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HFRO 226

HILL FARMING RESEARCH ORGANISATION

ANNUAL REPORT 1979

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HILL FARMING RESEARCH ORGANISATION

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1 MAY 1980

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B. SYSTEMS DEVELOPMENT

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REPRODUCTION

01001: Environmental and genetic factors affecting reproductive rate in hill and upland sheep

1. Pre-mating pasture intake and reproductive responses in North Country Cheviot ewes in different body conditions

R.G. Gunn, J.M. Doney, W.F. Smith, E. Barthram and D.A. Sim

In the 1977 experiment (see 1978 Annual Report), the Control ewes on the East Finella heft at Glensaugh gained nearly 6 kg on inbye pastures in the last 4 weeks prior to a synchronised mating. Amongst these ewes, the lighter and poorer condition (score 2½) individuals gained slightly more (6.8 kg) than the heavier and better condition (3- to 3) individuals (5.4 kg) and produced more lambs to first mating (1.54 vs. 1.35), although this difference could not be shown to be significant.

The present study was designed to examine this trend in more detail with greater control over the experimental treatments. The three oldest age groups of NCC ewes at Glensaugh were randomized into two groups at weaning in early August 1978. One group was then allowed to recover condition as rapidly as possible on hill and inbye pasture (H) while the other was restricted on poor grazing (L) until mid-October. Both groups were then run on good quality pasture (herbage allowance of 175 kg DM/ewe) for 4 weeks prior to a synchronised mating in mid-November (HH and LH). Chromic oxide dosing and faecal sampling of sample ewes in different condition classes were carried out over two periods up to and during mating. Estimates of intake will be derived from the levels of N, DM and chromic oxide in the faeces when the analyses have been carried out by the laboratory. Data on reproductive response were obtained from ovulation rate in slaughtered cast ewes and from recorded lambing in the remainder.

A summary of the results for the two groups is as follows:

Group	No. of ewes	Liveweight(kg) & condition score at mating less			Slaughtered sample			Lambing sample	
		14 wks	4 wks	0 wks	Ovulation rate (no. of ewes)	Ova loss (%)	Potential lambing rate	Lambing rate* (no. of ewes)	Litter size†
HH	52	65.1	70.4 3.00	73.5 3.15	2.24 (17)	32	1.53	1.43 (35)	1.67
LH	50	66.9	62.7 2.51	72.0 3.05	2.20 (25)	29	1.56	1.52 (25)	1.81

* Per ewe mated † Per ewe lambing

Looked at in this way there were no significant differences between the groups in any reproductive parameter althogh very substantial differences in live weight and condition were created between 14 and 4 weeks prior to mating. The excellent pasture available in this year for the last 4 weeks successfully enabled these differences to be eliminated.

However, when the responses were examined according to the condition the ewes were in at 4 weeks before mating, regardless of which treatment they had been in previously, a quite different picture emerged:

Condition score at mating-4 wks	No. of ewes	Liveweight (kg) at mating-4 wks	Liveweight (kg) and condition score at mating	Ovulation rate (no. of ewes)	Lambing rate‡ (no. ewes)	Litter size†	Estimated* ova loss(%)
⩾3+(3.33)	16	75.3	75.7 3.31	2.66 (3)	1.15 (13)	1.67	37
3	29	71.2	75.6 3.17	2.25 (8)	1.48 (21)	1.63	28
3-	22	66.9	72.7 3.09	2.30 (10)	1.50 (12)	1.80	22
2½	19	62.1	70.8 3.00	2.38 (8)	1.73 (11)	1.90	20
⩽2+(2.09)	16	56.7	67.2 2.89	1.92 (13)	1.67 (3)	1.67	13

* Estimated from ovulation rate and litter size

‡ Per ewe mated

† Per ewe lambing

These results suggest a similar trend to that described above for the 1977 experiment. With an analysis of the 2 years' results which is designed to take into account the similarity of trend in the 2 years, it is possible to show that the lighter and poorer condition (⩽ score 2½) ewes produced significantly ($P < 0.1$) more lambs than the heavier and better condition ewes (> 3-). Since the trend is less obvious in ovulation rate, although admittedly from relatively few animals, it is suggested that most of this variation in response is due to ova loss. Calculating ova loss on the basis of ovulation rate in the slaughtered ewes and litter size in the lambing ewes confirms the likelihood of this effect. The effect of flushing of leaner NCC ewes on pasture where they can freely satisfy their appetite demand may therefore be to reduce ova loss relative to that in fatter NCC ewes which may have a lower appetite stimulus. The failure to demonstrate any effect on a treatment group basis highlights the probable importance of individual variation in appetite demand in a grazing situation and the data on intake measurement are awaited with interest.

2. <u>Pre-mating pasture intake and reproductive responses in Blackface ewes in different body conditions</u>

R.G. Gunn, J.M. Doney, W.F. Smith, E. Barthram and D.A. Sim

Analysis of the liveweight and reproductive responses according to the level of body condition at 4 weeks before mating of Blackface ewes on pasture at Bush in 1978 has not shown such trends as have been described elsewhere in this Report for North Country Cheviot ewes. The Blackface breed has been looked at more critically this year at Glensaugh in comparison with a larger scale repeat study on the Cheviot breed. The latter will not be reported on until next year since the reproductive responses are based on lambing data. The Blackface study, using 150 draft ewes, can be reported since the responses have been based on data derived at slaughter at return to service or at 6-9 weeks after first mating.

Ewes were allocated to two groups in mid-September by condition score and number of lambs reared. One group (L) was run on bare hill pasture to reduce condition until 4 weeks before a synchronised mating and the other group (H) was run on good pasture to encourage a rapid recovery. For the last 4 weeks before and including mating all ewes (groups LH and HH) were run on inbye pastures providing initial herbage allowances of between 80 and 110 kg DM/ewe. Eighteen ewes were dosed with chromic oxide and faecal sampled during this period to provide data for the estimation of intake. After mating, ewes were fed on pasture until being slaughtered for counts of corpora lutea and embryos.

Both the quantity and quality of the available herbage were lower than had been hoped for and liveweight and condition responses were only moderate. A summary of the results for the two groups is as follows:

Group	No. of ewes	Liveweight (kg) & condition score at mating less 9 wks	4 wks	0 wks	Ovulation rate	Ova loss (%)	Potential lambing rate*	Litter size†
HH	72	48.3 2.24	52.0 2.42	53.8 2.46	1.57	22	1.22	1.40
LH	78	46.9 2.13	45.6 1.97	51.6 2.24	1.41	33	0.95	1.19

* Per ewe mated † Per ewe in lamb

The previously restricted LH ewes failed to overcome the relative deficit over the last 4 weeks, produced fewer (NS) and lost more (NS) ova, and as a result had significantly lower potential lambing ($P < 0.01$) and litter size ($P < 0.05$) rates. This result emphasises the greater importance of condition rather than dynamic nutritional state in the pre-mating period in this breed.

Examination of the data according to the condition the ewes were in at 4 weeks before mating showed no indication of the trends indicated in the North Country Cheviot study. This is a very similar result to that obtained from the analysis of data derived from the 1978 study on ova loss in Blackface ewes on pasture at Bush. For comparison, the results of the two Blackface studies are shown as follows:

Condition score at mating-4 wks	Year of study	No. of ewes	Liveweight (kg) & condition score at mating-4 wks	mating	Ovulation rate	Ova loss (%)	Potential lambing rate*	Litter size†
≥ 3	'78	66	60.9 2.87	59.8 2.91	2.06	25	1.55	1.62
	'79	19	59.7 2.87	61.3 2.91	2.05	33	1.37	1.63
2½	'78	49	55.3 2.50	57.0 2.66	1.92	19	1.55	1.69
	'79	31	53.4 2.50	55.0 2.56	1.58	27	1.16	1.38
2+	'78	28	51.2 2.25	53.3 2.49	1.75	20	1.39	1.63
	'79	32	47.4 2.25	50.7 2.34	1.44	26	1.06	1.26
≤ 2	'78	18	49.7 1.92	53.5 2.38	1.78	31	1.22	1.69
	'79	68	44.1 1.83	49.4 2.09	1.31	26	0.97	1.18

* Per ewe mated † Per ewe in lamb

Even allowing for the between-year differences in grading and the flock make-up as well as for the deliberate selection of the better condition ewes in 1978, there is sufficient similarity in response to suggest that in the Blackface breed the provision of good pasture in the period prior to mating is unlikely to increase the reproductive response of leaner ewes relative to those in already better condition. It may also be suggested that it is probably easier to put the condition on the ewe earlier, as in group HH, than to try and put it on later, as in group LH. It must, however, be said that the herbage quality and allowance in these two experiments were not as high as that provided for the North Country Cheviot ewes in 1978 and the results of the 1979 Cheviot study are awaited with interest.

It is also of interest to report that at Glensaugh in 1979 there were differences in response between Blackface ewes in different fields, associated, presumably, with pasture quality and allowance:

Field	No. of ewes	Liveweight (kg) at: mating-4 wks	mating	Ovulation rate	
Tup Park*	35	48.8	55.7	1.60	($P < 0.05$)
Brae Field	98	48.6	51.7	1.42	

*Stocking rate was based on calculated herbage allowance and was as nearly similar as subjective estimation of quality would allow, with the numbers made up by NCC ewes.

Some general comments on the last 3 years' pasture-based reproductive studies are in order. There are two main conclusions that must be highlighted. The first is that regulation of performance is much more difficult to achieve on pasture than it is with controlled levels of feeding. This is confounded partly through the difficulty of establishing adequate and suitable levels of pasture and partly through the variation in individual animal appetite and intake in a grazing situation. Clearly there is a further need to examine animal/pasture relationships during the recovery and mating periods if previous experimental findings on animal reproductive response are to be effectively put into practice on pasture.

The second main conclusion is that results have emphasised the problem as being largely one of high barrenness and embryo wastage. It is also suggested that this is likely to be as much a problem of fertilisation failure on the part of the ram as of the ewe.

3. The effect of live-weight and body condition recovery prior to mating on ovulation rate and early embryo mortality in Blackface and Cheviot ewes

R.G. Gunn, J.M. Doney, S.M. Rhind, W.F. Smith, A. McFadzen, M. Smales, D.A. Sim and D. Zygoyiannis

Previous studies have shown that early embryo mortality as ova loss is likely to be high following high levels of pre-mating nutrition in ewes in initially poor body condition, whether or not their ovulation rate is increased. In a study in 1978 (see 1978 Annual Report) with BF ewes in poor condition (CS = 1.5 to 1.75) at 8 weeks before mating and raised to CS = 2.0 to 2.25 at mating by varied patterns of nutritional provision, results suggested that the rate of recovery may well be important and that high levels of pre-mating nutrition (> 2 x maintenance) may have adverse effects on some aspects of ova survival relative to maintenance or $1\frac{1}{2}$ x maintenance feeding.

Since previous studies have also implied a differential response between the BF and Cheviot breeds to pre-mating treatment, the present study was designed to compare the response within a single experiment. To provide a potentially higher ovulation rate and embryo wastage rate for the other part of the study on changes in endocrine status, ewes in better initial condition than in 1978 were used even although such better condition was considered to possibly mitigate against the response achieved with much leaner ewes in 1978.

From early September, 80 draft BF ewes off the Schil and 80 draft Cheviot ewes (mixed NCC and NCC x SCC) off Hairney Law, Auchope and Park Law were group-fed in the Sourhope shed to reduce variation in body condition by late September. Ewes in each breed were then allocated to two groups and for the next 8 weeks were managed as in the 1978 Group H_8 and Group M/AL treatments. Group H_8 ewes were fed at a level to raise condition slowly by 0.5 of a score in 8 weeks while Group M/AL ewes were fed at maintenance for 4 weeks and then fed ad lib. for the last 4 weeks up to and including synchronised mating on 19-21 November. Food levels of pelleted dried grass and hay were adjusted on the basis of weekly weighings and gradings. Hay was fed to all ewes at between 11 and 12 g/kg LW/day. Dried grass fed ranged from approximately 7 g/kg LW/day for ewes on maintenance through 13 g/kg LW/day for ewes being slowly raised in condition to 22 g/kg LW/day for ewes being fed ad lib. After mating, all ewes were fed at maintenance until after the completion of the blood sampling programme for the endocrine status study (see below) when they were slaughtered at between 50 and 65 days for ovulation and viable embryo counts.

Mean body condition scores and live weights (kg) at 8 and 4 weeks before and at mating were as follows:

Breed	BF		Cheviot	
Group	H_8	M/AL	H_8	M/AL
Mating - 8 weeks	2.06 48.3	2.08 48.0	2.09 48.8	2.09 48.6
Mating - 4 weeks	2.27 53.0	2.18 50.6	2.24 53.3	2.11 49.2
Mating	2.47 55.2	2.36 56.7	2.37 55.4	2.36 56.2

Patterns of live-weight change were as planned but apparent changes in body condition were less than had been intended.

In the examination of reproductive responses, the failure to slaughter returns to service at the time of return, as in aid to the study on changes in endocrine status, led to the loss of some information on ovulation rate and the loss of most information on early wastage of single-shed ova and on total early wastage of multiple-shed ova.

The reproductive responses that could be determined were as follows:

			BF			Cheviot			Both	
			H_8	M/AL	All	H_8	M/AL	All	H_8	M/AL
No. of ewes returning to service			8	5	13	7	4	11	15	9
Ewes holding to 1st mating	No. with 1-3 ova	1	12	8	20	17	20	37	29	28
		2	17	20	37	14	14	28	31	34
		3	1	5	6	0	1	1	1	6
	Ovulation rate		1.63	1.91	1.78	1.45	1.46	1.45	1.54	1.68
Ewes with some loss (%)			45	37	41	32	26	29	38	31
No. of ewes with 0-3 embryos at slaughter		0	9	8	17	8	6	14	17	14
		1	21	15	36	22	23	45	43	38
		2	9	13	22	9	11	20	18	24
		3	0	4	4	0	0	0	0	4
Potential lambing rate*			1.00	1.33	1.16	1.03	1.13	1.08	1.01	1.23
Litter size†			1.30	1.66	1.48	1.29	1.32	1.31	1.30	1.48

* Per ewe mated   † Per ewe in lamb

There were no significant differences in ovulation rate between groups within breeds and this pattern is unlikely to be altered by the missing values from the ewes returning to service. The apparently greater ovulation rate of the BF ewes relative to that obtained in 1978 and particularly in group M/AL is likely to be related to the greater potential in this population and to their greater live weight and body condition which for many ewes may also have been within the range of greatest sensitivity to current nutrition. Ovulation rate in the BF ewes was therefore significantly greater overall than it was in the Cheviot ewes.

All aspects of ova loss are likely to have been influenced by the considerable stress imposed on the ewes by the daily blood sampling between days 11 and 30 which was necessary for the endocrine status study. Whether this is likely to have operated uniformly throughout all groups or could have led to differential response it is not possible to say. Accepting this as a potential limitation, the results of this study do not suggest that high levels of pre-mating nutrition have more adverse effects on some aspects of ova survival than do less high levels of pre-mating nutrition. The trends, if anything, are the other way. This may well be due to the higher level of body condition since previous studies have only suggested the predicted response in ewes in initially poor condition. It is, however, of interest that the proportion of ewes returning to service increased as body condition declined, while the proportion of them which were successfully mated at the first return was 73% in groups H_8 (11/15) but only 22% in groups M/AL (2/9) ($P < 0.05$). The remaining 27% of the ewes in groups H_8 which returned were mated at the second return while 44% of the ewes in groups M/AL were mated at the second return and 34% at the third return. What cannot be identified from this study is whether this greater delay in remating in the M/AL ewes was due to failure to hold to previous returns or to delayed return to service associated with late wastage. Returns to service, however, can be due to ram factors rather than ewe factors and although rams were moved daily between the pens there was considerable variation between mating sub-groups within treatment groups, ranging from 0 to 33% with no discernable pattern attributable to treatment.

Although a range of estimated wastage rates can be calculated for the ewes returning to service, it must be concluded that for valid interpretation of wastage responses it is necessary to record returns to service accurately and to slaughter them at the time of return.

4. Changes in endocrine status associated with embryonic death in Scottish Blackface and Cheviot ewes during early pregnancy

S.M. Rhind, J.M. Doney, R.G. Gunn, W.F. Smith, D.N. McFarlane, A. McFadzen, M. Smales, D.A. Sim and D. Zygoyiannis

The aim of this work was to determine the pattern of changes in circulating progesterone levels during the first month of pregnancy in ewes of the two breeds and treatment groups used in the above experiment and to establish precisely the relationship between the time of embryonic death and the associated fall in circulating progesterone levels.

The relationship, if any, between plasma concentrations of progesterone and prolactin during early pregnancy will also be investigated as there is some evidence that abnormally high levels of prolactin, possibly associated with stress, may interfere with luteal functioning and progesterone production, and result in embryonic death.

Blood samples were collected by jugular venepuncture at approximately days 6, 11 to 30 and 46 after mating and the hormone concentrations in the plasma will be determined in due course by radio-immunoassay.

5. Fertility in Greyface ewes. The effect of changes in liveweight and body condition before and after mating on lamb production

R.G. Gunn, T.J. Maxwell, J.M. Doney, W.F. Smith, E. Barthram, R.D.M. Agnew and D.A. Sim

This experiment was designed to study further the importance of direction of liveweight change at mating time in relation to lamb production in Greyface ewes. For 4 weeks in August-September, the spread of body condition in 268 Greyface ewes and gimmers was reduced by controlled grazing of pasture paddocks providing a range of herbage allowances between 80 and 210 kg DM/head. This period was also used to establish a range of pasture availabilities for the treatments to be subsequently imposed. From 20 September until a synchronised mating from 8 November, half the ewes (Group H) were run on pastures providing high levels of herbage allowance (> 175 kg and > 200 kg DM/head for ewes and gimmers, respectively) to raise liveweight and condition. The rest of the ewes (Group L) were run on pastures providing low levels of herbage allowance (< 65 kg and <75 kg DM/head for ewes and gimmers, respectively) to reduce liveweight and condition. After mating, half the ewes in each group were transferred to pastures of the opposite level of availability for 5 weeks (groups HH, HL, LH and LL). Initial herbage allowances varied from 95-165 kg DM/head for groups HH and LH and from 50 to 65 kg DM/head for groups HL and LL. These allowances could not be maintained at this late stage of the season, with the result that the high levels dropped fairly rapidly and alternative paddocks had to be found for the low groups which initially raised the low allowance to 100 kg DM/head at one week after mating.

The mean liveweight response of the different groups was as shown in Fig. 1. The difficulty experienced in the post-mating period in providing herbage allowances to satisfy the treatment design was matched by the liveweight responses. Such differences in liveweight as were achieved post-mating had disappeared by the end of the period, with the intended high treatment at this time actually resulting in an overall loss.

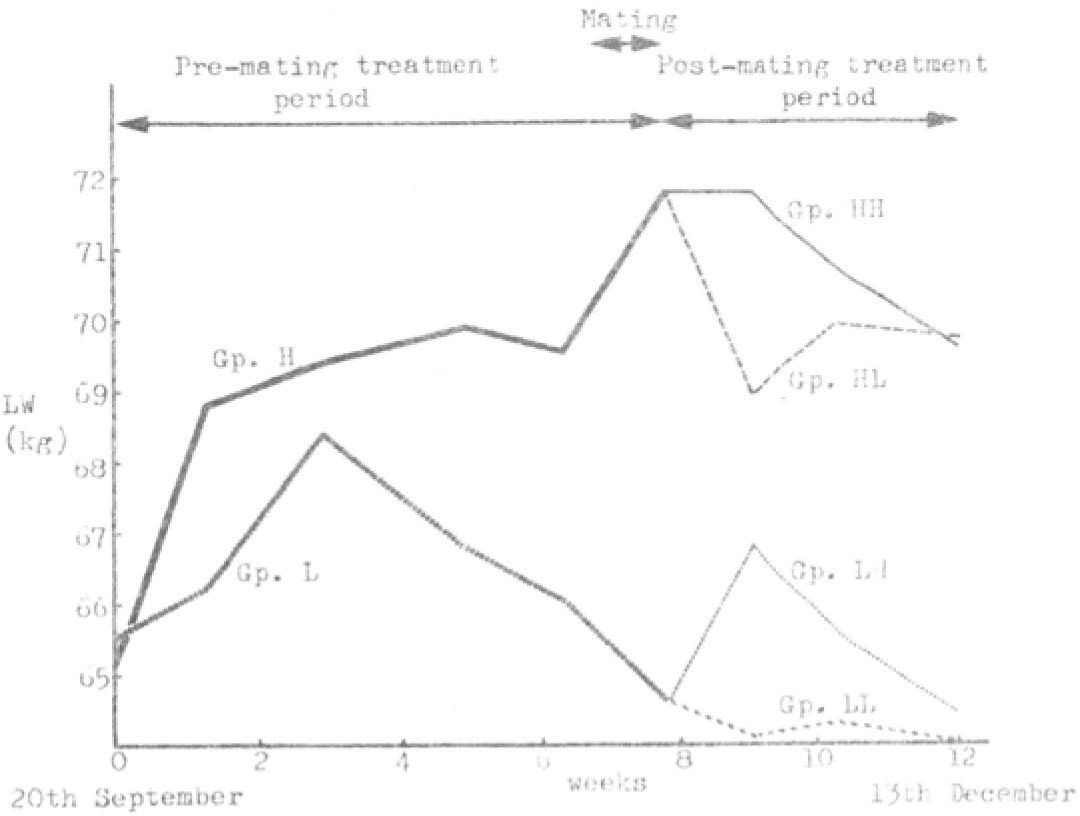


Fig. 1. Liveweight response of Greyface ewes and gimmers.

Information on ovulation rate and early embryo mortality was obtained after slaughtering the draft age and case ewes in mid-December. The rest of the ewes received identical management in mid- and late pregnancy and lambing performance was recorded.

The mean liveweights (LW) and body condition scores (CS) of the ewes and gimmers in the H and L pre-mating groups and the mean ovulation rates the slaughtered sample are shown in the following table:

Pre-mating Treatment		No.	Mating – 7 wks LW(kg)	Mating – 7 wks CS	Mating LW(kg)	Mating CS	Ovulation rate (no. of ewe
H	Ewes	100	64.6	2.87	72.6	3.26	2.59 (22)
	Gimmers	30	66.2	3.46	69.7	3.63	–
L	Ewes	97	65.6	2.90	65.3	2.86	2.17 (18)
	Gimmers	29	65.3	3.45	62.9	3.19	–

The gimmers, being initially fatter, responded less to the H treatment and more to the L than did the ewes. Pre-mating treatment did, however, create significant liveweight and condition differences in both classes. While the use of cast ewes as a slaughter sample additional to the draft age can be considered as introducing a potential bias, the ovulation rate of the group H ewes was significantly ($P < 0.05$) greater.

Ovulation and wastage data from the slaughtered sample and some lamb production data based on first mating of the lambing sample are shown in the following table for groups HH, HL, LH and LL.

Treatment group		No.	Slaughtered sample No.	Ovulation rate	Returns to service(%)	Ova loss (%)	Potential lambing rate	Lambing sample No.	Lambing rate*	Barren to 1st mating (%)	Litter size†
HH	Ewes	50	13	2.77	31	44	1.54	37	1.35	27	1.85
	Gimmers	15	-	-	-	-	-	15	1.53	0	1.53
	Both	-	-	-	-	-	-	52	1.40	19	1.74
HL	Ewes	50	9	2.33	25	32	1.44	41	1.44	20	1.79
	Gimmers	15	-	-	-	-	-	15	1.73	13	2.00
	Both	-	-	-	-	-	-	56	1.52	18	1.85
LH	Ewes	48	8	2.38	43	56	1.00	40	1.40	23	1.81
	Gimmers	15	-	-	-	-	-	15	1.47	20	1.83
	Both	-	-	-	-	-	-	55	1.42	22	1.81
LL	Ewes	49	10	2.00	18	20	1.60	39	1.18	26	1.59
	Gimmers	14	-	-	-	-	-	14	1.43	7	1.54
	Both	-	-	-	-	-	-	53	1.25	21	1.57

* Per ewe (or gimmer) mated

† Per ewe (or gimmer) lambing

An unexpected feature of the results was the high ovulation rate of the slaughtered LH ewes, although the numbers involved were few. This was, however, matched by a relatively high lambing performance, particularly in terms of litter size which was significantly ($P < 0.05$) greater than that of group LL ewes.

In view of the similar pre-mating liveweight and condition of the ewes in groups LH and LL this result is difficult to explain, particularly with the only limited post-mating treatment effects. Other results of interest were the significantly greater ova loss experienced by the slaughtered ewes in groups HH and LH which were supposed to have a high level of post-mating nutrition but did so for only a brief period. The relatively high barrenness rate to first mating incorporates those ewes which return to service. This tends to lower the apparent lambing rate which rose to 1.65, 1.73, 1.58 and 1.45 for groups HH, HL, LH and LL, respectively, when lamb production to second mating was included.

It is of interest that the exposure of the gimmers to teaser rams and the subsequent oestrus synchronisation were associated with a significantly ($P < 0.05$) lower barrenness plus return to first service rate (10%) than that of the ewes (24%). This resulted in a lower lambing rate to first mating for the ewes (1.34 vs. 1.54; $P < 0.1$) but no difference in litter size (1.76 vs. 1.72).

Since the responses by treatment group include some individual variation in direction of liveweight change about the time of mating, examination of lambing performance was carried out by direction of change prior to mating as well as post-mating. Those ewes and gimmers gaining liveweight prior to mating produced significantly ($P < 0.05$) more lambs fo first mating (1.56) and also weighed more than the ewes and gimmers maintaining (1.30) and losing weight (1.31). In those ewes and gimmers which maintained weight during the 9 days immediately after mating, litter size was significantly ($P < 0.05$) greater (1.87) than in those gaining

(1.69) or losing weight (1.67). Since this was inversely associated with barrenness there was no difference in lambing rate. Within each pre-mating category of liveweight change, lambing rate increased progressively with the direction of post-mating change with the exception of the few animals gaining throughout:

Pre-mating	G*			M*			L*		
Post-mating	G	M	L	G	M	L	G	M	L
No.	7	35	37	16	23	21	40	24	13
Lambing rate	1.57	1.63	1.49	1.44	1.30	1.19	1.43	1.21	1.15
Barren to 1st mating (%)	0	14	16	0	30	29	23	33	15
Litter size	1.57	1.90	1.77	1.44	1.88	1.67	1.84	1.81	1.36

* G = Gaining, M = Maintenance, L = Losing, liveweight.

These results tend to confirm previous years' findings that loss of weight over the mating period is associated with a depression in lambing performance. This appears to be due more to a failure to hold to first service or an increase in barrenness/total wastage than to any difference in litter size and may therefore be an expression of failure of fertilisation. The lambing response of the ewes in the pre-mating high groups was disappointing, particularly in view of the high ovulation rate in the slaughtered sample. This was associated with a high wastage and merits further examination.

LACTATION

01002: <u>Factors affecting lactation yield and its consequences in lamb growth</u>

1. <u>The interaction of ewe and lamb genotype on milk consumption and lamb growth</u>

J.M. Doney, J.N. Peart, W.F. Smith, D.A. Sim and J. Riva

Previous studies have demonstrated differences in the pattern of milk production associated with breed of ewe. Other work has shown that, within a single ewe breed, lamb genotype can influence maternal milk yield by differences in demand. The present experiment was designed to examine the extent to which previous findings on differences in milk intake and growth of lambs reared by different ewe breeds could be confounded by associated differences in lamb genotype.

In September 1978 the group of East Friesland crossbred and pure Blackface ewes, all born in 1975 to Blackface ewes on House o' Muir hill and reared together under hill conditions, were transferred to improved pasture to achieve more uniform and higher body condition at mating. After synchronisation of oestrus the BF ewes were mated to BF rams and the crossbred ewes to Suffolk rams. After x-ray diagnosis at 100 days 36 ewes of each breed type were transferred to individual pens in the sheephouse. Parturition was further synchronised by administration of dexamethosone. All lambs were removed from their dams immediately at birth and were re-allocated in a pre-determined sequence:

After all transfers were completed 48 ewes (8 groups of 6 ewes - 2 ewe breeds x 2 lamb breeds x 2 single or twin suckling) were retained. Pelleted food was offered ad libitum and records of milk production, milk quality and ewe and lamb liveweight were taken at weekly intervals for 14 weeks.

Mean daily milk production results of the 4 single-suckled and 4 twin-suckled groups are shown in Figure 1a and 1b, respectively (see over).

In the early weeks of lactation the mean intake of milk was influenced by both ewe and lamb breed such that crossbred lambs suckling crossbred ewes established a higher intake than did pure BF lambs on crossbred ewes. Similarly pure BF lambs established a higher intake from crossbred dams than they did when suckling pure BF ewes. The crossbred lambs succeeded in increasing the yield of their pure BF foster-mothers whereas BF lambs did not utilise the full potential of their crossbred foster-mothers.

In later lactation, after the 5-7 weeks, as all lambs grew and as the plateau phase of lactation was reached the breed-of-lamb effect declined and maternal potential became the limiting factor in milk intake. Mean lamb liveweight at 100 days differed in response to all three factors, breed of ewe, breed of lamb and number suckled per ewe (Table 1).

Table 1

Breed of ewe	EFX				BF				
Breed of lamb	3-cross		BF		3-cross		BF		Mean
Suckling regime									
No. suckled	S	T	S	T	S	T	S	T	
100 day weight (kg)	43.6	38.0	36.6	31.5	41.1	36.3	32.8	29.6	36.2
Deviation from mean	+7.4	+1.8	+0.4	-4.7	+4.9	+0.1	-3.4	-6.6	

Breed of lamb and type of rearing had the greatest influence on lamb weight at 100 days but the effects of maternal differences in lactation were also significant (average weight differences for breed of lamb, type of rearing and breed of ewe, respectively, were 7.1, 4.6 and 2.4 kg).

The relationship between cumulative liveweight gain of lambs and cumulative milk intake from birth to 14 weeks of age are shown in Figures 2a and 2b. (see over). These figures also include data from a separate study (see next section) in which the ad lib. intake of milk replacer and liveweight gain was measured from birth to 12 weeks of age. There appears to be a linear relationship common to all groups in the early stages of growth, when milk is likely to form the sole component of diet. Deviations from this linear relationship occurred at different stages, related to liveweight. Lambs with milk intakes which are low relative to their growth potential (i.e. twins compared to singles or crossbred lambs suckling Blackface ewes) deviate at an earlier stage. This deviation could be accounted for by either a differential change in efficiency of utilisation of milk or compensatory differences in solid food intake. Although this was not measured in this study, the latter explanation is the more likely and indicates the need for further studies on dynamic changes in diet components in relation to lamb genotype, milk availability and characteristics of the solid food on offer.

Liveweight change of ewes was affected only by number of lambs reared. Ewes with singles gained liveweight from parturition and at the end of 14 weeks the BF & EFX ewes had gained 10.4 and 9.9 kg, respectively. Ewes rearing twins showed small but positive gains during the first 3 weeks and thereafter also gained progressively such that the total gains in 14 weeks were 4.4 and 5.9, respectively, for BF and EFX ewes.

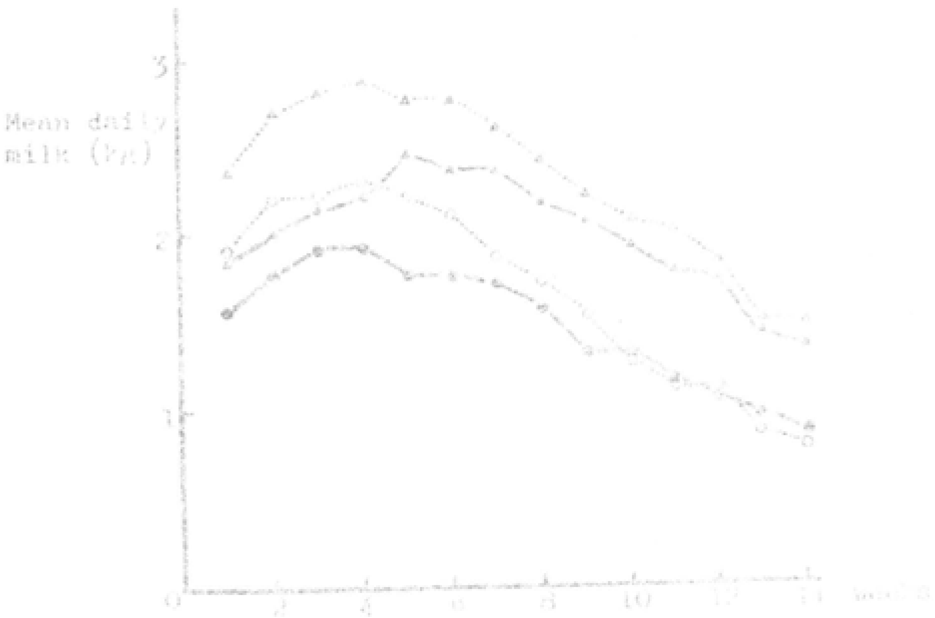


Fig. 1a. Mean daily milk production of single-suckled ewes.

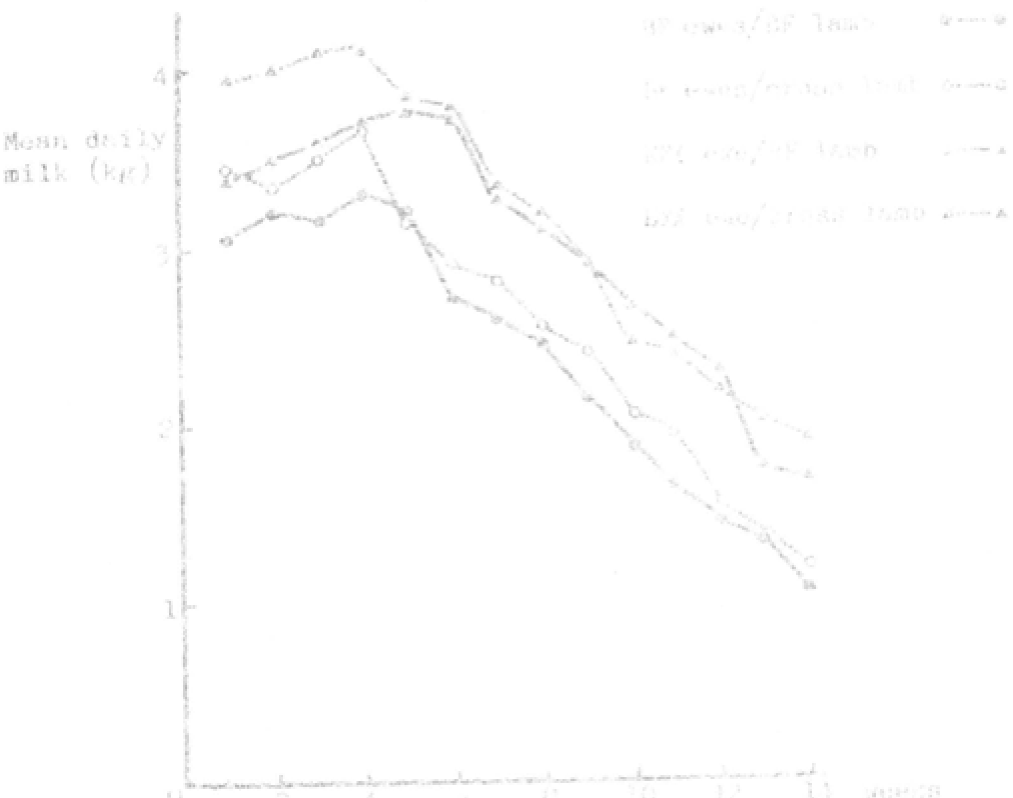
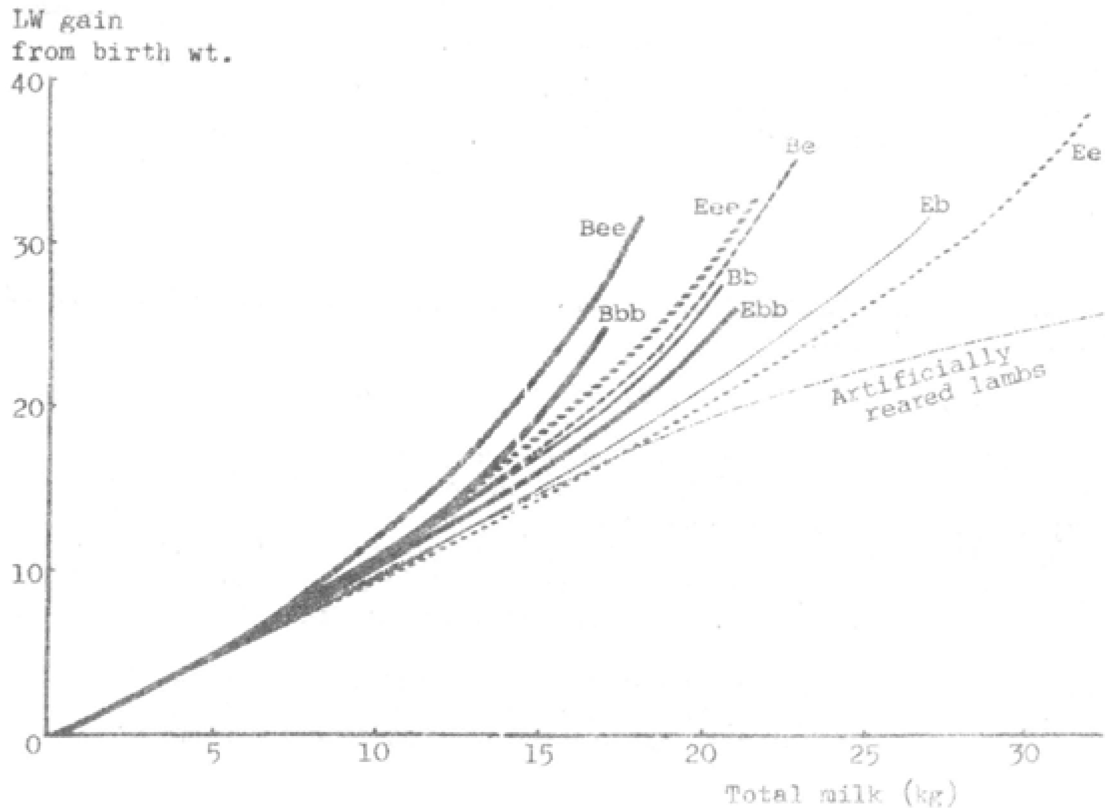


Fig. 1b. Mean daily milk production of twin-suckled ewes



EWE			LAMB	
			single	twin
Blackface	B	Blackface	b	bb
East Friesland	E	Cross	e	ee

Fig. 2 Relationship between cumulative liveweight gain of lambs and cumulative milk intake.

Results from the analysis of milk composition were similar to those in previous years. SNF% showed no differences associated with the main factors or with week of lactation. Fat % in all groups showed a tendency to fall slightly to around the 6th week and to increase thereafter. In all weeks the fat % content of milk from BF ewes was significantly higher than that from EFX ewes irrespective of suckling factors (overall mean 6.4 and 5.0%, respectively).

2. A preliminary trial on lamb rearing with milk replacer

J.M. Doney, A.D.M. Smith, W.F. Smith and J.N. Peart

In preparation for field scale studies in which the milk intake of grazing lambs could be controlled a preliminary trial of techniques involved in the feeding of milk replacer was carried out on 6 Dorset cross lambs from birth to 12 weeks of age. These lambs were fed to determine whether ad lib. intake of milk would be related to the ewe lactation curve. Results, which are included in Figure 2 of the preceding report, show that milk intake reached a much higher peak level than would be obtainable from the ewe (mean maximum 4.2 kg/day) and that there was no fall with increasing age. Solid food was not consumed to any significant extent but this may have been influenced by the form of presentation.

3. Endocrine studies of lactating ewes of contrasting breeds in relation to milk yield and body composition

S.M. Rhind, J.N. Peart, J.M. Doney, D. McFarlane and D.A. Sim

The levels and pattern of milk production of East Friesland x Scottish Blackface ewes are substantially different from those of Scottish Blackface ewes (see 01002, expt. 1). While under genetic control, these differences must be mediated through differences in the endocrine status of ewes of the two breeds which in turn controls the partitioning of nutrients in the ewe, between milk and body tissue, and the efficiency of utilisation of nutrients for milk production.

The aim of the present work was to determine the patterns of change in several hormones during the course of lactation in the ewes in experiment 1 and to establish the inter-relationships between the hormones and between hormone status and milk yield.

Blood samples were collected by jugular venepuncture from all ewes, at weekly intervals during lactation. The plasma was divided into aliquots and the concentrations of insulin, growth hormone, thyroxine, triiodothyronine cortisol and prolactin are currently being determined.

NUTRITION IN PREGNANCY

02002: Studies on the nutritional physiology of the pregnant ewe

1. The effect on sheep production of the interaction between nutrition during mid-pregnancy and other phases of the production cycle

A.J.F. Russel, T.J. Maxwell and I.R. White

The objectives of this experiment, which was initiated at Lephinmore in October 1976 are:

1. To study the effects of different nutritional states during mid-pregnancy on the subsequent performance of sheep within systems of management which provide different levels of summer nutrition and

2. To examine, in the long-term and within a systems context, the effects of the interaction between different levels of mid-pregnancy and summer nutrition on production from hill sheep.

The experiment is being carried out on the 360 ewes of the Low End flock. From the completion of mating in early January until the beginning of the late pregnancy supplementary feeding in early to mid-March, the ewes are divided into three groups. Different patterns of live-weight change are induced over this mid-pregnancy period by varying inputs of concentrates.

During late pregnancy the inputs of supplementary feeding are designed to maintain the same controlled moderate degree of undernourishment in all three groups.

After lambing and throughout lactation, half of the ewes from each mid-pregnancy nutrition group (i.e. a total of 180) are grazed on improved pasture until weaning (high level of summer nutrition); the remaining 180 ewes are maintained on the indigenous hill pasture (low summer nutrition).

All ewes graze the hill area after weaning in August. Those on the high summer nutrition treatment return to the improved pasture again in late September or early October, and remain there for at least the first part of the mating period, before joining the remaining ewes on the hill sometime in December.

The experiment thus comprises six groups, each of 60 ewes (three levels of mid-pregnancy or winter nutrition x two levels of summer nutrition). The design can also be regarded in some respects as a comparison of two systems of management (the traditional system and the two-pasture system) incorporating an examination of the effects of different levels of mid-pregnancy nutrition. It is planned that the experiment will continue for a number of years to permit the examination of any cumulative or carry-over effects from one year to another. To facilitate this aspect of the investigation, replacement ewe hoggs are retained as far as possible in the groups into which they are born.

Records of live weight and condition score are obtained at regular intervals throughout the year, and blood samples are collected periodically from ten ewes per group for assessments of nutritional state.

At the end of the first year of the experiment the live weight of ewes in all groups had increased by some 5 kg, there being very little difference between groups. The different nutritional treatments during subsequent years have been effective in producing differences in live weight. The high "summer" nutrition groups have obtained a live-weight advantage of some 3 kg from the grazing of improved pasture over the premating period, and this has been maintained to the beginning of the mid-pregnancy period and indeed was still apparent to a small extent at lambing time. The mid-pregnancy nutritional treatments have also been effective in producing markedly different patterns of live-weight change, the range in mean live weights between the extreme groups at the end of the period being about 8.5 kg.

Live-weight changes during and after lactation were such that the differences apparent between the various groups at the end of pregnancy had virtually been eliminated by September. This is considered to be due in part to the lower levels of production from the ewes in the low summer nutritional treatment groups, and possibly to some improvement in the quality of grazings available to these ewes.

The quantities and costs of the concentrate inputs to the three winter nutrition groups during mid- and late-pregnancy are summarised in Table 1.

Table 1. Quantities and costs of mid and late pregnancy concentrate inputs (1978/79)

	High	Medium	Low
Mid-pregnancy (kg/ewe)	33.5	12.3	5.5
(£/ewe)	3.90	1.43	.64
Late pregnancy (kg/ewe)	24.8	27.3	23.9
(£/ewe)	2.89	3.19	2.79
Total (kg/ewe)	58.3	39.6	29.4
(£/ewe)	6.79	4.62	3.43

Hay was also used as storm feeding. Differences in the inputs of concentrates required to maintain the same prescribed nutritional states in the three groups during late pregnancy were small.

There were no differences in lamb birth weights between High and Medium levels of mid-pregnancy nutrition, but the birth weights of single lambs from the Low group appear reduced.

The data in Table 2 show that the reduced birth weights of lambs from the low mid-pregnancy nutritional treatment affected lamb weights at marking and at weaning. By weaning the difference in mean weight of lambs at birth had increased by a factor of more than three. There was some evidence of an effect of level of "summer" nutrition (i.e. pre-mating nutrition) on lamb birth weight but its effect during the subsequent lactation was small and resulted in an advantage of less than 1 kg in weaning weight.

Table 2. Mean weights (kg) of single lambs from ewes in the six treatment groups, at birth, marking and weaning (1978/79)

Summer Nutrition		Winter Nutrition High	Medium	Low	Mean
High	Birth	4.3	4.3	3.9	4.2
	Marking	12.6	12.0	11.0	11.8
	Weaning	26.0	25.0	24.3	25.1
Low	Birth	4.0	4.0	3.7	3.9
	Marking	11.5	11.2	10.7	11.1
	Weaning	24.9	24.3	23.7	24.3
Mean	Birth	4.2	4.2	3.8	4.0
	Marking	12.1	11.6	10.9	11.5
	Weaning	25.5	24.7	24.0	21.7

The production data for the year are summarised in Table 3.

Table 3. Percentages of lambs born, marked and weaned, and weight of weaned lambs produced from ewes in the six treatment groups (1978/79)

Summer Nutrition		Winter Nutrition High	Medium	Low	Mean/Total
High	Lambing %	122	105	105	110.7
	Marking %	107	98	92	99.0
	Weaning %	103	98	88	96.3
	Total output weaned lamb (kg)	1516	1420	1216	4152
Low	Lambing %	87	92	100	93.0
	Marking %	75	74	78	76.0
	Weaning %	72	69	77	72.7
	Total output weaned lamb (kg)	1096	1007	1091	3194
Mean/Total	Lambing %	104.5	98.5	102.5	101.9
	Marking %	94.3	86.0	85.0	87.5
	Weaning %	87.5	83.5	82.5	84.5
	Total output weaned lamb (kg)	2612	2427	2307	7346

Production of weaned lamb from ewes on the high level of summer nutrition was some 30% greater than from those on the low summer treatment, due partly to higher lambing and weaning percentages and partly to heavier birth and hence weaning weights. The results in Table 3 indicate that the main effect of the high level of summer nutrition operated through the use of improved pasture before and during mating; the effect operating during lactation was smaller than previously, and subjective assessment would attribute this to a deterioration in the reseeded areas in the severe winter of 1978-79 and the exceptionally wet summer in 1979.

Production differences due to the mid-pregnancy nutritional treatments were less than that attributable to summer nutrition, the difference between the extreme winter treatments being of the order of 13%. This again comprised effects of lambing and weaning percentages and of birth and hence weaning weights.

2. The effect of diet quality on tissue mobilisation in pregnant ewes

A.J.F. Russel, S.M. Rhind, I.R. White and D.N. McFarlane

The dependence of pregnant ewes on body reserves is now widely accepted, as is the need to be able to quantify the use of these reserves in terms of body fat and protein. The limited information available on the catabolism of fat and protein in undernourished pregnant ewes has mostly been obtained against particular experimental backgrounds, and little can be inferred from this as to the effects of diet quality on tissue mobilisation. Body protein can be used as a source of energy as well as of nitrogen, but it is not known whether the proportions of body fat and protein catabolised can be influenced by the quantities and/or proportions of energy and nitrogen in the diet.

It is important to obtain information in this area to be able to interpret with better understanding changes in ewe live weight (for example, the catabolism of protein tissue to yield a specific amount of energy will result in a much greater live-weight loss than if that energy were derived from fat). It is also possible that the catabolism of one type of tissue in preference to another could have important effects on production which are not yet recognised. If the catabolism of body tissue is influenced by the concentrations of dietary energy and nitrogen, this is likely to have an important bearing on the formulation of supplements to be fed to ewes grazing different types of indigenous herbage.

For these reasons a preliminary investigation of the effects of diet quality on tissue mobilisation was initiated at Lephinmore in November 1979. A total of 60 cast-for-age Scottish Blackface ewes, mated to Blackface rams following oestrus synchronisation, were used in the study. Twelve ewes were slaughtered shortly after mating to provide information on initial body composition. Two groups, each of 24 ewes, were confined to small heather-dominant areas and received isocaloric supplements containing chromic oxide and either 6.5 or 19.1% crude protein. The two groups alternated between the grazing areas, initially at fortnightly intervals, and later weekly.

Blood samples were collected at regular intervals to characterise nutritional status, and analyses of these in terms of plasma free-fatty acid, 3-hydroxybutyrate, glucose, urea, total serum protein and albumin concentrations are awaited. Samples of faeces were also collected to provide an estimate from chromic oxide concentrations of grazed herbage intakes.

Twelve ewes from each of the two groups were slaughtered at approximately 90 days of gestation and the remaining 12 from each group in the last few days of pregnancy. The empty bodies and products of conception will be analysed chemically to provide estimates of the changes in body composition over the course of the investigation, and of the effects of treatments on foetal weight and composition.

3. <u>Changes in endocrine status of ewes during late pregnancy in response to different levels of dietary protein</u>

S.M. Rhind, A.J.F. Russel, D. McFarlane and I.R. White

To obtain a better understanding of the mechanisms involved in the control of body tissue mobilisation the endocrine status of the ewes in the above experiment was investigated.

Blood samples were collected by jugular venepuncture from the 24 ewes slaughtered near term. These were collected at approximately 25, 60, 80, 100, 120 and 140 days after mating. Owing to the difficulties of obtaining a realistic estimate of plasma levels of hormones, some of which are released into the blood in pulses, six samples were taken at hourly intervals on each of these days; thus short term variations in hormone levels would be taken into account.

The plasma samples were divided into aliquots and are currently being assayed for growth hormone, insulin, cortisol, glucagon, prolactin, thyroxine and triiodothyronine. The inter-relationships between the concentrations of these hormones and nutritional indices such as plasma free fatty acid, 3-hydroxybutyrate, urea and glucose levels will be examined and related to changes in body composition during pregnancy.

Since absolute levels of hormones do not necessarily provide a true indication of their rate of secretion or utilisation, on three occasions during pregnancy, at approximately 30, 90 and 130 days, estimates were obtained of the half-lives of most of the hormones under investigation. Those of the thyroid hormones were not measured because they are several days in length.

A dose of the appropriate hormone, calculated to raise circulating levels by at least 300%, was rapidly infused into the jugular veins of two ewes arbitrarily selected from each treatment group and blood samples were then collected after 2, 5, 8, 10, 15, 20, 25, 30, 45, 60 and 90 minutes so that the rate of decline of plasma concentrations of the hormones could be assessed. The same type of hormone was infused into each of the five groups of four animals on all occasions i.e. none of the animals was infused with more than one hormone.

NUTRITION : SUPPLEMENTATION

02005: Studies on the supplementation of low quality roughage diets for sheep

1. The effects of supplementation on the nutritive value of heather and *Agrostis/Festuca* diets

R.W. Mayes, C.S. Lamb and A.P. Thompson

When heather is fed to sheep the availability of non-ammonia nitrogen (N) is very low. With low voluntary intakes of heather is is thus likely that the amounts of amino acid being absorbed from the small intestine are very small. This suggests that performance of sheep grazing heather may not simply be limited by digestible energy supply but also (or maybe primarily) by amino acid supply. Since ruminal digestion of heather appears to be limited by low N availability, supplementation with N (and energy) should not only improve organic matter digestibility but also increase amounts of amino acids being absorbed due to increased microbial protein synthesis.

Sheep grazing on heather hills normally include indigenous grasses (e.g. *Agrostis/Festuca*) in their diet. Therefore, effects of supplementation must be assessed from a knowledge of the digestion and utilisation of such dietary mixtures. Because it is likely that it is the availability of fermentable energy and not N that limits ruminal digestion of *Agrostis/Festuca* (A/F) the type of response in rumen fermentation to addition of N or energy would depend upon the relative proportions of heather and A/F in the diet. In the following two experiments the production rates of volatile fatty acids (VFA) and microbial protein, and sites of digestion of N and organic matter are being determined in sheep receiving heather and A/F mixtures and when supplemented with urea and starch.

Experiment 1. Twelve wethers fitted with rumen, duodenal and ileal cannulae were fed continuously either A/F alone, 2/3 A/F:1/3 heather, or 1/3 A/F:2/3 heather at 500 g DM/day for 26 days. Ruminal production of acetic, propionic and butyric acid was determined by an isotope dilution technique. Microbial protein flow from the rumen was determined from the incorporation of ^{35}S into bacteria. Excreta, duodenal and ileal collections were made to determine N balance and sites of digestion of N, energy, amino acids and fibre.

Experiment 2. Similar procedures were adopted using 11 cannulated wethers receiving freeze-stored herbage (1/3 A/F:2/3 heather at 500 g DM/day). Six of the sheep also received daily, by continuous intraruminal infusion, a suspension of starch (120 g) and urea (7.25g).

Results available are shown in Table 1.

Table 1. Mean dry matter and N digestibility, N balance, N intake and plasma urea results for Experiments 1 and 2

	Dry matter digestibility (%)	Nitrogen digestibility (%)	Nitrogen intake (g/day)	Nitrogen balance (g/day)	Plasma urea (mM)
EXPERIMENT 1					
A/F alone	45.6	43.0	5.89	-2.55	2.50
2/3 A/F:1/3 heather	41.2	33.8	6.22	-2.29	1.88
1/3 A/F:2/3 heather	39.9	20.5	6.19	-2.44	1.15
EXPERIMENT 2					
1/3 A/F:2/3 heather	42.6	31.7	6.22	-2.42	1.54
1/3 A/F:2/3 heather + starch + urea	48.4	50.0	9.61	-0.29	1.73

In Experiment 1 an increase in the amount of heather in the diet was associated with a reduction in diet DM and N digestibility and plasma urea concentration. Nitrogen intake and N balance were similar for each diet although the amount of apparently digested N increased as the proportion of A/F in the diet increased. This extra absorbed N did not appear to be retained in the animal.

In Experiment 2 infusion of starch and urea into the rumen improved DM and N digestibility. The supplementary urea N was apparently retained in the animal.

2. Volatile fatty acid production in the rumen of sheep given roughage and concentrate diets when the concentrate supplement is given once daily or continuously

R.W. Mayes, J.A. Milne, C.S. Lamb, A.M. Spence, A.P. Thompson and H.A. Fisher

Ewes at pasture are usually given supplements either once daily, as for example in the experiment reported on p.A.26, or feed from blocks or licks (see p.A.23). The measurement of volatile fatty acid (VFA) production in the rumen under these circumstances may be used for the estimation of digested energy intake since VFA represents the major end-product of energy digestion. To measure VFA production in the rumen when supplements are ingested in one or more discrete meals poses difficulties since the usual isotope dilution method requires that the animal be fed continuously to produce steady-state conditions in the rumen. The feeding of conventional supplements is likely to produce non-steady-state conditions in the rumen. Morant, Ridley and Sutton (1978) have recently suggested a possible approach to the measurement of VFA production under such conditions. A modification of that approach has been used in the experiments described below.

It is often necessary to estimate production rates of individual VFA's such as acetic and propionic acid and this is facilitated if their production rates can be measured simultaneously. However, this is only possible if interconversions of the two acids are negligible. To examine the extent of their interconversions and of the possibility of their oxidation in the rumen a four-pool model of carbon (C) flows between rumen bicarbonate, acetic acid, propionic acid and plasma bicarbonate was evaluated in one of the experiments. The position of the C label in the propionic acid molecule may have an important effect on the measured production rate of that acid, so a comparison between 1-^{14}C and 2-^{14}C labelled propionate was also included in one of the experiments.

In Experiment 1 six rumen-fistulated Scottish Blackface wethers were offered one of 3 treatments (fresh perennial ryegrass (FPRG),1.2 kg DM/day; 0.8 kg DM/day + 0.45 kg/day cereal-based supplement; 0.46 kg DM/day FPRG + 0.85 kg/day supplement) The FPRG was offered thrice daily and the supplement once daily. A solution of Cr-EDTA as a liquid-phase marker and ^{14}C-labelled acetate or propionate were continuously infused into the rumen for 28 hours. Following an intraruminal injection of ^{51}Cr-EDTA at the beginning of the infusion period, rumen liquor samples were taken hourly for 24 h. Analysis of these samples enabled the estimation of VFA production under non-steady-state conditions to be made.

In Experiment 2 the same treatments were used except that dried perennial ryegrass (DPRG), given continuously, replaced the fresh grass. The 3 treatments produced diets containing 0, 30 and 60% of the supplement. The treatments were compared using 6 rumen-fistulated sheep in two 3 x 3 incomplete latin square designs. Within each 32-day period the supplement was given by continuous feeder for the first 16 days and then once daily to allow comparisons of VFA production rates under steady- and non-steady-state conditions on each treatment. Interconversions between acetic acid, propionic acid and ruminal and plasma bicarbonate pools were evaluated using the 4-pool model. A comparison between 1-^{14}C and 2-^{14}C labelled propionate was made in the steady-state condition.

Results from Experiment 1 and the non-steady-state periods in Experiment 2 are not yet available. Table 1 shows measured production rates of acetic and propionic acids and C flows evaluated from the 4-pool model from sheep in steady-state conditions.

Table 1. Experiment 2. Mean production (irreversible loss) rates of acetic and propionic acids and C flows between acetic, propionic and ruminal and plasma bicarbonate pools (gC/day) in sheep receiving DPRG and supplement in steady-state conditions

			Diet		
Supplement in Diet (%)	0	0	0	30	60
^{14}C-label in propionate infused	1-^{14}C	2-^{14}C	Combined*	1-^{14}C	1-^{14}C
Production Rates					
Acetic Acid	135	131	133	139	179
Propionic Acid	99	47	64	80	110
C-Flows from 4-pool Model					
Acetic Acid:					
Produced from diet	132	127	129	136	175
Converted to propionate	7	1	4	6	10
Oxidised in rumen	11	2	7	1	6
Absorbed	117	127	122	131	164
Oxidised in tissues	71	81	77	74	105
Propionic Acid:					
Produced from diet	73	34	37	60	76
Converted to acetate	0	2	2	1	0
Oxidised in rumen	64	0	13	38	47
Absorbed	44	46	52	41	77
Oxidised in tissues	37	31	37	38	55
Ruminal CO_2:					
Produced from diet	99	54	89	60	76
Fixed into acetate	3	1	2	2	6
Fixed into propionate	30	9	24	17	40
Entering from plasma	107	40	67	37	43
Absorbed	163	60	103	73	98
Eructated as CO_2 or CH_4	85	25	47	16	25

*Derived from the sources of data given in the first two columns.

It appears that replacement of 30% of the DPRG by supplement did not affect the production rates of acetic or propionic acids. Production rates of VFA in the rumen were greater for the 60% supplement diet. The measured production rate of propionic acid when 1-^{14}C propionate was infused was double the rate obtained from infusion of 2-^{14}C propionate. It appears that little interconversion of acetic acid C with propionic acid and ruminal bicarbonate took place, and thus estimates of amounts of acetic acid absorbed were broadly similar to the measured production rates. The apparent amount of propionic acid oxidised in the rumen was zero when 2-^{14}C propionate was infused, but considerable (38-64 g/d) when 1-^{14}C propionate was infused; this suggests that in the rumen only the 1-C atom in the propionate molecule can be oxidised and that values given for such oxidation when 1-^{14}C propionate is infused are approximately three times too high. The third column in Table 1 represents C flows obtained when the primary data sources of the first two columns were combined into a 5-pool model in which the 1-C and the 2(+3) - C positions on the propionate molecule were considered as separate pools. These values are approximate since assumptions were made that all interchange with ruminal bicarbonate occurs in the 1-C position and that all three propionate carbon atoms interchange with the acetate pool. The amounts of propionic acid absorbed estimated using 1-^{14}C propionate and using 2-^{14}C propionate are both similar to the combined estimate. This suggests that 1-^{14}C propionate can validly measure quantities of propionate absorbed if measured in conjunction with ruminal and plasma bicarbonate in a 3-(or more) pool model. By infusion of 2-^{14}C propionate a valid estimate of propionic acid absorption can apparently be made without the need to include ruminal and plasma bicarbonate in any compartmental model. The relatively large amounts of rumen bicarbonate C fixed into propionate suggests that much of the propionate is synthesised in the rumen by the succinate-methylmalonate pathway.

Reference

MORANT, S.V., RIDLEY, J.L. and SUTTON, J.D. (1978). Br. J. Nutr. 39, 451.

3. An automated method for separation of rumen volatile fatty acids for scintillation counting

R.W. Mayes and C.S. Lamb

In order to estimate the production rates of individual volatile fatty acids (VFA) by isotope dilution techniques it is necessary to separate the acids by preparative gas-liquid chromatography (GLC) before estimating their specific radioactivities. In response to an increased number of VFA production measurements the separation procedure has been automated.

As each acid is eluted in gaseous form from the preparative column (10% PEG 400 Monostearate, 1% orthophosphoric acid on chromosorb AW) 99% is passed through an Autoanalyser mixing coil through which 0.015M NaOH is pumped (2 ml/min). The acid is trapped by the alkali solution which passes into scintillation vials placed in the large turntable of a fraction collector. The movement of the turntable is controlled by a programmable timing unit. When the first acid (acetic) is eluted the electrical response from the flame ionisation detector, through which the remaining 1% of the acid has passed, starts the timer. The timer is programmed to subsequently move the turntable at such times that each of the major acids (acetic, propionic and butyric) is delivered into a separate scintillation vial. After drying overnight the eluted fractions are taken up in 1ml of 3% metaphosphoric acid containing an internal standard. Before estimating the radioactivity a portion (0.25 ml) is removed for measurement of the concentration of acid in the vial. Tests with 14C-labelled acetic acid included in standard VFA mixtures have shown that complete separation can be achieved with recoveries of 95-97%. No carry-over of radioactivity from one fraction to the next, or from one acid in a sample to the same acid in the next sample, has been detected.

This method has increased sample throughput to 60 per week. An automatic injection unit has recently been fitted which allows the equipment to be left unattended overnight. This should enable over 100 samples to be processed each week.

4. The effect of method of feeding and the nature of the supplement on the nutrition of pregnant ewes grazing a heather and *Agrostis*/*Festuca* hill during winter

Margaret Lippert, J.A. Milne and A.J.F. Russel

In improved systems of management at high stocking rates on predominantly heather hills there is some evidence (see HFRO Annual Report 1978 p.A13) that supplementary feeding during mid-pregnancy, even when the ewe is fed adequately in late pregnancy, may increase lamb birth weight and lambing percentage. Results from experiments in which a heather:*Agrostis*/*Festuca* (2/3:1/3) diet was offered *ad libitum* and various supplements were given indicated that the once daily feeding of a supplement containing 3 g N as urea and 100 g starch did not reduce roughage intake (HFRO Annual Report 1978 p.A16) and would lead to intakes of digestible energy such that only small ewe liveweight losses would be expected to occur in mid-pregnancy. The proportion of heather to *Agrostis*/*Festuca* in the diet is also likely to have an important influence on animal production responses.

As the first of a series of experiments examining the nutritional responses to the form and type of supplement fed, particularly in mid-pregnancy, an experiment was conducted on Birnie Hill, Glensaugh in 1979/80. The experimental area of 100 ha was divided into 4 plots of equal area such that three of the plots contained approximately 20% *Agrostis*/*Festuca* vegetation with the remainder of the area being predominantly heather and the fourth plot contained 40% *Agrostis*/*Festuca* vegetation. Each plot was grazed by 50 ewes throughout pregnancy and during day 30-100 of pregnancy the following treatments were imposed on each group of sheep:

1. 40% Agrostis/Festuca area - no supplement given
2. 20% Agrostis/Festuca area - no supplement given
3. 20% Agrostis/Festuca area - 1 x daily fed pelleted supplement to provide the equivalent of 3 g N as urea and 100 g starch
4. 20% Agrostis/Festuca area - a supplement containing the same concentration of energy and nitrogen as treatment 3, given as a feed block.

During late pregnancy the sheep in each group were fed to achieve a moderate level of undernourishment based on weekly measurements of plasma 3-hydroxybutyrate concentration.

Measurements were made of ewe liveweight change and lamb birthweight, and ewe blood metabolite and rumen VFA and NH_3 concentrations. Feed block consumption and between-animal variation in supplement intake was investigated and the proportion of *Agrostis*/*Festuca* in the diet and its digestibility examined. Preliminary observations on the grazing behaviour of the sheep and information on grazing times and total daily bites taken using the bitemeter equipment were obtained. The results of the experiment are not yet available.

NUTRITION : METABOLISM

02009: Mineral nutrition and animal performance

1. Copper studies Alderhope

A. Whitelaw, C.C. Evans, Robin H. Armstrong, A.R. Fawcett, A.J.F. Russel and A.J. Macdonald

In 1979 further studies towards suitable prophylactic measures for commercial aplication in the field against the induced form of hypocuprosis encountered at Sourhope were carried out. Comparisons were made where lambs derived from ewes given copper at parturition were

(a) given repeated injections of copper
(b) unsupplemented other than via the dam's milk
(c) given a single injection at marking time
(d) given a single injection at dipping time

Additional studies included the oral administration of cupric oxide needles to ewes and to lambs, and a comparison of Cu supplemented and non-supplemented lambs of the Cheviot breed. Full statistical analysis is not yet complete but all ewes given copper by injection at parturition showed adequate plasma copper concentrations till approximately four weeks prior to weaning. Ewes given oral cupric oxide needles showed very adequate plasma copper concentrations which were maintained well beyond weaning. Ewes not supplemented with copper by either route became hypocupraemic and remained so up to weaning.

(a) Lambs from dams given copper at parturition with repeated copper injections to themselves remained in copper sufficiency.

(b) Lambs from dams given copper at parturition and not given further copper showed a short period of protection obtained from their dam's milk, but thereafter became hypocupraemic.

(c) Lambs from dams given copper at birth and themselves given an injection of copper at marking time maintained sufficiency until about four weeks prior to weaning.

(d) Lambs from dams given copper at birth and themselves given copper by injection at clipping time were hypocupraemic between marking and clipping but thereafter were normocupraemic by weaning.

Briefly, those supplemented either repeatedly or by a single injection at marking showed similar liveweight gains, both being superior to those given an injection at clipping and markedly superior to lambs given copper only via the dam's milk.

Lambs given an oral dose of 2 g cupric oxide needles at marking time showed a very satisfactory response in plasma copper concentrations and in liveweight gains.

The conclusions from this in terms of prophylactic response show that copper given to the ewe will help protect the lamb from becoming hypocupraemic in its early suckling phase. The use of a further copper injection at marking time to the lamb has practical advantages over repeated copper injections with little penalty in liveweight gains. The use of cupric oxide needles to dams may have an application prior to parturition which is much more practical than a copper injection at parturition and moreover has a longer response in maintaining the ewe itself in normocupraemia.

The use of cupric oxide needles orally to lambs at marking time is a superior means of attaining optimum plasma copper concentrations and liveweight gains.

It is therefore probable that cupric oxide needles given to the ewe and lamb can be tailored to commercial practice in the prophylaxis of induced copper deficiency associated with pasture improvement, and work in 1980 will be directed towards establishing this.

The trial involving the Cheviot breed produced responses in supplemented and unsupplemented twins in plasma copper concentrations, fleece changes and liveweight gains of a similar order to those seen in the Blackface breed in 1976, and it can be postulated that the levels of molybdenum and sulphur arising in improved pasture similar to those at Alderhope will eliminate or minimise breed differences in copper status.

02010: Studies of the metabolism of the grazing ewe

1. Factors affecting the rate of fat mobilisation by the pregnant ewe

J.A. Milne, A.J.F. Russel, A.M. Spence and H.A. Fisher

It is recognised that the hill ewe may lose as much as 20% of her body weight during the winter period and catabolise more than half of her content of ether-extractable fat during pregnancy. The factors affecting the rate at which fat is catabolised are not well understood nor are there satisfactory methods of measuring a small degree of undernourishment over an extended period such as during mid-pregnancy. In this experiment the effect of the fat content of the ewe at mating on its rate of fat utilisation during pregnancy was examined. The rates of change in fat content were measured by the serial slaughter technique, by a prediction *in vivo* from the measurement of tritiated water (TOH) space and by the measurement of free fatty acid entry and oxidation rates of individual free fatty acids (FFA) in blood plasma.

A group of 72 Blackface ewes with a wide range of fat content (15-55% of empty body weight) were housed on day 30 of pregnancy and allocated to two levels of feeding according to predicted fat content. The levels of feeding were designed to produce a moderate and a more severe level of undernourishment which were obtained by feeding two levels of a poor-quality hay in mid-pregnancy and two levels of a hay and concentrate diet in late pregnancy. At days 30, 100 and 140 a representative group of ewes was slaughtered and *in vivo* estimates of the fat content of all ewes by TOH infusion were made. Six ewes from each level of feeding were used to measure the entry and oxidation rates of individual FFAs using ^{14}C-labelled acids. These sheep were housed in metabolism crates with continuous feeders and measurements were made during every third week of pregnancy. The plasma samples obtained were analysed and separated for radioactive counting by the use of high performance liquid chromatographic techniques.

From the serial slaughter data it was found that from day 30-100 of pregnancy the moderately undernourished ewes lost 22% of their fat content and the more severely undernourished ewes lost 37% of their fat tissue and 8% of their protein tissue, mostly from muscle. Between day 100 and 140 of pregnancy the moderately undernourished ewes lost 42% of their fat content at day 100 and 12% of their protein content whilst the more severely undernourished ewes lost 48% of their fat content and 21% of their protein content. Because analyses of the TOH and FFA data are not yet complete it is not yet possible to draw any conclusions on the effect of fat content of the ewes at mating or her subsequent rate of fat tissue mobilisation.

From weekly blood samples clear differences were established from days 30-100 in FFA concentration in plasma between the two levels of feeding and between ewes carrying one or two lambs. During this period no effect of level of feeding or parity on 3-hydroxybutyrate concentration in plasma was observed but from days 100-140 of pregnancy both FFA and 3-hydroxybutyrate concentrations were affected by level of feeding and parity.

2. Factors affecting the partition of nutrients in the lactating ewe. 1. The nature of the diet

J.A. Milne, S.M. Rhind, A.M. Spence and H.A. Fisher

In the HFRO Annual Report 1978 (P.A22) it was reported that Greyface ewes in good body condition, nursing twins in early lactation and grazing low amounts of spring herbage, which depressed lamb liveweight gains, responded to the feeding of a cereal-based supplement by gaining liveweight rather than by increasing milk yield as measured by the liveweight gain of the lambs. An experiment was conducted to widen the range of situations to which this finding might apply.

Three groups of 10 Scottish Blackface ewes in poor body condition and nursing single lambs were individually fed one of 3 levels of a barley-based supplement, namely 0, 450 and 1150 g/day for the first 10 weeks of lactation. The ewes grazed swards maintained at 500 kg DM/ha for the first 6 weeks of lactation and at 800 kg DM/ha for the next 4 weeks. The liveweight gains of the lambs and the ewes over two periods are given in Table 1 below.

Table 1. Lamb and ewe liveweight changes during lactation

		Level of supplement (g/day)			SE
		0	450	1150	
	Weeks				
Lamb liveweight gain (g/day)	2-6	152	205	236	± 17.6
	6-10	284	301	360	± 29.2
Ewe liveweight gain (kg/day)	2-6	0.175	0.134	0.299	± 0.0569
	6-10	0.236	0.252	0.191	± 0.0505

In weeks 2-6 lamb liveweight gains increased significantly ($P < 0.001$) with increasing level of supplement and, in agreement with previous findings, liveweight gain of the ewes on the highest level of supplement was significantly ($P < 0.01$) greater than on the lower amounts. In weeks 6-10 lamb liveweight gains on the highest amount of supplement were significantly greater ($P < 0.05$) than on the lower levels but there was no effect of supplement on ewe liveweight gain.

A descriptive study was also made during the experiment of the weekly changes in blood metabolite and hormone concentrations of the ewes on the different diets as lactation proceeded and a representative group of animals was slaughtered at the beginning and the end of the experiment to determine changes in the tissue composition of the ewes. The results of these two sets of measurements are not yet available.

INPUT/OUTPUT (03002/04007)

03002: Hill land improvement; the nutritional and productivity consequences of a range of improvement techniques applied to a range of hill pasture and soil types.

04007: Cycling of nutrients in grazed hill pasture

1. Improvement-Response experiments at Sourhope

J. Eadie, M.J.S. Floate, R.A. Hetherington, T.G. Common and A.D. Ironside

Almost 10 years data on 3 grazing experiments with improvement treatments including grazing control, lime, phosphate, and oversown ryegrass and clover, have been collected. Previous Reports have included some data on herbage and animal production, grazing days, vegetation and soil changes and nutrient cycling. The three sites F2, G3, F4 were established in 1969, 1970 and 1971 respectively, and detailed recording has been carried out on a 3 year cycle so that all sites now have at least 2 years in which full data are available.

Information is currently being summarised for presentation of 2 papers at the British Grassland Society Symposium "The Effective Use of Forage and Animal Resources in the Hills and Uplands". The 2 papers are to be presented under the general title "Long-term responses of grazed hill pasture types to improvement" in two parts:- "I. Pasture production and nutritive value", and II, Nutrient cycling and soil changes".

2. Litter loss rate
(a) Sourhope

M.J.S. Floate and P.J. Vickery

During the summer of 1978 a decomposition study was jointly undertaken with Dr P J Vickery of the CSIRO Pastoral Research Laboratory, Armidale, NSW on the grazed plots of F2, G3, F4 sites at Sourhope and the data was subsequently analysed while Dr Floate was working at the CSIRO Pastoral Research Laboratory during 1978-79.

Dead litter was collected from each of 15 plots, put into coarse (5 mm) and fine (40 μ) mesh bags and placed on the soil (A_0 horizon) surface of the plot from which it was collected under protective cages for periods of 56 and 115 days (Periods 1 and 2 respectively). At the end of each period DM loss, OM loss, N loss and P loss were calculated from differences between start and finish weights and composition.

Table 03002.1. Relative loss rate (g/g/day) of DM from litter on 5 treatments at 3 sites at Sourhope during 2 overlapping periods of decomposition

Period 1 = 56 days

Site / *Treatment	F2	F4	G3	Mean
1	.0014	.0005	.0008	.0009
2	.0025	.0010	.0006	.0014
3	.0016	.0012	.0005	.0011
4	.0017	.0016	.0009	.0014
5	.0015	.0013	.0009	.0012
Mean	.0017	.0011	.0007	.0012

Site, Treatment and Interaction effects signif. 0.1%

Period 2 = 56 + 59 = 115 days

Site / *Treatment	F2	F4	G3	Mean
1	.0052	.0016	.0014	.0027
2	.0071	.0022	.0016	.0036
3	.0062	.0022	.0017	.0034
4	.0067	.0023	.0015	.0035
5	.0071	.0020	.0016	.0036
Mean	.0064	.0021	.0015	.0033

Site effects signif. 0.1%. Treatment effects signif. 5.0%

*Treatments: 1 = Grazing Control, 2 = 1 + lime, 3 = 2 + phosphate, 4 = 3 + oversown clover, 5 = 4 + oversown ryegrass.

The placing of litter on the site from which it was collected allowed the interpretation of results as the integrated effects of nature of substrate and soil treatment but did not permit a direct comparison of treatments at each site, or between sites. For this purpose standard cotton strips (from ITE Merlewood) were buried in each plot for 4 weeks and their tensile strength, after washing, was compared with control strips.

There was no significant difference in the OM or DM loss rates between coarse and fine mesh bags, possibly indicating a minor role for invertebrate participation in decomposition at these sites. The results for DM relative loss rate (g/g/day) in fine mesh bags are typical (Table 03002.1). These data show that there were significant differences between treatments and between sites. At all sites decomposition was least on the control treatments C, and all other treatments, which included lime, showed no significant differences in either the shorter or longer decomposition period. It was concluded that of the applied treatments, lime had the greatest effect on stimulating organic matter breakdown as a preliminary to mineralisation of available plant nutrients. During both shorter and longer decomposition periods, the relative loss rate was significantly higher on the F2 site than on the other 2 sites, of which G3 gave the slowest rate of decomposition.

Data for N loss and P loss were surprising in that both indicated that more of these nutrients had been lost from litter materials decomposing in the field than would have been expected from earlier (1970) laboratory incubation studies. In these earlier studies however the amount and form of mineralised nutrients could be determined while in the field study losses were recorded without knowledge of the form of end product. Further work is required to elucidate the reasons for differences between laboratory and field results. The comparisons between sites and between treatments indicated broadly similar conclusions to those reported above for DM and OM loss rates.

The conclusions regarding treatment effects were confirmed by the cotton strip tests, but this data for site effects ranked F4 below G3 (N.S. difference): Cotton strip decomposition was significantly greater at F2 site than either F4 or G3 (Table 03002.2).

Table 03002.2. Loss in tensile strength (%) of standard cotton strips (0-4 cm) on 5 treatments at 3 sites at Sourhope

Site	F2	F4	G3	Mean
Treatment				
1	87.7	47.9	52.2	62.6
2	94.9	91.1	92.0	92.7
3	88.9	86.7	95.4	90.4
4	88.8	98.1	97.8	94.9
5	96.3	89.5	95.5	93.8
Mean	91.3	82.7	86.6	86.9

Site and treatment effects signif. 0.1%

(b) Glensaugh

J.J. Yates (University of Tasmania), M.J.S. Floate, J. Hodgson and J. Bircham

During 1979 a complementary litter decomposition experiment was conducted on improved upland pasture at Glensaugh where the main treatment differences were heavy and light grazing pressure. These treatments resulted in large differences in standing herbage crop, and in its relative content of dead material. The technique in this study was to separate green and dead herbage from each of several small cut quadrat areas, enclose the resulting dead material in a steel mesh cage, and attempt to recover undecomposed material after a defined period of time. Difficulties were encountered with the labour involved in carrying out separations, with the small amount of material - especially on the more heavily grazed treatments, and with soil contamination of the recovered residues. Because of these problems, but especially because of the very small sub-sample weights, and some difficulty in definition of dead and green fractions no conclusive results were obtained.

UTILISATION : NUTRITION

03003: Improvement of hill and upland pasture utilisation by grazing cattle and sheep

1. Diet selection and nutrient intake by cattle and sheep grazing a series of hill and upland pasture communities

J. Hodgson, Richard H. Armstrong, S.A. Grant, D.E. Suckling, M.M. Beattie, T.D.A. Forbes, R.A. Hetherington and T.G. Common

The project described in the 1977 report (p.A43) was continued, observations being made on Agrostis/Festuca (7-18 May and 17-28 September), Nardus (21 May-1 June and 8-19 October) and ryegrass (2-13 July) sites, and also on a Molinia dominated community (11-22 June and 20-31 August) on a Forestry Commission site in the Borders.

(a) Herbage intake and digestibility of the diet (1978 results)

The first results for estimates of diet digestibility and herbage intake from the 1978 season are now available, and are shown in Table 1. The corresponding results of observations on the ingestive behaviour of the animals and of the botanical composition of the sward and the diets of sheep and cattle are given in the 1978 report (pages A28 and C24-27, respectively).

Table 1. Digestibility of the diet selected and herbage intake of sheep and cattle.

Sward	Animal species	Extrusa OM digestibility (Means 3-4 animals)	Herbage intake (kg OM/day) (Means 6 animals)
Lolium perenne (29 May - 2 June)	Cattle	.81 ± .011	9.03 ± .503
	Sheep	.82 ± .007	1.54 ± .047
Agrostis/Festuca (3-7 July)	Cattle	.70 ± .015	13.53 ± .662
	Sheep	.69 ± .008	2.23 ± .088
Nardus (19-23 June)	Cattle	.68 ± .016	12.76 ± .555
	Sheep	.67 ± .023	1.50 ± .105

The estimates of extrusa digestibility shown in Table 1 are not corrected for variations in saliva contamination. On this basis, sheep and cattle appeared to be selecting diets of similar digestibility. This observation, and the high intakes on the Agrostis/Festuca and Nardus communities, may be due to the large amounts of green material present on the indigenous swards at the time of measurement (see 1978 Report, p.C24-27). More recent measurements on the same plots indicate greater differences in diet composition between cattle and sheep (this report, p.C.29).

(b) Measurements of grazing mechanics

T.D.A. Forbes

Measurements of grazing time, bite rate and bite weight were continued in 1979 on all the hill communities. The techniques of measurement are described in the 1978 Annual Report. The results are described briefly below.

Table 1. Grazing time (min/day). Means of 4 animals

Sward	Dates	Cows	Sheep
Agrostis/Festuca	14/5 - 18/5	657	660
Nardus	28/5 - 1/6	651	612
Molinia	18/6 - 22/6	714	457
Ryegrass	9/7 - 13/7	591	533
Molinia	27/8 - 31/8	661	516
Agrostis/Festuca	24/9 - 28/9	546	597
Nardus	15/10 - 19/10	559	633

Av. SE. ± 17.71

Grazing times appear to be excessive for the cattle and low for the sheep on the Molinia site in June due possibly to behavioural responses by the animals to annoyance by flies. The cows stand and shake their heads whilst the sheep lie down for much of the time with their heads below the level of the grass.

The 1979 data shows the same general seasonal trends as in 1978, in that the cows spent more time grazing than the sheep in the early part of the year and less time in the autumn, though the sequence of plant communities was different (1978 Report, p.A28).

Table 2. Bite rates (bites/min). Means of 11-13 animals.

Sward	Dates	Cows	Sheep
Agrostis/Festuca	14/5 - 18/5	67.6	68.0
Nardus	28/5 - 1/6	64.8	57.3
Molinia	18/6 - 22/6	53.1	49.9
Ryegrass	9/7 - 13/7	59.0	58.4
Molinia	27/8 - 31/8	49.9	42.7
Agrostis/Festuca	24/9 - 28/9	70.3	69.5
Nardus	15/10 - 19/10	60.8	56.4

Av. SE = 1.64 (SE of Diff. 2.22 to 2.41)

As in 1978, bite rates were slowest on communities where selection might be expected to be greatest. The higher bite rates by both cattle and sheep in 1979 compared to 1978 on both Agrostis/Festuca and Nardus swards is probably due to a change in sward structure as a result of grazing carried out between the 1978 and 1979 measurements.

This year it was possible to obtain bite weight data from sheep as well as cattle, except on the second Molinia grazing when the height of the sward effectively hid the sheep from view. The results for the cattle are fairly consistent within communities but show greater differences between communities than in 1978, and also, bite size is much reduced on the previous year. A similar pattern is evident with the sheep. The bite size for sheep on the ryegrass in 1979 was less than half the 1978 value.

The Agrostis/Festuca and Nardus sward were grazed quite heavily between 1978 and 1979 and the reduction in bite size probably reflects the change in sward conditions.

Table 3. Bite weight (g DM/bite). Means of 4 animals

Sward	Cattle	Sheep
Agrostis/Festuca	0.14 ± 0.02	0.021 ± 0.003
Nardus	0.24 ± 0.01	0.034 ± 0.004
Molinia	0.42 ± 0.07	0.063 ± 0.008
Ryegrass	0.45 ± 0.09	0.043 ± 0.008
Molinia	0.41 ± 0.06	-
Agrostis/Festuca	0.16 ± 0.04	0.036 ± 0.003
Nardus	0.26 ± 0.04	0.037 ± 0.009

2. Studies on the voluntary intake of herbage cut from a range of hill and upland pasture communities, and on relationships between in vivo and in vitro digestibility within this material.

Richard H. Armstrong, J. Hodgson, T.G. Common, R.A. Hetherington, G.R. Bolton and M.M. Beattie

The aims and conduct of this experiment, together with results from the first year's work, were described in the 1978 report (pages A.25-27). Subsequently the second year's in vivo and in vitro digestibility and intake trial has been completed, and statistical analysis of the results is in progress.

a) Voluntary intake and in vivo digestibility

Levels of intake of the three control feeds were higher in 1979 than they were in 1978. Consequently the values for the 1979 feeds will be adjusted by covariance before data for both years can be combined. Meantime the regression of organic matter intake expressed per $kgW^{0.75}$ (Y) on OM digestibility (X) of all 24 feeds is: $Y = 1.24x - 26.8, r = .77$.

This is a poorer relationship and has a lower coefficient than the 1978 data alone. However the intake of high quality Agrostis/Festuca herbage was very low relative to its high digestibility, and indeed lower than that of the lowest quality A/F feed (table 1). This has occurred once previously;

furthermore, drying the frozen herbage at low temperature led to an approximate twofold increase in intake. It is suggested that the intake depression may have been due to the presence of mycotoxins, possible from Eusarium spp., which are known to occur on Agrostis/Festuca swards. Currently samples of the herbages are being screened for toxins by the Department of Microbiology at the Edinburgh School of Agriculture.

Table 1.

Herbage	Year of Feeding	≠ Dig. of OM (*in vivo*)%	Dig. of OM (*in vitro*) % (IVD_F)	Intake of OM/ $W^{0.75}$ (g/kg)
AF 1	1979	76.8	72.3	37.9
AF 2	1978	61.3	62.0	34.3
AF 3	1978	52.0	49.9	30.0
(AF 3)	1979	52.9	51.7	48.7
N 1	1978	63.4	62.1	62.1
N 2	1978	52.5	53.1	41.7
N 3	1979	50.0	44.7	33.6
M 1	1979	67.1	61.8	69.6
M 2	1978	54.3	47.1	43.5
M 3	1978	47.5	39.9	27.8
E 1	1979	60.6	59.2	65.4
E 2	1979	52.4	48.6	41.3
E 3	1979	37.1	28.0	16.7
T 1	1979	62.3	55.0	48.4
T 2	1978	57.2	46.7	40.9
T 3	1978	46.4	35.2	21.0
L 1	1979	79.6	81.2	72.8
L 2	1978	67.5	68.7	56.3
L 3	1978	58.9	59.7	38.6
(L 3)	1979	61.1	61.3	51.8
T.r.1	1978	78.8	79.1	70.4
T.r.2	1979	68.4	66.5	80.3
Hay	1978	60.3	55.1	47.7
(Hay)	1979	60.8	55.6	54.1

≠ Note that *in vivo* digestibility values have been adjusted for any refusal which occurred using the *in vitro* values of those refusals. The adjustment amounted for less than 1% unit in all cases.

AF = *Agrostis/Festuca*
N = *Nardus stricta*
M = *Molinia caerulea*
E = *Eriophorum vaginatum*
T = *Trichophorum caespitosum*
L = *Lolium perenne*
T.r.= *Trifolium repens*

Excluding the AF 1 herbage from the data changes the relationship between $OMI/W^{0.75}$ and OMD to: $Y = 1.50x - 40.6$, $r = 0.87$. This relationship is similar to that for lowland grasses and legumes reported by Osbourn (1970).

b) In vitro/In vivo digestibility relationships

In vitro digestibility values of all feeds are given in table 1.

As in the first year there is a tendency for *in vitro* values to understate *in vivo* values, more especially at low levels of digestibility. The equation embracing all 24 feeds is given by: $Y = 0.78x + 15.86$, $r = 0.966$, RSD $\pm$ 2.72, where Y = *in vivo* dig., x = IVD_F.

These data are currently undergoing analysis at the ARC unit of statistics; it may be that the error term can be reduced by expressing the relationship across a given species (or community) or sets of species.

The same feed samples have been subjected to *in vitro* digestion at the Grassland Research Institute using the pepsin-cellulase technique. The resulting relationship is given by: $Y = .63x + 29.6$, R.S.D. ± 4.49. This reflects the situation observed with higher quality herbage, but it is also less useful for predictive purposes than the conventional process.

Currently samples of the herbages are being used as standards in the routine digestion of oesophageal extrusa samples from sheep and cattle grazing a series of hill and upland plant communities (see page A.29).

c) Oesophageal extrusa samples

Samples of extrusa obtained from sheep and cattle fistulated at the oesophagus and fed controlled amounts of the experimental herbages indoors have also been subject to *in vitro* digestion. Digestibility of extrusa samples is several units higher than that of the feed from which it is derived, and the difference is about 4% units greater for sheep than for cattle.

The difference also increases with dry matter % of the feed (which is usually negatively correlated with quality), and with the use of foam rubber throat plugs which are used to increase 'recovery' of grazed herbage. All these differences may be associated with the degree of ensalivation which occurs during eating; it is hoped that the current statistical analysis will elucidate this, and subsequently allow adjustment of *in vitro* digestibility values of samples collected in grazing experiments.

d) Heather trials

The main experiment did not include heather (*Calluna vulgaris*). A further small digestibility trial has just been completed using four separate feeds, each fed to 6 sheep indoors. The experiment was conducted in exactly the same manner as for 1978 and 1979 work. Currently chemical and statistical analysis are taking place with a view to comparing the relationship between *in vivo* and *in vitro* digestibility, and at the same time providing standards of known *in vivo* digestibility for routine analysis of samples grazed from swards containing heather.

3. The influence of the proportion of clover in a mixed grass/clover sward on diet composition and herbage intake in grazing sheep

J. Hodgson, W.G. Souter and G.T. Barthram

The results of the previous trial in this series (1978 Annual Report) indicated that, when comparisons were made between the composition of the diet and of the surface horizons of the sward within which animals were grazing, selection in favour of clover in a mixed sward was relatively small, and was largely independent of clover context. In this trial the sheep were allowed access to the experimental swards for limited periods of time.

In 1979 the approach was modified to allow continuous stocking by sheep of six paddocks 0.1 to 0.2 ha in area, in which variations in the ratio of grass (Caprice perennial ryegrass) to clover (S100 white clover) were established by varying seed rate and preliminary management, and by herbicide treatment. The paddocks were stocked continuously from May to September inclusive with Blackface wethers, and stocking rates adjusted to maintain comparable sward heights (approximately 3 cm) on all treatments. A paddock on an established sward of perennial ryegrass, which was kept hard grazed throughout 1978 and 1979, was included as a seventh treatment.

Detailed measurements were made of herbage mass and the botanical composition of the sward, and of diet composition and herbage intake by the sheep, on three occasions during the year. Results are not yet available.

4. Ingestive behaviour in sheep and cattle

A.R.M. Chambers, J. Hodgson and J.A. Milne

Development and testing work on the bite meter described in the 1977 (p.C91) and 1978 (p.C41) reports has now been completed.

The bite meter involves the use of an accelerometer to monitor the characteristic plucking movements of the head associated with the biting of mouthfuls of herbage, and a microswitch to record jaw movements. In 1979 the accelerometer was used, in association with a conductive plastic linear motion potentiometer which allowed a quantitative evaluation of jaw movement and which was mounted in place of the jaw switch, in a series of detailed studies of ingestive behaviour under a range of sward conditions. The results of these observations indicated that:

(a) maximum acceleration of the head during biting was substantially greater in sheep (0.76-0.90 g) than in cattle (0.47-0.53 g), and jaw movements were much more regular in amplitude in the sheep.

(b) acceleration of the head increased significantly as sward height decreased in sheep, but not in cattle.

(c) the ratio of jaw movements to head movements was always greater than unity for sheep and cattle, and in two out of three comparisons the ratio was significantly greater on tall than on short swards, indicating that the ratio of manipulative mouth movements to actual bites varies with sward conditions.

The results of the development and testing work are now being prepared for publication, and the meter should shortly be available commercially.

5. Influence of grazing management on herbage production and intake in mixed species upland pastures

J.S. Bircham, J. Hodgson, G.T. Barthram and W.G. Souter

Four swards of different herbage mass were maintained in as near steady state as possible from late May until mid-August under continuous stocking with greyface ewes and lambs, following a common treatment under intensive continuous stocking by sheep for four years previously. The swards were perennial ryegrass - Poa annua associations with some white clover. The herbage masses and heights maintained, the stocking rates necessary to maintain them and the resulting differences in species composition are given in table 1.

The objectives of the experiment were to examine the dynamics of plant tissue turnover at the level of the individual tiller or stolon under different herbage masses, and to determine the response of the grazing animal in terms of herbage intake, and ingestive behaviour to these same herbage masses. Both leaf growth and net accumulation declined when the maintained herbage mass was less than 1200kg OM/ha (table 2), whereas the decay component, while inconsistent, tended to increase with increasing herbage mass. Ryegrass tillers contributed most to overall sward net accumulation whereas Poa annua tillers, although in the lower herbage mass swards comprising a substantial proportion of the total population, contributed very little.

The increase in the herbage intake of both ewes and lambs with increasing herbage mass was reflected in the overall liveweight gains measured (table 3). Intake per bite increased with increasing herbage mass, but rate of biting did not change significantly; grazing time was highest on intermediate treatments (table 3).

Table 1. Mean herbage mass, botanical composition, herbage height and stocking rate for period early June to early August 1979.

Herbage Mass kg OM/ha	600	900	1200	1900
Stocking Rate[1/] ewes/ha	51.9	33.2	14.3	12.5
Herbage Height cm	1.4	2.0	3.3	6.5
Botanical Composition (% DM)				
Ryegrass	33	37	50	51
Poa annua	54	47	24	29
White clover	2	6	14	9

[1/] Ewe and single lamb unit. Stocking with ewes and lambs on the 600 kg OM/ha treatment was discontinued in mid-July.

Table 2. Growth, senescence and net accumulation of individual sward components at four herbage masses (kg OM/ha/d).

Herbage Mass kg OM/ha	Lamina[†] growth	Lamina senescence	Lamina net accumulation	Sheath + Lamina[‡] net accumulation
Ryegrass				
500	24.6	9.8	14.0	16.5
900	32.3	14.9	17.4	22.3
1200	79.5	21.6	57.8	69.0
1900	75.1	43.0	32.1	52.3
Poa annua				
500	1.1	0.8	0.3	0.4
900	29.6	30.1	-0.5	5.9
1200	11.7	5.5	6.2	10.1
1900	8.7	10.2	-1.5	0.2
White clover				
500	3.0	0.2	2.9	3.1
900	1.2	0.1	1.1	1.2
1200	3.7	0.1	3.5	4.4
1900	5.6	1.5	4.1	5.5
Total				
500	28.7	10.8	17.2	20.0
900	63.1	45.1	18.0	29.4
1200	94.9	27.2	67.5	83.5
1900	89.4	54.7	34.7	58.0

† For white clover lamina includes petiole ‡ Sheath for white clover is stolon tissue

Table 3. Herbage intake of ewes and lambs; grazing time, bite rate and bite size of ewes only for a two week period in June. Ewe and lamb liveweight gains as indicated.

Herbage Mass kg OM/ha	600	900	1200	1900
Herbage Intake g OM/day				
Ewes	773 ± 18	902 ± 87	1905 ± 338	2554 ± 347
Lambs	277 ± 27	354 ± 36	736 ± 43	779 ± 63
Grazing Time				
Ewes (hrs)	10.6 ± 0.6	12.9 ± 0.2	12.5 ± 1.0	10.4 ± 0.4
Bite Rate				
Ewes (bites/min)	90 ± 10	84 ± 4	82 ± 7	90 ± 7
Bite Size mg OM/bite	13.6	13.9	31.1	45.5
Liveweight Gain[1/] g/day				
Ewes	-187	-122	78	103
Lambs	7	79	240	309

[1/] Liveweight gains are for a period of approximately 6 weeks commencing in early June and finishing at clipping in mid-July.

6. The rate of disappearance of dead plant material in grazed swards

J.J. Yates (University of Tasmania), M.J.S. Floate, J. Hodgson and J.S. Bircham

Measurements were made of the rate of disappearance of dead plant material, in a small-scale study in September, on two of the paddocks (those maintained throughout the season at approximately 800 kg and 1700 kg DM/ha) used in the previous experiment.

Twelve sample turves were dug from each paddock, and the herbage on a 10 cm x 20 cm quadrat on each turf separated into live and dead material in the laboratory. The dead material from each quadrat was returned to an adjoining paired quadrat area from which all herbage had been removed, and remained *in situ* under a protective cover of stainless steel mesh from 6 September until 10 October, when the residual material was collected. The amount of dead material in some quadrats was very small, creating some difficulties in the handling and recovery of samples.

Relative rates of disappearance (g/g per day) for the 800 and 1700 paddocks were 0.06 ± 0.007 and 0.03 ± 0.004 in terms of dry matter, and 0.06 ± 0.007 and 0.04 ± 0.004 in terms of organic matter. In both cases the difference was significant ($P < 0.01$), despite substantial within-treatment variation. These rates are substantially higher than most others reported in the literature, and the greater relative rate of disappearance of material from the 800 plot, where the actual amount of dead material was much less than on the 1700 plot (0.4 ± 0.04 vs. 1.5 ± 0.16 g OM/quadrat), was unexpected. The results make a useful contribution to our information on tissue turnover in grazed swards, and require further investigation.

GENOTYPES

01004: The effectiveness of improved genotypes of hill sheep in utilising better hill resources

1. A comparison of the performance of Blackface and crossbred ewes in improved hill conditions

J.M. Doney, T.J. Maxwell, R.G. Gunn, W.F. Smith and E. Barthram

In 1974, on the Mid and West Finella hirsels at Glensaugh, an internal cross-breeding structure was established to allow comparisons of the performance of two first-cross ewe genotypes Border Leicester x Blackface and Texel x Blackface with the pure bred Blackface ewes.

Detailed comparisons will be carried out when the final age structure has been achieved.

The performance results for 1979 are given in Tables 1 and 2 which show the pre-mating weights of each age and breed group of ewes (November 1978) the number of lambs, and the weaning weights of lambs by genotype. All cross-bred ewes were mated to Dorset Down rams.

Table 1. Ewe bodyweights (kg)

Breed of ewe	Premating November 1978			Weaning August 1979		
	Mid Finella	West Finella	Mean	Mid Finella	West Finella	Mean
Blackface						
Born 1973	71.0 (4)	68.2 (6)	69.3	67.8 (3)	61.4 (4)	64.1
1974	68.1 (12)	59.5 (6)	65.3	62.3 (8)	55.2 (6)	59.2
1975	66.5 (19)	60.9 (20)	63.6	65.7 (17)	56.7 (19)	61.0
1976	65.0 (21)	53.7 (18)	59.8	64.2 (20)	56.3 (16)	60.7
1977	57.5 (24)	53.1 (21)	55.4	55.0 (24)	52.3 (21)	53.8
All ages	63.9 (80)	57.3 (71)	60.8	61.4 (72)	55.4 (66)	58.5
Border Leicester x Blackface						
Born 1974	75.9 (4)	68.0 (2)	73.3	70.4 (4)	63.8 (2)	68.2
1975	71.9 (7)	65.7 (9)	68.4	63.2 (7)	58.7 (9)	60.6
1976	66.9 (10)	64.6 (11)	65.7	64.8 (10)	62.6 (10)	63.7
1977	63.0 (11)	58.1 (9)	60.8	58.0 (11)	55.3 (8)	56.8
All ages	67.8 (32)	63.3 (31)	65.5	62.8 (31)	59.4 (29)	61.2
Texel x Blackface						
Born 1974	69.5 (6)	66.2 (8)	67.6	66.7 (6)	78.1 (7)	72.9
1975	70.5 (6)	67.8 (11)	68.8	64.6 (5)	61.6 (9)	62.6
1976	63.3 (8)	57.4 (8)	60.3	64.5 (6)	58.0 (8)	60.8
1977	56.3 (12)	52.3 (8)	54.7	52.1 (12)	51.4 (8)	51.8
All ages	63.2 (32)	61.5 (35)	62.3	59.8 (29)	57.4 (32)	58.5

Table 2. Lamb weaning weight by genotype

Dam	Sire	Heft	Mean Weaning Wt (kg)	No. of Lambs	Combined Mean (kg)
Blackface	Blackface	Mid F.	27.5	34	27.8
		West F.	28.1	28	
Blackface	Texel	Mid F.	25.2	26	26.5
		West F.	27.8	24	
Blackface	Border Leicester	Mid F.	27.0	16	26.4
		West F.	26.0	20	
Texel x Blackface	Dorset Down	Mid F.	28.5	31	29.4
		West F.	30.1	42	
Border Leicester x Blackface	Dorset Down	Mid F.	29.6	33	27.9
		West F.	26.8	50	
Texel x Blackface	*Blackface	Mid F.	31.7	8	31.7
		West F.	-	-	
Border Leicester x Blackface	*Blackface	Mid F.	29.6	12	29.6
		West F.	-	-	

*Result of a breakout by Blackface tups ten days before tupping was due to start.

CATTLE

02008: Beef cattle : characterisation of nutritional state under different systems of management; studies on reproduction, lactation and calf growth

The herd calving policy was changed in 1978 to allow greater flexibility to meet the needs of the nutrition and grazing studies. Approximately half of the cows were served to calf as usual in March/April 1979 (Spring calving herd), but rebreeding for the rest of the cows was delayed so that they calved in November 1979 (Autumn calving herd). The two herds have similar proportions of Hereford x Friesian and Blue-Grey cows, but different age structures. In future the Autumn calving herd will be used primarily for nutrition studies; the spring calving herd, which is already based at Hartwood, will be used mainly for grazing studies.

1. Spring calving 1979. The influence of nutrition in early lactation and single- or twin-suckling on the performance of beef cows and their calves

J.N. Peart, J. Hodgson, A.J.F. Russel, J. Eadie, A. Whitelaw and M. Begg

Thirty two Hereford x Friesian (HF) and 19 Blue-Grey (BG) cows which were expected to calve to Charolais bulls within the period of 26 February to 1 May 1979 were maintained on pasture after weaning in early September 1978 to attain body condition scores in the range 2.5 to 3.0. They were housed in individual stalls in November 1978, and fed hay and concentrate to supply 80-100% of estimated maternal energy maintenance requirements during the last 8-12 weeks of pregnancy.

All the calves born were cross-fostered between the two cow genotypes so that no cow reared her own calf, and in addition 12 cows of each genotype fostered an additional Friesian calf. The Friesian calves were purchased from selected local farms and transported to Glensaugh within a few hours of birth. To ensure that calves were always available a calf bank was formed, using two recently calved Ayrshire cows as temporary foster mothers. Most calves were fostered to their designated mothers within 24 hours of birth. All home-bred and purchased calves received colostrum soon after birth. Cows were allocated, within genotype, suckling regime and order of calving to one of three nutritional treatments which involved the provision of hay for maintenance and dairy concentrate for either 2.5, 10.0 or 17.5 kg milk per day. The calves were offered chopped hay from 4 weeks of age, in quantities increasing to 2.5 kg/day. The nutritional treatments were continued until the cows and calves were turned out to graze on 24 May.

Extensive winter kill of grass plants on one experimental sward limited the scope of the grazing phase of the study, which was confined to one 5 ha field of a long-established mixed sward. Cows and calves from the M + 2.5 and M + 17.5 treatments only, with equal numbers rearing single and twin calves, were continuously stocked on this field from 24 May to 24 September, and sward height was controlled at 3-5 cm (herbage mass 1000-1500 kg DM/ha) by varying stocking rate. The rest of the cows and calves grazed as a single group, but their grazing was not closely managed. A Charolais bull ran with each group of cows from 25 May until 10 August.

The cows were weighed and assessed for body condition at 2-week intervals during late pregnancy and throughout a 26-week lactation period. Calves were weighed at birth and then at 2-week intervals. Estimates of milk production were made every 2 weeks, using an oxytocin-machine milking technique, and milk samples were taken for qualitative analysis. Further milk samples were taken on 3 days each week for progesterone assay by Dr A.R. Peters at Nottingham University.

Calf scour occurred soon after calving started, and all calves from all sources were affected. Details are given on p. B.26. Nineteen calves were lost from the experiment, mainly as a result of the scour; mortality rates were similar in calves from HF and BG cows, and in bought-in calves, but were greater in twin-suckled than in single-suckled calves. Calves which died were usually replaced, and the indoor phase of the study was eventually completed with 9 single- and 8 twin-suckled BG cows, and 15 single- and 13 twin-suckled HF cows.

The scour clearly affected calf performance directly, and probably also milk production and cow weight change indirectly. The results summarised in Tables 1 to 3 should therefore be interpreted with caution. The results of the re-breeding programme, following the 1980 calving season, are not yet collated.

Table 1. Mean milk production (kg/day)

	Early lactation (8 weeks)		Grazing Phase (18 weeks)	
Nutrition Group	Single	Twin	Single	Twin
BG cows				
M + 2.5	8.30 (3)	8.85 (3)	8.76 (2)	8.46 (3)
10.0	9.15 (4)	10.08 (2)	-	-
17.5	9.34 (3)	13.77 (2)	7.85 (3)	11.70 (1)
HF cows				
M + 2.5	7.91 (6)	8.65 (4)	9.96 (5)	8.66 (4)
10.0	9.54 (4)	14.33 (4)	-	-
17.5	10.31 (6)	14.23 (3)	10.82 (6)	10.53 (2)

No. of cows shown in brackets.

Table 2. Live-weight changes (kg). Combined data of BG and HF cows

Early Lactation Treatment	Post-part to turnout		Turnout to weaning		Post-part to weaning	
	Single	Twin	Single	Twin	Single	Twin
M + 2.5	-49	-66	+75	+73	+11	- 8
M + 10.0	+17	-27	+64	+90	+66	+48
M + 17.5	+41	+20	+51	+16	+43	+21

Table 3. Mean live-weight gain (g/calf/day) of calves

Nutrition Group	Indoors		Grazing	
	Single	Twin	Single	Twin
	Suckling BG cows			
M + 2.5	623	455	1029	807
M + 10.0	709	377	1147	921
M + 17.5	720	556	978	869
	Suckling HF cows			
M + 2.5	527	320	1244	832
M + 10.0	795	554	1096	1018
M + 17.5	608	665	907	831

2. Blood metabolites as indices of energy status in suckler cows

A.J.F. Russel, I.A. Wright (Post-graduate student), J.N. Peart, and M. Begg

In earlier experiments on the nutrition of the pregnant suckler cow a close relationship was demonstrated between plasma 3-hydroxybutyrate (3-OHB) concentration and energy intake. It is reasonable to assume that in these experiments the animals from which the relationship was derived had similar energy requirements, but because these could not be estimated with reasonable confidence it is not possible to use this relationship to assess energy status (i.e. the magnitude of the energy deficit or surplus) which is likely to be more important in many situations than an estimate of energy intake.

The delayed re-breeding of half the cows to establish an autumn calving nutrition herd afforded an opportunity to obtain the necessary information with non-pregnant, non-lactating cows, and an experiment was conducted at Glensaugh between October and December 1978 with the following objectives:

1. to quantify the relationship between the circulating concentrations of certain blood metabolites and energy status in suckler cows.

2. to examine the energy requirements for maintenance in suckler cows, and the effects of genotype and of body condition on these maintenance requirements and on rates of live-weight change at sub-maintenance levels of feeding.

The experiment was conducted on 29 Hereford x Friesian and 26 Blue-Grey non-pregnant, non-lactating cows. Levels of feeding ranged from 50 to 120 per cent of anticipated maintenance requirements. The cows were weighed, blood sampled and condition scored twice weekly for six weeks.

The approach adopted has been to estimate individual rates of live-weight change from regressions of live weight on time, and to regress these in turn on energy intake. Maintenance requirements are calculated as the energy intakes corresponding to zero live-weight change.

The analyses to date indicate that maintenance requirements are significantly affected by condition score, such that the requirements of 500 kg cows are reduced by some 6 MJ ME for each unit increase in body condition. There is also an indication of a genotype difference in the change in live weight corresponding to a one unit change in condition score. The estimate of energy available from tissue catabolism in animals fed submaintenance levels of energy intake is of the order of 26 MJ ME per kg live-weight loss, a figure which is in close agreement with published values.

On completion of the biochemical analyses the concentrations of circulating metabolites (principally FFA, 3-hydroxybutyrate and glucose) will be related to energy intakes, and from a knowledge of maintenance as estimated above, the concentrations relating to specific energy states will be determined.

3. Studies on the in vivo estimation of body composition of suckler cows

I.A. Wright (post-graduate student) and A.J.F. Russel

Economic considerations of suckler cow nutrition necessitate that the suckler cow undergoes cyclical changes in body condition throughout the year. Any research programme into the nutritional requirements of the suckler cow must take into account the contribution that body reserves can make to production, and also the effect that the laying down of these reserves has on the cows' nutritional requirements. It is therefore crucial to the suckler cow research programme that the extent of body reserves of both energy and protein can be quantified. At present there is little information on methods that could be used to measure body composition in live cows with the required degree of precision or that are suitable for routine use.

In December 1978 a study of methods of estimating body condition in suckler cows commenced. A number of techniques are being evaluated with the aim of assessing which method or combination of methods is of most use in nutritional research.

Four suckler cow genotypes are being considered Hereford x Friesian, Blue-Grey, Galloway and Luing, and the British Friesian is included for comparison. There are 16 non-pregnant, non-lactating cows of each genotype, giving 80 animals in all. The body condition of each cow is manipulated individually by control of nutrition to give 2 cows of each genotype at each half condition score grade from 1 to 4½.

Various measurements providing indirect estimations of body composition are made on each cow, which is then slaughtered two days later, and subjected to analysis for whole body composition. The indirect estimates and direct measurements will be related by regression analysis to provide prediction equations from which *in vivo* estimation of body composition can be made.

The measurements providing indirect estimation of body composition are:-

1. Live weight
2. Skeletal size
3. Total body water as estimated by deuterium oxide dilution
4. Blood/plasma volume as estimated by Evans Blue dilution
5. Subcutaneous fat thickness and eye muscle area measured ultrasonically with the "Scanogram"
6. Body condition score

After slaughter the carcass is split into two sides, one of which is separated into:-

1. Subcutaneous fatty tissue
2. Bone
3. Muscle plus associated fatty tissue

In addition the thin flank joint is separated into subcutaneous fatty tissue, intramuscular fatty tissue, muscle and bone. These components, and the omental and mesenteric fatty tissue, the perirenal fatty tissue and all remaining non-carcass components are minced separately and sampled for chemical estimation of water, fat, protein and ash.

During the first 15 months of the experiment 63 cows have been slaughtered and it is hoped to have slaughtered the projected number of 80 cows by mid summer 1980.

In addition to providing methods of measuring body composition in vivo, valuable information will be provided on the differences among genotypes in the partition of fat among the major depots. It is already becoming clear that breeds differ in this respect.

Results to date are encouraging and it is hoped that it will be possible to measure body composition in vivo with a degree of accuracy that will be useful for future nutritional work.

B. SYSTEMS DEVELOPMENT

Introduction

The purpose of the systems development programme is to test the principles which determine the integration of resources in improved systems of sheep production from hill land. In order to make extrapolation of the findings to other situations possible, field scale studies are being carried out in the widely different but limited range of environments represented by the three research stations where the essential biological monitoring and control over their management can be maintained.

The assessment of the worthwhileness of an animal production system within the context of a hill farm must be an economic one; system changes require capital investment and an assessment of the returns to such marginal capital is an important part of the evaluation process. Furthermore, the robustness of the system has to be tested which requires that stocking rates have to be increased at least to the point at which individual animal performance declines significantly.

Within the context of the present synthesis, responses to a wide range of alternative forms of input are required to provide a basis for assessing the outcome of these systems at the practical farm level. Land improvement, for example, can be brought about in a variety of ways; species composition, the presence or absence of clover, the use of fertiliser, will each have an effect on animal output responses and these require quantification. There is also the problem of examining the continuing flow of new information not only in the context of the present synthesis but also with respect to new systems possibilities. It is apparent that only a limited range of inputs can be tested using field scale studies because of the resources in land, animals and personnel that they require.

Systems modelling and the application of mathematical and computing techniques are currently being investigated as a means of extending the systems approach and examining the effect of the more comprehensive range of inputs. The approach has also been adopted to examine the effects of land allocation strategies as between agriculture and forestry on the economic viability of their integration.

The development programme also includes upland sheep systems experiments designed to study the inter-relationships among stocking rate, data of lambing, levels of pasture production, individual animal performance and flock output.

YEAR ROUND GRAZING SYSTEMS

03004: Develop improved year round grazing systems for animal production from hill pastoral resources

Introduction

The basis of the year round grazing studies has been the integration of improved pasture with the open hill in such a way as to ensure the maximum impact of improved pasture on sheep performance. This has meant that improved pasture has been used for ewes from the time of lambing up to weaning (mid-August) and again, following the mid-season rest, during premating and mating period. During the remainder of the year the sheep stock has been kept on the open hill. This procedure represented a considerable change from the traditional year round set-stocked grazing system.

Any attempt to improve sheep performance was expected to exacerbate under-nutrition in late pregnancy; it was therefore necessary to accompany land improvement with the provision of adequate supplementary feed during this period. Early and late lambing ewes have been identified by harnessing rams with crayon blocks and mating has taken place in enclosures. It was anticipated that this would lead to more efficient use of supplementary feed prior to lambing and better control over stock during lambing.

The main differences between the five studies reported derive from differences in their soil and vegetation, and consequently in the methods and level of expenditure that have been required for land improvement.

YRGS I: Low capital input on a grassy hill - Hairney Law/Auchope

R.H. Armstrong, J. Eadie and T.J. Maxwell

Land Resources

There are 283 ha of mainly grassy pasture which has been subdivided in such a way as to enclose some 100 ha 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 (7.2 ha) are now allocated on an all-the-year round basis to the system and during lactation are primarily used for twin nursing ewes. During 1975, 10.1 ha of the *Agrostis/Festuca* area was oversown following surface cultivation with a spiked bar rotavator. The seed mixture was applied at 28 kg/ha and comprised 18 kg perennial ryegrass, 7 kg timothy and 3 kg white clover. This was followed by 250 kg/ha of a 21:14:14 (N:P:K) compound fertiliser and heavy rolling. During 1976, 11.3 ha was sprayed with Asulox at a cost of £33.11 per hectare. In 1977 the more accessible 15 ha of the 18.2 ha in paddock I was treated with ground magnesium limestone at the rate of 7.5 tonnes per hectare. One hectare was enclosed and reseeded using a paraquat-rotavation technique on a trial basis.

In March 1978 the same 15 ha were further treated with 1.8 tonnes of basic slag per hectare (excluding the one hectare which had been reseeded on a trial basis in 1977, and had received its slag at the time of reseeding).

Then in May 1978, a further 4.5 ha of the slagged ground were reseeded by the paraquat-rotavation technique which had proved successful the year before in the trial reseeding of 1977, and thus by the autumn of 1978 there was a total of 5.5 ha of reseeded ground within Paddock I, i.e. one hectare reseeded in 1977, and 4.5 ha reseeded in 1978.

At this point the decision was taken to extend the fence erected around the trial reseed of 1977 to take in approximately 1.6 ha of non-reseeded ground in Paddock I, and so in effect the original 18.2 ha of Paddock I was reduced by 2.6 ha, this new small enclosure now being referred to as Paddock IA.

Thus the original Paddock I of 18.2 ha was split into a small paddock (IA) comprising 1 ha of reseeded ground and 1.6 ha of non-reseeded ground, and a much larger area (Paddock IB) comprising 15.6 ha of ground of which 4.5 ha had been reseeded.

In June 1979 the 1.6 ha of non-reseeded ground in Paddock IA was oversown with 2¼ kg/ha of clover seed, and at the same time a further 1.6 ha of hill ground within Paddock IB was fully reseeded using the paraquat-rotavation technique, to make a total of 6.1 ha of reseeded ground. It should be noted that the 4.5 ha of Paddock IB which had been reseeded the previous year was successfully sprayed in June 1979 with MCPB/MCPA to control a bad infestation of boar thistles, and that all ground reseeded prior to 1979 received a top-dressing of 250 kg/ha of compound fertiliser (20:10:10) in early May.

In August 1979, 13.4 ha of ground within Paddock 2 was given 6.34 tonnes of Ground Magnesium Limestone/ha and 943 kg of Phossac (20% P_2O_5)/ha, the intention being to reseed the more accessible parts of this area over the next two years. To this end 3.4 ha of this ground, selected for reseeding in the spring of 1980, and lying to the north end of Paddock 2 was resprayed with Asulox to kill off a regrowth of bracken which was becoming increasingly evident after having been effectively suppressed as the result of an earlier spraying in autumn 1974.

Cattle

As previously 25 hill cattle were carried on the resource from May until December with short periods elsewhere.

Sheep Stocks and Livestock Reconciliation

Ewes and Gimmers Nov. 1978	Cast	Deaths	Gimmers brought into flock	Hoggs born 1979	Ewes and Gimmers Nov. 1979
622	111	37	157	180	631

Total Stock Numbers

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
NCC	175	210	260	269	300	295	292					
SCC	223	241	254	259	273	305	309					
Total	398	451	514	528	573	600	601	620	621	623	622	631

Sheep year 1978/79

a) Winter Feeding Hairney law (4 crop, 3 crop and half the 2 crop ewes)

Colborn blocks put out 20.12.78
29.12.78 Nine bales hay fed during snow
15. 1.79 Commence feed beet-pulp (1 x 50 kg bag to-day) then up to 1 lb/hd. Hay cut back to 2 bales.
Hay feeding stopped 20.2.79
Started to feed cobs 1.3.79
9. 3.79 Completely on cobs (5 bags) + 2 bales hay
29. 3.79 Cobs up to 6 bags. Hay increased according to snow

	January	February	March (1st to 17th incl.)
S.P.B.	2,500 kg	4,600 kg	-
Colborn blocks	58	42	25
Hay	180 bales	70 bales	30 bales
Cobs	-	-	2,500 kg

	March (18th to 31st incl.)	April (1st to 15th incl.)	April (16th to 30th incl.)	May
S.P.B.	-	-	-	-
Colborn blocks	17	30	28	-
Hay	68 bales	10 bales	40 bales	-
Cobs	1250 kg	1350 kg	2075 kg	2050 kg
Pencils	-	-	300 kg	-

<u>Auchope</u> (half the 2 crop ewes and all gimmers)

As for Hairney Law up to 20.2.79
20.2.79 Hay reduced to 1 bale
1.3.79 Commenced feeding cobs to ewes
9.3.79 Completely on cobs (4 bags) + 2 bales hay
15.3.79 Hay increased to 6 bales depending on snow

	January	February	March (1st to 17th incl.)
S.B.P.	2,000 kg	3,900 kg	-
Colborn blocks	44	25	14
Hay	142 bales	46 bales	35 bales
Cobs	-	-	1,500 kg

	March (18th to 31st)	April (1st to 15th incl.)	April (16th-30th) + May
S.B.P.	-	-	-
Colborn blocks	17	15	21
Hay	59 bales	10 bales	31 bales
Cobs	1,100 kg	1,550 kg	2,525 kg

<u>Hoggs</u> (Hairney Law and Auchope - 162 Hoggs)

2.12.78 Hogg feeding commenced

	December	January	February
S.B.P.	450 kg	800 kg	1050 kg
Grass Nuts	450 kg	800 kg	1050 kg
Ewe and Lamb Mix	100 kg	-	-
Colborn Blocks	3 blocks	1 block	3 blocks
Lamb Pellets	75 kg	-	-
Barley	75 kg	-	-
Hay	-	71 bales	42 bales
Cobs	-	-	-

	March (1st to 17th)	March (18th to 31st)	April
S.B.P.	500 kg	150 kg	-
Grass Nuts	500 kg	150 kg	-
Colborn	2 blocks	1 block	-
Hay	18 bales	16 bales	10 bales
Cobs	175 kg	275 kg	250 kg

Total feed consumption (kg) and costs per head

	Ewes and Gimmers	Hoggs
Hay	23.3	19.4
Feed blocks	10.9	1.2
Beet pulp cubes (S.B.P.)	21.0	18.2
Ewe cobs	25.7	4.3
Ewe pencils	0.5	-
Grass nuts	-	18.2
Ewe and lamb mix	-	0.6
Lamb pellets	-	0.5
Rolled barley	-	0.5
Total cost per head	£7.62	£5.01

b) Lambing Performance

Ewes to tup	622
Tup eild	26
Kebs	1
Ewe losses to lambing	16
Total lambs born (alive & dead)	808 (129.9%)
Total lambs marked	721 (115.9%)
Total lambs weaned	705 (113.3%)

c) Lamb Weights (kg)

Birth weights,	singles	4.4
	twins	3.5
Marking weights,	singles	10.5
	twins	6.9
Weaning weights,	singles	26.3
	twins	24.5

d) Wool Production (kg)

Age 4 crop, 3 crop, 2 crop, 1 crop, Gimmers, All ages: Fleeces not weighed in age groups. Total weight wool = 1238.5kg (592 ewes) = 2.1 kg Av. Fleece Wt.

e) Ewe Body Weights (kg) 1978/79

	Nos.	Pre-mating Nov. 1978	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov. 1979	Nos.
5 crop	20	70.2	66.5	67.2	51.9	59.9	64.7	29
4 crop	113	65.5	61.4	61.7	48.6	58.0	62.4	94
3 crop	114	62.2	60.1	61.0	49.5	59.1	62.0	95
2 crop	104	59.4	58.1	59.0	47.1	58.2	56.9	120
1 crop	128	55.7	58.7	60.2	51.9	51.6	58.0	136
Gimmers	143	52.8	52.8	53.6	46.7	46.8	52.9	157
All ages	622	59.1	58.2	59.1	48.9	54.3	58.1	631

Summary of Production and Performance 1968/79

f) Pre-mating Ewe Body Weight (November) (kg)

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
NCC	54.8	56.1	58.9	59.5	60.3	54.7	56.7	58.0	53.6	57.7	59.1	58.1
SCC x NCC	47.8	50.2	53.2	55.8	58.2	52.8	54.8					

g) Production Data

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Stock Numbers	398	451	513	528	573	600	601	620	621	623	622
Weaning Percentage	84.7	86.7	102.5	104.7	99.5	91.5	102.7	108.5	106.9	105.1	113.3
Total Weight Lamb Weaned	7786	9188	14177	14046	14193	14329	16042	17902	17596	16470	17837
Total Weight Wool (including hoggs)	850	1017	1253	1369	1561	1454	1535	1543	1503	1523	1601

YRGS II: On blanket bog - Lephinmore/Midhill

T.J. Maxwell, J. Eadie, D.C. Currie and T.K. Whyte

Land Resources

There is a total of 444 hectares of which 349 ha is open hill ground, mainly blanket bog. The remaining area is in two categories: Calluna-Eriophorum moorland adjacent to the open hill, and enclosed improved grassy pasture contiguous with the lower part of the Calluna-Eriophorum area.

A mosaic of grassy pasture has been created within the Calluna-Eriophorum area by surface reseeding, so that some 35% of its 69 ha has been so improved. The 69 ha is divided into two paddocks PI and PII, the latter being larger and adjoining the open hill. The formation of the mosaic was largely completed in 1973 by the creation of 5.6 ha in PI and 4.5 ha in PII. PI is the lower of the two paddocks and contains a greater proportion of reseeded pasture; in 1974 division fences were erected within it to increase the capacity to graze twin nursing ewes and gimmers separately during lactation on improved pasture.

Two areas at the top of PII totalling 2.4 ha received 350 kg/ha of compound fertiliser (15:15:21) in two equal applications during August 1977 and May 1978.

The 26 hectares of enclosed improved pasture includes 14.3 ha which has been reseeded. During the summer of 1978 fields '8 East' and '8 Mid' received a dressing of 205 kg/ha of basic slag (14% P_2O_5). Field '8 Mid' was topped in late July 1979 and subsequently sprayed with Perselect (24 DB/MCPA), to eradicate rushes.

On the hill an area of 28 ha known as Hunt's Bog was fenced in 1978 to provide a facility for feeding gimmers prior to lambing.

Sheep Stocks and Livestock Reconciliation

Ewes and Gimmers Nov. 1978	Cast	Deaths*	Gimmers brought in	Hoggs born 1979	Ewes and Gimmers Nov. 1979
444	88	33(4)	124	125	447

* Includes black loss (in brackets)

Sheep Year 1978-79

a) Winter Feed

Feeding of hay commenced on the hill on 5th January 1979 due to heavy snowfall. During January and early February a total of 4.570 tonnes of hay were fed on the hill at the shelter belt. A total of 2.854 tonnes of hay were fed to lean ewes which were fed separately, and 3.360 tonnes were fed in the lambing areas during late pregnancy.

Standard Rumevite blocks were introduced on 10th January and a total of 93 blocks were consumed on the hill, in PI, and PII until concentrate feeding was introduced in early March.

Concentrate feeding began on 10th March on the hill, gimmers being fed separately in Hunt's Bog from 13th March.

Amounts fed as follows:-

	Ewes	Gimmers
10th March	75 g cobs	75 g cobs
13th March	227 g cobs	283 g cobs
15th March	340 g cobs	340 g cobs
25th March	397 g cobs	397 g cobs
27th March	454 g cobs	454 g cobs
7th April	510 g cobs	510 g cobs

510 g cobs were fed to early and late lambing ewes and gimmers throughout lambing until 15th May, when amount fed was gradually reduced. All concentrate feeding ceased on 25th May. Ewes and gimmers with twins and young lambs were also fed concentrates throughout this period.

A number of lean ewes were fed separately through the winter in production and management areas, being given additional feeding.

The total feed consumption per ewe, gimmer, and hogg for the winter was as follows:-

	Ewes and Gimmers	Hoggs
Hay	24.29 kg	101.19 kg
Ewe cobs	26.10 kg	-
Ewe pencils	-	16.76 kg
Rumevite	4.71 kg	-
Total cost/head	£ 5.25	£ 8.29

Hoggs were housed from 9th November 1978 until 9th April 1979 and went to the hill on 11th April 1979.

b) Lambing Performance

Ewes to tup	444	
Tup eild	34	
Kebs	7	
Ewe losses to lambing	16	
Total lambs born (live and dead)	470	105.9%
marked	422	95.0%
weaned	407	91.7%

c) Lamb Weights (kg)

Birth weights, singles	4.0
twins	3.1
Marking weights, singles	10.5
twins	9.8
Weaning weights, singles	23.3
twins	22.3

d) Wool Production (kg)

Age 4 crop	1.5
3 crop	1.7
2 crop	1.7
1 crop	1.7
Gimmers	1.9
All ages	1.7

e) Ewe Body Weights (kg)

Ages	Nos.	Pre-mating Nov. 1978	Pre-Feeding	Pre-Lambing	Marking	Weaning	Pre-mating Nov. 1979	Nos.
4 crop	41	51.8	44.9	47.4	40.8	45.2	53.8	44
3 crop	82	53.5	45.9	49.8	43.4	48.1	51.8	83
2 crop	105	52.1	44.4	47.5	42.5	47.2	49.5	90
1 crop	97	48.9	41.1	44.6	40.3	44.9	45.9	106
Gimmers	119	45.8	36.2	41.9	37.4	41.0	43.4	124
All ages	444	49.9	41.9	45.8	40.7	45.0	47.8	447

f) Pre-mating ewe bodyweight (November) (kg)

1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
44.9	49.3	49.4	51.2	49.9	48.3	47.9	47.1	49.2	49.8	49.9	47.8

g) Production Data

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Stock Nos.	339	361	373	384	422	433	434	458	452	454	444
Weaning %	85.0	92.5	103.5	103.6	103.3	98.2	91.0	91.3	92.9	92.1	91.7
Total Wt. lamb weaned	7207	8500	10268	9924	10218	10870	9638	9701	10419	10583	9428
Total Wt. Wool	652	772	772	814	815	856	934	915	882	898	924

YRGS III: High capital input on a grassy hill - Sourhope/Alderhope

R.H. Armstrong, J. Eadie and T.J. Maxwell

This project is dependent for its improved pasture component on a high input of capital in a complete reseeding operation. The principles which have already been outlined and applied with regard to the use of improved pasture in relation to the open hill in year-round grazing systems are also being applied in this system.

At present further development of the project is postponed until the studies on copper deficiency, which has occurred in the flock, are complete.

Land Resources

The area of 130 ha is of mainly grassy pasture dominated by *Molinia* heath, the latter being interspersed with *Festuca*. *Agrostis*/*Festuca* communities are present, but they are species-poor and represent a smaller proportion of the total area than the other sheep units at Sourhope. During 1970, 3.2 ha of reseed were established with further reseeds established in 1972 (3 ha), 1973 (6.2 ha) and 1974 (3.2 ha). During 1975 all reseeds were treated with 6.3 tonnes per ha of ground magnesium limestone and 880 kg of superslag (16% P_2O_5) per ha. In early May 1979, all four reseeded areas were top dressed with 250 kg/ha of compound fertiliser (20:10:10).

Sheep Stocks and Livestock Reconciliation

Ewes and Gimmers Nov. 1978	Cast	Deaths	Gimmers brought into flock	Hoggs born 1979	Ewes and Gimmers Nov. 1979
266	41	14	58	65	269

Sheep Year 1978/79

a) Winter Feeding

29.12.78	Commenced feed hay to ewes
1. 1.79	Stockade blocks put out for ewes
12. 1.79	Commenced feed SBP (2 x 50 kg bags)
14. 2.79	SBP increased to 2½ x 50 kg bags
21. 2.79	SBP decreased to 2 x 50 kg bags. Hay being fed throughout.
14. 3.79	Commenced feed 100 kg cobs - stopped SBP
22. 3.79	Cobs increased to 125 kg - snow
8. 4.79	Stopped feeding hay. Cobs reduced to 100 kg.
16. 4.79	Cobs reduced to 75 kg. Hay reintroduced.
5. 5.79	Ewes with twins fed pencils from to-day.
12. 6.79	All feeding stopped

	December	January	February	March (1st to 17th)
Hay	12 bales	90 bales	62 bales	32 bales
Stockade Blocks	-	15	18	6
SBP	-	1,900 kg	2,800 kg	1,100 kg
Cobs	-	-	-	725 kg

	March (18th to 31st)	April (1st to 17th)	April (18th to 30th)	May
Hay	29 bales	22 bales	28 bales	24 bales
Stockade blocks	16	-	12	13
SBP	-	-	-	-
Cobs	1,200 kg	1,625 kg	500 kg	1,180 kg
Pencils	-	-	175 kg	1,225 kg

Hoggs started feeding 28.11.78

Total feed:- (61 hoggs)

SBP	1074 kg
Grass nuts	1074 kg
Ewe and lamb mix	21 kg
Barley	21 kg
Lamb pencils	21 kg
Cobs	494 kg
Hay	55 bales

Total feed consumption per head for ewes and gimmers and for hoggs was as follows:-

	Ewes and Gimmers (kg)	Hoggs (kg)
Hay	22.5	18.0
Feed blocks	6.0	-
Beet pulp cubes	21.8	17.6
Ewe cobs	19.7	8.1
Ewe pencils	5.3	-
Whole oats	-	-
Grass nuts	-	17.6
Ewe and lamb food	-	0.3
Rolled barley	-	0.3
Lamb pencils	-	0.3
Total cost per head	£ 6.58	£5.09

b) Lambing Performance

Ewes to tup	266	
Tup eild	8	
Kebs	-	
Ewe losses to lambing	3	
Total lambs born (alive and dead)	358	(134.6%)
" " marked	319	(119.9%)
" " weaned	306	(115.0%)

c) Lamb Weights (kg)

Birth weights, singles	4.7
twins	3.5
Marking weights, singles	11.6
twins	6.5
Weaning weights, singles	27.7
twins	26.4

d) Wool Production (kg)

Total (Ewes and gimmers) 348.3 kg (249 ewes)

Average weight = 1.4 kg

e) Ewe Body Weights (kg)

	Nos.	Pre-mating Nov. 1978	Pre-Feeding	Pre-Lambing	Marking	Weaning	Pre-mating Nov. 1979	Nos.
4 crop	39	60.9	59.8	60.7	49.0	52.5	57.0	53
3 crop	56	58.5	59.0	59.8	46.5	51.9	59.6	48
2 crop	53	59.7	59.9	60.9	48.1	53.1	59.1	54
1 crop	58	58.4	57.4	59.0	47.0	52.4	55.2	56
Gimmers	60	55.1	51.0	51.6	43.0	48.1	54.1	58
All ages	266	58.3	57.1	58.1	46.5	51.5	56.9	269

Summary of Production and Performance (1972-79)

f) Pre-mating ewe body weight (November) (kg)

1972	1973	1974	1975	1976	1977	1978	1979
54.4	51.8	55.7	54.5	55.3	56.8	58.3	56.9

g) Production Data

	1973	1974	1975	1976	1977	1978	1979
Stock Nos.	217	222	242	255	272	259	266
Weaning %	112.9	109.0	116.6	106.3	112.9	97.3	115.0
Total Wt. lamb weaned (kg)	6615	6534	7981	7751	8934	7056	8325
Total Wt. wool including hoggs (kg)	493	490	560	542	536	501	469

YRGS IV: On heather moor - Glensaugh, Cairn and Birnie (combined report 1977-78 and 1978-79)

T.J. Maxwell and J. Eadie

The establishment of two similarly managed units on heather moor has been a prelude to the testing on a practical scale of ideas emerging from the current heather research programme. The results reported have been obtained within the context of the year round grazing system outlined in the Introduction and provide the basis from which a grazing system will be planned to take account of the particular characteristics of heather moorland.

Land Resources

The Cairn and Birnie lie on the north-eastern part of Glensaugh on land rising from 150 to 470 m, divided into two fenced hirsels of 205 and 167 hectares respectively. The Cairn encloses an area 22% greater than the Birnie but a higher proportion is 'black' ground (78%) compared with 62% on the more grassy Birnie. The mean elevation of the Cairn is also greater at 330 m than that of the Birnie at 240 m. Each hirsel contains lambing paddocks and improved pasture with additions in 1973 bringing the total areas up to those specified above.

During the summer of 1978 20 hectares of the Redstone Hill were enclosed and divided into two equal areas of 10 ha. In one of the areas (south) four-half ha square reseeds and in the other (north) four half ha rectangle reseeds were created. The reseeded areas were cleared of heather by brashing, given 6 tonnes/lime/ha and 400 kg/superphosphate/ha in July. They were then oversown with a grass/clover seed mixture with an application of 600 kg/ha of compound fertiliser and 600 kg/ha ground mineral phosphate in late July. The area was lightly grazed for the first time during the late summer and autumn with ewe hoggs.

In 1979 a further 15.7 hectares on Thorter hill was reseeded, using a similar strategy. Two enclosures of approximately equal area were created in which there were respectively four near-square, and three elongated strip reseeds.

A top dressing of 375 kg/ha of compound fertiliser (22:11:11) was applied to the Redstone Hill reseed in May 1979 and 125 kg/ha of Nitrochalk in July.

A monitoring programme was initiated in September 1979 on the Redstone Hill reseed. This programme has been designed to assess botanical changes in the callunetum associated with the introduction of reseeded areas of differing configuration, and the effects of grazing on the indigenous and introduced vegetation.

Livestock Reconciliation

		Ewes and Gimmers Nov. 1977	Cast	Dead	Gimmers brought into flock	Hoggs born 1978	Ewes and Gimmers Nov. 1978
1977-78	Cairn	177	31	9	50	58	187
	Birnie	215	53	8	55	59	209
		Nov. 1978					Nov. 1979
1978-79	Cairn	187	55	10	56	72	178
	Birnie	209	58	11	58	68	198

Sheep Years 1977-78 and 1978-79

a) Winter Feeding

Concentrates:- Cairn 77-78

Dates	Ewes (g/hd)	Gimmers (g/hd)
6 Jan. - 7 March	113.4	113.4
8 March - 16 March	113.4	170
17 March - 6 April	170	283
7 April - 2 May	454	454
3 May - 12 May	282	282

Birnie 77-78

Dates	Ewes (g/hd)	Gimmers (g/hd)
6 Jan. - 7 March	113	113
8 March - 16 March	113	170
17 March - 6 April	170	283
7 April - 2 May	454	454
3 May - 12 May	232	232

Concentrates:- Cairn 78-79

Dates	Ewes and Gimmers (g/hd/day)
30 Dec. - 8 March	133.7
9 March - 22 March	270.3
23 March - 2 April	337.8
3 April - 12 April	475.5
13 April - 30 April	543.5
1 May - 13 May	679.3
14 May - 20 May	543.5
21 May - 24 May	407.6
25 May - 31 May	271.7

Birnie 78-79

Dates	Ewes and Gimmers (g/hd/day)
30 Dec. - 8 March	119.6
9 March - 15 March	240.4
16 March - 22 March	300.5
23 March - 2 April	360.5
3 April - 12 April	480.8
13 April - 30 April	600.9
1 May - 13 May	731.7
14 May - 20 May	609.7
21 May - 24 May	365.8
25 May - 31 May	243.9

Hay was fed as follows:-

	Cairn Ewes and Gimmers (g/hd/day) 77-78	Cairn Ewes and Gimmers (g/hd/day) 78-79	Birnie Ewes and Gimmers (g/hd/day) 77-78	Birnie Ewes and Gimmers (g/hd/day) 78-79
December (18/12/78)	-	326	-	185
January (10/1/78)	93	448	96	428
February	823	677	667	662
March	614	432	528	393
April (until 28/4/78 and 28/4/79)	472	478	396	443
Totals kg/hd	57.3	63.4	48.3	59.4

Total feed and costs per head

		Cairn 77-78		Cairn 78-79		Birnie 77-78		Birnie 78-79	
Ewes	concentrate (kg)	26.13	£3.00	46.3	£5.68	25.63	£2.95	47.6	£5.84
	hay "	57.34	£3.69	63.4	£3.80	48.27	£3.10	59.4	£3.56
			£6.69		£9.48		£6.05		£9.40
Gimmers	concentrate (kg)	29.0	£3.34	as ewes		28.5	£3.28	as ewes	
	hay "	57.3	£3.69	as ewes		48.3	£3.10	as ewes	
			£7.03		£9.48		£6.38		£9.40

Hoggs '77-78

The Cairn and Birnie hoggs were fed concentrates and hay outside from 4 November. Both hefts were housed on 6 January and fed indoors till turnout at 15 April. Feeding stopped on April 28. Concentrate feeding was identical on both hefts.

4 November - 18 December	113 g/hd/day
19 December - 7 January	170 g/hd/day
8 January - 31 January	227 g/hd/day
1 February - 28 April	283 g/hd/day
Total consumption =	44.11 kg/hd

Hay was fed as follows:-

Cairn

4 November - 18 December	280 g/hd/day
19 December - 28 April	420 g/hd/day
Total consumption =	76.30 kg/hd

Birnie

6 December - 18 December	241 g/hd/day
19 December - 28 April	482 g/hd/day

Hoggs '78-79

The Cairn and Birnie hoggs were fed concentrates outside from 24th November and hay from the 30th December. Both hefts were housed on January 8th and fed inside till turnout on 4th April. Hay feeding stopped at turnout but concentrate feeding continued till April 12th.

Feeding was identical for both hefts.

Concentrates:

November 24th - January 8th		107 g/hd/day
January 9th - April 12th		214 g/hd/day
Total consumption	=	24.78 kg/hd

Hay:	g/hd/day
December	384.6
January	527.3
February	588.6
March	641.0
April	641.0

Total feed consumption and costs per head

	Cairn				Birnie			
	77-78		78-79		77-78		78-79	
Concentrate (kg)	44.1	£5.07	24.8	£3.04	44.1	£5.07	24.8	£3.04
Hay (kg)	76.3	£4.88	55.2	£3.31	76.3	£4.88	55.2	£3.31
		£9.95		£6.35		£9.95		£6.35

b) Lambing Performance

	Cairn		Birnie	
	77-78	78-79	77-78	78-79
Ewes to tup	177	187	213	209
Ewes eild	16	15	31	14
Ewe losses to lambing	4	3	0	1
Total lambs born	174(98.3%)	209(111.8%)	212(99.0%)	285(136.4%)
Total lambs marked	158(89.3%)	194(103.7%)	196(92.0%)	253(121.1%)
Total lambs weaned	153(86.4%)	190(101.6%)	189(88.7%)	247(118.2%)

c) Lamb Weights (kg)

	Cairn		Birnie	
	77-78	78-79	77-78	78-79
Birth singles	4.2	4.3	4.4	4.3
twins	3.7	3.7	3.6	3.3
Marking singles	12.1	13.5	12.8	11.7
twins	11.3	11.2	10.3	9.5
Weaning singles	28.4	30.0	28.4	27.3
twins	25.3	26.7	26.1	24.0

d) Wool Production (kg)

	Cairn		Birnie	
	77-78	78-79	77-78	78-79
4 crop ewes	1.98	1.46	1.76	2.12
3 crop ewes	1.70	2.01	1.80	2.27
2 crop ewes	2.10	2.05	2.20	2.26
1 crop ewes	2.26	2.20	2.28	2.21
Gimmers	2.32	2.14	2.17	2.25
All ages and gimmers	2.14	2.08	2.12	2.24
Hoggs	1.61	2.16	1.58	2.23

e) Ewe Bodyweight Changes (kg) 77-78

Age	Nos.	Pre-mating Nov.77	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.78	Nos.
CAIRN:								
4 crop	9	59.72	60.56	67.05	53.81	57.31	56.27	12
3 crop	25	53.74	51.69	53.50	46.63	50.87	58.30	36
2 crop	43	53.24	52.09	55.93	49.27	53.45	55.83	42
1 crop	48	50.83	48.96	53.50	45.97	50.80	53.01	47
Gimmers	51	47.28	44.57	48.48	44.19	48.88	49.92	50
All ages	176	51.26	49.45	53.38	46.77	51.26	54.03	187
BIRNIE:								
4 crop	15	59.16	57.70	62.73	50.18	54.32	60.18	11
3 crop	36	55.38	51.94	58.56	49.37	52.00	58.41	44
2 crop	56	54.24	52.61	58.29	49.87	52.28	60.72	48
1 crop	52	52.58	48.59	54.46	49.06	53.47	57.20	51
Gimmers	53	47.17	40.22	48.00	43.27	48.01	52.71	55
All ages	212	52.78	48.79	55.07	47.95	51.59	57.26	209

Ewe Bodyweight Changes (kg) 78-79

Age	Nos.	Pre-mating Nov.78	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.79	Nos.
CAIRN:								
4 crop	12	56.27	51.64	53.14	46.80	54.11	61.96	12
3 crop	36	58.30	57.85	59.64	50.50	57.16	60.12	20
2 crop	42	55.83	55.32	58.51	49.20	55.72	60.00	41
1 crop	47	53.01	52.94	55.50	48.90	56.64	55.61	49
Gimmers	50	49.92	46.02	48.04	43.81	50.55	52.95	56
All ages	187	54.03	52.47	54.83	47.83	54.73	56.72	178

Age	Nos.	Pre-mating Nov.78	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.79	Nos.
BIRNIE:								
4 crop	12	60.18	60.05	62.95	50.00	51.61	58.05	10
3 crop	44	58.41	58.58	63.42	47.80	50.34	60.92	30
2 crop	48	60.72	59.96	63.78	48.01	51.88	58.22	49
1 crop	51	57.20	53.94	56.36	45.45	51.22	56.70	52
Gimmers	54	52.71	47.14	49.55	42.22	48.26	55.33	57
All ages	209	57.26	54.87	58.24	45.88	50.40	57.49	198

Summary of Production and Performance 1972-1979

f) Premating Ewe Bodyweights 1972-79

	1972	1973	1974	1975	1976	1977	1978	1979
Cairn	52.8	51.8	55.8	50.0	47.5	51.26	54.03	56.72
Birnie	49.8	49.8	55.1	52.0	45.1	52.78	57.26	57.49

g) Production Data

	Stock Nos.	Weaning %	Total weight lamb weaned	Total weight wool
Cairn				
1973	188	97.9	5061	-
1974	191	96.8	5078	-
1975	190	111.6	5307	410
1976	204	99.0	4909	433
1977	198	67.34	3452	381
1978	187	86.4	4173	442
1979	178	101.6	5468	486
Birnie				
1973	204	99.1	5230	-
1974	206	81.9	4459	-
1975	204	115.2	6151	485
1976	221	115.8	6042	523
1977	225	81.77	5089	565
1978	215	88.7	5243	529
1979	209	118.2	6308	575

YRGS. V: Barnacarry/Feorline

T.J. Maxwell, J. Eadie, D.C. Currie and T.K. Whyte

The acquisition by the Forestry Commission of Feorline which is adjacent to the Barnacarry unit on Lephinmore, gave both parties an opportunity to pursue the possibility of integration. Barnacarry has been of limited use to the Organisation due to difficulty of access. Both parties examined the whole area of Feorline and Barnacarry to see whether some re-allocation of land could be made to provide an area of plantable land for the Commission at least as large as would otherwise have been available to them and at the same time provide an agricultural unit with development potential and with suitable access. It was intended that the new unit be used to examine the production and economic implications of the integration of improved land with the unimproved blanket bog vegetation.

An exchange of land was agreed. The Organisation acquired 156 ha of Feorline (71 ha deemed plantable) and the Forestry Commission acquired 95 ha of Barnacarry, 92 ha of which were plantable. On the basis of the land exchange the Forestry Commission agreed to provide access roads in advance of the date they would normally have been required for extraction.

The unit of Barnacarry/Feorline, extends to some 349 ha, of which approximately 30-40 ha are improvable and accessible for improvement.

Stock numbers will be increased gradually to assess performance in relation to the new unit. During 1975/76 the Feorline hill was subdivided to provide two enclosed areas, the Strone Park (18.2 ha) and Lochan Park (18.6 ha), which are suitable for improvement but are currently used for lambing and mating.

As a means of initially improving the quality of the enclosed areas and providing increased output from the unit a herd of 12 suckler cows was introduced in 1977. This was increased to a total of 15 cows in 1978. An area of 4 hectares of inbye pasture has been allocated for conservation and calving. The performance of the herd will be closely monitored.

Winter feeding of sheep is based on cereal based blocks. Hoggs will be wintered off the hill in 28 ha of enclosed forest adjacent to the area.

Land improvement will be carried out in relation to the increase in stock numbers and levels of individual performance achieved.

Sheep Stocks and Livestock Reconciliation

Ewes and Gimmers Nov. 1978	Cast	Deaths*	Gimmers brought in	Hoggs born 1979	Ewes and Gimmers Nov. 1979
259	46	19(10)	79	61	273

* Includes black loss (in brackets)

Sheep Year 1978-79

a) Winter Feed

All ewes and gimmers were gathered from Barnacarry Hill to Lochan Park on 10th January 1979 - deep snow. Five standard Rumevite blocks were made available on 11th January, and a total of 575 kg fed over a period of 4 days. Gate opened to hill on 16th January, but all gathered to Lochan Park again on 26th January - more severe snow and frost. Total of 1,215 kg hay fed over a period of 10 days. A further 4 standard Rumevite blocks were made available on 29th January, and this feeding continued in Lochan Park, and on both Barnacarry and Feorline Hills until lambing time. Blocks were also available in lambing areas. throughout lambing until 14th May 1979.

Hoggs were housed from 7th November 1978 until 12th April 1979, and went to Barnacarry Hill on 13th April.

The total feed consumption per ewe, gimmer, and hogg for the winter was as follows:-

	Ewes and Gimmers	Hoggs
Hay	6.91 kg	104.87 kg
Ewe Pencils	-	17.26 kg
Rumevite	14.77 kg	-
Total cost/head	£2.54	£8.58

b) Lambing Performance

Ewes to tup	259	
Tup eild	22	
Kebs	3	
Ewe losses to lambing	6	
Total lambs born (live and dead)	256	(98.8%)
marked	195	(75.3%)
weaned	184	(71.0%)

c) Lamb Weights (kg)

Birth weights,	singles	3.8
	twins	2.7
Marking weights,	singles	10.4
	twins	10.2
Weaning weights,	singles	24.6
	twins	25.5

d) Wool Production (kg)

Age 4 crop	1.3
3 crop	1.5
2 crop	1.8
1 crop	1.6
Gimmers	1.9
All ages	1.7

e) Ewe Bodyweights (kg)

Age	Nos.	Pre-mating Nov.1978	Pre-Feeding	Pre-Lambing	Marking	Weaning	Pre-mating Nov.1979	Nos.
4 crop	34	49.2	45.7	47.5	43.8	49.6	51.9	32
3 crop	42	49.4	48.1	50.0	45.2	49.7	51.3	52
2 crop	60	47.4	45.6	47.2	43.9	48.8	50.5	45
1 crop	49	45.0	41.7	42.0	42.4	47.6	47.8	65
Gimmers	74	42.3	38.5	39.5	39.4	45.4	45.1	79
All ages	259	46.1	43.2	44.9	42.6	47.9	48.9	273

Summary of Production and Performance 1975-79

f) Pre-mating Ewe Bodyweight (November) (kg)

1974	1975	1976	1977	1978	1979
47.2	44.1	46.6	45.5	46.1	48.9

g) Production Data

	1975	1976	1977	1978	1979
Stock Nos.	227	243	251	256	259
Weaning %	78.4	76.5	74.9	82.8	71.0
Total Wt. Lamb Weaned	4530	4692	4668	5377	4543
Total Wt. Wool	468	482	502	525	533

OFF-WINTERING/INWINTERING SYSTEMS

03005: Develop off-wintering systems of animal production from hill pastoral resources

IWS I: On a grassy hill - Sourhope/Rigg and Gairs

R.H. Armstrong, J. Eadie and T.J. Maxwell

Land Resources

The Rigg and Gairs are two similar units, each of 101 ha, 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. On the Gairs Unit a substantial area of improved pasture has been made available. An area of 15 ha 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 ha of *Molinia/Nardus* grass heath at 450 m received 6.35 tonnes lime and 1.65 tonnes slag per ha. It was later sprayed with Paraquat, rotavated and direct reseeded in mid-July with 380 kg per ha of high phosphate compound. This area was grazed for the first time in the autumn of 1971. In 1975, ground magnesium limestone at 6.3 tonnes/ha and super-slag (16% P_2O_5) at 0.88 tonnes/ha was applied to the Gairs reseed. In early June 1979 reseed E_2 on Gairs received 250 kg/ha of a compound fertiliser (22:11:11).

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.

Stocking Policy

The breed changeover from a South Country Cheviot to a Blackface ewe stock is now complete. The change was achieved by September 1979.

The policy of grazing cattle on both Rigg and Gairs thus enabling an equalisation of grazing days on each heft became impracticable in 1977 due to inadequate pasture, and in that year cattle grazing took place only on the Gairs. It was decided that no cattle would be grazed on either the Rigg or the Gairs from 1978, and in the autumn of 1978 sheep stock numbers on both sides were reduced, the Rigg to 271 and the Gairs to 275.

Sheep Stocks and Livestock Reconciliation

Both the Rigg and Gairs have carried South Country Cheviots. Stocking rate increases were 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 flock. In 1974 Blackface hoggs were purchased to replace the Cheviot hoggs on both units. Cheviot ewe stocks were replaced progressively by Scottish Blackfaces. For this reason the flock data is presented separately for the two breeds.

[illegible] stock [illegible]

	Ewes and Gimmers Nov. 1978	Cast	Deaths	Gimmers brought in	Hoggs born 1979	Ewes and Gimmers Nov. 1979
Rigg:						
Cheviot	40	38	2	-	-	-
Blackface	231	20	6	59	65	264
Total	271	58	8	59	65	264
Gairs:						
Cheviot	45	44	1	-	-	-
Blackface	230	10	8	59	65	271
Total	275	54	9	59	65	271

Total Stock Numbers

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Rigg:											
Cheviot	205	205	238	278	279	298	234	152	93	40	-
Blackface	-	-	-	-	-	-	65	128	191	231	264
Gairs:											
Cheviot	209	207	233	260	279	297	240	165	111	45	-
Blackface	-	-	-	-	-	-	65	132	199	230	271

Sheep Year 1978-79

a) Winter Feeding

Rigg ewes and gimmers housed 9.1.79

Commence ration of 500 gm hay
230 gm S.B.P.
120 gm conc.

Gairs ewes and gimmers housed 19.1.79

Commence ration of 500 gm hay
230 gm S.B.P.
120 gm conc.

21.2.79 All Rigg and Gairs feed altered as below:-

625 gm hay
280 gm S.B.P.
120 gm conc.

26.3.79 All Rigg and Gairs feed altered as below:-

625 gm hay
280 gm S.B.P.
170 gm conc.

6.4.79 Rigg and Gairs ewes only (not gimmers) feed raised as below:-

625 gm hay
280 gm S.B.P.
230 gm conc.

* All SCC and BF late lambers put out of sheds 11th/12th April - early lambers lambed in sheds.

Total Feed

(kg)	Pre-housing	Inwintered	Post-lambing	Total	Per head
Hay	1860	31220	5030	38110	69.8
SBP	150	11712	125	11987	22.0
Stockade blocks	-	-	160	160	0.3
Colborn blocks	-	-	506	506	0.9
Ewebol pencils	-	7150	-	7150	13.1
Grass Nuts	-	-	700	700	1.3
Ewebol cobs	-	-	8830	8830	16.2
				Cost per head	£8.51

Hoggs Rigg and Gairs hoggs housed 8.1.79:- (124 hoggs)

340 gms hay
113 gms ewebol pencils
113 gms S.B.P.

Some smaller hoggs on:-

340 gms hay
128 gms pencils
128 gms S.B.P.

24.1.79 Ration increased to:-

340 gms hay
120 gms pencils
170 gms S.B.P.

5.2.79 Ration increased to:-

400 gms hay
120 gms pencils
230 gms S.B.P.

8.3.79 Hay increased to 500 gms

Smaller hoggs ration increased to:-

340 gms hay
170 gms pencils
230 gms S.B.P.

10.4.79 Hoggs out of shed

Pre-housing (27.11.78 to 8.1.79)

S.B.P.	250 kg
Grass Nuts	250 kg
Ewe and lamb mix	100 kg
Hay	27 bales
Lamb Pencils	50 kg
Barley	50 kg

Hoggs Total Feed:- (kg)

		per head
Hay	5240	42.3
S.B.P.	2300	18.5
Ewe Pencils	1425	11.5
Grass Nuts	250	2.0
Ewe and Lamb Mix	100	0.8
Barley	50	0.4
Lamb Pencils	50	0.4
Cost per head		£5.08

b) Lambing Performance

	Ewes Mated	Eild	Keb	Ewe losses to lambing	Total lambs born	Marked	Weaned
Rigg:							
Cheviot	40	1	1	-	53(132.5%)	51(127.5%)	49(122.5%)
Blackface	231	13	-	1	312(135.1%)	300(129.9%)	279(120.8%)
Gairs:							
Cheviot	45	-	-	2	66(146.7%)	53(117.8%)	51(113.3%)
Blackface	230	11	-	3	337(146.5%)	309(134.3%)	300(130.4%)

c) Lamb Weights (kg)

	Rigg		Gairs	
	Cheviot	Blackface	Cheviot	Blackface
Birth weights, singles	3.8	4.3	4.2	4.3
twins	2.9	3.4	3.1	3.5
Marking weights, singles	8.7	9.5	11.2	11.3
twins	6.5	6.9	6.4	7.3
Weaning weights, singles	22.3	27.4	27.6	31.5
twins	22.5	25.9	22.4	27.5

d) Wool Production (kg)

Gairs:

Cheviot	79.6
Blackface	432.7

Rigg:

Cheviot	72.5
Blackface	448.0

e) Ewe Body Weights (kg)

Rigg:

Ages	Nos.	Pre-mating Nov.78	Pre-Feeding	Pre-Lambing	Marking	Weaning	Pre-mating Nov.79	Nos.
4 crop	40	55.6	58.2	63.0	48.2	52.2	59.3	44
3 crop	53	58.0	58.8	62.9	49.9	54.9	57.9	63
2 crop	67	55.8	56.7	61.1	48.3	54.1	58.3	48
1 crop	55	54.9	54.4	58.0	46.9	53.7	56.6	50
Gimmers	56	51.1	52.3	55.5	45.1	51.4	53.0	59
All ages	271	55.1	56.0	59.9	47.7	53.3	56.9	264

Gairs:

Ages	Nos.	Pre-mating Nov.78	Pre-Feeding	Pre-Lambing	Marking	Weaning	Pre-mating Nov.79	Nos.
4 crop	45	59.0	58.5	63.4	48.7	58.0	60.3	48
3 crop	53	58.8	60.3	65.7	52.4	56.9	60.2	49
2 crop	55	56.2	56.6	61.6	49.8	56.9	61.2	58
1 crop	63	55.3	56.0	61.2	50.6	58.0	56.1	57
Gimmers	59	50.6	50.2	54.3	43.5	51.3	53.2	59
All ages	275	55.7	56.1	61.0	48.8	56.0	58.0	271

Summary of Production and Performance 1969-1979

f) Pre-mating Ewe Body Weights (kg)

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Rigg:											
Cheviot	48.3	49.7	51.5	51.2	50.6	50.0	51.8	53.8	55.6	55.6	-
Blackface	-	-	-	-	-	-	-	48.5	52.1	55.0	56.9
								52.4	54.0	55.1	
Gairs:											
Cheviot	49.9	50.5	51.9	53.5	52.9	54.1	53.8	56.6	56.7	59.0	-
Blackface	-	-	-	-	-	-	-	48.5	51.5	55.1	58.0
								54.7	54.4	55.7	

g) Production Data

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Rigg:										
Stock Nos.	205	205	238	278	279	311	299	290	284	271
Weaning %	83.0	87.0	100.8	87.8	91.0	89.6	90.6	105.2	105.6	121.0
Total Weight lamb weaned (kg)	3706	4432	5712	4324	6155	6257	6640	8218	7920	8519
Total Weight wool (kg)	402	534	641	732	680	670	674	567	525	521
Gairs:										
Stock Nos.	209	207	233	260	279	305	305	297	310	275
Weaning %	83.0	96.0	91.4	93.1	87.0	87.2	99.0	109.4	111.9	127.2
Total Weight lamb weaned (kg)	3581	5246	5176	5675	6394	6381	7943	9248	9542	9956
Total Weight wool (kg) (including hoggs)	461	524	634	752	766	732	738	643	624	512

SIMULATION

03009: Systems modelling

1. Agriculture/Forestry Integration

T.J. Maxwell and A.R. Sibbald

Testing of the integration procedure and its method of assessment of a range of options has continued with the addition of a third commercial farm to those currently being examined. Adjustments have been made to the procedure in the light of the experience gained by studying these practical examples.

The results from the first study farm of 560 ha in Argyll are now complete and indicate that it is possible to achieve an integrated scheme of agriculture and forestry that is, in overall economic terms, more productive than either industry alone.

A second study of a farm in Dumfriesshire of some 1400 ha is not yet complete. Preliminary results indicate that the land is more productive in agriculture than in forest . However up to 20% of the land area could be planted to achieve a significant forest production level with minimal effects on agriculture if some land improvement is carried out.

The third farm is in Lanarkshire and covers 720 ha. Preliminary results indicate that the land would be more productive in trees than in agriculture. The landowner has decided that, while trees should be planted, a viable farm unit must remain. It seems possible that about 60% of the farm area could be planted and that with better use of existing inbye and a small amount of additional pasture improvement, a viable agricultural unit could be created.

A methodology to allow a rapid build-up of flock numbers by the retention of a proportion of over-age ewes is currently being tested. The effect of this procedure on farm economics, coupled with the effect of retaining extra ewe lambs for flock number increase must also be assessed.

One generalisation that can be made from the present state of these three studies of agriculture and forestry integration is that it is dangerous to generalise. Each farm or estate where agriculture and forestry are to co-exist should be considered separately.

DATA HANDLING

01004; 02002; 03004; 03005; 03008; 48001

A.R. Sibbald, E.V. Deans and T.J. Maxwell

Data from each of the Systems Development's eight projects in operation at three of the Organisation's farms continued to be submitted to Headquarters for processing and summary by computer. A further two projects, namely, Mid-pregnancy nutrition at Lephinmore and Hill Sheep Development in operation at commercial farms and Kirkton Farm belonging to the West of Scotland College of Agriculture, yielded more data for processing and summary. The total number of ewe, gimmer, hogg and lamb records processed throughout the year, relating to all projects, approximated 23,000.

Most of the computer work was done on the ICL 2980 computer at E.R.C.C. Bush using the VME/B system and latterly the EMAS service. However, computer work relating to the Hill Sheep Development project continued to be carried out on the PDP 11/20 computer at S.I.A.E.

1. PDP 11/03 Micro-computer System

The data capture and processing procedures, described briefly in last year's report, have been used successfully throughout the year on continuous-flow analyser data. Outputs from 3-hydroxybutyrate, glucose, urea, total protein and albumin analysers have been processed and results tabulated.

The result tabulation procedures have been improved and added to in order to speed up the return of results to research staff.

Another development has been in the capture of data from foetal heart beat detectors and the analysis of these data by autocovariance techniques.

A new, fixed disk has been added to the system. This will greatly extend data storage capacity and will permit the simultaneous capture of data from more analysers, when initial software problems have been overcome.

VETERINARY MONITORING

02008; 03004; 03005

A. Whitelaw, A.R. Fawcett and A.J. Macdonald

Laboratory

	1977	1978	1979
Faecal Worm Egg Counts	5500	5441	2467
Pasture larvae counts	100	95	43
Haematology	-	376	1067
*Plasma copper estimations	4504	4767	2421
*Serum vitamin B_{12} estimations	910	2679	393
*Liver copper estimations	20	221	90
*Milk copper estimations	416	302	80
Glutathione peroxidase (selenium) estimations	-	-	87
Calcium-Magnesium	-	20	48
Bacteriology Virology	-	-	426
Miscellaneous	405	729	91

*Carried out by the biochemistry departments under C.C. Evans and E. Skedd.

Records of disease were provided by staff at the Research Stations. V.I. Reports were collated with these.

Veterinary programmes for each farm are produced annually for cattle and sheep and are adjusted as required.

LEPHINMORE

Sheep 03004; 03005

General

Overall loss in the flocks was 7.4% including 1.3% black loss. The losses were proportionately the same in each flock. More than half of the deaths were for animals found dead, with no observed clinical signs or post-mortem examination to give a basis for diagnosis. Ten percent was deemed to have couped and an equivalent number to have drowned although in these it is possible that illness may have put them in such a situation.

The climatic conditions prevalent in the winter and spring were not conducive to good health and poorer weaning rates in lambs reflect this.

Liver Fluke

The national forecast indicates an increased risk and fascioliasis outbreaks have been reported by some V.I. centres. The level in the undosed flock at Midhill has never exceeded 0.3% since the completion of the strategic dosing programme, and the next two years will probably underline the value of this approach.

Cattle 02008

No serious health problems were encountered in the herd. Animals returning from Hartwood were affected with ringworm. This responded to treatment, but it does show how the transmission of disease between farms can occur and underlines the importance of notifying stock movements and the application of precautionary measures to prevent this.

SOURHOPE

Sheep 03004; 03005

General

The overall death rate of 4.1% when seen against the severe climatic conditions prevalent in the winter of 1979 compares well with previous years. When examined against the records there is no indication of any specific disease being a problem. The number of animals found dead, drowned or couped accounted for over 50% of the total loss. An outbreak of respiratory disease in Rigg and Gairs lambs probably relates to a change in practice in that these flocks were lambed indoors in 1979. Whilst there was no overt clinical disease in the ewes in the house, there was some coughing, probably due to parainfluenza virus.

Parasitic helminths are controlled by strategic dosing designed to combat the two main peaks of infective larval activity which are associated with the contaminated improved pastures. There is at the moment no foreseeable possibility of providing clean pasture or adopting a clean grazing system. The most important strategic dose is to the ewes at lambing time.

Copper studies carried out on the Alderhope improved pastures are reported elsewhere (p.A.23). A study in the hypothermia/starvation/exposure syndrome in neonatal lambs by ADRA showed promise in recuperative measures but was disappointing in that recovered lambs succumbed later in life. Scrapie in Cheviots is being watched carefully.

Veterinary preventive programmes are reviewed annually and the rational use of vaccines and anthelmintics adjudged on strategy and economy.

Cattle 02008

No major disease problems were reported. The very sporadic cases of listeriosis occurring in cows have an association with silage feeding. The annual farm report refers to poor fertility in the Hereford bulls and this was reflected in conception rates in the herd.

GLENSAUGH

Sheep 03004

General

The most frequent cause of death was respiratory disease, amounting to 40% of diagnoses on post-mortem examination. The greatest loss occurred in the Greyface flock where pasteurellosis and Jaagsiekte occurred in about equal numbers. A portion of the Greyface flock bought in close to lambing suffered accordingly in the adverse weather conditions prevailing at lambing.

The records of ill-health maintained at Glensaugh were excellent, allowing the interpretation of losses to be made with confidence. Preventive programmes were implemented fully and the cooperation is appreciated.

Cattle 02008

The herd suffered two major outbreaks of enteric disease in calves in 1979. The first outbreak in the spring was associated with rotavirus and coronavirus infection associated with Escherischia coli of varying antibiotic sensitivities. Predisposing factors were a susceptible population boosted by the presence of bought in calves, electrical failure at a critical time and adverse weather causing problems in the cattle shed.

Morbidity was 100% and mortality was high, 19 calves dying. The reoccurrence of enteritis in previously treated calves was a major problem and the use of electrolytes, antibiotics, sulphonamides and other drugs was unsatisfactory. It is possible of course that mortality could have been even higher without their use. Pathological damage to the intestine was severe and the surviving calves suffered from this in their eventual performance. Accounts of similar and even more serious outbreaks were recorded in Veterinary Investigation reports. HFRO are actively collaborating with ADRA Moredun in studies of rotavirus and coronavirus vaccines.

The second outbreak occurred in autumn calves and contrasted markedly with the first. Morbidity was high, mortality nil and apart from a recurrent enteritis calves were not clinically affected. ADRA found the cause to be a cryptosporidium (a member of the group Coccidia). There is only one recent reference to the infection in the U.K. literature and it has only recently been referred to in the U.S.A. as an organism causing enteritis in calves. One of the characteristics of cryptosporidia is that they are surface feeders and antigenicity is accordingly poor. This means that because immunity is low, recurrent attacks occur.

Apart from labour involvement in repeated treatments, the effect upon calves has been low and they have thriven well. There were no isolations of coronavirus or rotavirus. An outbreak of summer mastitis in dry cows caused concern, but most cases responded to treatment. New recommendations regarding the frequency of dry cow therapy during the danger period will be implemented in future.

HARTWOOD 99007

Preventive programmes will be implemented at this farm. Fairly intensive monitoring will be required, particularly in cattle stock. Important problems are lungworm disease and summer mastitis.

The intention at Hartwood is to utilise clean grazing systems to control parasitic gastro-enteritis. This will depend upon good fencing, rigid control of stock movements and precautions with stock moved on to the farm.

Cattle moved off the farm could take lungworm infection to our other farms and control measures will need to be absolute.

SURGERY

	Sheep
Rumen cannulation	6
Abomasal Pouch	3
Oesophageal fistulation	10
Ovariectomy	33
Duodenal and ileal cannulation	16

LAND USE

03010: The collation and analysis of statistical information on hill and upland farming and land use

1. Hill Sheep Farming in Scotland : A Study of the Agricultural Statistics

A.D.M. Smith and J. Eadie

Data used have been abstracted from the statistics of the Department of Agriculture and Fisheries for Scotland.

a) An analysis of data based on the Winter Keep (Scotland) Scheme identified three classes of hill farm determined by land types, length of grazing season and stocking rate capacity. The between farm class distribution of total hill land, crop/grass:rough grazing ratios and livestock stocking rate comparisons indicate a varying degree of land use intensity on hill farms.

Table 1. Distribution by farm types, of hill land and livestock - Scotland

	A	B	C	
No. of farms	480	922	2,041	3,443
%	13.9	26.8	59.3	100
Land area (ha)	172,001	505,896	2,418,458	3,096,435
%	5.5	16.3	78.1	100
Crop & grass	59,827	76,463	87,759	244,049
% of land area	34.8	15.1	3.6	7.9
Rough grazing	109,388	423,317	2,309,929	2,842,635
% of land area	63.6	83.7	95.5	91.8
No. of sheep	177,968	390,373	1,317,229	1,885,570
% of total	9.4	20.7	69.8	100
No. of cattle	41,281	67,561	103,776	212,618
% of total	19.4	31.8	48.8	100
Stocking Rate				
Land Area				
ha/ewe	1.0	1.3	1.8	
ha/cow	4.2	7.5	23.3	
Rough Grazing				
ha/ewe	0.6	1.1	1.7	
ha/cow	2.6	6.3	22.7	

By subdividing hill ewe breeding stock into flock range groupings it was possible to construct a pattern of hill sheep farm size and livestock distribution.

Table 2.

Flock Size	Farms No.	%	Land area ha	Mean ha	%	Sheep Nos.	%	Cattle Nos.	%
< 200	877	25.5	157294	179	5.1	101317	5.4	39586	18.6
201-300	483	14.0	155676	322	5.0	120057	6.4	26711	12.6
301-400	404	11.7	217196	537	7.0	140648	7.4	22269	10.5
401-500	357	10.4	253303	709	8.2	161621	8.6	20882	9.8
501-750	571	16.6	577671	1012	18.6	349778	18.5	38264	18.0
751-1000	258	7.5	341645	1324	11.0	222465	11.8	17962	8.4
1001-1250	180	5.2	287374	1596	9.3	200324	10.6	15586	7.3
1251-1500	113	3.3	238599	2111	7.7	154472	8.2	10895	5.1
> 1500	200	5.8	867676	4338	28.0	434888	23.1	20463	9.6
	3443	100	3096435		100	1885570	100		100

A more detailed farm class analysis of two flock size groupings provides basic information of within class ranges of crop/grass:rough grazings and associated stock populations.

Table 3.

MEAN AREA

Flock Size 1-200	Land (ha)	GRASS (ha) Mow	N/Mow	Crop + Grass	Rough Grazing %	Mean Herd Size	Mean Flock Size
Class C	233.9	9.6	19.7	34.4	83.6	38	114
Class B	139.9	12.7	28.4	49.8	63.0	44	118
Class A	133.3	19.0	46.4	82.0	36.6	62	112
All Types	179.3	12.6	28.2	49.5	70.7	45	115

MEAN AREA

Flock Size > 1500	Land (ha)	GRASS (ha) Mow	N/Mow	Crop + Grass	Rough Grazing %	Mean Herd Size	Mean Flock Size
Class C	4494.5	16.2	39.6	61.8	97.9	90	2188
Class B	3921.7	41.8	113.2	176.0	94.9	176	2120
Class A	1751.5	48.8	161.3	269.2	82.5	189	2006
All Types	4338.3	20.0	51.5	81.0	97.4	102	2174

b) A study of hill sheep population changes 1967/78 and major factors which affect distribution trends, is in progress.

C. PLANTS AND SOILS

PLANT NUTRITION

04003: Nutrient requirements of white clover and sown grasses in hill soils

1. The effect of hill pasture improvement on the uptake of copper, molybdenum and sulphur in herbage.

C.C. Evans and P. Newbould

The collection and analysis of herbage from improved and associated unimproved pasture at Alderhope, Sourhope has continued during 1979. The S, Mo and Cu concentrations of the herbage which are shown in Table 1, confirm previous observations of increased Mo and S levels in improved pasture as compared to unimproved pasture.

Table 1. Elemental concentrations of herbage from improved and unimproved pastures at Alderhope sampled on three occasions in 1979.

Sampling Date	S g/kg	Cu ppm	Mo ppm
a) Improved			
29/5	5.2 ± 0.14	6.3 ± 0.40	3.9 ± 0.31
18/7	2.6 0.12	4.5 0.14	2.3 0.12
31/8	3.2 0.12	4.0 0.32	4.0 0.18
b) Unimproved			
29/5	1.8 ± 0.04	6.8 ± 0.20	0.9 ± 0.08
18/7	1.8 0.07	5.5 0.20	0.8 0.06
31/8	1.7 0.06	4.8 0.13	0.9 0.09

The S, Mo and Cu values have been used to calculate the true available (TA) dietary copper (see Annual Report 1978 p.C2) and these are shown in Table 2 together with those for 1977 and 1978 for comparison.

Table 2. True available copper as calculated for sheep grazing improved and associated unimproved pasture at Alderhope 1977-79.

True available Dietary Copper - ppm

	Improved			Unimproved		
	1977	1978	1979	1977	1978	1979
May	0.10	0.12	0.10	0.33	0.32	0.33
July	0.14	0.15	0.15	0.27	0.29	0.27
Aug/Sept.	0.13	0.13	0.12	0.25	0.24	0.24

Regular annual patterns of dietary TA copper have now emerged with the indigenous pasture typically yielding 2-3 times that for improved with the latter at levels substantially below the minimum necessary (0.24 ppm) for growing lambs and lactating ewes (0.61 ppm). TA copper levels in the improved pasture were lower in the spring whereas the opposite was the case in the unimproved, where early growth contained higher TA Cu which then steadily declined until the time of weaning.

<u>The uptake of sulphur, molybdenum and copper by perennial ryegrass and white clover as influenced by the application of fertilisers including copper</u>

Samples from the glasshouse pot experiment described in the previous report have now been chemically analysed although a full statistical analysis is still awaited. The object of this experiment was to provide basic data of the effects of fertiliser application, including copper, upon the uptake of S, Mo and Cu by both S23 perennial ryegrass (PRG) and S184 white clover (WC). The relative concentrations in the grazed pasture of these elements have been shown previously to be important in the determination of the incidence and severity of the induced type of copper deficiency identified in sheep which grazed some reseeded improved hill pasture.

Fertiliser application rates in the fully factorial, randomised block 4 replicate pot experiment were equivalent to - ground limestone (lime) - 5022 kg/ha; 15:15:21 NPK fertiliser - 250 kg/ha; superslag (slag) 1255 kg/ha; copper oxide - 22 kg/ha. Fertilisers were applied alone and in all possible combinations. A peaty podsolic soil from Alderhope which had an initial pH of 4.2, was used in 6" plastic pots. Soil moisture was maintained at 65% Field Capacity by surface watering with deionised water. Samples for analysis were constituted by bulking the first 4 harvests of relatively juvenile growth taken over a period of 4 months (PRG) or 5 months (WC). At this stage in the absence of a complete statistical analysis the following general observations can be made.

<u>pH</u>

The pH of the soil is important as it is a significant determinant of Mo concentrations in plant tissues from improved hill soils where both available soil Mo and plant tissue Mo increases directly with increasing soil pH. Moreover, interactions between line and copper uptake by plants which may also be due to pH effects have been reported.

There was a tendency for soil pH to fall, even in the control treatments, such that pH's were generally lower at the end of the experiment (mean of all treatments - 4.8) than at the start (5.3) for both PRG and WC. The effect of increasing pH by both lime and slag was additive as Lime and Slag treatments were higher than either when applied alone. Initially NPK reduced pH when applied to Lime but not Slag treatments.

<u>Dry matter yield</u>

Growth rate is one of the many factors which can determine elemental concentrations in plant tissues with a tendency for rapid growth rates to reduce concentrations (dilution effect). As anticipated, lime, NPK and slag all substantially increased DM particularly when in combination. NPK had a greater effect on PRG than WC while lime and slag increased DM of WC to a greater extent than PRG. There was some evidence that copper also increased yield of DM in both plants.

<u>Plant tissue concentrations</u>

<u>Sulphur</u>

The mean S concentration for all treatments of PRG (0.52%) was approximately twice that of WC (0.27%). This species difference was also found on the same soil in the field situation at Alderhope but to a smaller extent. All fertilisers (except copper), and particularly NPK, reduced S levels in both PRG and WC which suggests that there was an inverse relationship between growth rates and S plant concentrations.

Molybdenum

The mean Mo concentration in PRG was approximately 30% higher than that of WC. NPK reduced Mo levels whereas they were increased by both lime and slag in both PRG and WC possibly due to the pH effect; application of copper had little effect. The Mo concentration of both PRG (2.2 ppm) and WC (1.5 ppm) were significantly lower than would be expected for the same soil in the field except in periods of rapid growth (see Table 1).

Copper

The Cu concentration of all treatments in the absence of fertiliser Cu was low for both WC (4.3 ppm) and PRG (3.4 ppm). This may indicate that the Alderhope peaty podsol is marginal in Cu supply at high plant growth rates. The effect of copper application was to increase the mean tissue Cu levels for all treatments for both WC (12.9 ppm) and PRG (7.6 ppm). The responses of these 2 species to applied Cu are similar to those reported in the literature (Reith, 1975). In the absence of fertiliser Cu the effect of lime in both PRG and WC was to increase Cu levels whereas lime reduced the responses to applied Cu. Cu levels were lower in treatments which included NPK and slag when compared to those without.

Reference

REITH, J.W.S. (1975). Copper deficiency in plants and effects of copper on crops and herbage. In "Copper in Farming". A symposium run by Copper Development Association, 25-41.

2. The interaction between the form of phosphorus fertiliser and the rate of applied calcium carbonate

Anne Rangeley

The growth of white clover was depressed when grown in peat with high levels of added calcium carbonate (see HFRO 220). One explanation was that the calcium carbonate inhibited the dissolution of the added phosphorus in the limed soil. The form of phosphorus applied in the experiment was tricalcium orthophosphate which is not very soluble (2×10^{-3} g/100 ml cold water). A further experiment was carried out using the same levels of calcium carbonate (equivalent to 0, 1.5, 3.0 and 6.0 tonnes/ha) as before but phosphorus was applied (at 1.45 kg P/ha) as either tricalcium orthophosphate ($Ca_3(PO_4)_2$) or as the more soluble monocalcium orthophosphate ($Ca(H_2PO_4)_2H_2O$ - solubility 1.8 g/100 mls cold water).

In the absence of lime fewer seedlings established themselves when compared to all the limed treatments (Fig. 1), probably because the plants were deficient in calcium. The effect was more pronounced where monocalcium orthophosphate was used because this compound provided one third the amount of calcium as tricalcium orthophosphate.

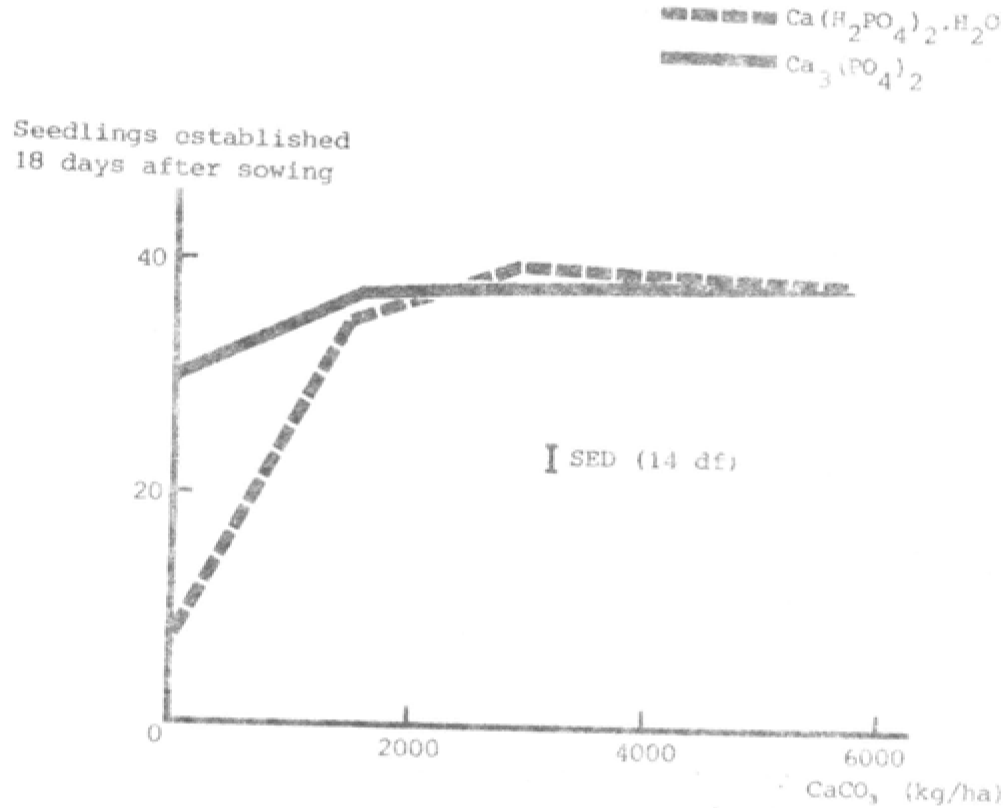


Fig. 1. The effect of added calcium carbonate and two forms of phosphorus on the number of seedlings of white clover established in the Lephinmore deep peat thirteen days after sowing.

Plants yielded the most when 1.5 tonnes/ha calcium carbonate was applied and the yield was not affected by the form of added phosphorus (Fig. 2). Yields in the absence of calcium carbonate were related to the number of seedlings which established (see Figs. 1 and 2), but depression in growth when calcium carbonate was applied must have been caused by differences in growth rate. Depressions in growth with monocalcium orthophosphate were not as great as with tricalcium phosphate (Fig. 2) and the concentration of phosphorus in the shoots of plants given the more soluble form of phosphorus were greater than when given tricalcium orthophosphate (Table 1). The concentration of P in the shoot decreased as the level of added calcium carbonate increased. Depressions in growth with high lime were associated with levels of P in the shoot at or below 0.23% P in the dry matter. The critical concentration of phosphorus in the shoots of clover is about 0.2% P (Rangeley, 1980) therefore the data suggests that the growth depressions which occur when soils are overlimed is, at least, partly caused by low availability of phosphorus.

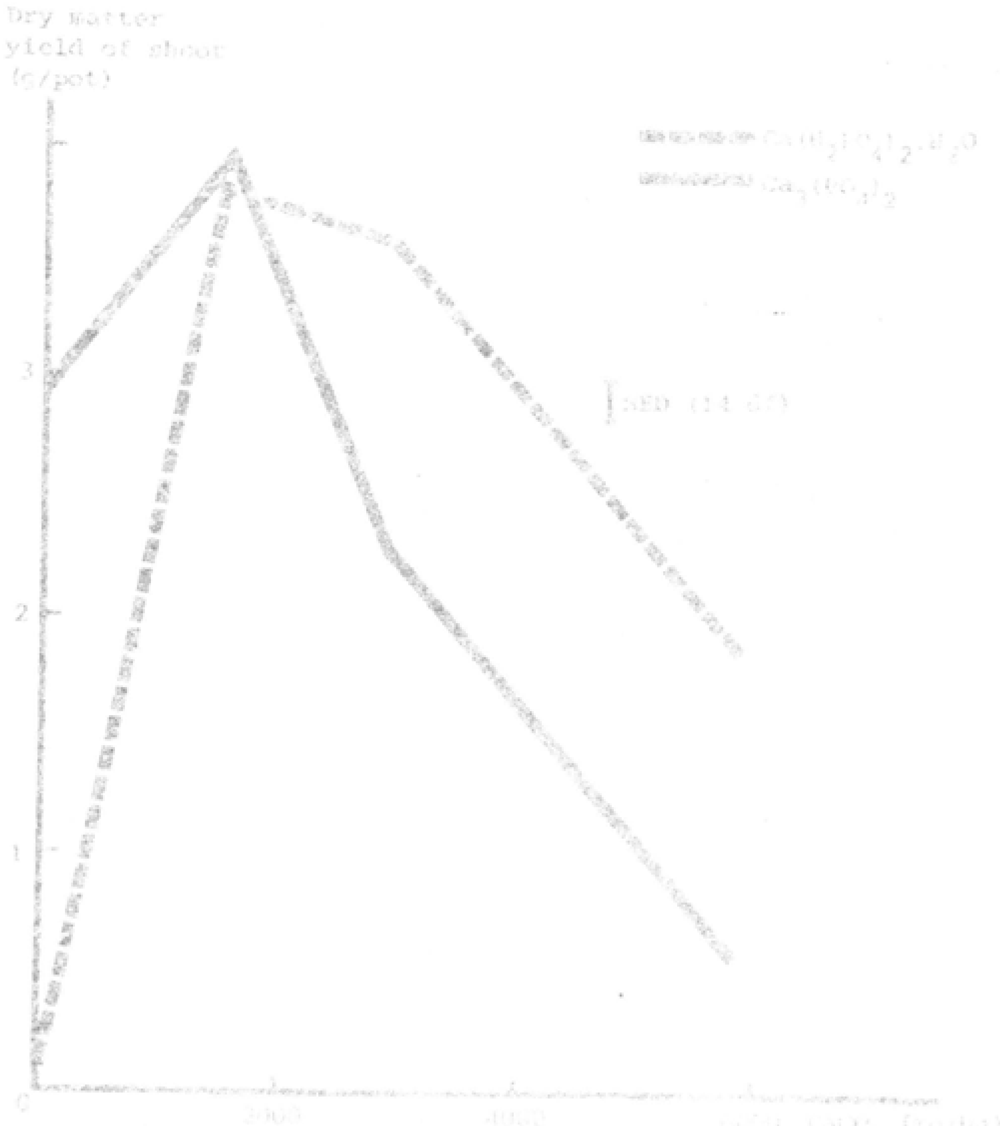


Fig. 2. The effect of added calcium carbonate and two forms of phosphorus on the yield of the shoots of white clover grown in the [illegible] deep peat.

Table 1. The effect of two forms of calcium phosphate and four levels of calcium carbonate on the concentration of phosphorus in the shoots.

	Phosphorus in shoots (%)				SED
	Calcium carbonate (kg/ha)				(14 df)
	0	1450	2900	5800	
$Ca(H_2PO_4)_2H_2O$	-	0.42	0.35	0.23	
$Ca_3(PO_4)_2$	0.39	0.35	0.20	0.17	

Reference

RANGELEY, Anne (1980). PhD. Thesis, University of Edinburgh.

3. The effect of deficiency of phosphorus and potassium on the growth of white clover

Anne Rangeley and Julia Leask

In a pot experiment, white clover, grown in peat, was given combinations of applied phosphorus and potassium fertilisers. The aim of which was to identify the effects of deficiency on the growth of the plant and to explain why there were synergistic increases in growth when applications of the two elements were balanced (see HFRO 212).

Table 1 shows that most of the variation in yield, due to treatment, can be explained by a variation in the number of leaves and not by the weight of a single leaf.

A variation in leaf number can be caused by differing rates of either leaf production or leaf senescence. Data in Table 2 suggests that when phosphorus is deficient the rate of production of leaves is reduced but senescence is unaffected; whereas when potassium is deficient the rate of leaf production is reduced to a small extent but the leaves senesce earlier. This early senescence is associated with deficiency symptoms on the leaves. Brown necrotic spots appear on the margins of the older leaves, eventually the spots coalesce and the leaf dies. Plants deficient in phosphorus have no very obvious deficiency symptoms, the plants are small, the leaves tend to be dark bluey green and the stems may turn red when severely deficient.

While the treatments had little effect on the weight of a single leaf there were differences in the area of a single leaf, deficiency of both phosphorus and potassium reduced the area of the leaf (Table 3).

Therefore phosphorus, and to a lesser extent potassium, affect the rate at which leaves are produced, and potassium affects the length of life of the leaf. To obtain the maximum area for an individual leaf, adequate supplies of both phosphorus and potassium are required.

Table 1. The total dry matter yield of green leaves (mg/pot), the number of green leaves and the mean weight of a single leaf of white clover grown in Lephinmore peat given different levels of phosphorus and potassium fertiliser.

	Treatment					Variation explained when regressed on yield (%)
	P0 : K0	P1 : K1	P1 : K2	P2 : K1	P2 : K2	
Total dry matter yield of green leaves (mg/pot)	62	397	306	591	1189	-
Number of green leaves (per pot)	7	32	27	55	101	85
Mean weight of a single leaf (mg)	9	12	11	11	12	24

Key to Treatment P0:K0 = 0P and 0K
P1:K1 = 40 kg P : 40 kg K/ha
P1:K2 = 40 kg P : 160 kg K/ha
P2:K1 = 160 kg P : 40 kg K/ha
P2:K2 = 160 kg P : 160 kg K/ha

Table 2. The total number of leaves, and the percentage of green leaves on white clover plants grown in Lephinmore peat when given different levels of phosphorus and potassium fertiliser.

	Treatment*					SED (76 df)
	P0 : K0	P1 : K1	P1 : K2	P2 : K1	P2 : K2	
Total No. of leaves (per pot)	10	35	30	83	113	4.5
Percentage of green leaves (per pot)	70	91	90	66	89	4.1

Table 3. The mean weight (mg) and leaf area (cm^2) of a single leaf of white clover given different levels of phosphorus and potassium fertiliser when grown in peat.

	Treatment*					SED (76 df)
	P0 : K0	P1 : K1	P1 : K2	P2 : K1	P2 : K2	
Weight of a single leaf (mg)	9	12	11	11	12	0.8
Leaf area of a single leaf (cm^2)	1.2	2.3	2.3	2.8	3.5	0.15

* See Table 1 for key to treatments.

BRACKEN CONTROL

04004: Effect of bracken control on herbage production and pasture formation

1. The effects of added phosphate on pasture production following control of bracken

G.E. Davies and G.J. Baillie

The trial, started in 1977 at Sourhope, has been reported on already in two previous annual reports (1977 and 1978) but because the field work has now been concluded it is proposed to give a brief summary of the findings over the three year period (1977-1979).

The two trial sites were previously sprayed with asulam (11.2 l ha^{-1}) in 1973 and although in normal agricultural practise phosphate would be applied in the year following spray treatment it was decided that its inclusion at an earlier stage, because of large sampling and experimental errors, would have made the interpretation of results difficult. Phosphate application was therefore delayed till the spring of 1977 when one half of each main treatment, i.e. control and sprayed, received the equivalent of 628 kg ha^{-1} of granulated mineral phosphate (27% P_2O_5).

Results

Bracken cover

The degree of control obtained during the three year period after phosphate application in the spring of 1977 is given in Table 1.

Table 1. Number of bracken fronds per m^2 (nearest whole number) and mean height measurements (nearest cm)

		Control		Sprayed		% reduction	
		No.	Height	No.	Height	No.	Height
Site 1	1977	33	52	2	34	95.5	34.5
	1978	27	53	3	40	89.1	24.7
	1979	39	68	5	48	87.4	28.4
Site 2	1977	34	45	2	28	95.8	35.5
	1978	28	47	2	33	92.6	30.2
	1979	39	57	5	40	88.4	29.1

Results showed that the increase in the number of fronds on the sprayed plots for the two sites was approximately 8% whilst up to 1976 the increase was minimal and approximated only 0.5%. It was also significant that prior to 1977 the reduction in the height of fronds remaining on the sprayed plots was approximately 50% whilst from 1977 onwards this was reduced to 30%. Thus, although control is still good, there has been a more rapid recolonization of the sprayed plots together with an increase in the vigour of the remaining fronds.

Frond numbers remained unaffected by the phosphate treatment on both control and sprayed treatments and on both sites. Frond heights on the control plots however showed an increase in height and these results were significant for one of the sites (Table 2).

Table 2. The effect of phosphate application (1977) on frond heights (nearest cm) in the control plots.

	Site 1			Site 2		
Year	P0	P1	Sig.	P0	P1	Sig.
1977	50	54	NS	41	48	***
1978	52	54	NS	44	50	*
1979	65	70	NS	54	61	*

*** P < 0.1%   *P < 0.05%

Frond numbers and height on both treatments will be recorded for a few more years since the duration of control is an essential factor in making an economic assessment.

Accumulative dry matter yields of underlying vegetation

There was no apparent response to phosphate application on either control or spray treatment during the three year period. Results given in Table 3 are for the final harvest taken at the beginning of November and therefore give the total yield from April to November.

Table 3. Accumulative dry matter yields ($kg\ ha^{-1}$) 1977-79

		Control			Sprayed		
	Year	P0	P1	Sig.	P0	P1	Sig.
Site 1	1977	2161	2384	NS	3624	3255	NS
	1978	2507	2704	NS	2981	2422	NS
	1979	2169	2471	NS	4106	3830	NS
Site 2	1977	1714	1904	NS	2142	2324	NS
	1978	1928	2537	NS	2002	2267	NS
	1979	1663	1526	NS	1738	1941	NS

% Green herbage

Over the two year period (1977-1978) the proportion of green herbage was greater on the phosphate treated plots and in most harvests this difference was significant. In 1979 however there were no significant effects at any of the harvest dates for the two sites. Table 4 gives the results for the final harvest in November and since there were no significant interactions with main treatment effects the results are shown for P0 and P1 treatments only.

Table 4. % Green herbage (November harvest).

	Site 1			Site 2		
Year	P0	P1	Sig.	P0	P1	Sig.
1977	45.3	73.7	**	57.0	75.3	**
1978	49.9	77.8	**	48.7	80.1	**
1979	51.7	46.0	NS	56.9	56.3	NS

** P < 1.0%

Phosphorus and nitrogen content of the green herbage

Samples of herbage taken from the plots in 1977 have now been chemically analysed for phosphorus and nitrogen present in the green material. Statistical analysis of the data is not yet complete and results given in Table 5 are for the final harvest only. Similar trends were present in the other three harvests taken on both sites. Perhaps it should be noted that in the data presented there were a few significant interactions with the main treatments but it is doubtful whether any of these were of biological significance and for the purposes of this report and until the data is completely analysed they have been excluded.

Table 5. Concentrations (%) and uptake (gms/sq.m) of nitrogen and phosphorus in the green herbage (November 1977).

	Control			Spray		
Site 1	PO	P1	Sig.	PO	P1	Sig.
P %	0.26	0.28	NS	0.21	0.25	**
Uptake	0.35	0.54	**	0.21	0.56	***
N%	2.10	2.08	NS	1.53	1.76	NS
Uptake	2.72	3.99	**	1.54	3.93	***
Site 2						
P%	0.25	0.30	NS	0.23	0.23	NS
Uptake	0.26	0.46	**	0.22	0.34	*
N%	1.96	2.09	NS	1.80	1.67	NS
Uptake	2.06	3.28	NS	1.75	2.56	NS

Although significant in only one instance (Site 1, Spray P1) there is little doubt that taking the data as a whole both element concentrations have increased slightly on the phosphate treated plots. There were no marked seasonal trends (not shown) although the first harvest taken in May showed higher concentrations for both nitrogen and phosphorus than in later harvests. With the exception of nitrogen at Site 2 uptakes of both elements were significantly greater on the phosphated plots. This was mainly due to the greater amount of green herbage (Table 4) in the fertilised plots rather than any increase in nutrient concentration.

To sum up it seems that these results confirm the findings of other workers where it has been shown that when the soil nutrient supply is inadequate the plant makes up its deficiencies by the transference of mobile elements such as nitrogen and phosphorus from the older leaves to the growing points of the younger ones. As a result of this transference, senescence is hastened, hence the greater amount of dead material present on the non-phosphated plots. More difficult to explain is the increase in plant nitrogen concentrations on the fertilised plots. Evidence is available however that with the application of phosphates and provided soil nitrogen is adequate an increase in the concentration of nitrogen can occur (see below*). It is doubtful however whether the soil nitrogen supply was adequate at the site examined. Perhaps a more likely explanation is simply an increase in root growth brought about by the phosphate, and therefore enhancing the uptake of nitrogen. Finally it is of relevance to enquire that if a more demanding system had been imposed on the pasture, such as simulated grazing, whether the effect of phosphate application would have been to produce differences in total herbage rather than in green herbage between non and fertilised plots.

* (Hanway and Moldenhaven, 1965)

Further work will entail chemical analysis of the 1978 and 1979 herbage. The latter year is of special interest since indications are (Table 4) that the phosphate effect has only lasted two years i.e. up to 1978.

Reference

HANWAY, J.J. and MOLDENHAVEN, W.C. (1965). The influence of nitrogen and phosphorus fertilisation on nutrient status and profitability of bromegrass on Ida soils. II. Effect on chemical composition of bromegrass. Res. Bull. 532 Iowa agric. Exp. Stn. 315-322.

2. The effects of lime and phosphate on pasture production following control of bracken.

G.E. Davies and G.J. Baillie

An introduction to the work which was done at House o' Muir was given in the Annual Report 1977, p.C24.

Asulam was applied at the beginning of August 1977 at the commercial rate of 11.2 l ha^{-1} and lime (5 m tons ha^{-1}) and phosphate (628 kg ha^{-1}) in November 1978 and March 1979 respectively. Results for 1978 (Annual Report 1978, p.C7) were taken prior to fertiliser application. A summary of the 1979 results is given below together with some of the 1978 results for comparison.

Results

Bracken cover

There was no apparent fertiliser effect on either frond numbers or height and therefore data given in Table 1 is for main treatments only. Control is still good with even less bracken than in the previous year whilst reduction in frond heights remain the same.

Table 1. Number of bracken fronds per m^2 (nearest whole number) and mean height measurements (nearest cm).

	Control		Sprayed		% reduction	
Year	No.	Height	No.	Height	No.	Height
1978	33	86	1	35	97.8	59.0
1979	38	83	<1	31	99.3	59.0

Botanical composition

Two years after being severely reduced by the effects of asulam spraying, the broad-leaved grasses have made some recovery. The cover of fine-leaved grasses and herbs have also increased slightly, the net result being a reduction in the amount of bare ground in 1979. Whether lime and phosphate will eventually encourage an increase in the cover of the more productive species remains to be seen but this year's results showed no fertiliser effect. Table 2 gives the results for the main treatments.

Table 2. The effect of spraying on botanical composition (main species) and the amount of bare ground (% cover).

Percentage cover assessed using a 10 point quadrat (1440 points per main plot treatment).

Year	Treatment	At.Ac.Pp.	Df.Fo.	Herbs	Bare ground
1978	Control	19.7	43.3	21.2	6.9
	Spray	8.1	50.8	18.1	11.0*
1979	Control	20.1	49.6	19.8	4.1
	Spray	12.7	54.8	20.6	6.7

Key: Species At = Agrostis tenuis Ac = Agrostis canina
Pp = Poa pratensis Fo = Festuca ovina
Df = Deschampsia flexuosa *P < 5.0%

Accumulative dry matter yield

The data for 1979 given in Table 3 has not yet been corrected for bracken litter therefore yields, especially on the control plots, will be slightly lower than those presented. Comparisons between treatments however are still valid and show that the sprayed treatment gave an increase in yield of 46% over the control whilst the greatest effect of fertiliser application ocurred on the sprayed and phosphated plots in the absence of lime where P1 exceeded Po by approximately 60%.

Table 3. Accumulative dry matter yields (kg ha^{-1}), April-November 1979

		Control		Spray	
Year		PO	P1	PO	P1
1979	LO	1310	1663	1539	2461
	L1	1174	1313	1904	2046

The lack of any significant response to lime and the large effect of phosphate in the absence of lime can probably be attributed mainly to the fact that 50% of the herbage is composed of Deschampsia flexuosa. The species is a known calcifuge and thrives within a pH range of between 3.50 and 4.00. Jowett and Scurfield (1952) give data showing a reduction in yield at the higher level of pH. The mean pH of the House o' Muir site, previous to the application of lime and phosphorus was 3.59. It is therefore possible that the additional lime could have adversely affected the yield of this species. The converse seems to be true when the soil phosphate supply is increased (Hackett, 1965). There is less evidence available on other grass species present in the trials although data presented by Bradshaw (1960) shows similar responses by Agrostis tenuis. It is hoped that further elucidation of the data will be possible when both plant and soil analysis have been completed. The experiment continues.

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HACKETT, C. (1965). Ecological aspects of the nutrition of *Deschampsia flexuosa* (L) Trin. II. The effects of Al, Ca, Fe, K, Mn, N, P and pH on the growth of seedlings and established plants. Journal of Ecology 53, 315-333.

JOWETT, G.H. and SCURFIELD, G. (1952). Statistical investigation into the success of *Holcus mollis* L. and *Deschampsia flexuosa* (L) Trin. Journal of Ecology 40, 393-403.

EFFECTS OF UTILISATION : MOORLAND

04005: The effect of seasonal patterns and different intensities of utilisation on the growth of moorland

1. Effects of utilisation by grazing sheep on the structure, stability and productivity of blanket bog.

Sheila A. Grant, G.R. Bolton and Lynne Torvell

Grazing treatments continued in this long term experiment which is now in its ninth year. Plots at each of three sites are grazed at three stocking rates, equivalent to approx. 0.5, 1.0 and 1.5 ha/sheep, and the seasonal patterns of grazing reflect those of the hill component of a two pasture system.

Estimates of heather utilisation are made annually after each winter's grazing and floristic composition is recorded using point quadrats every July. Harvests to assess effects on the standing crop and green dry matter yields are made at three yearly intervals (see 1977 Annual Report).

The vegetation, in addition to showing responses to management, has been markedly influenced by climatic trends over the nine year period. Two of the sites had been burned in 1969 so that the heather, which was only two years old when the experiment began, has been passing through successive stages of a burn sub-sere viz.:- poineer, building, mature, and in the case of the unburned site where the heather is quite aged, passing from the mature to the degenerate phase. The vigour of the annual season's growth of several species varied greatly between the years of the mid-seventies with their unusually dry summers and mild winters and the more typical years of the early and late seventies with wet summers and severer winters. *Calluna* cover, for example, was greatly effected by grazing management in the early years of the study, but the drier weather of the mid-seventies encouraged vigorous growth of heather; significant effects attributable to management disappeared only to re-appear in the summer of 1979 following a return to more usual weather conditions the previous season.

The table below shows the % cover of *Calluna* at the start of the experiment and in summer 1979 after eight years of differential grazing.

% Calluna cover at the start of the experiment

Site	Grazing pressures to be imposed: Low	Intermediate	High	Means
Off wintering	21.0	20.2	23.5	21.6
Year round grazing 'wet'	19.3	18.4	18.2	18.6
Year round grazing 'dry'	37.5	36.3	35.2	36.3
Mean	25.9	25.0	25.6	

Least significant difference between means 3.2

% Calluna cover 1979

Site	Grazing pressures Low	Intermediate	High	Means
Off wintering	47.5	53.8	41.8	47.7
Year round grazing 'wet'	45.5	44.8	36.0	42.1
Year round grazing 'dry'	63.8	66.8	44.3	58.3
Means	52.3	55.1	40.7	

Least significant difference between means 9.9

Effects of Eriophorum vaginatum, which is co-dominant with Calluna and Erica tetralix on all three sites, are becoming more marked with each successive year. The changes are now approaching significance and, as with Calluna, cover is unaffected on plots subjected to intermediate compared with low grazing pressure, but markedly reduced on plots subjected to high grazing pressure. The table below compares % cover of Eriophorum vaginatum at the start of the experiment and after eight years of grazing.

% Eriophorum vaginatum cover (green leaf) at the start of the experiment

Site	Grazing pressures to be imposed Low	Intermediate	High	Means
Off wintering	14.4	14.1	17.0	15.2
Year round grazing 'wet'	12.2	9.0	10.5	10.6
Year round grazing 'dry'	14.3	14.1	10.3	12.9
Means	13.6	12.4	12.6	

Least significant difference between means 8.1

% Eriophorum vaginatum cover (green leaf) 1979

Site	Grazing pressure Low	Intermediate	High	Means
Off wintering	11.8	13.0	11.0	11.9
Year round grazing 'wet'	12.3	14.3	5.8	10.8
Year round grazing 'dry'	16.5	16.3	1.0	11.3
Means	13.5	14.5	5.9	

Least significant difference between means 9.3

($P < .10 = 7.1$ ∴ difference 'High' plots compared with others, P lies between .05 and .10).

The 'high' plot from the year round grazing 'dry' site shows most signs of stress. Floristic composition has been reduced to virtually mono-specific status with species other than heather almost eliminated. In the past, utilisation of the heather has been consistently assessed below that of the 'high' plot on the year round grazing wet site. This was largely because of the initially greater availability of heather on the dry site where the heather was unburned. The heather is thus much older on the dry site and older heather, with its reduced ratio of assimilating to non-assimilating tissue, is less well able to tolerate defoliation. This fact, together with the increasing floristic poverty, is thought to account for the narrowing of the gap in heather cover on the high plot at the dry site compared with the other sites and for the similarity in current levels of heather utilisation on both the wet and dry year round grazing 'high' plots.

REGROWTH

04006: Growth and harvested production by continuously grazed swards

1. Growth rate and harvested yield of continuously grazed pastures.

J. King and E.M. Smith

The yield harvested from a pasture by grazing animals depends upon both the growth rate and the proportion of this which is harvested. However, growth rate and harvested yield are not independent of one another, their interaction, operating through such factors as growth-form and tiller density, has an influence on both growth rate and harvested yield.

A series of experiments is being carried out to explore these relationships.

In 1979 a field experiment was done on a continuously grazed sward of S23 ryegrass at House o' Muir. The object was to study the effect of grazing pressure on pasture growth-rate. Four paddocks were grazed to produce four levels of leaf area index (LAI) and herbage mass. All the swards were vegetative. LAI and herbage mass were measured weekly throughout the experiment from July to late September but detailed measurements of leaf growth and net canopy photosynthesis were concentrated in two periods. The first of these commenced on July 3 and the second on August 15 or 22 depending on which measurements were being made.

Measurements were of two kind:-

(1) Leaf growth was calculated from measurements of leaf extension rate, length/weight ratio and tiller density. Both the gross rate of leaf production and the net rate after allowing for senescence losses could be calculated. A summary of this data appears under Project 04010.

(2) Net canopy photosynthesis (Pnc) was measured at 100, 200, 300 and 400 Wm^{-2} of visible light on turf samples removed from the paddocks. This gave an estimate of the growth potential of the swards at different values for LAI.

The results of the canopy photosynthesis measurements were as follows.

The measured values for Pnc at 400 Wm^{-2} irradiance are shown in Fig. 1 (see over) plotted against LAI for the two measurement periods 3/7 - 20/7 and 22/8 - 7/9. Data from all four paddocks have been combined. The relationship between Pnc and LAI over this range of LAI was always linear and it is apparent that the slope of the regression lines was significantly less in August/September than in July.

In the interval between the two periods three changes have taken place.

(a) The shortest grazed swards in August/September had an LAI > 2 whereas in July the same swards had values below 1.5.

(b) At a given LAI below 3 Pnc was greater in August/September than in July. This indicates that the swards became photosynthetically more efficient after a few weeks of heavy grazing. Either foliage became more prostrate, intercepting more light or the average rate of single leaf photosynthesis increased.

(c) At high LAI levels (> 4) the canopies became less efficient between July and September giving lower rates of Pnc at the same LAI.

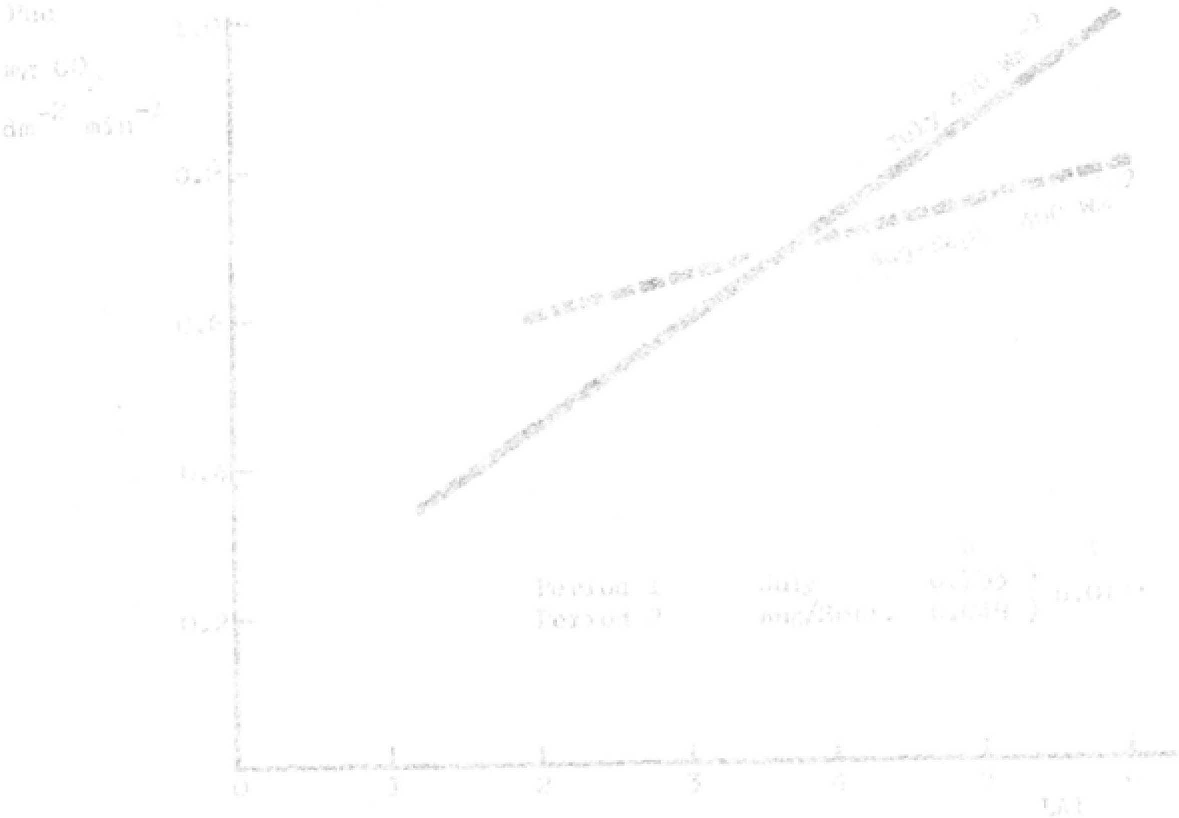

Fig. 1. Relationship of net canopy photosynthesis to Leaf Area Index (LAI).

These effects cannot at present be readily accounted for. The increase in photosynthetic efficiency on the short swards was associated with an increase in tiller density (Table 1) to a very high value and presumably also with an increase in the proportion of young leaf.

It will be necessary to examine the role of these factors in promoting high pasture growth rates. High density pastures can be achieved by management or by using suitable species and may allow increased growth rates and harvested yields from continuously grazed pastures.

The carbon exchange method can be developed to measure daily dry matter increment by the canopy rather than simply net weight of carbon fixed from the atmosphere. This development has been advanced in the past year and it is hoped to be able to re-calculate the results in terms of dry weight.

Table 1. Sward characteristics during measurement periods

House o' Muir : High Field 1979

PERIOD 1 (3-18/7/79)

Nominal herbage height (cm)	2	3	4-5	5-6
Leaf area index (LAI)	1.3-2.4	1.9-3.1	2.9-4.2	2.9-6.0
Herbage mass kg OM ha^{-1}	832-1056	1003-1332	1150-1764	1958-2491
Tiller no. : m^2 '000 3/7/	31.9 ± 1.6	35.2 ± 3.5	35.4 ± 4.0	39.7 ± 1.5
18/7/	49.0 ± 4.5	41.9 ± 3.4	37.8 ± 3.2	41.4 ± 1.5
Light interception % 24/7/	63.4 ± 6.8	77.5 ± 1.5	85.4 ± 4.4	90.8 ± 3.9

PERIOD 2 (20/8 - 10/9/79)

Nominal herbage height (cm)	2	3	4-5	5-6
Leaf area index (LAI)	2.1-2.8	2.5-3.4	2.6-3.9	3.7-6.0
Herbage mass kg OM ha^{-1}	940-970	1250-1350	1380-1480	1750-2350
Tiller no. : m^2 '000 22/8/	41.5 ± 4.1	46.3 ± 3.5	42.0 ± 3.5	39.4 ± 1.8
28/8/	51.6 ± 2.5	53.6 ± 1.8	44.2 ± 3.9	39.1 ± 2.6
Light interception % 18/9/	60.9 ± 10.2	77.0 ± 2.2	83.8 ± 5.4	90.4 ± 4.0

2. Comparative productivity of hill grass species

J. King and E.M. Smith

Last year data for net canopy photosynthesis was obtained from cut swards of *Agrostis tenuis*, *Poa pratensis*, *Cynosurus cristatus* and Ryegrass. This showed that while there were no differences between Ryegrass and *Poa* or *Cynosurus*, *Agrostis* gave significantly lower values than Ryegrass. The evidence suggested that the single leaf photosynthetic rate of *Agrostis* might be inferior.

In 1979 measurements were made of single leaf photosynthetic rates of a number of hill species and of Ryegrass. The results are summarised in Table 1.

It can be seen from the data for 4-11/2/80 that with the exception of *F. rubra* all the species gave significantly lower rates of photosynthesis than S23 Ryegrass when measurements were made on the younger leaves. There were no differences when older leaves were measured.

The data for 18-29/2/80 is more equivocal. The ranking of species is the same as for the earlier data but for the younger leaves differences are less marked. The older leaves gave variable results.

The more variable results obtained after 18/2/80 may reflect the fact that the plants had grown considerably with consequent increased variation in age of tiller and in degree of mutual shading between tillers.

These results need to be confirmed and the reasons for the differences explained. Furthermore, if they are confirmed, it will be necessary to reconcile differences in leaf photosynthesis with the apparent lack of difference in sward photosynthesis between some of the species which was observed in 1978.

Table 1. Rates of photosynthesis for single leaves of hill grass species compared with S23 ryegrass. Leaf 1 = youngest fully expanded leaf
Leaf 2 = second youngest fully expanded leaf

	Data for 4-11/2/80 Photosynthetic rate mg CO_2 dm^{-2} min^{-1}			
	Leaf 1	t	Leaf 2	t
S23 ryegrass	0.482	-	0.276	-
C. cristatus	0.376	3.11*	0.253	0.64^{ns}
P. pratensis	0.306	4.32*	0.249	0.78^{ns}
A. tenuis	0.305	4.67*	0.229	1.53^{ns}
F. rubra	0.394	1.94^{ns}	0.352	1.79^{ns}

t values show significance of difference from ryegrass

	Data for 18-29/2/80 Photosynthetic rate mg CO_2 dm^{-2} min^{-1}			
	Leaf 1	t	Leaf 2	t
S23 ryegrass	0.388	-	0.294	-
C. cristatus	0.355	1.09^{ns}	0.322	0.709^{ns}
P. pratensis	0.313	2.19*	0.194	2.36*
A. tenuis	0.296	2.76*	0.209	2.10^{ns}

NUTRIENT CYCLING

04007: Cycling of nutrients in grazed hill pasture

1. Feasibility study of the "Reverse Isotope Dilution Method"

M.J.S. Floate and A.R. Till (CSIRO)

Preliminary experiments at CSIRO Pastoral Research Laboratory, Armidale by Dr A.R. Till, had indicated that the "reverse isotope dilution method" had promise as a means of measuring the relative release rates of P and S from different fertiliser materials. The method is based on ^{32}P and ^{35}S uptake from soils, whose labile pools of these nutrients had been previously labelled, and its dilution by nonlabelled S and P derived from added materials whose relative release rates could be evaluated by reference to control treatments. The preliminary experiments had been conducted with undisturbed pasture cores from the field station at Chiswick where the soil was characterised by relatively high P status, and low P buffering capacity.

During 1978-79, M.J.S. Floate collaborated with A.R. Till to test the feasibility of the method on a wider range of soils, and using organic sources of nutrients as well as mineral fertilisers. Four soils were selected, of which 2 were developed on basalt and contained about 600 mg P kg^{-1} soil while the other 2 soils were from granitic areas with only about 200 mg P kg^{-1}. Within each pair, one soil had a low P buffering capacity (< 100 μg P/g soil sorbed at 0.2 ppm P final concentration) while the other soil had a higher buffering capacity (> 200 μg P/g soil).

All soils were labelled with ^{35}S and ^{32}P, and treated with materials listed in Table 1 then seeded with ryegrass. Herbage growth in controlled environment cabinets was measured at 14 day intervals and the dried herbage was analysed for total P and S and the specific activity of ^{32}P and ^{35}S was also determined.

Experiment IDS.I (mineral fertilisers) was continued for 38 weeks to give 19 harvests, and a second injection of ^{32}P was applied after harvest 10. Experiment IDS.II (organic P sources) was terminated after 20 weeks which gave 10 harvests. Detailed analysis of the data has not yet been carried out but preliminary inspections of some results from the first 10 harvests is looking very encouraging (A.R. Till). What is now required is joint detailed interpretation of the data leading to publication of first results and the setting up of the next phase of experimentation.

Table 1. Treatments applied to 4 contrasting soils in the feasibility studies IDS.I and II.

Expt. IDS.I (using mineral fertilisers)		
Control	-	no added P or S
S.50	-	50 kg P ha^{-1} as superphosphate
S.100	-	100 kg P ha^{-1} as superphosphate
CS.50	-	50 kg P ha^{-1} as lime-coated superphosphate
CS.100	-	100 kg P ha^{-1} as lime-coated superphosphate
Expt. IDS.II (using organic sources of P)		
Control	-	no added P or S
Supers.	-	0.51 g/pot superphosphate (9.0%P) ≡ 25 kg P ha^{-1}
Coated Supers	-	0.57 g/pot lime-coated superphosphate (8.0%P) ≡ 25 kg P ha^{-1}
Grass	-	54.5 g/pot dried grass litter (.084%P) ≡ 25 kg P ha^{-1}
Lucerne	-	13.4 g/pot lucerne meal (.34%P) ≡ 25 kg P ha^{-1}
Dung	-	6.3 g/pot sheep faeces (.73%P) ≡ 25 kg P ha^{-1}
Glycerophosphate	-	0.47 g/pot Na Glycerophosphate (9.8%P) ≡ 25 kg P ha^{-1}

2. P-K maintenance treatments on reseeded pasture on peat (04007/03002)

M.J.S. Floate, Anne Rangeley and G.R. Bolton

Total ryegrass and clover DM production responses to PK top-dressing in the first season measured in cut and grazed plots were reported in the Annual Report for 1978 (HFRO 223). The reported ryegrass response to P_{30} occurred on one replicate (II) only of the grazed plot experiment, while on the other replicate there were some indications (although not statistically significant) of clover, and of total DM response to K_{50}. It is now believed that the differences between replicates may be due to past differences in the timing of P and K topdressing although total amounts were similar: K had been applied more recently on Rep II while P had been applied more recently on Rep. I.

Discussion of treatment and replicate effects in HFRO 223 (1978) was based entirely on cut-herbage yield data, but results are now also available for Grazing Days (per ha) and Calculated Intake (kg/ha) (Table 2). Calculation of intake is based on 24 hour faecal collections from circles of 2 m radius on 13 separate days between 31.5.78 and 10.11.78. From faecal DM, faecal N and the appropriate regression equation, intake (kg/ha) for each 24 hour period was calculated. Knowing the number of sheep on each plot in that period, it is possible to calculate individual plot mean intake values which were in the range 0.99-1.58 kg per sheep per day on plots A-F (mean 1.23 kg), and in the range 0.98-1.48 kg per sheep per day on plots N-Z (mean 1.23 kg). With the errors involved in collection, sampling and analysis, and the assumptions made in using the regression equation for calculation, these values are in good agreement with the assumed intake of 1.4 kg per sheep per day. Using these values the total seasonal DM intake for each treatment on plots A-F and N-Z has been calculated. Data are given in Table 2 and indicate very similar broad conclusions (not yet tested statistically) to those reached previously using cut-herbage DM data: Rep I suggests a response to applied K, Rep II suggests a response to applied P, and the mean values (if they have any real meaning) suggest an interactive effect of P and K together.

Table 2. Grazing days and calculated DM intake on improved pasture with PK topdressing on peat in 1978.

1978 treatment (plot)			Intake (kg/sheep/day)	Grazing days	Calculated Total intake (kg/ha)
POKO - exhaustion (B)			1.33	2278	3030
P30K50 - maintenance (E)			0.99	3020	2990
P30K50 - topdressing (C+D)			1.48	2330	3448
P80K100 - topdressing (A+F)			1.04	3281	3412
POKO	I	(R)	1.36	1784	2426
	II	(Y)	1.34	2365	3169
	$\bar{x}$		1.35	2075	2801
POK50	I	(N,Q)	1.46	2163	3159
(Annual	II	(V,W)	1.08	2306	2469
+bienn.)	$\bar{x}$		1.27	2235	2838
P30KO	I	(S)	1.30	1858	2415
	II	(U)	1.24	2795	3466
	$\bar{x}$		1.27	2327	2955
P30K50	I	(P,T)	1.12	2446	2709
(Annual	II	(X,Z)	1.13	3367	3805
+bienn.)	$\bar{x}$		1.13	2907	3270

Replicate differences have persisted into 1979 when the design should have allowed for a comparison of annual and biennial K topdressing. Total DM yields (sum of standing crop at beginning of each 3 grazing periods in June, July and October) were low by comparison with 1978 and were less than 2000 kg ha^{-1} on all plots (c.f. max yield > 4000 kg ha^{-1} in 1978). These data, together with total grass and clover yields from the 3 cuts for 6 treatments on both replicates are given in Table 3. Although the results have not been statistically analysed the following comments can be made:-

1. Overall total DM yield, and particularly clover yield, was greater on Rep I than on Rep II.

2. Evidence persisted of K response on Rep I and of P response on Rep II.

3. Differences between replicates were so great as to render mean values worthless.

4. There appears to be no significant difference between annual and biennial K treatments.

In addition to the main PK experiment a subsidiary experiment (on plots A-F) has provided some information on lime and N interaction with PK topdressing. Treatments applied (kg ha^{-1}) in each of 3 years are listed below.

Plot	1977*	1978	1979	Total applied 1977 - 1979
C	POKO	P30 K50	P15 K25	P = 45 K = 75
D	POKO	P30 K50	P15 K25**	P = 45 K = 75
B	P80 K100	PO KO	PO KO	P = 80 K = 100
E	P80 K100	P30 K50	P30 K50	P = 140 K = 200
A	PO K100	P80 K100	P80 K100**	P = 160 K = 300
F	PO K100	P80 K100	P80 K100	P = 160 K = 300

* All plots subdivided and one half treated with 5 t ha^{-1} lime.
** Plots subdivided in 1979 and one half treated with 75 kg N ha^{-1} after 2nd grazing.

Table 3. The effects of annual and biennial topdressing on total DM, ryegrass and clover yield (kg ha^{-1}) from 3 cuts on 2 replicates in a grazing trial on peat (1979).

	Replicate	PO KO	PO K50 (B)*	PO K50 (A)*	P30 KO	P30 K50 (B)*	P30 K50 (A)*
Total DM	I	1376	1876	1670	1449	1626	1799
	II	1593	1217	1028	1788	1727	1304
Ryegrass	I	949	1132	1117	1033	1105	1230
	II	1053	844	693	1364	1236	992
Clover	I	146	437	243	97	275	230
	II	82	54	76	59	29	53

*A = annual
B = biennial (K treatment omitted in 1979)

3. P x K maintenance treatments on reseeded pasture on peat

In conjunction with the grazed experiment there was also a cut-plot trial in which several combinations of PK treatments were applied annually. In 1978, both ryegrass and white clover responded to P applied at 30 kg P/ha, but there was no additional response to greater levels of P. White clover but not ryegrass responded to K, and the response was greatest with up to 100 kg K/ha although there was also smaller, additional response to 150 kg K/ha.

The herbage separations have not been completed for samples taken in 1979, so the yields given in Table 4 are only for total herbage DM. The total herbage consisted of, on average, 64% white clover by weight in 1978 and was again dominated by clover in 1979. So the total dry matter yields given for 1979 probably reflect the responses to treatment by white clover. The data shows that there was a response to K up to 100 kg K/ha but there was no response to larger amounts of K or to P. The minimum yields in 1978 and 1979 were similar (1275 and 1139 kg/ha respectively), but the maximum yields differed with 3564 kg/ha herbage produced in 1978 and 1946 kg/ha produced in 1979. The smaller response to treatments in 1979 may be related to the climatic conditions, the summer of 1978 was warmer than that of 1979.

No statistical analysis of the results has been made but the following observations are interesting:

1. In 1977 lime increased mean yield by 2% to 2800 kg DM ha^{-1}
   In 1978 lime increased mean yield by 35% to 3600 kg DM ha^{-1}
   In 1979 lime increased mean yield by 44% to 2100 kg DM ha^{-1}

2. Similar lime responses were recorded on all PK treatments

3. As for the main PK experiment, yields in 1979 were low compared with 1978

4. Yields in 1979 (kg ha^{-1}) following split plot lime treatment in 1977, and split plot N after the 2nd grazing in 1979 were as follows: (means for plots A and D).

   LoNo = 1260, L1No = 1932, LoN1 = 2049, L1N1 = 2731

On average this represents a yield increase of 794 kg ha^{-1} (50%) due to N topdressing and 677 kg ha^{-1} (41%) due to lime.

It may be concluded that even when clover is present in these grazed swards, and PK maintenance treatments are applied, that over and above the responses to topdressing, there was a large response to applied N, and hence that N supply is a serious limitation to pasture production on peat. Because of the extreme variations between replicates I and II in this experiment a new site with revised experimental design, is proposed for 1980. This will be needed to follow up the conclusions reached in the paper entitled "An investigation of problems of improved pasture production on deep peat, with special reference to K responses and interactions with lime and P" which has been submitted to "Grass and Forage Science".

Table 4. The effects of annual top dressings of phosphorus and potassium on total dry matter yield (kg/ha) from two cuts during 1979, in a cut herbage experiment on peat

Level of								
phosphorus	0	0	30	30	30	40	40	50
potassium	0	50	0	50	100	50	100	150
Total DM yield (kg/ha)	1332	1557	1139	1523	1946	1181	1816	1773

NITROGEN FIXATION

OM(KW): Factors affecting the fixation of nitrogen by white clover in hill pastures and the relationships between nitrogen fixation and photosynthesis

1. Factors limiting growth and nitrogen fixation in white clover nodulated with rhizobia of different effectivity

A. Haystead and C. Marriott

Using a modification of a technique described in a previous report (1977 p.C.42) we have measured CO_2 exchange, acetylene reduction and H_2 evolution by nodulated root systems S184 white clover grown with two strains of rhizobia a highly effective strain (BL2B) and a moderately effective strain (BL3A). The plants were grown at two irradiances 150 and 70 Wm^{-2} (p.a.r) to determine the effect of photoassimilate supply rate on highly effective and moderately effective plant/rhizobia associations. Fig. 1 shows the efficiencies of the various associations in terms of carbon respired per unit of nitrogen fixed for the four treatments. Both associations at high and low irradiance show low efficiency in the early stages of growth, with efficiency increasing as the plants grow. The less effective association does not seem however to attain the efficiency of the highly effective association, their peak values being 10 gC/gN and 5 gC/gN respectively.

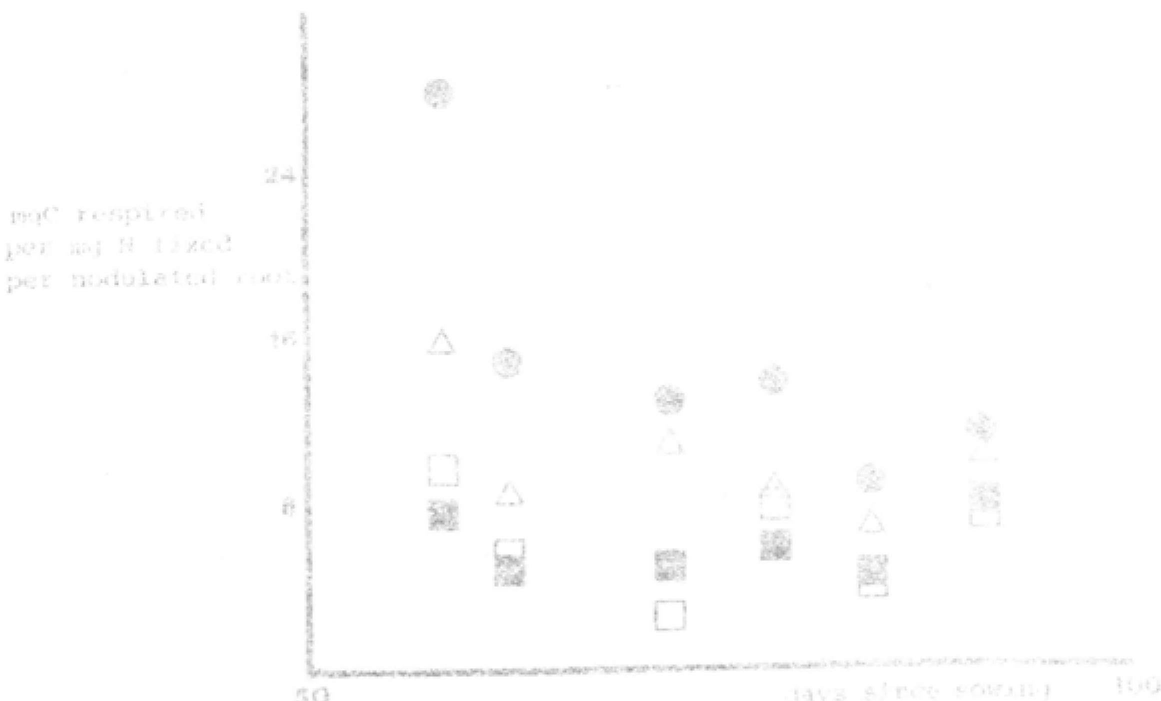

Fig. 1. Carbon respired per unit of Nitrogen fixed for two white clover/rhizobia associations at two irradiances (150 and 70 Wm^{-2}).

The efficiency with which N_2 is fixed by a rhizobium/legume association depends on the efficiency of reductant utilisation by the bacteroids and on the extent to which H_2 evolved by the nitrogenase is recycled by the nodule uptake hydrogenase. Inefficiency in an inneffective association could therefore be due to either or both of these factors. Table 1 shows the proportion of the electrons supplied to the nitrogenase which are lost to the system in non-productive proton reduction at a point in the growth curve when maximal efficiency has been attained. Both associations appear to be innefficient in this respect losing over 50% of the reductant in the evolution. The deficiency between the two however seems not to be related primarily to the evolution but to the efficiency with which carbohydrate is utilised by the bacteroids.

Table 1. Relative efficiency* of highly effective and moderately effective associations of R. trifolii and T. repens (S184).

Association	Relative efficiency
Highly effective	0.52
Moderately effective	0.59

* Relative efficiency is determined as $\frac{\text{energy used to reduce } N_2}{\text{total energy flux to nitrogenase}}$

or experimentally.

$$\frac{H_2 \text{ evolved in } N_2}{C_2H_2 \text{ reduced}}$$

(Schubert and Evans (1977)).

2. CO_2 exchange in the leaves of NO_3 assimilating and N2 fixing Vicia faba and Trifolium repens

A. Haystead and C. Marriott

Legume plants supplied with high levels of nitrate will reduce it to ammonia even in the presence of an effective symbiosis and a supply of N_2. Moreover they will in most cases grow faster and have a higher nitrogen content. Studies in our laboratory have shown that white clover respires a larger proportion of its photoassimilate in fixing N_2 nitrogen than a plant reducing an equivalent amount of NO_3-nitrogen (1978 report p.C.13). The effect of NO_3 assimilation in photosynthetic tissue has been further examined by measuring CO_2 exchange by equivalent leaves on N_2 fixing and NO_3 reducing plants of field bean in a single leaf IRGA cuvette systems. The results (Figs. 1 and 2, overleaf) indicate that at an irradiance which gives a reasonable growth rate (a) there appears to be no competition between CO_2 and NO_3^- for photosynthetically produced reductant and that (b) there does not appear to be a higher rate of CO_2 loss (photorespiration) in the light in NO_3 assimilating leaves. The greater efficiency of NO_3 reduction in plants with a nitrate reductase located in leaves compared with N_2 fixing plants can perhaps be attributed to the fact that much of the reductant utilised in reducing NO_3^- to NO_2^- and more likely NO_2^- to NH_3 is "free" in the sense that it would otherwise be lost to the system as heat.

Reference

SCHUBERT, K.R. and EVANS, H.J. (1977). In: Recent developments in N_2 fixation Academic Press, London, pp. 469-485.

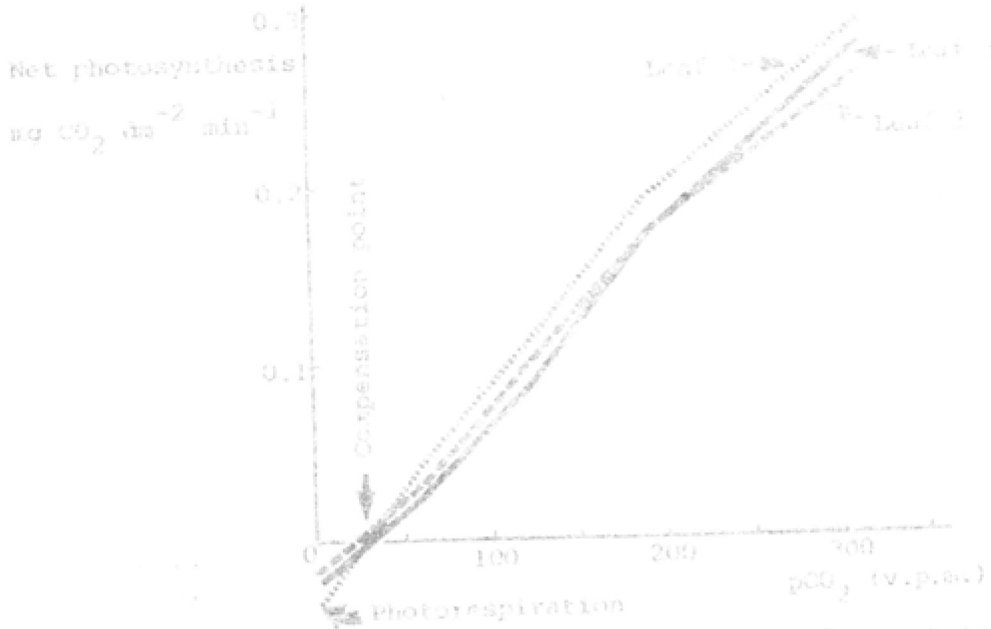

Fig. 1. Representative data showing effect of pCO_2 on photosynthesis in first three fully expanded leaves of field bean (N_2 fixing).

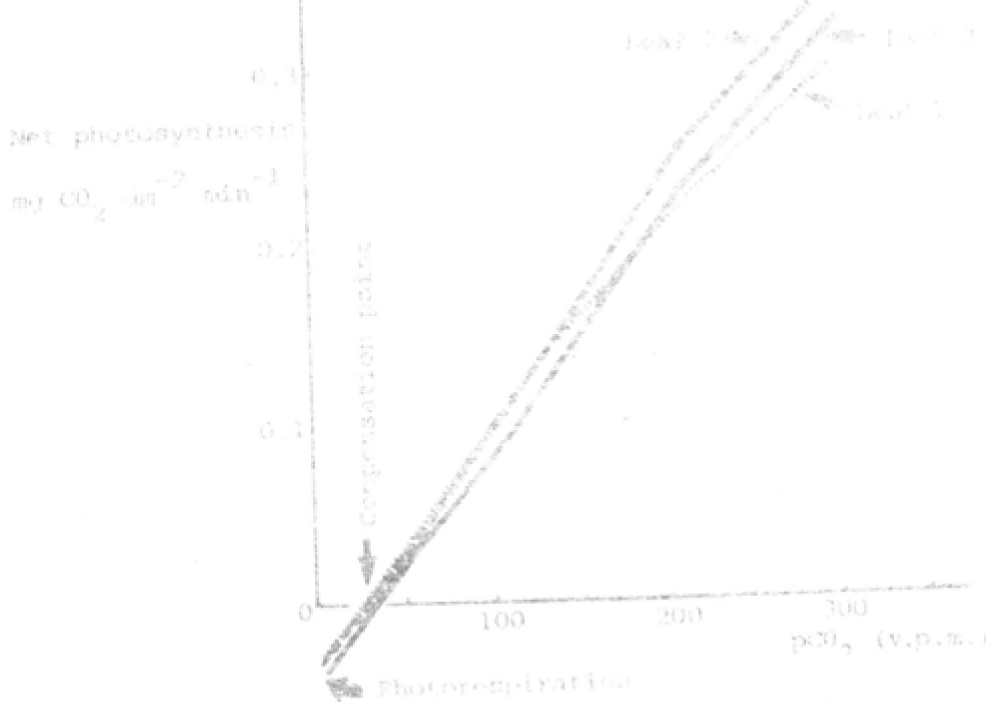

Fig. 2. Representative data showing effect of pCO_2 on photosynthesis in first three fully expanded leaves of field bean (NO_3 assimilating

WHITE CLOVER SYNBIOSIS

04009: Microbial requirements of white clover growing in hill soils

1. Mycorrhizal field trials

A. Rangeley, P. Newbould, M.J. Daft (Dundee Univ.), J. Leask and M. Thornton

In 1979, samples of white clover herbage were taken from two field trials, both were on brown earth soils but the trials were sited at different locations. In the spring of 1978 a trial was set up at Sourhope, the procedures and treatments for which were described in HFRO 223, but the yields and levels of root infection for both 1978 and 1979 are reported here. The field trial at Cleish was set up early in 1979, and the experimental details are briefly described below, with the yields for 1979.

SOURHOPE

The effects of two inoculants, G. mosseae L1 and G. caledonius, on the growth of white clover were tested in the presence and absence of a dressing of superphosphate. The fertiliser was applied just before sowing. The annual dry matter yields and the levels of root infection in October 1978 and December 1979 are given in Table 1.

Table 1. The effect of Glomus mosseae (L1), G. caledonius and superphosphate on shoot dry weight and root infection of white clover grown at Sourhope on a brown earth.

Cultivar	Super phosphate (kg P/ha)	Inoculant	1978 Yield (kg DM/ha)	1978 Infected Root (%)	1979 Yield (kg DM/ha)	1979 Infected Root (%)
Huia	0	None	344	83	1070	23
		G. mosseae L1	500	82	1271	46
		G. caledonius	216	45	598	46
	40	None	326	76	841	25
		G. mosseae L1	542	74	1126	33
		G. caledonius	200	64	1930	49
SED (16 df)			163	6.2	284	4.7

In 1978, the statistical error was high and none of the treatments had any significant effect on yield. However inoculation with G. caledonius tended to reduce yield and also to reduce the level of mycorrhizal infection. Inoculation with G. mosseae L1 tended to increase yield but had no effect on the level of infected root. On closer examination inoculation with G. mosseae L1 (an endophyte with coarse hyphae) did increase the proportion of infection caused by coarse endophytes (Table 2). The indigenous endophyte which predominantly infected roots in the Sourhope soil had fine hyphae.

Table 2. Effect of inoculation with *Glomus mosseae* (L1) on the infection in white clover roots caused by fine and coarse endophytes

Inoculant	Superphosphate (kg P/ha)	Infected root (%) Fine	Coarse	Total[†]
None	0	67	15	83
G. mosseae L1		63	42	82
None	40	71	10	76
G. mosseae L1		55	30	74
SED (10 df)		7.1	4.7	6.2

[†] The sum of the fine and coarse infection can be more than the total infection because both types of endophyte can occur in the same section of root.

In the second year, 1979, the yields of clover were in the same relative order to those in 1978 except when inoculated with *G. caledonius* and given superphosphate. The yield from this treatment was significantly ($P > 0.01$) than any other treatment, and has demonstrated that inoculation can have highly beneficial effects on the growth of white clover in the uplands of Britain when the seed is inoculated in the field. An earlier report of enhanced growth from mycorrhizal plants grown in the field in Wales was from preinoculated seedlings which were transplanted in the field (Hayman and Mosse, 1979).

CLEISH

The effect of four mycorrhizal inoculants (*G. macrocarpus*, *G. clarus* and two isolates of *G. mosseae*) and superphosphate (0 and 50 kg P/ha) on the growth of white clover was measured in the field at Cleish. The soil was ploughed and rotovated; 4 tonnes lime/ha, 100 kg K/ha, trace elements and none or 50 kg P/ha were applied. To ensure close contact between seed (sown at 5 kg/ha and inoculated with rhizobia) and mycorrhizal inocula, the seed and inocula were placed in four drills which ran the length of each 2 x 4 m plot. Equal volumes (6 m^3/ha) of each inoculant or sterile sand were applied. The experiment was sown 21-22 June 1979 and harvested once on 11 October 1979.

Inoculation with *G. mosseae* (L1) reduced yield with superphosphate and tended to reduce yield in the absence of superphosphate. The other inoculants had no effect on yield. Superphosphate at 50 kg P/ha doubled the yield of clover. (Table 3).

Levels of root infection ranged between 53% and 79%. There were no significant differences between individual treatments; infection in uninoculated plants was similar to infection in inoculated plants, but overall the effect of superphosphate was to increase the level of infection (Table 3).

Table 3. The effect of four mycorrhizal inoculants and superphosphate on the dry matter yield and root infection of white clover grown at Cleish on a brown earth

Cultivar	Super-phosphate (kg/ha)	Inoculant	Dry matter yield (kg/ha)	Root infection (%)
S184	0	None	39	70
		G. mosseae L1	21	53
		G. mosseae	37	57
		G. macrocarpus	48	73
		G. clarus	42	61
	50	None	98	65
		G. mosseae L1	57	77
		G. mosseae	94	64
		G. macrocarpus	100	79
		G. clarus	102	77
SED (27 df)			10.5	16.1

The effects of inoculation of white clover with mycorrhizal fungi on the hill can therefore have varying effects from causing a depression in growth in the year of sowing to greatly increasing growth in the second year. The results do suggest that careful selection of strains which are matched to the environmental conditions, soil type, cultivar of white clover and strain of *Rhizobium* may, in the future, result in more efficient use of phosphorus fertiliser.

Reference

HAYMAN, D.S. and MOSSE, B. (1979). Improved growth of white clover in hill grasslands by mycorrhizal inoculation. *Ann. appl. Biol.*, 93, 141-148.

2. Investigation of the effects of treating clover seed with calcium peroxide

P. Newbould, A. Rangeley and J. Leask

A study of the possible benefits to clover establishment and nodulation from applying calcium peroxide to, or adjacent to seeds has commenced in collaboration with Laporte Industries Ltd (UK), Interox co-ordination (Solvay and Cie, Belgium) and the Microbiology Department, Rothamsted Experimental Station.

Calcium peroxide (CaO_2) is a chemical which dissolves in the soil to release oxygen and yields calcium hydroxide which combines with CO_2 to form calcium carbonate. Its use has been shown to markedly assist germination and early root growth of rice and sugar beet which are often sown into waterlogged or compacted soils. More recently, the coating of soybeans with calcium peroxide has been shown to enhance nodulation and nitrogen fixation in addition to germination. The possibility that similar effects might be found with clovers, and particularly white clover, has been investigated in three preliminary pot experiments. Seeds of white clover (cv. Grasslands Huia and S.184) and crimson clover (*T. incarnatum*) inoculated with rhizobia and coated with various combinations of inert carrier and calcium peroxide, or pellets containing the chemical, which can be placed close to the inoculated seeds, were provided by Laporte. The following results were obtained:

1. In a limed, fertilised, peaty podsol, kept at field capacity, germination and establishment of white clover was generally poor and coating with CaO_2 had no beneficial effects on this or on nodulation.

2. In a brown earth soil pellets of calcium peroxide placed beneath or adjacent to white clover seed at sowing, or inserted in the soil after germination, had no effect on the number of seeds which germinated, on the time taken to germinate, on the dry weight of the plant, or on the number of nodules.

3. Coated and uncoated seed of crimson clover was grown in a brown earth and peaty podsol. Comparisons were made amongst limed and unlimed soils at 50% and 100% water holding capacity. Crimson clover failed to germinate at 100% water holding capacity. At 50% water holding capacity less than half the seeds germinated and the coating had little effect in the peaty podsol but tended to reduce germination in the brown earth. When harvested the plants had few nodules and the number was not affected by the calcium peroxide treatment.

Further work is needed to identify why clover doesn't respond in the same way as soybeans to treatment with calcium peroxide. In addition more work is required to define appropriate rates, forms and times of application of the chemical.

EFFECTS OF UTILISATION

04010: Effects of utilisation by grazing hill sheep and beef cattle on growth and production of pastures

1. Floristic and morphological composition of diets selected by sheep and cattle grazing various pasture types at different seasons of the year.

S.A. Grant, J. Hodgson, D.E. Suckling, T.D.A. Forbes, L. Torvell and C. Williams

Plant communities grazed in the third year of this project included *Agrostis/Festuca* (7-18 May and 17-28 September), *Nardus* (21 May - 1 June and 8-19 October), Ryegrass (2-13 July) and *Molinia* (11-22 June and 20-31 August). The *Agrostis/Festuca* and *Nardus* communities had been grazed the previous year when both pastures, with five years history of underutilisation, had accumulated a considerable quantity of herbage. After the experimental grazings of 1978 the *Agrostis/Festuca* pasture was hard grazed (mixed sheep and cattle) to reduce the herbage mass to that more typical of such pasture on a well managed hill farm; lime (at one ton per acre) was added in January 1979. The *Nardus* pasture also was grazed, mainly by sheep, the objective again being to reduce herbage mass on the inter-tussock vegetation to a more typical amount.

The changes in herbage mass and state between years was accompanied by quite marked effects on the composition of the diets selected by the sheep and cattle. Table 1 summarises data for the *Agrostis/Festuca* pasture and Table 2 that for the *Nardus* pasture.

On the *Agrostis/Festuca* pasture, herbage mass in autumn 1979 was less than 40% of the amount present in summer of the previous year, and the live-dead ratio was improved from 47% to 59%. Herbage separations for May 1979 have still to be completed, but the lateness of the growing season, plus the poor performance of cattle in selecting live herbage, suggests that the live-dead ratio of the sward in May was much lower than in September. The difference in percentage live herbage in the diet of sheep compared with cattle for May 1979, together with the sharper decline with time within grazing periods in the percentage live herbage in the diets of cattle (% live herbage in sheep diets at the beginning compared with the end of the week fell from 82.8 to 76.6 and from 88.9 to 84.6 in autumn 1978 and 1979 respectively compared with cattle where the decline

Table 1. Agrostis/Festuca pasture. Diet composition as affected by herbage availability and season

SWARD STATE	1978 JULY	1978 OCTOBER	1979 MAY	1979 SEPTEMBER
Herbage Mass (gm^2)	692 ± 38	519 ± 36	337 ± 21	262 ± 16
Green DM (gm^2)	322 ± 27	275 ± 20	Data to be processed	154 ± 9
DIET COMPOSITION				
Grasses				
% Broad leaf				
Sheep	21.5 ± 10.2	30.7 ± 7.7	21.9 ± 5.1	70.3 ± 4.9
Cattle	52.2 ± 9.3	57.7 ± 3.3	34.9 ± 6.0	57.1 ± 7.2
% Fine leaf				
Sheep	9.4 ± 1.4	26.6 ± 1.1	63.6 ± 6.6	14.8 ± 1.4
Cattle	15.9 ± 5.1	19.4 ± 2.5	36.8 ± 7.6	26.7 ± 3.7
Herbs				
% Dicots				
Sheep	62.3 ± 7.2	31.6 ± 9.3	1.5 ± 0.6	6.3 ± 4.4
Cattle	11.3 ± 3.7	3.9 ± 3.0	0.9 ± 0.4	0.5 ± 0.2
All Species				
% Live				
Sheep	95.4 ± 0.7	82.8 ± 2.3	80.2 ± 1.8	88.9 ± 1.4
Cattle	89.5 ± 1.3	75.6 ± 6.4	49.6 ± 2.9	78.5 ± 3.1

The diet composition data are means of the percentage specific frequencies of the various sward components in oesophageal fistula extrusa samples from four animals (occasionally three) collected at the beginning of each grazing period.

Table 2. Nardus dominant pasture. Diet composition as affected by herbage availability and season

SWARD STATE Inter-tussock vegetation	1978 JUNE	1978 SEPTEMBER	1979 MAY	1979 OCTOBER
Herbage Mass (gm^2)	1059.8 ± 123.3	1317.4 ± 123.8	/562 ± 176.7/	429.9 ± 60.7
Green DM (gm^2)	432.7 ± 30.3	384.3 ± 37.4	/95.9± 30.2/	151.7 ± 36.6
DIET COMPOSITION				
% Nardus				
Sheep	0.6 ± 0.4	1.9 ± 0.8	7.1 ± 4.2	1.9 ± 0.4
Cattle	6.5 ± 1.3	8.1 ± 3.2	20.6 ± 4.1	24.0 ± 0.8
% D. flexuosa				
Sheep	40.9 ± 5.9	53.1 ± 11.8	53.2 ± 2.6	40.4 ± 9.7
Cattle	18.1 ± 2.6	37.9 ± 3.9	29.1 ± 6.5	12.9 ± 2.8
% F. ovina				
Sheep			4.7 ± 1.2	9.8 ± 3.8
Cattle			15.8 ± 3.9	15.6 ± 5.3
% Broad leaf grass				
Sheep	10.9 ± 2.8	27.2 ± 9.6	10.1 ± 5.6	18.0 ± 10.3
Cattle	5.7 ± 1.3	19.8 ± 8.4	13.7 ± 2.8	38.3 ± 4.5
All species				
% Live				
Sheep	86.1 ± 1.9	82.7 ± 2.5	90.6 ± 3.1	82.1 ± 6.5
Cattle	87.7 ± 3.3	74.6 ± 2.8	74.0 ± 3.6	78.7 ± 1.0

The diet composition data are means of the percentage specific frequencies of the various sward components in oesophageal fistula extrusa samples from four animals (occasionally three) collected at the beginning of each grazing period.

was 75.6 to 58.2 and 78.5 to 65.4) illustrates the poorer selection efficiency of cattle compared with sheep. The change in the herb content of the diets between years is quite remarkable. This could reflect seasonal variation in availability (there was no grazing in mid-summer 1979) as well as changes in sward state between years. The seasonal variation in the content of broad-leaved and fine-leaved grasses in the diet is thought to result from the variation in their availability consequent on the interaction between preferential grazing of the broad-leaved grasses and the seasonal growth rhythms of the species.

On the Nardus pasture in 1979, the reduction in herbage mass on the inter-tussock vegetation, where most of the grazing activity has been shown to occur (see 1978 Annual Report) had a greater effect on the diet of cattle than sheep. The cattle ate substantially more Nardus than did sheep. By the end of the autumn week's grazing in 1979 Nardus accounted for 40% of the cattle diet but was still as low as 4% in the diet of the sheep. The cattle ingested a lower percentage of live herbage than sheep in late spring and, while ingesting a similar percentage of live herbage as sheep at beginning of the autumn grazing, unlike sheep, were unable to sustain the same quality later in the week.

In 1979 the fine leaved grasses Deschampsia flexuosa and Festuca ovina were identified separately in the diet samples; these species occur with similar frequency in the sward and together account for some 40% of point quadrat contacts. Sheep showed a marked selection for D. flexuosa which was over ten times as frequent in their diet in late spring as F. ovina (obviously inaptly named!) and over five times as frequent in autumn. Cattle ingested twice as much D. flexuosa as F. ovina in spring but similar amounts in the autumn. Head depth observations of grazing animals made by T.D.A. Forbes indicated that sheep and cattle grazed at similar levels in the sward in spring but that sheep, while having a similar range of grazing depths to cattle, spent proportionately more time at grazing depths 15 cm below the sward surface in autumn.

The Molinia pasture was grazed for the first time in 1979. The percentage specific frequency of the main sward components as they occurred in the sward as a whole, at the sward surface (1st contact only of point quadrats) and in oesophagea fistula extrusa samples of grazing sheep and cattle are summarised in Table 3 (June 1979) and Table 4 (August 1979). Holcus species (mainly H. mollis) were not distributed at random in the sward but occurred in various sized patches where cover was quite high. Sheep, and to a lesser extent cattle, selectively grazed these more mixed Molinia-Holcus patches. Juncus species similarly had a patchy distribution and cattle grazed the rushes more readily than sheep as they encountered the rush dominant areas. Grass flowerheads and stems were mostly immature in June, the flowers still enclosed in the sheaths, and in this condition sheep did not avoid grazing the floral tillers. In August however, when mature grass flowers and stems formed a continuous, diffuse and tall layer above the leaf layer, sheep avoided the floral tillers (c.f. similar behaviour on Agrostis and Nardus communities reported in 1978). With the exception of the somewhat sporadic high rush content and slight selection for Holcus, cattle were relatively unselective when grazing. The contrast in behaviour of sheep and cattle with respect to the grazing of the grass flowerheads, stems and rushes, was reflected in the head depth observations of grazing animals made by T.D.A. Forbes in August. Over 95% of sheep observations occurred with their heads completely obscured i.e. in the lower leaf horizon; nearly 30% of cattle observations were in the upper diffuse flowery layer.

2. Growth studies on continuously grazed sown swards

S.A. Grant, G.T. Barthram, L. Torvell and S. Sharrock

Little information exists at present on the relationships amongst crop growth rate, the proportion of the crop which is eaten by grazing animals and the proportion which remains to senesce in situ as affected by pasture management.

Table 3. Molinia dominant pasture. Percentage specific frequency in the sward and in the diets of grazing sheep and cattle

JUNE 1979

	WHOLE SWARD	SWARD SURFACE	SHEEP 18 June	SHEEP 21 June	CATTLE 18 June	CATTLE 21 June
Molinia (leaf)	36.1	59.4	15.8±8.4	53.3±15.6	36.3±7.1	43.4±10.4
Holcus spp (leaf)	0.9	1.4	35.5±6.4	17.9± 7.5	9.2±2.7	3.9± 0.6
Other grasses (leaf)	15.9	11.5	5.8±2.6	0.7± 0.4	14.2±6.4	2.8± 0.7
Grass flower-head, flower-stem and sheath	5.9	10.8	15.2±3.5	13.5± 5.5	23.7±3.3	17.8±3.8
Juncus spp	1.5	2.1	1.6±1.5	5.5± 3.2	5.0±2.1	17.4±12.8
Total live	71.7	90.6	96.6±0.9	97.8± 0.7	96.5±1.5	94.4± 2.1

The data for the diet composition are means of samples from four animals.

Table 4. Molinia dominant pasture. Percentage specific frequency in the sward and in the diets of grazing sheep and cattle

AUGUST 1979

	WHOLE SWARD	SWARD SURFACE	SHEEP 27 Aug.	SHEEP 30 Aug.	CATTLE 27 Aug.	CATTLE 30 Aug.
Molinia (leaf)	46.2	42.0	11.9±2.9	37.9±13.5	32.5± 8.7	52.3±18.5
Holcus spp (leaf)	1.5	2.8	34.9±8.4	19.9± 9.1	3.7± 1.4	6.2± 5.6
Other grasses (leaf)	14.6	4.4	14.9±2.9	5.3± 2.0	2.0± 0.6	4.1± 1.3
Grass flower-head, flower-stem and sheath	9.2	37.0	6.1±2.5	3.0± 0.6	35.4± 4.8	28.4±11.6
Juncus spp	1.7	5.0	0.5±0.5	0.3± 0.3	22.1±10.7	0.4± 0.3
Total live	83.4	98.9	93.7±1.5	90.4± 2.5	97.0± 1.1	89.1± 2.1

The data for the diet composition are means of samples from four animals.

Under continuous grazing the amplitude of herbage mass fluctuations is small relative to those found under rotational grazing and cutting. Recent work (see 1976 Annual Report) showed that vegetative swards which were managed to constantly maintain a range of herbage mass varying from 400-1500 kg DM ha^{-1} (cut with battery operated shears) achieved similar levels of gross and net herbage accumulation over the period mid June - mid August (the duration of the experiment). The swards showed considerable adaptation in terms of adjustment in tiller size and number, reduced production per tiller being compensated for by increase in tiller numbers on the shorter swards. The experimental period, however, coincided with a droughty spell of weather and it was possible that lack of moisture was the main limiting factor.

In 1979 it was decided to investigate the relationships between management, growth rate and harvested yield further in a series of collaborative experiments with Dr J. King (project 04006). Two sites were chosen, one at House o' Muir and one at Glensaugh, for field experiments in which the primary objective was to monitor pasture growth rates under continuous grazing. At House o' Muir measurement of crop growth rates were made using both carbon exchange and tiller measurement techniques; at Glensaugh tiller measurements only were used.

The chosen swards were ryegrass dominant. Four plots were established at both sites. All plots were uniformly hard grazed during the main reproductive phase i.e. late April - June. Nitrogen fertiliser was applied at the rate of 60 kg N ha^{-1} at the beginning of May and 40 kg N ha^{-1} at the beginning of June. From July onwards differential management was imposed, sheep being removed from plots and then re-introduced when herbage mass reached the designated levels, viz. 500, 1000, 1500 and 2000 kg OM ha^{-1}. Thereafter sheep numbers were adjusted in relation to frequent herbage height/herbage weight measurements to maintain the swards at near constant herbage mass. Nitrogen was applied at fortnightly intervals at a rate of 20 kg N ha^{-1}.

__Measurements:__ There were two measurement periods. The first period occurred immediately after the swards reached the designated herbage mass and before the swards were adapted to the management regimes. The second measurement period occurred after several weeks had elapsed and sward morphological adaptations had taken place. The measurements made and results from both measurement periods using carbon exchange techniques are given on p.C.15.

Tiller measurements to determine gross production and losses by senescence were made on 50 marked tillers per plot. The tillers were arranged in five transects of ten tillers; the transects were located in a restricted random manner, one transect being sited in each fifth of plot length. Fresh populations of tillers were marked each week, protected from grazing by small enclosures and remeasured after six days. Four or five samples per plot, each composed of several random bundles of tillers, were collected each week during measurement periods to determine weight per unit leaf length of immature green leaf and of mature green leaf and to determine mean weights per tiller of ryegrass tillers and the main weed species. Ten 7.6 cm diameter cores were collected weekly from each plot at House o' Muir to determine tiller numbers per unit area; at Glensaugh 15 samples per plot, each 3.6cm^2, were collected at fortnightly intervals.

__Results__: Results are presented for the second measurement period only i.e. for swards which had been allowed time to adapt to the management regimes. The data summarised in Table 1 are overall plot means of three weekly measurements at House o' Muir and four weekly measurements at Glensaugh. Table 2 lists the ryegrass equations for the relationships between net production per tiller, tiller number per unit area and net production per unit area and herbage mass (kg OM ha^{-1}) using the weekly means for the computation.

Table 1. Management and herbage production. 1979 grazing experiments

Summary of data - House o' Muir, Highfield

Plot means three weeks 10-30 August

	TREATMENT			
Herbage mass (kg OM ha^{-1})	950	1258	1475	1997
Herbage height (cm)	2.07	3.10	4.00	5.90
LAI	1.17	2.01	2.14	3.52
Net production/tiller (mg/tiller/d)	0.136	0.158	0.199	0.274
Tiller Nos. (tiller m^2)	45060	52340	45770	37370
Net production/unit area (kg DM $ha^{-1}d$)	60.7	83.3	91.6	102.0

Glensaugh, Hardpark

Plot means four weeks 8 August-4 September

Herbage mass (kg OM ha^{-1})	444	837	1327	1674
Herbage height (cm)	1.10	2.13	3.48	5.35
Net production/tiller (mg/tiller/d)	0.101	0.176	0.216	0.213
Tiller Nos. (tiller m^2)	48280	53910	35180	34220
Net production/unit area (kg DM $ha^{-1}d$)	50.5	91.2	76.1	75.9

Table 2. Regression Equations, House o' Muir

		Probability of significance	Percentage variation explained
Production per tiller (mg/tiller/d) and herbage mass (kg OM ha^{-1})			
linear	$Y = 0.00792 + 0.00013x$	$P < 0.001$	82
quadratic	$Y = -0.01392 + 0.00016x - 9.45x^2$ @ - 9	$P < 0.001$	82
Tiller No. (No. m^2) and herbage mass			
linear	$Y = 58570 - 9.4629x$	$P < 0.05$	34
quadratic	$Y = 29353 + 30.5526x - 0.01264x^2$	$P = 0.053$	48
Production per unit area (kg DM $ha^{-1}d$) and herbage mass			
linear	$Y = 37.2496 + 0.03322$	$P = 0.02$	43
quadratic	$Y = -48.7876 + 0.15105x - 0.00004x^2$	$P < 0.03$	55

Regression Equations, Glensaugh

		Probability of significance	Percentage variation explained
Production per tiller (mg/tiller/d) and herbage mass (kg OM ha^{-1})			
linear	$Y = 0.09277 + 0.00008x^2$	$P < 0.01$	43
quadratic	$Y = 0.02672 + 0.00021x - 5.66x^2$ @ - 8	$P < 0.01$	52
Tiller No. (No. m^2) and herbage mass			
linear	$Y = 55012 - 11.3225x$	$P < 0.01$	40
quadratic	$Y = 59175 - 19.9288x + 0.00356x^2$	$P = 0.03$	41
Production per unit area (kg DM $ha^{-1}d$) and herbage mass			
linear	$Y = 58.05914 + 0.01479x$	$P > 0.30$ NS	7.5
quadratic	$Y = 31.86357 + 0.06895x - 0.00002x^2$	$P > 0.36$ NS	14

At both sites gross production and net production per tiller were linearly and positively related to herbage mass. At House o' Muir senescence rates were also related linearly and positively to herbage mass so that increased production per tiller with increase in tiller size was partially offset by increased senescence. Senescence rates were 15% of gross production at low herbage mass and 21% at high herbage mass. At Glensaugh senescence rates were more erratic and no clear trend emerged.

Tiller numbers were negatively related to herbage mass. The data indicate a humped quadratic relationship (+ + -) with peak tiller numbers at a herbage mass of around 1000 kg OM ha^{-1}.

Net production per unit area showed a significant positive relationship with herbage mass at House o' Muir with the quadratic - + - curve providing a better fit, though not significantly so, than the linear relationship. This curve suggests that production is reduced below 1500 kg OM ha^{-1} but little affected above this value. The regressions for the Glensaugh data were not significant but analysis of variance on the weekly means indicate that production was reduced on the hardest grazed plot compared with the other three plots. Taken together, the data suggest that the lower limit to maintained herbage mass at which the sward can operate its various compensatory morphological and other adaptations to full effect lies between 800 and 1500 kg OM ha^{-1}.

SOIL CHEMISTRY

04011: Interactions between acidity, aluminium and phosphorus availability in hill soils

1. Lime requirement and CEC

M.J.S. Floate

No work has been carried out on this project during 1979, partly due to the absence of M.J.S. Floate, and partly due to staff shortage. It is intended that when a replacement SO is appointed, priority shall be given to the investigation of lime response in relation to CEC, and to the importance of pH-dependent charge and its relationship with aluminium and organic matter content of soils.

2. Lime response field experiments

M.J.S. Floate, A.D. Ironside and L.J. Sheppard

The lime response experiment on peat at Lephinmore has been terminated. Main conclusions were reported in the Annual Report 1977 (HFRO 220) and subsequent data did not provide much additional information as the severe patchiness of individual treatment plots prevented accurate measurements.

The lime response experiment on Brown Podzolic soil at Stanhope, started in 1975, began to show significant differences between treatments in 1978 (Annual Report for 1978, HFRO 223). By that time yield of both grass, and particularly of clover was declining on Lo treatments compared with all others. These trends are illustrated in Fig. 04011.1 (over) where total annual DM yield is expressed as % of yield on the top treatment (5 tonne lime per ha). This method of expression is used because it takes account of seasonal effects and the fact that total yield was low in 1977 due to accidental grazing! Data for the first year (1975) are omitted because these were for one harvest only, were very low, and did not show any significant differences between treatments.

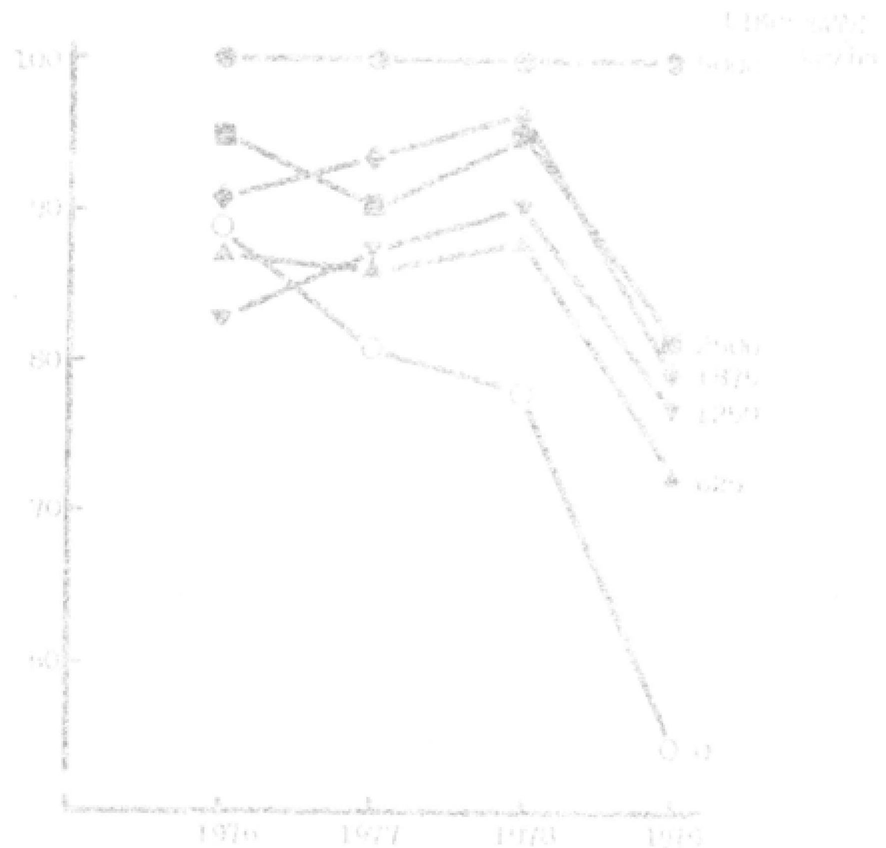

Fig. 04011.1 Relative yield of total herbage [illegible] on reseeded pasture treated in 1976 with [illegible] of lime

The trend for relative yield to fall off on low treatments continued in 1979 when only 54% of the yield at the [illegible] tonne lime rate was obtained. There were no significant differences between the yields on intermediate treatments, but the total yield at the highest lime rate ([illegible] kg DM per ha) was significantly greater than on any other treatment.

The steady relative fall in yield on the [illegible] treatment suggests that maintenance lime was required, perhaps prior to 1978, but the experiment was continued in its original design through 1979 in an attempt to determine the time interval before there were indications of the need for maintenance lime on other treatments. The indications from the 1979 data are that the time may now be approaching. In order to follow this trend, and to measure the response to maintenance lime applied before pasture yields fall too drastically, a revised design is proposed for 1980. The plots will be subdivided with no further treatment applied to one half, but with a repeat of the original treatment on the other half. One half of the nil treatment will be treated with 2.5 tonne lime per ha to determine whether pasture recovery is possible.

3. Aluminium-Phosphorus-Calcium interactions

L.J. Sheppard and M.J.S. Floate

Some observations, and conclusions, from experiments on the interactions between soil acidity (and related aspects of [illegible]) and the availability of native and added P were reported in [illegible] Report, 1978, HFRO 223). Experimental work on this project was completed during 1979 and the work is now being written up as a Ph.D. thesis entitled "Interactions of aluminium and phosphorus in acid hill soils" ([illegible]). It is premature to summarise the main conclusions as the final thesis will not be submitted until late spring 1980.

GLASSHOUSES, GROWTH ROOMS, MICRO-CLIMATE

54001: Maintain glasshouses at Bush

1. Glasshouses, growth rooms, microclimate

D.E. Suckling

Glasshouse and growth room facilities have functioned as normal although both glasshouses were severely damaged by gales on three occasions and many replacement panes of glass were needed. Earth leakage breakers have now been fitted in both glasshouses to enhance electrical safety in the often humid conditions.

The automatic weather stations at Lephinmore and Hardpark, Glensaugh, have both been functioning well with almost 100% return of data for the tapes that have been analysed. Another set of equipment was installed to monitor the Birnie Hill project (02005) at Glensaugh. The results from this station have yet to be processed.

ANALYTICAL SERVICES

54002

1. Inorganic chemistry

C.C. Evans and J. McKenzie

During the year 21,700 analyses were made from 11,900 samples of plant tissue, soil extracts, biological fluids including blood and milk, ruminant tissue and digesta. Analytical provision was made to 15 individual projects. In addition small numbers of samples were analysed by specialised techniques (mainly x-ray fluorescence) for the GRI and ADRA (3 projects in total).

Method Development

A method for the determination of copper in milk has been developed. Two ml of fresh milk was freeze dried and ashed overnight at 450°C in borosilicate glass tubes. The residue was extracted with 4 ml (1 + 1 v/v) hydrochloric acid and the copper concentration of the extract was estimated by atomic absorption spectrophotometry. The precision was determined as satisfactory by 20 replicate analyses which gave an SE of the mean of 0.0028 μg Cu/ml at the 0.122 μg Cu/ml level. Accuracy as measured by the recovery of known amounts of copper to milk samples in a number of tests was found to be satisfactory as the mean recovery was 98.2%.

At the request of the Veterinary Investigation Centre, ESCA, Bush, a comparison of the respective methods for the determination of copper in blood plasma was carried out. Aliquots of a number of plasma samples were analysed at both laboratories and the results compared. At a mean concentration of 0.79 μg Cu/ml the SD of the differences was 0.029 μg Cu/ml which was considered highly satisfactory.

Demineralised Water

Since installation of the demineralised water unit in 1973 the feed water has been taken from a storage tank. This has been found to be increasingly unsatisfactory due to the build-up of organic matter in the feed water. This caused OM entrainment in the demineraliser ion exchange resin which necessitated more frequent regeneration. In consequence the feed water has been changed to the mains supply. As this is at a much greater pressure a solonoid valve has been fitted for flow control.

2. Tracer chemistry

A.R.M. Chambers

A new Packard Scintillation Tri-Carb 460c counter has been purchased and this is now working well.

During the year ^{3}H, ^{14}C, ^{57}Co, ^{35}S and ^{103}Ru have been counted on a routine basis.

3. Electronics

A.R.M. Chambers

Various electronic instruments have been repaired and maintained and advice on electronics has been given to members of staff. Some of the projects carried out are listed below:-

(a) Determination of foetal number Project 02002 with I.R. White

During this year various methods have been tested. The methods tried have been foetal electrocardiograph and phonocardiograph signal detection, ultrasonic scanning, and microwave doppler investigation. The first two methods were found to be unsuccessful due to the very poor signal to noise ratio and no results were obtained even after using auto correction techniques.

From work carried out with ultrasonic scanners it was concluded that in order to produce results which were quick and reliable a rectal probe would have to be used. At the present there is no rectal probe on the market, and it was envisaged converting a linear array scanner head, however finance has not been available to purchase a suitable head.

The fourth method has proved very promising. This method uses an X-band doppler radar module. The advantages of this method over ultrasonic doppler are two-fold, firstly there is no need to get good skin contact with the device as a radio beam passes readily through air, and secondly the beam is wide and therefore less searching is required. The radio waves are transmitted into the body where they are reflected from the various surface within it. If the surfaces are moving then a doppler shift occurs which is detected by the receiving circuit.

The doppler signal is then filtered to remove unwanted signal produced by slow moving surfaces to leave signal produced only by fast moving surfaces such as the heart which has very fast moving surfaces relative to other organs. By looking at the periodicity of the remaining signal it is possible to say if a heart signal is present and if so if there is one or more than one.

Initial trials have been successful where the foetus has been close to the surface and foetal heart and breathing has been detected, but with sheep it was found that the layer of muscle under the skin caused too much alternation of the radio beam.

For future work on sheep it is suggested that a frequency of between 10 and 100 MHz be tried as this would give adequate penetration.

(b) Project 02005

A sequential timing controller has been made to interface with a GLC to enable automatic separation of various VFA's within a sample.

(c) Project 01002

As part of an automatic lamb feeder device a novel method for detecting individual lambs has been designed and built. This consists of a very low current device which is worn by the lamb and transmits very short pulses of infra-red light at precise time intervals. The receiving circuit which will be situated on the milk dispenser, will detect the light pulses, and will measure the time interval between them. If the correct time interval is measured for that particular feeder, the feeder circuit will be energised.