Pre-feeding	Marking	Weaning	Pre-mating Nov. 73	Nos.
3 Crop	58	58.0	53.0	44.9	51.7	55.0	34
2 Crop	47	57.1	51.2	45.2	52.0	53.7	60
1 Crop	75	50.8	45.0	41.5	49.2	51.1	47
Ginners	54	46.2	40.0	36.8	46.4	48.0	46
All ages	234	52.8	47.1	42.0	49.6	51.8	187

Ewe body weight changes (kg) - Birnie

4 Crop						55.6	9
3 Crop	50	55.2	51.6	46.6	52.0	52.8	31
2 Crop	45	52.1	46.7	44.5	48.0	51.1	56
1 Crop	65	48.5	43.8	43.8	47.6	49.8	48
Ginners	59	45.1	38.7	40.9	45.6	46.2	54
All ages	219	49.8	44.9	43.8	48.1	49.8	202

INWINTERING SYSTEMS (05C)

Inwintering Systems with and without Land Improvement

IWS I. On a grassy hill. Sourhope/Rigg and Gairs
(R.H. Armstrong, J. Eadie, T.J. Maxwell and P. Watchorn)

Land Resources

The Rigg and Gairs are two similar units, each of 101 hectares, each traditionally stocked with 130-140 ewes and gimmers. Both sheep stocks are inwintered for the same length of time in the same wintering house. The difference between the units, an important part of the study, is that in the Gairs a substantial acreage of improved pasture has been made available. An area of 15 hectares of Agrostis-Festuca pasture was enclosed, and limed and slagged early in the winter of 1969/70. During the summer of 1971 this was oversown with clover. Further, in the spring of 1971, 10 hectares of Molinia/Nardus grass heath at 450 m received 6350 kg lime and 1650 kg slag per hectare. It was later sprayed with Paraquat, rotavated and direct reseeded in mid-July with 380 kg per hectare of high phosphate compound. This area was grazed for the first time in the Autumn of 1971.

The improved pasture areas are used and integrated with the unimproved hill in a similar way to that outlined for the year-round grazing system.

Cattle

A cattle stock numbering 24 was grazed in such a way as to equate the number of grazing days per month spent on the Gairs with the number of days on the Rigg. They were maintained on these areas from 1st May to 31st December.

Sheep Stocks

Both the Rigg and Gairs carry South Country Cheviots. Stocking rate increases have been made equally on the two units by purchase of ewe lambs in late summer which were then wintered with those hoggs retained from that season's lamb flock.

Livestock Reconciliation

	Ewes & gimmers Nov. 72	Cast	Deaths	Gimmers brought in	Hoggs Purchased	Hoggs Homebred	Ewes & Gimmers Nov. 73
Rigg	278	63	9	73	-	68	279
Gairs	260	64	9	72	-	71	279

Total Stock Numbers

	1969	1970	1971	1972	1973
Rigg	205	205	238	278	279
Gairs	209	207	233	260	279

Sheep Year 1972/73

(a) Winter feeding

The ewes and gimmers were housed on the 23rd February and given feed as follows:-

23rd February:

Ewes	114 g Conc.	227 g SBP	681 g Hay
Gimmers	114 g Conc.	227 g SBP	568 g Hay

22nd March:

Ewes	171 g Conc.	227 g SBP	681 g Hay
Gimmers	171 g Conc.	227 g SBP	568 g Hay

30th March:

Ewes	227 g Conc.	227 g SBP	681 g Hay
Gimmers	227 g Conc.	227 g SBP	568 g Hay

6th April:

Ewes	341 g Conc.	227 g SBP	681 g Hay
Gimmers	284 g Conc.	227 g SBP	568 g Hay

Total Feed given per head:

Hay	51.86 kg
SBP	20.36 kg
Conc.	17.18 kg
Total cost	£2.31

The hoggs were given 42.95 kg hay and 13.45 kg concentrate at a cost of £1.38/head.

(b) Lambing Performance

	Ewes & gimmers mated	Tup eild & keb	Ewe losses to lambing	Total lambs born	Marked	Weaned
Rigg	278	34	2	274 (98.6%)	252(90.3%)	244(87.8%)
Gairs	260	25	0	277 (106.5%)	247(95.0%)	212(93.1%)

(c) Lamb Weights (kg)

	Rigg	Gairs
Birth weights, singles	4.0	4.2
twins	3.3	3.6
Marking weights, singles	9.3	9.8
twins	8.9	8.4
Weaning weights, singles	21.5	23.4
twins	23.2	23.6

(d) Wool Production (kg)

Age	Rigg	Gairs
4 Crop	2.0	2.0
3 Crop	1.8	2.4
2 Crop	2.3	2.2
1 Crop	2.3	2.4
Gimmers	2.2	2.4
All ages	2.1	2.3

(e) Ewe Bodyweight Changes (kg) - Rigg

Ages	Nos.	Pre-mating Nov. 72	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov. 73	Nos.
4 Crop	46	55.3	49.9	56.0	48.4	52.4	54.9	35
3 Crop	43	53.4	47.8	54.0	46.6	51.7	55.5	27
2 Crop	32	54.2	48.5	55.5	46.2	53.0	54.9	66
1 Crop	76	51.4	45.8	52.7	46.9	52.6	49.6	78
Gimmers	81	46.4	41.3	47.8	41.3	46.1	43.8	73
All ages	278	51.2	45.8	52.3	45.4	50.6	50.6	279

Ewe Bodyweight Changes (kg) - Gairs

4 Crop	34	56.6	51.7	58.2	49.4	53.2	60.3	35
3 Crop	39	60.3	55.0	61.9	53.2	58.1	56.4	34
2 Crop	39	55.3	51.4	57.6	50.1	55.0	55.9	69
1 Crop	74	53.5	48.4	54.7	48.5	54.7	52.6	69
Gimmers	74	47.7	42.3	48.8	42.9	49.0	44.9	72
All ages	260	53.5	48.5	55.0	48.0	53.4	52.9	279

There has been a progressive increase in the ewe body weights at mating until this year.

Premating Ewe Bodyweights

	1969	1970	1971	1972	1973
Rigg	48.3	49.7	51.5	51.2	50.6
Gairs	49.9	50.5	51.9	53.5	52.9

Production Data - Rigg

	1970	1971	1972	1973	1974
Stock numbers	205	205	238	278	279
Weaning percentage	83.0	87.0	100.8	87.8	
Total weight of lamb weaned (kg)	3706	4432	5712	5324	
Total weight of wool	402	534	641	732	

Production Data - Gairs

	1970	1971	1972	1973	1974
Stock numbers	209	207	233	260	279
Weaning percentage	83.0	96.0	91.4	93.1	
Total weight of lamb weaned (kg)	3581	5246	5176	5675	
Total weight of wool	461	524	634	752	

IWS II. On Blanket Bog. Lephinmore/Low End.
(T.J. Maxwell, J. Eadie and D.C. Currie)

Land Resources

This is an area of Calluna and Eriophorum moorland, consisting of two similar units, each of approximately 160 hectares, traditionally carrying 100 ewes and gimmers. Both units have the use of 13 hectares of 'common' enclosed grassy pasture. Both sheep stocks are inwintered in the same house for the same length of time. One of the units, an area of blanket bog, has a substantial acreage of improved pasture (15 hectares) which was enclosed, limed and slagged and an oversown grass/clover pasture established. This unit is referred to as 'inwintering + land improvement'.

Sheep Stocks

Scottish Blackface ewes are used. Stocking rate increases have been made equally on the 'inwintering' and 'inwintering + land improvement' sides.

Livestock Reconciliation 1972/73

	Ewes & gimmers Nov. 72	Cast	Deaths	Gimmers brought in	Hoggs born 1973	Ewes & Gimmers Nov. 73
'Inwintering'	166	24	14	48	86	176
'Inwintering + land improvement	160	25	5	44	86	174

Total Stock Numbers

	1969	1970	1971	1972	1973
Inwintered	106	114	143	166	176
Inwintered + land improvement	102	112	137	160	174

Sheep Year 1971/72

(a) Winter Feeding

The ewes were inwintered on 18th January. The feeding given to the early lambing ewes was as follows; (the late lambing ewes received similar amounts, the increases being made some 10 days later):-

	Ewes	Gimmers
Jan. 18	908 g Hay, 114 g Conc.	908 g Hay, 114 g Conc.
March 17		681 g Hay, 227 g SBP, 114 g Conc.
24	908 g Hay, 227 g Conc.	681 g Hay, 227 g SBP, 227 g Conc.
31	908 g Hay, 341 g Conc.	668 g Hay, 171 g SBP, 341 g Conc.
April 10	908 g Hay, 398 g Conc.	668 g Hay, 171 g SBP, 398 g Conc.

Total consumption of concentrate per ewe was 14.8 kg.
" " " sugar beet pulp per ewe was 2.35 kg.
" " " hay per ewe was 75.42 kg.
" cost of feed per ewe was £2.50.

The hoggs were housed on 8th December and given 114 g concentrate and 681 g hay. On 8th March they were given 114 g concentrate, 227 g sugar beet pulp and 341 g hay.

The total feed cost per hogg was £2.34.

(b) Lambing Performance

	Inwintered	Inwintered + land improvement
Ewes to tup	166	160
Tup eild / keb	16	10
Ewe losses to lambing	2	2
Total lambs born	175 (105.4%)	204 (127.5%)
Total marked	154 (92.8%)	166 (103.8%)
Total weaned	154 (92.8%)	164 (102.5%)

(c) Lamb Weights (kg)

Birth weights,	singles	4.1	4.2
	twins	3.0	2.9
Marking weights,	singles	12.6	13.0
	twins	10.7	11.8
Weaning weights,	singles	25.6	25.0
	twins	21.3	21.2

(d) Wool Production (kg)

Ages		
5 Crop	0.7	1.4
4 Crop	1.5	1.0
3 Crop	1.3	1.4
2 Crop	1.3	1.4
1 Crop	1.4	1.5
Gimmers	1.5	1.8
All ages	1.4	1.5

(e) Ewe Bodyweight Changes (kg) - Inwintered

Age	Nos.	Pre-mating Nov. 1972	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov. 73	Nos.
5 Crop	3	51.0	49.8	52.0	47.5	50.7	48.6	5
4 Crop	15	52.0	52.2	54.4	51.9	52.1	47.8	16
3 Crop	22	51.2	50.0	52.0	49.1	50.5	46.5	18
2 Crop	24	47.1	46.8	48.9	46.8	48.4	45.5	41
1 Crop	48	45.6	44.2	46.0	45.8	46.9	43.5	48
Gimmers	54	45.5	44.1	46.4	44.3	44.8	36.9	48
All ages	166	47.2	46.2	48.2	46.5	47.4	43.0	176

Ewe Bodyweight Changes (kg) - Inwintered

5 Crop	6	52.6	50.5	52.1	47.3	49.1	53.6	5
4 Crop	16	53.4	52.8	56.1	48.3	50.7	50.9	16
3 Crop	24	51.6	51.1	52.8	47.2	48.8	50.5	18
2 Crop	20	50.5	49.5	52.0	47.1	49.2	48.2	45
1 Crop	48	47.5	45.7	47.6	46.1	47.2	45.6	46
Gimmers	50	47.6	46.0	47.5	45.5	44.7	39.1	44
All ages	160	49.2	47.8	49.7	46.6	47.2	45.8	174

ERRATA

SYSTEMS DEVELOPMENT

P59

SCC x NCC

Hay	4.54 kg	Protein concentrates (14% CP)	12.6 kg
Sugar beet pulp	16.91 kg	Total cost per head	£1.19

P61

Livestock reconciliation

Ewes and gimmers Nov. 1972	Cast	Deaths	Gimmers brought in	Hoggs born 1973	Ewes and gimmers Nov. 1973
422	83	19	113	119	433

P68

b) Lambing performance

Ewes & gimmers mated		Tup eild & keb	Ewe losses to lambing	Total lambs born	Marked	Weaned
Rigg	278	34	2	274 (98.6%)	252 (90.3%)	244 (87.8%)
Gairs	260	25	0	277 (106.5%)	247 (95.0%)	242 (93.1%)

Premating Ewe Bodyweights (kg)

	1969	1970	1971	1972	1973
Inwintered	50.0*	49.3	48.2	47.2	43.0
Inwintered + Land improvement	49.5*	49.4	48.5	49.2	45.8

* Gimmers' weights unavailable for inclusion

Production Data - Inwintered

	1970	1971	1972	1973	1974
Stock numbers	107	115	143	166	176
Weaning percentage	80.0	93.0	103.5	92.8	
Total weight lamb weaned (kg)	2279	2857	3775	3775	
Total weight wool (kg)	205	257	282	293	

Production Data - Inwintered + Land Improvement

	1970	1971	1972	1973	1974
Stock numbers	102	112	137	160	174
Weaning percentage	71.0	104.5	97.1	102.5	
Total weight lamb weaned (kg)	2015	3324	3511	3800	
Total weight wool (kg)	179	246	274	304	

BOGHALL (07C)

Inwintering and Land Improvement
(T.J. Maxwell, J. Eadie with E.S.A.)

This joint study between HFRO and the Edinburgh School of Agriculture has continued. Further inputs of improved pasture were introduced during the year. The results of the study are reported separately as a joint report.

A brief summary of the production data since 1969 is given below:-

Production Data

	1969	1970	1971	1972	1973
Stock numbers	413	423	381	419	419
Weaning percentage	106.0	104.0	115.0	115.0	106.0
Total weight lamb weaned (kg)	10726	11038	11180	12296	10813
Total weight wool (ewes only)	448	472	533	690	564

There has been a decline in premating ewe body weight from the greatest weight achieved during the life of the study of 58.0 in 1969 to 54.5 in 1973.

Premating Body Weight (kg) 1965-73
and ewe numbers

	1965	1966	1967	1968	1969	1970	1971	1972	1973
Numbers	286	293	350	350	413	423	381	419	419
Weight	56.7	57.2	55.4	53.5	58.0	55.4	57.4	56.1	54.5

Number of ewes prior to 1965 was around 200.

UPLAND (08C)

Sheep Production Systems in the Uplands
(T.J. Maxwell, J. Eadie, J.D. Macdonald and A.L. Fairlie)

Sheep production from upland pastures; an examination of the relationships among pasture production, stocking rate and lambing date.

Introduction

In a sheep enterprise based on pastoral resources output is influenced by the level and seasonal pattern of pasture production and by stocking rate. These two factors interact to create a nutritional pattern which influences individual sheep performance. The choice of lambing date will affect the relationship at any stocking rate between nutrient provision from pasture and nutrient need and will have nutritional and therefore production consequences.

Most animal production systems in the uplands include the conservation of pasture surplus to grazing requirement, to provide bulk food for the winter. The choice of stocking rate and lambing date will influence the magnitude of these surpluses.

It is desirable to examine relationships among pasture production, stocking rate and lambing date within the context of whole systems of production because the impact of a decision made at one point in time will have effects throughout the whole production process. It is also important to recognise that within systems of production decisions cannot be made independent of the levels and timing of inputs (e.g. stock numbers, fertiliser inputs, time of lambing) particularly since these inputs must ultimately be economically justified.

During the year Greyface ewes were acquired and the necessary fencing, etc. was established so that the investigation could commence at tupping in October and November 1973.

The area of land to be used is that situated at the east end of Glensaugh including the Bowes Field, Hogg Park, Hard Park and Forestry Park. An area of hill, Forestry Park hill, will be used for wintering.

Four systems of production will be examined for a minimum period of three years:-

1. Greyface ewes stocked at 4 ewes/acre lambing 7th March
2. " " " " 6 " " " " "
3. " " " " 4 " " " 7th April
4. " " " " 6 " " " " "

During 1973 the Greyfaces were grazed on this area unfenced. Some were tupped in October 1972 with a Dorset Down ram and the remainder with a Suffolk ram.

Lambing Performance

Ewes to tup	97	
Tup eild	7	
Ewe losses to lambing	0	
Total lambs born	159	(163.9%)
Total lambs marked	148	(152.6%)
Total lambs weaned	148	(152.6%)

Lamb weights (kg)

Birth weights,	singles	5.1
	twins	4.3
Marking weights,	singles	17.5
	twins	14.3
Weaning weights,	singles	40.5
	twins	35.9

The ewes produced an average wool clip of 3.3 kg/ewe.

Ewe Body Weight Change (kg)

Age	No.	Pre-mating Nov. 72	Pre-feeding	Pre-lambing	Marking	Weaning
2 Crop	16	-	71.5	76.9	66.8	68.3
1 Crop	29	-	72.3	76.1	66.8	66.3
Gimmers	52	67.8	66.0	69.2	61.2	62.1
All ages	97	73.9	68.8	72.6	63.5	63.9

A further 142 Greyface ewes were purchased bringing the total number to 229. The ewes have now been split into their System groups.

SIMULATION (090)

The development of simulation models of hill and upland sheep production systems
(T.J. Maxwell, A.R. Sibbald, A. Vine and J. Eadie)

The objective of the modelling programme is to understand more fully the mechanisms and processes of systems of sheep production which are based on the utilisation of pasture; to establish the relative importance of the component variables and test those which appear to significantly affect output in field experiments.

The crucially important feature of pasture based systems of production is in the amount and quality of pasture ingested by the grazing animal. It is evident from existing models that this has proved to be the most difficult aspect of the system to model. Too often the modeller has limited himself within the bounds of existing knowledge and data.

Conceptually, pasture may be regarded as a continuous distribution of units of digestibility, the distribution changing in response to:-

(a) pasture growth

(b) pasture maturation and senescence

(c) pasture removal, which depends on animal selection and voluntary intake.

A model has been constructed on the basis of this frame-work and a preliminary evaluation of existing data has been made.

Production of new herbage

The information available is in terms of net herbage production over various regrowth periods. Ideally what is required is data on the rate of herbage growth per unit of herbage available and how this varies with time and (b) the rate of loss of material to the litter layer. This information is essential to describe the quantity and quality of material and its distribution in time and space. It is also necessary if the effect of grazing on the subsequent regrowth of the pasture is to be understood.

Maturation and Senescence of Pasture

There is considerable data available on whole plant digestibility of many pasture species throughout the year, but only a little on the separate parts.

There is also information on the factors governing leaf appearance and since there is generally a constant number of leaves per tiller, it has been possible to make some rough assessments as to the rate of leaf ageing.

More precise information is required regarding this component of the model and experiments have been set up in an attempt to provide it.

Pasture Removal

There is little published quantitative data on what the animal selects particularly on an individual tiller basis; but there is information on pasture composition before and after grazing and on the general manner in which sheep will graze. More precise information is clearly required.

Voluntary intake is expressed as a function of body weight and digestibility of ingested pasture.

DATA HANDLING (04C-09C)

Records and Statistics
(A.R. Sibbald, J.M. Brown, E.V. Deans and T.J. Maxwell)

The programme of maintenance, checking and analysis of sheep records from each of the projects has continued. During the year the records from the sheep on the Upland Grazing Experiment at Glensaugh were added to the recording system and record maintenance is now also being undertaken for the West of Scotland College of Agriculture's Kirkton Face Trial.

Some preliminary statistical analyses of the accumulated records have been carried out using various computer-based statistical packages. The results of these will determine the nature of the 'production' runs to be carried out during the coming year.

METHODS OF ECONOMIC APPRAISAL (06C)

(T.J. Maxwell and A.R. Sibbald)

The computer program for making economic appraisals of capital investment in hill sheep systems, described in the Annual Report 1972, has been further developed. The inclusion of cattle in a system to be appraised is now possible and, in addition, the program has been made more 'interactive'. This means that the program asks the user questions or prompts him to make responses which allow changes in the project under investigation to be made quickly and easily before another appraisal is made for comparison.

The program was used during the year as a practical investment appraisal tool during a course organised by the Scottish Agricultural Development Council for the in-service training of agricultural advisory staff in hill sheep management systems. The course participants, although unfamiliar with computers, were able to make economic appraisals of their own ideas of practical hill sheep projects to test their economic viability.

It is anticipated that the program will prove to be of further practical use in the coming year.

SYSTEMS DEVELOPMENT (04C)

Biological Monitoring
(M.J.S. Floate)

a) YRGS Paddocks. Sourhope/Auchope and Hairney Law

Biennial soil sampling at fixed reference points was carried out in 1968, 1970 and 1972 and comparative results for pH and litter layer thickness were given in the Annual Report 1972.

Data for Available P and K, expressed in concentration and weight per unit area terms, are given in Table 1:-

Table 1 (04C)

Available nutrients in soils of Auchope and Hairney Law paddocks 1968-72

Sample		"Available"-P		"Available"-K	
		1968	1972	1968	1972
		mg/100 g			
Auchope	L	14.41 ± 1.74 NS	12.36 ± 1.41	146.0 ± 6.7 NS	162.8±8.7
	0-5 cm	0.58 ± .08 ***	1.05 ± .10	39.3 ± 2.9 NS	42.2±3.9
	5-10cm	0.36 ± .05 ***	0.76 ± .05	30.3 ± 2.7 NS	31.8±2.4
Hairney Law	L	14.76 ± 1.54 NS	14.43 ± 1.24	153.3 ± 4.3 **	182.7±9.4
	0-5 cm	0.69 ± .07 ***	1.29 ± .09	50.4 ± 2.3 NS	47.9±2.4
	5-10cm	0.45 ± .06 ***	0.96 ± .06	38.2 ± 2.0 NS	40.4±2.5
		g/m^2			
Auchope	L	0.50 ± .05 **	0.30 ± .03	5.0 ± 0.3 NS	4.5±0.3
	0-5 cm	0.14 ± .01 ***	0.26 ± .02	10.6 ± 0.1 NS	11.2±0.8
	5-10cm	0.12 ± .01 ***	0.24 ± .02	10.6 ± 1.1 NS	10.1±0.7
	Total	0.76	0.80	26.2	25.8
Hairney Law	L	0.59 ± .06 NS	0.48 ± .04	6.4 ± 0.3 NS	7.0±0.7
	0-5 cm	0.13 ± .01 ***	0.28 ± .02	9.8 ± 0.4 NS	9.9±0.5
	5-10cm	0.12 ± .01 ***	0.24 ± .02	10.4 ± 0.6 NS	9.7±0.6
	Total	0.84	1.00	26.6	26.6

These data show that there has been a reduction in the weight of available P in the litter layers at both sites which is offset by a significant increase in the weight of P in the 0-5 cm, 5-10 cm mineral soil layers. Overall there is no loss due to increased stocking and the small gain which the data shows is probably not significant. The change in distribution of P in the soil is due to the reduction in both of the litter layers and to a significant increase in the concentration of P in the mineral layers. There has been little change in distribution, weight or concentration of available K in the soils at either site.

Final conclusions must await a statistical analysis of the results which are means of 25 individual samples.

b) YRGS Paddocks PI, PII Lephinmore

Reference was made to the analysis of pairs of soil samples taken from indigenous and improved areas in PI and PII, and to the problems of interpretation of inconsistent results in Annual Report 1972.

Table 2 (04C)

Summary of "Available" P and K content in improved and untreated soils on PI, PII

Site and Treatment	"Available" P g/m²		"Available" K g/m²	
	0-5 cm	0-10 cm	0-5 cm	0-10 cm
Overall means (n)				
PI untreated (8)	0.74	1.20	6.12	10.46
PI improved (8)	0.58	1.03	4.81	7.73
PII untreated (6)	0.32	0.78	4.09	7.27
PII improved (6)	0.48	0.94	4.37	7.39
Means of site untreated > improved				
PI untreated	0.85	1.42	6.18	10.44
PI improved	0.42	0.84	4.08	7.06
PII untreated	0.54	0.97	4.21	8.80
PII improved	0.30	0.49	2.92	6.25
Means of site improved > untreated				
PI untreated	0.63	0.98	5.84	10.57
PI improved	0.74	1.22	7.00	12.41
PII untreated	0.21	0.58	4.02	5.73
PII improved	0.57	1.38	5.10	8.53

The results showed that of the 8 sites on PI, that in the unimproved soils there was more "available" P at 4 sites, and more "available" K at 6 sites. On PII half the sites' studies had more "available" P and K in the unimproved soils.

On average "available" P and K were higher in the unimproved soils on PI and the improved soils on PII (Table 2).

Tests have been conducted with these and other soils to devise more reliable methods of assessing soil nutrient status (03D) and as part of this program different extraction methods and sorption methods have been applied to these soils. The results to date confirm the trends reported above.

Only the L-value studies, in which P uptake is measured, have suggested that Lephinmore peat is lower in P supplying power than other soils studied.

Measurements of plant DM production using moving cages on improved and indigenous areas on PI were made during 1973, the herbage is being analysed for P and K uptake, and soil samples were taken adjacent to the cutting areas. When the analysis of these samples is available it is hoped that an integrated assessment of soil and plant components of the system may explain some of the anomalies.

DM production data for indigenous and improved areas give an average of 3562 kg/ha for indigenous areas and 5238 kg/ha for improved areas. The range of values for individual samples was 2919-3915 and 3403-6489 respectively. These ranges are wide and indicate the problems of obtaining reliable production data for grazed areas of bog vegetation.

VETERINARY MONITORING

Lephinmore (04C 05C)
(A. Whitelaw and A.R. Fawcett)

Sheep

There has been no major cause for concern. Animal Health Records have been kept faithfully. Contagious ophthalmia occurred in the IWS(2) hoggs, ewes and gimmers in November and December. This responded to treatment and no serious eye lesions occurred. However in terms of labour and in cost of treatment this disease is troublesome.

Toxoplasma abortion occurred in the IWS ewes and gimmers at lambing but the incidence was low. It would appear that most of the stock is immune - but cases can occur in animals not exposed to infection and mixing of hoggs with ewes and gimmers is the only recommendation that one can make.

Colibacillosis occurred in some of the IWS lambs housed at lambing, but the incidence was low.

Nematodiriasis occurred in the lambs in the development plots in May. Preventive measures have been included in the Veterinary Preventive Programmes and in addition small plots seeded with Nematodirus eggs are being used to attempt to forecast the hatch in 1974.

A revised programme of Flukicide dosing has been instituted this year. The rationale is based on work by Armour & Corba and it is hoped that by strategic dosing to kill immature flukes, the deposition of eggs on the pasture will be minimised.

An increase in the snail proportion on one of the reseeds is being watched and the use of a molluscicide is planned.

The results of the new programme against fluke disease are promising but experience has shown that the dosing regimes must be strictly followed.

Worm burdens of sheep have remained low as indicated by routine faecal egg counts.

The use of tracer lambs in the development areas has indicated that the present dosing regimes are very satisfactory. These undosed lambs acquired moderately heavy infections in the development plots.

One of the problems in controlling worm infestation at Lephinmore and the other farms is that there are no clean pastures available for strategic use.

Cattle

No problems were encountered.

Sourhope (04C 05C)

Sheep

Dystokia in the South Country Cheviot Breed were of a significantly higher incidence than in the other breeds.

Nematodiriasis occurred in June and indicates the necessity to attempt forecasting this disease as undertaken at Lephinmore, Castlelaw and Bush. Preventive dosing has been built into the veterinary programmes.

Cobalt deficiency: The results of a limited number of samples taken for Serum Vitamin B_{12} examination do not allow any firm conclusions to be drawn and it is hoped to carry out a more intensive survey of the Cobalt status in the sheep flocks at Sourhope.

Cattle

No serious problems were encountered in the cattle.

Glensaugh (05C)

Sheep

Investigations into Cobalt and Copper deficiencies carried out during the year indicate that deficiencies of both can occur on the development areas. Both these deficiencies can cause an insidious loss of production as well as clinical disease and Cobalt bullets and Copper injections were used to protect sheep at risk.

Work on Cobalt deficiency carried out on a group of lambs in conjunction with A.J.F. Russel is reported elsewhere.

Further work on these trace-deficiencies is planned for 1974.

No major disease problems arose in the sheep flocks.

Lesions due to head-fly were found to be a nuisance in the Blackface lambs. As yet no satisfactory answer to this problem has been found.

At lambing a small number of abortions were found to be due to Toxoplasmosis.

The results of monitoring the sheep flocks indicate that the antholmintic dosing programmes are satisfactory.

Preliminary investigations on the diagnosis and treatment of sub-clinical cobalt deficiency in weaned lambs (04C)
(A. Whitelaw, A.J.F. Russel, A.R. Fawcett and P.E. Moberly)

In 1971 and 1972 higher than normal incidences of lamb mortality at Glensaugh during September and October were attributed to a mineral deficiency. Although it was considered that the deficient element was probably cobalt, oral dosing with cobalt chloride was not notably effective in preventing further losses.

An investigation was conducted at Glensaugh in 1973 to monitor the Vitamin B_{12} status of weaned lambs throughout the autumn months, and to study the response of lambs to two forms of cobalt administration. Thirty Scottish Blackface ewe lambs weaned in early August were grazed on a Westerwolths grass

aftermath in a field with a mean soil cobalt level of 0.17 ppm (the generally accepted satisfactory lower level is approximately 0.25 ppm). All lambs were weighed and urine and blood sampled at regular intervals from August to November. Serum samples were assayed by the West of Scotland Agricultural College Veterinary Investigation Centre for Vitamin B_{12} concentration. Urine samples were assayed at HFRO for formininoglutamic acid (FIGLU) concentration. (Deficiencies of either Vitamin B_{12} or folic acid have been shown to cause an increase in urinary FIGLU excretion, even in the early stages of the deficiency syndrome).

Mean daily live-weight gains of the 30 lambs from weaning to late September were very poor, averaging about 70 g/day. During the subsequent two weeks to 10th October there was an average live-weight loss of almost 1.5 kg/head. Serum Vitamin B_{12} concentrations were low throughout the period from early August to 10th October and tended to decrease with time, mean concentrations falling from approximately 325 to 150 pg/ml. Over the same period mean urinary FIGLU concentrations increased consistently from about 0.05 to 0.30 µmole/ml, and the proportion of lambs with measurable amounts of FIGLU in the urine increased linearly from 14 to 83%.

On 10th October the lambs were divided into three groups. Group I lambs, which served as controls and received no cobalt treatment, were subjectively assessed as having shown no signs of cobalt deficiency; none had until that time shown measurable amounts of FIGLU in the urine. Lambs in Groups II and III were subjectively poorer and weighed on average some 5 kg less than those in Group I; many had measurable urinary FIGLU concentrations and many had at some stage been classified as showing signs of cobalt deficiency. Group II lambs were dosed orally with 200 mg cobalt chloride on 10th and 31st October. Cobalt bullets were administered to Group III lambs on 10th October.

From 10th October to 21st November the mean live-weight loss of the control lambs (Group I) was 3.7 kg (90 g/day). Mean live-weight increases of lambs in Groups II and III were similar at about 130 g/day to mid-November, after which all lambs tended to lose weight, probably as a result of a concurrent deterioration in pasture quality and availability.

Serum Vitamin B_{12} concentrations in the control (Group I) lambs decreased from $>$ 200 pg/ml on 10th October to $<$100 pg/ml on 7th November. During the subsequent two weeks these levels showed an increase to normal values ($>$ 1000 pg/ml) for which no explanation can be given at this point in time. The effect of the administration of cobalt bullets to lambs in Group II resulted in Serum Vitamin B_{12} concentrations increasing from a pre-treatment value of about 200 to $>$ 1000 pg/ml within seven days. These high concentrations were maintained until the end of the investigation in late November. Oral dosing with cobalt chloride was less effective than the cobalt bullets in increasing Serum Vitamin B_{12} concentration. Mean concentrations increased from about 240 to 540 pg/ml within one week of the first dose, but had declined to 210 pg/ml after a further two weeks. This concentration increased to 750 pg/ml two weeks after the second dose, but declined again thereafter.

The mean urinary FIGLU concentration in the control (Group I) lambs on 10th October was 0.08 µmole/ml (this was the first occasion on which FIGLU was detected in the urine of these lambs) and increased progressively to 0.20 µmole/ml on 7th November. During the subsequent two weeks, when Serum Vitamin B_{12} was unaccountably rising, mean urinary FIGLU concentrations decreased to 0.04 µmole/ml. Cobalt administration, either as a bullet or oral dose, reduced urinary FIGLU concentrations to negligible levels ($<$ 0.02 µmole/ml) within seven days. The dosed (Group III) lambs, however, showed a greater increase in urinary FIGLU excretion towards the end of the investigation than did the bullet treated (Group II) lambs.

Mean urinary FIGLU concentrations include a variable number of zero values. This was taken into account by using as a parameter the percentage of individuals in each group which had measurable excretions of FIGLU. In the control lambs (Group I) this value was 70% at the time of allocation to groups, fell to 20% in the following week, remained between 40-50% from then until 7th November, and finally decreased to 10% at the time when Serum Vitamin B_{12} unaccountably increased. In Groups II and III the proportion of lambs with measurable urinary FIGLU excretions was reduced from between 70 and 100% or less by cobalt administration. In the last two weeks of the investigation this parameter also increased in the treated lambs, to 40% in those which had received bullets and to 75% in those which had been dosed.

The results of this study indicate that there is clearly a cobalt deficiency problem which affects lambs grazing certain areas of Glensaugh, particularly during the months of September and October, and that this is likely to have been the cause of the deaths of lambs at this time in previous years. The study also suggests that this deficiency could be controlled by the administration of cobalt to the lambs, and that cobalt bullets would be more effective than oral dosing with cobalt chloride. Evidence of cobalt deficiency was found in mid-August and it is probable that dosing at weaning would be more effective in ensuring satisfactory lamb live-weight gains than the treatment given in this study in October.

Serum Vitamin B_{12} concentration was used in this study as the principal criteria of satisfactory cobalt status. The B_{12} assay is, however, carried out in only a few laboratories, and is subject to certain limitations which apply to all bio-assays. Although FIGLU concentrations were, in this study, measured in samples of urine without any knowledge of urine volume, and there were consequently no means of estimating quantitative 24 h FIGLU excretion rates, mean FIGLU concentrations and the proportion of lambs with positive urinary FIGLU tests appeared to be both negatively related to Serum Vitamin B_{12} concentrations. Positive urinary FIGLU tests were noted before clinical signs of cobalt deficiency were evident, and it is considered that this test may have a use, at least in a preliminary screening programme, and possibly as a quantitative measure of the magnitude of a suspected cobalt deficiency.

<u>The influence of changes in management associated with the development of new systems on the occurrence of premature broken mouth</u> (05C)
(R.G. Gunn and W.F. Smith)

Annual examination continues on the incisor dentition of the draft ewe age on each of the YRG and IW Systems at Sourhope and Lephinmore. There has been no change in either of the YRG Systems but in the Sourhope IWS the incidence of broken mouth continues to increase on both Rigg and Gairs, in the case of the former to nearly 80%. At Lephinmore, there has been no further increase this year in the incidence of broken mouth in the Low End IWS ewes. A long-term study has been initiated on the Low End flock to determine whether the use of hay racks with plastic mesh covers will reduce the amount of physical stress on the incisors during the inwintering period. In this, all age groups have been split and allocated to either plastic or metal mesh and will be kept in these treatment groups each winter. Counts of the number of incisors present and subjective assessments of their looseness and bite position on the pad are being and will be made for several years.

ANALYTICAL SERVICES (03S)

Inorganic Chemistry
(C.C. Evans)

The movement to the new Bush HQ has, in some respects, dominated the past year's activity. Initial difficulty in the cooling water supply to the X-Ray Spectrometer has been overcome by a limited redesign of the water flow system. Problems of temperature control in the X-Ray Spectrometer room have yet to be resolved. Some further thought is also being given to sound insulation of the ball-mill room.

Central Facilities

Responsibility for a number of central facilities has been established. The deionised water supply system is operating quite smoothly. A more efficient system of control and indication of water quality is to be installed in the corridor as opposed to the relatively inaccessable plant room. The Kjeldahl digestion systems remain inoperative due to unremedied constructional faults. Oven and furnace facilities are operating quite well although some tightening of procedures is envisaged while the spectrometer room functions with a minimum of supervision.

Chemical Analysis

The routine analysis of plant, soil and faecal samples has continued. 6,200 analyses were made during the year from 2,900 samples.

A large increase in the demand for analyses led to a review of the possibilities available in increasing sample throughput. The acquisition of an automated double beam atomic absorption spectrophotometer would appear to provide the most efficient instrument to complement the X-Ray Spectrometer.

Ruthenium Analysis

As ^{103}Ruthenium (Ru) phenanthroline has been shown to be a satisfactory solid phase marker in digestive physiology experimentation the possible use of non-radioactive Ru-phenanthroline has been investigated with Dr. J.C. MacRae. (J.C. MacRae and C.C. Evans, Proc. Nutr. Soc. 1974, 33, 10A). Consequently an X-Ray Spectrometric method was developed for faecal analysis. This method involved grinding the sample (10 + 1) with a grinding and briquetting aid, compression into a disc followed by X-Ray analysis. Instrumental sensitivity was found to be 15 counts $sec^{-1}ppm^{-1}$ with an LLD of 1.5 ppm Ru. Details of the method are being prepared for publication.

Tracer Chemistry
(A.R.M. Chambers)

Methods have been developed for counting ^{3}H, ^{32}P, ^{103}Ru and ^{51}Cr and these are now operating on a routine basis.

The development of a method for the measurement of urinary output in grazing sheep to assist Project 04B

Apparatus has been designed which automatically measures out all the urine from a sheep into a container, from which a small fixed sample is taken and the remainder drained away. The flow of urine into and out of this container is controlled by three solenoid valves: A, B and C; A when energised stops the flow of urine into the container (A) and valves B and C when energised allow the urine to drain from container (A), either into a collecting bag (B) or else to the outside (C). These solenoids are operated through two relays which are switched on and off through electronic logic,

by three light transmitting-light detecting components which monitor the level of the urine in the vessel.

The urine from a catheter in a sheep fills up the container until it reaches the top light detector, when the solenoids A and B are energised. The flow in then stops and the urine flows into a collecting bag until the level of the urine is opposite the middle light detector, when the solenoid B goes off and C goes on. The urine then drains away until the level reaches the bottom light detector, when the logic resets and all solenoids are switched off so that urine can again flow into the container.

The percentage of urine collected is therefore equal to the volume of urine the container holds between the middle and top light detector, compared to the volume between the top and bottom light detector.

A prototype has been designed and built at HFRO which has proved to be successful. A further eight were then made by NIAE which are in the process of being tested.

RED DEER EXPERIMENTS (01E)

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

The object of this enterprise, conducted jointly by the Rowett Research Institute and the Hill Farming Research Organisation, is to examine the potential of the red deer as a meat-producing animal. On 31st August 1973 the farm held 152 animals, enclosed on 550 acres of heather-dominated hill land. Twelve of the deer (3 stags, 9 hinds) were born in 1970 or earlier, 55 (6 stags, 49 hinds) in 1971, 38 (12 stags, 26 hinds) in 1972, and 47 (22 stags, 25 hinds) in 1973. Six calves born in 1972 and all those born in 1973 were born at the farm. During the year the stock was increased by the 47 calves born on the farm. Losses numbered 2 animals slaughtered for carcass analysis, 2 accidental deaths, and 1 animal which died of a urinary infection.

The animals remained quite manageable and there was little difficulty in mustering them for monthly inspection and in giving feeding supplements to selected groups. A few animals were introduced from the Institute, where they had been penned individually; calves less than 6 months old integrated reasonably well with the farm herd, but older animals tended to remain isolated and so presented management problems, despite their tameness.

During the rut in October 1972 the breeding stock was separated into groups and allocated to different paddocks with one or two stags to each group. When, after 27 d, a yearling stag was introduced to each group as a "chaser" it was promptly challenged by the prime stag. Twelve days later all stags and all hinds were allowed to mix freely. A total of 56 of the 58 breeding hinds, including 48 of the 49 yearlings, produced calves. On an assumed 240-d gestation period it was calculated that 44 successful matings had occurred when only one or two stags were with each group, 7 during the "chaser" period, and the remaining 5 during the subsequent free mixing.

Of the 56 calves produced, 3 were stillborn and 6 died subsequently, mainly as a result of maternal rejection, or starvation. The average weights of the stag and hind calves at birth were 7.0 and 6.3 kg respectively; this compares with mean weights of 8.4 and 7.5 kg for 10 stag and 47 hind calves caught in the wild in 1971 and weighed when about 4 d old. Weight gains up to 16th August 1973 averaged 2.0 kg weekly, indicating that the dams were maintaining lactation satisfactorily.

In order to study the behaviour of the hinds during parturition a group of workers from the Nature Conservancy collaborated in watching the deer continuously from a distance so that the animals were left undisturbed.

Hinds and stags, born in 1970-71, lost about 5 kg during the winter but grew quite rapidly from March onwards to achieve by August net annual gains of about 5 and 10 kg for hinds and stags respectively. The lactating hinds maintained weight or grew slowly through the summer, though no supplementary food was given after June. Measurements of chest girth and metatarsus length in the 1971-born deer showed that, while girth fluctuated in parallel with changes in body weight, the growth of the metatarsus gradually slowed to reach what was apparently adult length in March 1973, suggesting that growth of the long bones was complete at about 21 months of age. From weaning in September 1972 until March 1973, the 1972-born calves received a high-protein dietary supplement at a rate of 0.5 kg per day. Pregnant and lactating

hinds received a pelleted barley-based supplement at the same rate during May and June 1973. The calves gained 27 kg in weight between September 1972 and August 1973 when the stags were about 13 kg heavier than the hinds.

The behaviour of 9 lactating hinds and 3 non-lactating hinds while grazing an 8 ha mixed grass and heather pasture was recorded. On one day per week during the 8 weeks following June 21st, the places occupied by the hinds in the paddock were plotted at $\frac{1}{2}$ h intervals in order to determine the patterns of herd movement. Other observations showed that most of the diet was grass with some heather and that, after parturition, time spent grazing increased, and that the non-lactating hind spent less time grazing. When lactating, the hind took about 18,000 bites of herbage in a day compared with a range of 6,600 to 10,800 for the non-lactating hind.

(As in Rowett Research Institute
Annual Report 1973)

GLASSHOUSE
(D.E. Suckling)

The Organisation's first glasshouse at Bush, a single span 60 ft by 21 ft structure, finally came into service on the 5th November 1973. It has been fitted with twelve 8 ft by 3 ft and three 5 ft by 3 ft benches all with adjustable platforms and light gantries. Supplementary illumination is supplied using banks of fluorescent tubes of 400 watt mercury vapour discharge lamps (type MBFR/U). Heating and ventilation are controlled automatically.

Since opening, the glasshouse has been used for Projects 02D, 03D, 05D and 04B.

A second glasshouse is nearing completion; this is slightly shorter than the existing house but will have similar facilities.

VETERINARY
(A. Whitelaw and A.R. Fawcett)

Surgery

136	Surgical Operations were carried out	
124	under Home Office Licence	
37	Rumen cannulation	Project 03C
19	Ileum and Duodenum cannulation	" "
8	Re-entrant cannulation Duodenum and Ileum	" "
15	Oesophageal fistulation	" 04B
45	Endoscopies	" 01A
12	Vasectomies	"

Laboratory

Faecal worm eggcounts	2110
Total worm counts	36
Red and White cell counts and Haemoglobin	397
Snail counts	48

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