CONFIDENTIAL HFRO 220

HILL FARMING RESEARCH ORGANISATION

ANNUAL REPORT 1977

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HILL FARMING RESEARCH ORGANISATION

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1 APRIL 1978

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8 Cleaners

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REPRODUCTION

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

1. Fertility in Blackface ewes

Studies on the relative effects of good nutrition and achieved body condition on ovulation rate and embryo mortality in BF ewes

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

In earlier studies on the BF breed, ovulation rate has been shown to be positively related to body condition at mating, and not significantly affected by the level of current nutrition when condition score is 2.5 or above.

In BF ewes in condition 2 at mating, however, ovulation rate has been shown to be significantly and positively affected by the current nutritional level. In one experiment the ovulatory response to good nutrition in ewes in condition 2 appeared to be greater than might be expected from ewes being maintained in condition 2.5, but the relative response could not be checked in the particular experiment. The present study was therefore designed to test the relative effects of good nutrition and achieved body condition in BF ewes in conditions 2 and 2.5 at mating.

At the end of September, 130 draft BF ewes drawn from Finella, Cairn and Birnie at Glensaugh, and from House o' Muir, were moved to the Lephinmore shed and group-fed to bring them into conditions 1.5, 2 and 2.5 by mid-November. From then until a synchronised mating in the third week of December, the ewes in condition 2.5 were maintained (10 g pelleted dried grass (DG) + 9 g hay/kg LW/day) and the ewes in conditions 1.5 and 2 were fed to raise them to conditions 2 and 2,5 respectively (19 g DG + 12 g hay and 16 g DG + 12 g hay/kg LW/day, respectively.) After mating, all ewes were fed at maintenance until being killed for ovulation and viable embryo counts on day 22 ± 3.

Mean condition scores (CS), liveweights (LW), the number of ewes with 1-3 ova, ovulation rate (OR), the percentage embryo mortality (EM) and the potential lambing rate (PLR) and litter size at 22 ± 3 days after mating are shown in the following table:-

Mating - 5 weeks		Pre-mating food level	Mating		No. of ewes with 1-3 ova			OR	EM(%)	At 22 ± 3 days	
CS	LW(kg)		CS	LW(kg)	1	2	3			PLR	Litter size
2.51	54.6	M	2.52	55.4	18	25	0	1.58	37	1.00	1.30
2.03	48.6	H	2.41	54.3	13	34	2	1.78	39	1.08	1.51
1.56	43.6	H	2.02	51.0	15	14	1	1.53	37	0.97	1.38

The ovulatory response of ewes on good nutrition and rising in condition from 1.5 to 2 over 5 weeks was very similar to that of ewes being maintained at a higher live weight in condition 2.5. In ewes on good nutrition and rising in condition from 2 to 2.5 the ovulatory response was greater ($P < 0.1$) than in either of the other categories of ewe. Good nutrition therefore has a positive effect on ovulation rate over and above that associated with achieved body condition in BF ewes in the condition 2-2.5 range. Embryo mortality was not affected by condition or nutrition although the overall level was high and requires further study.

The ovulation rate of ewes rising in condition from 1.5 to 2 (1.53) was less than that recorded in a previous experiment in the Sourhope shed (1.90), but must be considered in the light of differences known to exist between sources of ewe. In the present study, the ewes from House o' Muir produced significantly fewer ova overall (1.45) than did the ewes from the Glensaugh hefts (1.72) and this was particularly the case in the condition 1.5 to 2 group (1.20 vs. 1.70). Clearly, differences in potential between sources of ewe, due to differences in previous treatment as well as to genetic differences, make interpretation of such studies difficult with the small numbers of ewes available from any one source.

Although no information is available from this study on the probable response of only maintaining ewes in conditions 1.5 and 2 over the 5 weeks to mating, the economic advantages of raising their condition by good nutrition over that period seem likely to be considerable. Based on pelleted dried grass at £80/tonne and hay at £40/tonne, the extra cost of raising condition from 1.5 to 2 and 2 to 2.5 was £1.14 and £1.01, per ewe, respectively, over and above the cost of maintenance feeding (£2.36) in the shed. An extra 5 or 6 lambs per 100 ewes would cover this extra cost, and this seems likely to be very many fewer than the probable response based on the average litter sizes and on previous results from ewes maintained in conditions 1.5 and 2. If such responses can be achieved in a grazing situation, the extra management costs are likely to be less and the potential returns even higher.

2. The effects of age of ewe on ovulation rate and early embryo mortality

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

In a previous study (Gunn, Doney & Russel, 1969) the lambing performance of mature BF ewes ($5\frac{1}{2}$ and $4\frac{1}{2}$ years old at mating) was shown to be significantly greater than that of young BF ewes ($2\frac{1}{2}$ years old and in similar condition at mating). Reanalysis of these data has shown this to be the case in both fat and thin ewes. No information was available from that study on the relative contributions of ovulation rate and embryo mortality to the difference in response. Significant differences in live weight, and therefore presumably size, were also apparent between the age groups at similar condition levels, and, since size differences are known to be associated with ovulation rate differences (Gunn, Doney & Russel, 1972), it is not possible to separate the relative contributions of age and size to the previous results.

The present study was designed to examine the effects of age, per se, on ovulation rate and early embryo mortality in BF ewes of similar size and condition. To achieve this latter requirement in ewes of differing ages, a group of ewe lambs was retained in 1975 and managed over the next 2 years to attain a similar live weight and size at $2\frac{1}{2}$ years as draft-age ewes off the same hill at $6\frac{1}{2}$ years. The management entailed a high standard of nutrition throughout rearing, with particular emphasis on the summer growing period, and early weaning of the gimmer lamb crop (at 2-3 days).

Body size measurements (body length, chest depth and hip width) were recorded in 1976 on these young ewes and also on the older age group of ewes with which they were to be compared. These were used to calculate a body volume (BL x CD x HP) which was the basis for selection of the draft-age ewes in September 1977. Both groups of ewes were then penned indoors in the Sourhope shed and differentially group-fed to bring them into condition 3 prior to a synchronised mating in late November. All ewes were fed at maintenance from at least 9 days before mating and for 23 ± 3 days after mating, and were then killed for ovulation and viable embryo counts.

Mean body volume, live weight (LW) and condition score (CS) of the young and old ewes prior to mating in 1976 and 1977 are shown in Table 1.

Table 1

	No.	Age (yrs)	Body volume (cu dm)	LW (kg) & CS at mating	Age (yrs)	Body volume at mating (cu dm)	LW (kg) & CS at	
							mating-10 weeks	mating
Young	44	1½	35.7	53.6 2.68	2½	45.6	63.1 2.81	66.9 3.00
Old	40	5½	43.9	60.1 2.55	6½	45.2	50.9 2.16	60.6 2.90

The LW and CS of both groups are also shown for 10 weeks before mating in 1977.

It can be seen that the management of the younger ewes was successful in eliminating differences in size. At the beginning of group feeding, at 10 weeks before mating in 1977, the older ewes were in poorer body condition and, despite differential feeding, this difference was not completely eliminated by mating time and a considerable difference in LW was still present.

A summary of the ovulation and embryo mortality data is shown in Table 2.

Table 2

	No. of ewes with 1-3 ova			OR	Loss of 1-3 ova				On day 23 ± 3					
									No. of ewes with 0-3 embryos				PLR	Litter size
	1	2	3		1	2	3	All	0	1	2	3		
Young	5	38	1	1.91	0 0%	21 28%	0 0%	21 25%	6	14	23	1	1.43	1.66
Old	1	36	3	2.05	1 100%	8 11%	3 33%	12 15%	5	2	31	2	1.75	2.00

Despite the lighter weight and slightly lower mean CS at mating, the older ewes had a slightly higher ovulation rate (OR) than did the younger ewes ($P<0.1$). This small difference may have been associated with the higher levels of nutrition given to the older ewes up to 9 days before the start of mating or even to genetic differences. It is also possible that there is a small but real effect of age independent of differences in size.

Loss of ova was lower in the older than in the younger ewes, and, although this difference was not significant overall, in the ewes shedding 2 ova the difference reached significance ($P<0.05$). Thus, as with ovulation rate, there is a suggestion that age may confer a slight advantage independent of size.

Acting additively, the small advantages to the older ewes of both higher ovulation rate and lower ova loss resulted in increased differences in both potential lambing rate per ewe mated at first service (PLR) and in surviving litter size at 22 ± 3 days ($P<0.1$ and $P<0.01$, respectively).

References

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3. The effects of time of post-mating endoscopy on ova loss

R.G. Gunn, A. Whitelaw, J.M. Doney, W.F. Smith, J. Riva and D.A. Sim

In the course of a study on the effects of age of ewe on reproductive response in the BF breed (see p A.2) the technique of endoscopy was used to determine ovulation rate of BF gimmers in mid-November at the second oestrus after synchronisation. To test the possible effects of time of examination on ova loss, endoscopy was carried out on one of three occasions; 3-4 days, 15-16 days or 28-30 days after mating, and the number of corpora lutea relating to the first mating was counted. Returns to service and the number of lambs subsequently born were also recorded.

Ovulation rates, as observed at endoscopy and after adjustment according to lambing (in five ewes more lambs were born than corpora lutea observed), are shown in the following table. Also shown are lambing rate to first mating per ewe mated and per ewe lambing.

Endoscopy on days	No. of ewes	Ovulation rate		Lambing rate to first mating	
		Observed at endoscopy	Adjusted after lambing	/ewe mated	/ewe lambing
3-4	16	1.88	2.00	1.25	1.43
15-16	15	2.00	2.07	1.27	1.46
28-30	14	1.50	1.64	1.00	1.56
	45	1.80	1.91	1.18	1.47

Unfortunately, ovulation rate in the ewes examined on days 28-30 was much lower than in the others, and lambing rate per ewe mated was also depressed due to more of them returning to service. There was little difference between the groups, however, in the lambing rate per ewe lambing.

The number of ewes returning to service (RTS) and the number of these which could not have been a consequence of total loss associated with the endoscopy, since they were recorded before or shortly after the examination, are shown in the next table. Also shown are ova losses to first mating, both total loss and that excluding the loss associated with the above RTS unrelated to endoscopy, and the number of ewes in which some loss occurred, again excluding the RTS unrelated to endoscopy.

Endoscopy on days	No. of ewes RTS		Ova loss to first mating				Ewes with some loss, excluding UTE	
	Total	Unrelated to endoscopy (UTE)	Total		Exluding UTE			
			No.	%	No.	%	No.	%
3-4	2	0	12	38	12	38	7	44
15-16	2	2	12	39	10	34	8	62
28-30	4	4	9	39	5	26	4	44

Although ova loss which could be related to endoscopy declined with later examination, the differences were too small to be shown to be significant. More of the ewes examined on days 15-16 had some loss which was possibly related to endoscopy than did ewes examined on the other two occasions but again the difference could not be shown to be significant. The level of overall loss was high and although there was no control group unexamined by endoscopy for comparison, such high losses require more detailed examination than was possible in this study.

4. Fertility in Greyface ewes

The effects of time of mating and stocking rate on body condition at mating and on lamb production

R.G. Gunn, J.M. Doney, T.J. Maxwell, J. Eadie, W.F. Smith, J. Riva and D.A. Sim

In 1973, four upland sheep production systems were established at Glensaugh using Greyface ewes and with a set of objective rules on which management decision was based. The four systems studied responses in 5 age groups of ewes stocked at 10 or 15 ewes/ha and mated in early October or early November. Replacement gimmers were bought in. The conduct of the systems experiments is described in detail elsewhere in this Report (see p D.27).

The object of the present study has been to obtain information on the effects of time of mating and stocking rate on body condition at mating, on the pattern of mating response and on the resultant lambing performance. In this, the fourth and last year of these systems in their present form, early mating started on 8th October 1976 and late mating on 5th November 1976. Body condition at mating and the associated lamb production are shown in Table 1.

Table 1

Time of mating		Low stocked				High stocked			
		Condition at mating	No. of ewes	No. barren	Lambing %*	Condition at mating	No. of ewes	No. barren	Lambing %*
Early mated	8-25 Oct.	3.23	47	0	181	3.06	68	1	193
	after 25 Oct.	3.17	3	0	200	3.13	2	0	100
		3.23	50	0	182	3.06	70	1	190
Late mated	5-22 Nov.	2.58	39	0	169	2.51	54	3	159
	after 22 Nov.	3.00	3	0	100	2.19	9	0	122
		2.61	42	0	164	2.46	63	3	153

* As a percentage of ewes lambing

Body condition at mating in the late-mated ewes was more adversely affected by the drought conditions experienced during the summer of 1976 than it was in the early-mated ewes. This was associated with a considerably lower lambing percentage in the former. Lambing percentage in the early-mated ewes was in keeping with the level of body condition at mating and apparently little affected by any residual nutritional effects of the drought. The between-system differences were partially reduced by the inclusion of the gimmers performance in the results. The bought-in gimmers were in very good condition and although the nutritional consequences of the systems produced some differential response, the gimmers were not in the systems long enough for their performance to be comparable with that of the older ewes.

The difference in response between gimmers and older ewes has been a feature of the last three years' results, with the gimmer performance being more an expression of their nutritional status prior to purchase than of their subsequent system.

In 1975 (Table 2) they were in poorer condition than the older ewes at mating and produced significantly fewer lambs; in 1976 there was no significant

Table 2

Age at lambing	Year	1975	1976	1977
2 years	No. of ewes	65	62	63
	Body condition	3.08	3.17	3.21
	Lambing %*	158	160	184
3-6 years	No. of ewes	159	164	162
	Body condition	3.27	3.25	2.71
	Lambing %*	193	175	165

* As a percentage of ewes mated

difference; while in 1977 they were in better condition and produced significantly more lambs.

In none of these years were the differences in lambing percentage between the early- and late-mated gimmers significant and the overall values were 169% and 165% respectively.

In 1975 and 1977, however, the differences in lambing percentage between the early- and late-mated older ewes were significant (207% vs. 178% and 180% vs. 149%, respectively). In 1976 and also in the very first year, 1974, when the systems were only being established, this pattern was partially upset by a substantial delay in the onset of oestrus in the early mating systems, with less than half the ewes taking the ram in the first 17 days. On the basis of time of mating, irrespective of system, both litter size and lambing rate declined significantly with a delay in mating (Table 3).

Table 3

Mated between	Condition at mating	No. of ewes & gimmers	No. barren	Litter size*	Lambing % †
6 and 25 Oct.	3.23	322	7	1.96	192
26 Oct. and 22 Nov.	3.02	535	17	1.78	172
23 Nov. and 25 Dec.	2.85	42	4	1.50	136

* Per ewe lambing

† As a percentage of ewes mated.

Although this decline in lamb production with time was associated with a decline in body condition at mating, previous studies on this cross-breed have also shown a significant decline in ovulation rate with time in ewes in similar condition.

Much of the difference between years and times of mating can, however, be explained in terms of the direction of live-weight change about the time of mating and the proportions of ewes gaining, maintaining and losing weight, quite apart from any effect of achieved body condition. Over the last 3 years (Table 4), ewes losing weight produced significantly fewer lambs than did ewes maintaining weight while both produced significantly fewer than did ewes gaining weight. The latter were also significantly heavier in estimated mating weight but there was no significant difference between ewes maintaining or losing weight.

Table 4

Direction of live-weight change about mating	Gaining	Maintaining	Losing
No. of ewes	114	339	221
Lambs born/100 ewes alive at lambing	196	178	158
Live weight at mating (kg)	70.4	67.9	66.6

Preliminary conclusions on the reproductive performance of Greyface ewes to be drawn from this study are (1) that lamb production is little affected by the level of body condition at mating above grade 2.5 but that below this level subsequent performance declines rapidly.

(2) that lamb production is closely linked to the direction of live-weight change about mating and therefore to the nutritional circumstances which apply, with loss of weight to be avoided if at all possible.

(3) that mating between 6 and 25 October is associated with a higher lamb production at birth (reduced by weaning) but difficulty in getting all ewes to exhibit oestrus during that period in every year negates much of the advantage.

(4) that the levels of stocking rate (10 and 15 ewes/ha) utilised in these systems produced very small and non-significant differences in lambing rate, particularly in older ewes.

5. Studies on factors affecting onset of oestrus in first-cross ewes as used in upland systems

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

In the Glensaugh upland systems studies with Greyface ewes, the onset of oestrus was delayed in the early mated groups in two out of four years (see p A.7). In a preliminary study on the possible causes of variation in time of onset of oestrus in 1976, oestrus was delayed in a greater proportion of ewes stocked at 15/ha than it was in ewes stocked at 10/ha but there was apparently little or no effect of live weight. In the present study the effect on onset of oestrus of a low level of nutrition, associated with the possibly stressful effect of group-penning indoors, was compared with that of above-maintenance nutrition in a grass paddock stocked at 9 ewes/ha.

Eighty-one Greyface and 18 Texel X BF ewes were randomised into two groups in mid-August. One group (H) was run in a grass paddock with two harnessed teasers and checked 3 x/week for keel marks. Supplementary feeding was supplied when the availability of grass declined. The other group (L) was penned indoors in the House o' Muir shed and fed between 750 and 1000 g chopped hay/head/day. Teasers were put in 2 x/day and observed to detect oestrus. The results of this study are shown in the following table.

Level of nutrition	No. of ewes	Period observed for onset of oestrus	No. of ewes exhibiting oestrus	Mean date and range of onset of oestrus	Live wt.(kg) and condition score	
					17 Aug	At onset of oestrus
H	49	17 Aug-11 Oct	45	28 Sept	68.5	70.7
				12 Sept-11 Oct	2.52	2.69
L	50	17 Aug-23 Sept	46	12 Sept	66.4	56.4
				25 Aug-22 Sept	2.54	2.24

The onset of oestrus was in fact earlier in the ewes on a low level of nutrition indoors than it was in the ewes on moderately good nutrition outdoors. This suggests that low nutrition, or the stress of indoor group-penning, or both, has stimulated an earlier onset and adds little to the understanding of the variation in time of onset experienced in the upland systems studies.

6. A comparative study of the effects of body condition on ovulation rate of Greyface and Texel x Blackface ewes

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

In the study of the effectiveness of new genotypes in utilising better hill resources (see pA.20) a reduction in stock numbers made 16 Greyface and 18 Texel x BF 2½- and 3½-year old ewes available for a preliminary study on body condition/ovulation rate relationships. These ewes were utilised in a study on onset of oestrus (see pA.8) which created a differential body condition. At the conclusion of this latter study in mid-October, the ewes on a high level of nutrition (H) were group-penned in the same shed as the ewes on a low level (L). Differential feeding continued until 2½ weeks before a synchronised mating and was replaced by maintenance feeding. Ewes were killed within 2 weeks after mating for an ovulation count.

Live weights (LW) and condition scores (CS) at 15, 11 and 2½ weeks before mating (M), the number of ewes with 1-3 ova and the mean ovulation rate (OR) are shown in the following table.

		LW & CS			No. of ewes with 1-3 ova			OR
		M-15 weeks	M-11 weeks	M-2½ weeks	1	2	3	
GF	H	59.5 2.44	60.9 2.63	63.1 2.56	1	7	0	1.88
	L	58.2 2.47	47.0 2.13	54.6 2.28	5	3	0	1.38
TEXEL X BF	H	59.7 2.50	61.8 2.72	65.0 2.69	1	7	1	2.00
	L	55.2 2.47	43.8 2.17	48.7 2.19	7	2	0	1.22

The number of ewes involved in this preliminary study are too few to give more than an impression of likely response but it is clear that ovulation rate has responded positively to, and in step with, the differences in live weight and condition which were achieved.

LACTATION

01002 : Factors affecting lactation yield and its consequences in lamb growth

1. Grazing intake and performance during lactation of Blackface ewes as influenced by pre-partum body condition and by pasture type

J.M. Doney, W.F. Smith, R.G. Gunn, J.N. Peart, M. Lynch and J. Riva

From previous studies carried out in controlled experiments using individually allocated concentrate diets it is known that the pattern of milk yield utilised by the suckling lamb depends on the interaction of a number of factors such as body condition of ewes at parturition, vigour of lambs at birth and, later, the relative proportion of milk and solid food in the lambs diet. The pattern of change in voluntary food intake by the ewe and its subsequent partition is of central importance in this interaction. Use of concentrate diets removes one source of variation and allows more precise experimentation, but it is evident that the variation in intake associated with changing pasture characteristics may modify the responses previously determined.

An experiment was carried out to give preliminary information on patterns of food intake, milk yield and associated lamb growth when ewes were grazed on two extreme pasture types during lactation. The interaction of the previous nutritional state of the ewes and of gross differences in lamb demand for milk with grazing intake and partition was also investigated.

A flock of 116 adult Blackface ewes in uniform body condition (2½- 3-) was separated into three groups 30 days after synchronised mating. All three groups were maintained on similar pasture of low avilability. Two groups were allowed to lose liveweight, equivalent to a 15-20% loss of maternal liveweight by parturition whilst the third group received supplementary feeding to achieve a small liveweight gain. Two weeks before lambing one low nutrition group (A) was transferred to a Nardus dominated hill enclosure whilst the second low nutrition group (B) and the well-fed group (C) were transferred to a prepared ryegrass/clover sward.

Six single- and six twin-suckled ewes were selected from each group for estimation of milk yield and grazing intake. Six non-lactating ewes in group A and 4 in group B were also included for estimation of grazing intake. Faecal output was estimated by a procedure of chromic oxide dosing and faecal grab-sampling carried out once-daily for 5 consecutive days following a 5-day period of dosing. Collections were carried out during weeks 3, 6 and 8. At the end of each collection period milk yield was estimated by the oxytocin method.

From week 5 drought conditions made it progressively more difficult to maintain adequate herbage allowance and quality. Observations were terminated at the end of the 8th week, by which time milk yield in both pastures had fallen considerably and had almost ceased completely on the hill enclosure.

Faecal samples from individual sheep were bulked by week of collection and analysed for chromic oxide, ash and faecal N%. Two regressions derived from ryegrass/clover and general hill pasture, respectively were used to estimate digestibility from faecal N% on the two pasture types. Estimates of digestible organic matter intake were calculated.

Estimates of diet digestibility, mean DOMI, mean daily milk yield, liveweight, and live-weight change, and lamb weights are given in Table 1. Assessment of the data is limited by the lack of continuous observations and by the use of arbitrary regressions to estimate digestibility. With these qualifications the following tentative points can be made:-

1. Within time of sampling and pasture type, diet selection is not significantly affected by lactational status.

	Twin-rearing ewes			Single-rearing ewes			Dry ewes	
Group	A	B	C	A	B	C	A	B
Period	a. Diet OM digestibility (%)							
Week 3	71.1	80.0	79.6	70.8	79.4	79.9	71.8	79.9
Week 6	71.4	77.4	78.3	70.7	78.0	78.2	72.3	79.3
Week 8	68.9	74.4	74.0	67.6	73.6	73.6	67.5	73.5
	b. Food intake (kg DOMI/d)							
Week 3	1.01	1.51	1.91	0.88	1.54	1.268	0.97	1.44
Week 6	1.04	1.42	1.51	1.06	1.59	1.33	0.99	1.15
Week 8	1.19	1.46	1.43	1.20	1.24	1.30	1.09	1.02
	c. Ewe liveweight (kg)							
Post-partum	53.3	58.2	64.3	53.2	58.3	64.3	53.3	60.5
78 days	47.3	64.0	66.0	49.8	65.1	66.5	51.7	69.8
36 days	46.0	62.1	63.0	50.0	66.2	65.3	52.6	69.5
62 days	49.2	62.8	61.2	51.5	64.5	64.7	54.4	68.3
	d. Milk yield (kg/d)							
21 days	1.12	3.18	2.13	1.00	2.10	2.35		
42 days	0.50	1.86	1.78	0.57	1.61	1.96		
56 days	0.31	1.40	1.33	0.25	1.22	1.24		
	e. Lamb live weight (kg)							
0 days	3.5	3.6	3.8	3.6	4.4	4.8		
22 days	6.6	9.8	10.4	9.2	12.7	13.0		
45 days	9.0	15.0	15.2	13.1	19.1	19.6		
60 days	10.4	17.8	18.2	14.2	22.5	22.4		

2. By the 3rd week post-partum, a period corresponding approximately with the expected peak of milk production, dry, single- and twin-suckled ewes which were previously undernourished and which were transferred to the better pasture were consuming similar quantities of herbage. At this level of intake the dry ewes had regained liveweight at a much more rapid rate than the lactating ewes. Twin-suckled ewes produced more milk and had a slightly lower live-weight gain than did single-suckled ewes. On the same pasture single-suckled ewes which were previously well-nourished consumed slightly less herbage (non-significant) than did the single-suckled undernourished ewes; their milk production was similar but liveweight increment was lower. In this period the previously-well-nourished, twin-suckled ewes consumed almost 50% more than corresponding single-suckled ewes.

3. Estimated diet digestibility on the Nardus-dominant pasture was considerably lower. This was reflected in low levels of intake and a lack of difference between dry and lactating ewes. Milk production was considerably depressed, especially in twin-suckled ewes and liveweight continued to fall.

4. By the 8th week the diet digestibility on the ryegrass/clover pasture had fallen considerably. Mean daily intakes, milk yield and the rate of liveweight change were similar in both groups. On the poor hill pasture intake was maintained despite a further fall in diet digestibility. Milk yield had fallen to a very low level but some recovery in liveweight was evident.

In the latter case it appears that early mammary involution may have been a direct response to either an excessively low level of intake or to the associated weight loss. Direct relationships amongst milk output, food intake and liveweight change were less evident in the more normal lactation patterns. Overall the relationships appeared as consequences of correlation with grouping factors such as number of lambs suckled, body condition and above all, pasture characters.

It might be suggested that factors associated with both lactation and low body condition as specific physiological states may lead to increase of food intake. The rate or extent of the response may be influenced by the lamb's milk demand and by associated changes in body tissue stores. It may be limited by inherent characteristics of the available food source and by the rate of increase in gut capacity. Individual ewe variation appears to be greater than that associated with small differences in either milk demand or body condition change.

Intake, determined in response to these interactions, itself determines total production, but the pathway of partition into milk, body composition change or maintenance may depend on a different level of interaction and is almost certainly time-related.

2. Comparisons of the patterns of milk production of East Friesland X Blackface crossbred with pure bred Blackface ewes and its influence on lamb growth (01002/01004)

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

Previous studies have shown that the milk production of British hill breeds of sheep in early lactation is mainly dependent on nutrition. However, even with well nourished ewes, the milk yield declines rapidly and continuously throughout the mid- and late-stages of lactation. Under hill grazing conditions the decline in milk yield and, therefore, milk intake of the lamb, coincides with a reduction of digestibility of hill vegetation resulting in reduced lamb growth rate. Attempts to improve lamb growth during the later lactation phase have been mainly centred on pasture improvement.

Limited evidence indicated that improved lamb growth in the later lactation phase may be obtained from an increased intake of milk. However, the pattern of milk production and shape of lactation curves of British hill breeds clearly indicate that they are not able to meet a requirement for sustained lactation. This potential can only be expressed by milch breeds of sheep the East Friesland was the only example available in Britain.

Pure bred East Friesland rams were mated with pure bred Blackface ewes to produce small flocks of crossbred ewes in each of 1974 and 1975. These ewes are being used in a series of studies to establish firstly, that this crossbred has a potential for a sustained lactation; secondly, the effect of sustained lactation on lamb growth as influenced by nutrition; thirdly, the effect on the ewe in terms of liveweight recovery and subsequent production.

EXPERIMENT I

The first study was concerned with measuring the milk yield of first crop E.F. X B.F. ewes and comparing the data with that of pure B.F. of the same parity. Both genotypes had been reared from birth under favourable lowland conditions and were well nourished in late pregnancy. The ewes were maintained in individual pens in a sheephouse during late pregnancy and throughout a 14-week lactation period, and were offered a high quality pelleted food ad libitum. The crossbred ewes rearing single or twin lambs produced significantly more milk (191 and 258 kg respectively) than the pure B.F. (144 and 208 kg respectively). The pattern of lactation differed between breeds. The crossbreds attained higher maximum yields and production was sustained at a higher level throughout lactation. In this situation where high quality solid food was available ad libitum to the lambs, differences in lamb growth rates due to greater milk intakes were expected to be small. Nevertheless, at 102 days of age the mean liveweight of single and twin lambs from the crossbred ewes were, respectively, 1.2 and 3.5 kg greater than those of the Blackface ewes.

Comparable groups of ewes of each breed made similar live-weight gains during lactation. There was little difference between breeds in total food intake of corresponding groups during the first 6 weeks of lactation. However, when expressed per unit of liveweight the food intake of the Blackface ewes was slightly greater. The total energy of the milk produced by the EF X ewes was consistently and significantly greater than that of the B.F. ewes. The values were:

Lactation week	BF Single MJ/day	BF Twin MJ/day	EF X BF Single MJ/day	EF X BF Twin MJ/day
6	7.14	11.07	9.77	13.44
11	6.90	8.22	9.33	10.66
14	4.85	5.16	7.35	9.58

The data of liveweight, food intake and production of total energy in the milk indicated a greater efficiency of food utilisation by the EF X ewes.

It was concluded that when nutrition is not limiting, EF X BF crossbred ewes have a capacity for sustained lactation and that this was beneficial to lamb growth. The results have been submitted for publication.

EXPERIMENT II

The second experiment was designed to measure some effects of different and varying planes of nutrition imposed upon second-crop EF X BF crossbred ewes during lactation.

Twenty-eight crossbred ewes born in 1974 were synchronised for oestrus and mated to pure bred East Friesland rams in November 1976. The ewes were grazed on pasture and given supplementary food to maintain body condition in the range of score 2 to 2½. The ewes were put in individual pens in a sheephouse at approximately 6 weeks prepartum and fed a pelleted food at 27 increasing to 32 g/kg during the final week of gestation. The food contained 66 g Digestible Organic Matter per 100 g. Similar food was rationed to the ewes throughout lactation and offered ad libitum to lambs from 4 weeks of age. One ewe died during pregnancy and one was barren. The remaining 26 ewes produced five sets of triplets, eighteen pairs of twins and three single lambs. Some lambs were fostered at birth as required to provide 20 twin-suckled ewes for lactation studies. The ewes were allocated at parturition to nutritional treatment groups to provide either maintenance plus 2 kg milk/day (L) or maintenance plus 4 kg milk/day (H). The treatments were continued or varied during lactation as follows:

Nutritional treatments during lactation periods (weeks)

Treatment group	0 - 4	5 - 8	9 - 14
1	H	H	H
2	L	H	L
3	L	L	L
4	L	H	H

Estimations of daily milk production of the ewes using an oxytocin technique were made at weekly intervals during a 14-week lactation. The milk from the ewes were analysed for fat, solids-non-fat and total solids from which Gross Energy values were calculated. The lambs were allocated separate pens adjacent to their respective dams with a creep access for suckling, but denied access to their dam's food. Ewe liveweight and body condition scores and lamb growth were also recorded at weekly intervals.

The results (Table 1) indicate that the lower level (L) of nutrition

Table 1

Mean milk production (kg/day)

Group	Weeks			Total Yield (kg)
	0 - 4	5 - 8	9 - 14	0 - 14
1 (HHH)	3.48	3.60	2.09	286
2 (LHL)	3.45	3.05	1.60	252
3 (LLL)	3.41	2.68	1.84	248
4 (LHH)	3.62	3.29	2.21	286

did not depress mean milk production during the 0 - 4 week period. The change from L to H after 4 weeks reduced the rate of decline compared with that of the LL group. The L treatment during the 9 - 14 week period clearly depressed milk yields. The total mean milk production during the 14 week lactation of Groups 1 and 4 was almost identical (286 kg) and that of Groups 2 and 3 was 252 and 248 respectively. All of these mean values are greatly in excess of those previously recorded from pure bred Blackface ewes when maintained under similar nutritional and management conditions. The percentage butter fat in the milks (Table 2) ranked inversely with milk yield and this effected Gross Energy values.

Table 2

Mean content of Butter Fat (B.F.) and Solids-non-fat (S.N.F.) in the milks (percent)

Group	Lactation Period, Weeks 0 - 4		5 - 8		9 - 14	
	B.F.	S.N.F.	B.F.	S.N.F.	B.F.	S.N.F.
1	7.6	10.5	5.9	10.7	5.8	10.9
2	7.9	10.3	6.1	11.0	6.6	11.4
3	7.7	10.6	6.9	10.4	5.9	10.6
4	6.8	10.5	5.0	10.7	4.7	10.8

All groups of lambs made satisfactory growth (Table 3), but excepting the 0 - 4 week period, lamb growth was not correlated with milk

Table 3

Lamb Growth

Group	Birth Wt kg	Lactation Periods, Weeks 0 - 4 (wt gain (g/day))	5 - 8 (wt gain (g/day))	9 - 14 (wt gain (g/day))	Wt at 14 weeks kg
1	4.6	252	369	297	34.0
2	4.5	259	379	322	35.4
3	4.5	278	379	335	36.4
4	4.2	296	345	350	36.2

production. This is not surprising when considering the comparatively large quantity of milk available to all lambs in early lactation associated with *ad libitum* access to high quality solid food during the mid- and later stages of lactation. A reduction in ewe liveweight and body condition occurred in all groups during early lactation (Table 4), but these changes did not appear

Table 4

Live weights (kg) and body condition scores of ewes

Group	Post-partum		Lactation Week 4		8		14	
	Wt.	Sc.	Wt.	Sc.	Wt.	Sc.	Wt.	Sc.
1	74.5	2.5	68.2	2.1	69.1	2.2	66.5	2.0
2	71.5	2.5	64.6	2.0	68.3	2.2	66.6	2.1
3	74.6	2.5	67.6	1.8	67.6	2.2	68.6	1.8
4	76.5	2.8	72.9	2.0	76.8	2.5	76.1	2.4

to be related to either food intake or milk production. The lack of relationship of these aspects was also noted in the previous study.

Summaries of uncorrected data are contained in Tables 1 to 4.

3. The inter-relationship of grazing intake, milk yield, liveweight-change and lamb growth as affected by genotype of ewe and by pasture characters

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

The concept of the role which sustained lactation may play in improving lamb growth from suckled ewes grazing upland pastures has been described in a previous section (page A.12). It has been shown that, in a pen-feeding system using pelleted concentrate, East Friesland x Blackface ewes provide a higher peak yield of milk and a more sustained lactation than do purebred Blackface ewes. Under these conditions there were no differences between breed types in voluntary food intake.

The second phase of the project was designed to study the interaction of genetic milk capacity with food intake, nutrient partition and lamb growth in a grazing situation. Since the study of lactation patterns in purebred Blackface ewes had shown that extreme differences in type and quality of pasture had significant consequences on intake, partition, and on the relationship between these characters in single- or twin-suckling ewes (page A.9), this experiment was designed to include two pasture types in successive years. In the first year (1976-7) maiden ewes ($1\frac{1}{2}$ years) of both breed type which had been reared in an improved hill environment from birth were mated to Dorset Down rams when in average body condition (score 2 to $2\frac{1}{2}$) and were subsequently maintained at this level throughout pregnancy. They were transferred to a prepared high-quality ryegrass/clover pasture three weeks before lambing. Lambing results are shown in Table 1.

Table 1

	Ewes to tup	No. Twins	%	No. Singles	%	Barren	%
BF	33	0	-	17	-	16	-
EF X BF	45	14	-	27	-	4	-

The large number of Blackface ewes which were found to be barren could be related to ewes which were lightly marked by the rams or which showed no obvious keel marks at mating. (Observations suggest that this may have been due to mixed breed matings of synchronised ewes allowing preferential mating by the rams or dominance of rams by ewes with greater libido. This effect will be investigated in future trials). Discounting barrenness as a special case, the cross-bred yearling ewes produced a significantly higher proportion of twin lambs (34% and 0% respectively). This may be contrasted with previous results when ewes of the same two types and age were mated in a higher body condition (3) and produced higher and similar proportions of twin lambs (77 and 74% respectively).

At parturition 2 groups of EFX ewes (8 with single lambs, 8 with twins) and one group of 8 BF ewes with single lambs were selected. The absence of twins born to BF ewes prevented formation of the fourth group. The experimental groups were transferred to a reserved area of pasture where the initial herbage allowance was high. This allowance was approximately maintained throughout the first 8 week period by adjustment of the fence-line but quality and quantity, as estimated by visual appraisal, thereafter declined. All ewes were dosed with 3 g chromic oxide pellets daily and faecal grab samples were collected on 5 days in each week. These are to be analysed to estimate faecal output and percentage of ash and nitrogen in the faeces. Estimates of mean diet digestibility and DOMI will be made for each group on a weekly basis. Interpretation of the experiment must await completion of these analyses.

Mean daily yield was estimated one day of each week by the oxytocin method. Individual samples were analysed for fat %, dry matter, and, by difference, solid-non-fat %. Ewes and lambs were weighed weekly. Performance data is summarised in Tables 2 to 5.

Crossbred ewes with single lambs yielded significantly more milk throughout lactation than did Blcakface ewes (Table 2). In three 4-weekly

Table 2

Mean milk yield (kg/day)

Group	Weeks 0 - 4	5 - 8	9 - 12	13 - 14	Total yield (kg)
BF Single	1.87	1.62	1.09	0.61	136
BFX Single	2.37	2.42	1.82	1.28	203
BFX Twin	2.98	2.89	1.77	1.21	231

periods followed by a two-week period, they yielded 27, 49, 67 and 110% more, respectively. Crossbred ewes with twin lambs yielded 26% more milk than did those with singles in the first 4 weeks and 19% in the second 4 weeks but in the subsequent periods the differences (-3% and -5%, respectively) were not signficant. Breed differences were similar to those in the first experiment (page A.12) but, for all the ewes the early lactation yield was higher and the late yield lower in the grazing situation than when ewes were pen-fed on a concentrate diet of constant quality (Fig. 1).

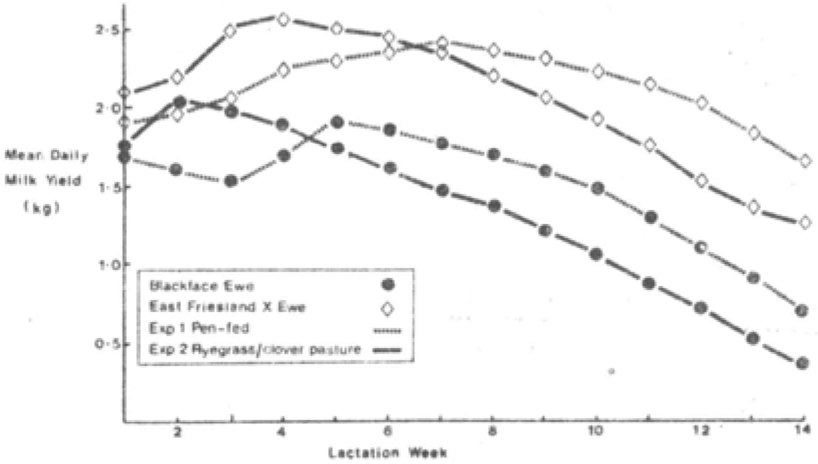

Figure 1

Interpretation of these differences awaits analysis of the faecal samples.

Lamb growth rates (Table 3) reflected the differences in milk intake,

Table 3

Mean lamb growth rates (g/d)

Group	Weeks 0 - 4	5 - 8	9 - 12	13 - 14	Total yield (kg)
BF Single	281	311	286	138	31.4
EFX Single	369	389	364	200	39.6
EFX Twin	254	289	293	175	30.0

mean liveweights at 100 days for single lambs from Blackface ewes and single and twins from crossbred ewes (all sired by Dorset Down rams) were 31.4, 39.6 and 30.0 respectively.

The mean liveweight of all groups of ewes (Table 4) fell to a minimum by

Table 4

Mean ewe liveweights (kg)

Group	Weeks 0 - 4	5 - 8	9 - 12	13 - 14
BF Single	48.2	52.9	56.1	55.8
EFX Single	53.1	58.4	60.9	61.8
EFX Twin	52.5	57.7	58.1	58.3

the third week after parturition, increased rapidly to the 8th week, and then more slowly till the end of the experiment. Body condition scores changed with liveweight. At parturition Blackface ewes with single lambs and crossbred ewes with single and twin lambs had mean scores of 2.2, 2.0 and 1.8 respectively. By the end of the recorded lactation these had reached 2.6, 2.3 and 2.2 respectively.

As in the previous, indoor, study the quality of milk produced by Blackface ewes, as determined by fat % was higher than that produced by crossbred ewes (Table 5). During the first period the mean values of fat

Table 5

Mean butter-fat content of milk (%)

Group	Weeks 0 - 4	5 - 8	9 - 12	13 - 14
BF Single	7.9	8.5	9.3	11.3
EFX Single	7.0	7.3	7.6	9.1
EFX Twin	7.2	7.8	7.9	9.0

% were 7.9 and 7.1 for Blackface and crossbred ewes respectively. Fat content of the milk rose rapidly towards the end of lactation, reaching mean values of 11.3% and 9.0% respectively in the final two weeks. There were no significant differences with groups or time in SNF% (overall mean 10.9%). Differences in milk quality reduced the difference between breeds slightly when milk yield was expressed in terms of gross energy.

The lambs were weaned at the end of the recorded lactation and all the ewes were returned to the hill grazings. Under these conditions behavioural or other factors led to slight differences in body condition recovery. It was decided that this aspect of comparison would be investigated at a later stage and the crossbred ewes were given preferential treatment to achieve equal recovery by mating time in preparation for the second phase of the lactation study. This experiment will be repeated in 1977/78 on an agrostis dominant hill pasture.

4. Milk production of mutton-Merino ewes

J.M. Doney (with the School of Agriculture and Institute of Animal Production, Prague)

This study was part of a project supported by the British Council under the conditions of the Anglo-Czechoslovak Cultural Agreement. The work was carried out between January and March 1977 at the State Farm of Tachov in Western Bohemia on a locally developed strain of Merino ewe (described as the Asch Merino). The strain was produced by crossbreeding from German, Czech and Russian Merino with the objective of creating a strain adapted to meat and wool production in a high altitude, high rainfall area.

The experiment was designed firstly to extend our comparisons of the two methods of estimating milk production in suckling ewes; that is by oxytocin injection followed by hand-milking and by test-weighing of lambs before and after suckling. The secondary objective was to evaluate the capacity of the strain to suckle twin lambs under local management conditions and to assess the economic response to increased food levels during lactation.

During the first six weeks after parturition the milk yield of 22 ewes (11 with twin lambs, 11 with single) was estimated over a 24 h period in each week by the lamb-suckling method. Immediately following the last test-weighing the ewes were hand-milked after an injection of 5 i.u. oxytocin. After a further 4 h the ewes were milked again, and the volume of the resulting milk was measured and samples were taken for analysis of fat and total solids content. Estimates of mean daily milk yield by both methods in each week are shown in Table 1. As with previous studies carried out on Blackface and

Table 1

Mean daily milk yield (kg) of Merino ewes suckling single or twin lambs. Estimates were made by the oxytocin (OX) and lamb-suckling (LS) techniques during the first 6 weeks of lactation. Within-week correlations between estimates are shown.

Week	Single lambs		Twin lambs		
	OX	LS	OX	LS	r
1	1.73 ± 0.081	1.57 ± 0.089	2.34 ± 0.143	2.27 ± 0.202	+ 0.775
2	1.85 ± 0.094	1.95 ± 0.098	2.72 ± 0.107	2.60 ± 0.112	+ 0.888
3	1.97 ± 0.067	1.96 ± 0.085	2.54 ± 0.118	2.67 ± 0.159	+ 0.901
4	1.79 ± 0.097	1.82 ± 0.131	2.64 ± 0.103	2.59 ± 0.094	+ 0.843
5	1.75 ± 0.082	1.63 ± 0.102	2.01 ± 0.136	2.13 ± 0.176	+ 0.806
6	1.56 ± 0.092	1.68 ± 0.084	1.76 ± 0.125	1.69 ± 0.118	+ 0.737
Mean	1.77 ± 0.056	1.77 ± 0.068	2.34 ± 0.152	2.33 ± 0.158	

East Friesland x Blackface ewes, the two methods gave similar mean estimates and the correlations between estimates on individual sheep within weeks were high. During this period the mean fat content of the milk was 7.3% for both groups of ewes. Mean lamb liveweights at 42 days of age were 18.6 and 11.4 kg, respectively, for single and twin suckled lambs. The mean daily rates of gain were 325 and 225 g/d respectively. At this time the experimented group, which had been offered the standard diet of the region with an additional 30% of concentrates, had an advantage over the main flock of over 2 kg in mean liveweight of single lambs, but there was no significant difference in the case of twin lambs. It appears that the relatively low milk yield of twin-suckling ewes is unlikely to be increased by economic levels of supplementary feed, and that the breed is more suitable to the rearing of good single lambs under the standard low-cost feeding system.

Milk recording continued for a further 8 weeks during which time the ewes began to graze pasture for a limited period each day. These results are still to be analysed.

During the period of this visit, results of studies commenced in the previous visits on the performance of other crossbred sheep and on the annual pattern of sperm production in rams were prepared for publication.

GENOTYPES

01004 : The effectiveness of new genotypes 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 J.Z. Foot

As the proportion of improved land associated with indigenous hill pasture is increased the performance of pure hill breeds improves and may approach the practical limits of their genetic potential in all aspects of production. The suitability of improved genotypes, formed by cross-breeding of the basic hill breed, for increased exploitation of improved hill environments is being examined in a long-term study carried out in the Mid and West Finella hill units at Glensaugh. Reseeds which were established many years ago were incorporated into the general management of the existing sheep stock on these units resulting in considerable increases in performance.

In 1974 an internal crossbreeding structure was established to allow comparisons of the performance of two first-cross ewe genotypes (formed by mating a proportion of the original stock to either Texel or Border Leicester rams) with the pure bred Blackface ewes. A balanced age structure is being developed within each of the three genotypes which make up the total flock. The distribution of ewe numbers by age at mating in 1977 (November) is shown in Table 1.

Detailed comparisons will be carried out when the final age structure is achieved. The performance results for 1977 are given in Tables 1 and 2 which show the pre-mating weights of each age and breed group of ewes (November 1976), 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 1976 Mid Finella	West Finella	Mean	Weaning August 1977 Mid Finella	West Finella	Mean
Blackface						
4 crop ewes	58.7 (18)	57.8 (20)	58.2	60.6 (18)	60.8 (19)	60.7
3 crop ewes	63.3 (20)	57.1 (21)	60.1	65.2 (18)	59.5 (21)	62.1
2 crop ewes	57.3 (17)	52.1 (17)	54.7	59.3 (17)	55.2 (15)	57.4
1 crop ewes	54.2 (22)	49.1 (22)	51.6	59.2 (22)	53.6 (22)	56.4
All ewes	58.3 (77)	54.0 (80)	56.1	61.0 (75)	57.3 (77)	59.1
Blackface x Border Leicester						
1 crop ewes	56.1 (20)	52.9 (19)	54.6	57.6 (19)	55.0 (18)	56.3
Texel						
1 crop ewes	57.0 (18)	54.5 (18)	55.8	57.9 (18)	55.3 (18)	56.6

Table 2

Lamb weaning weight by genotype

Genotype	Dam	Sire	Heft	Mean weaning weight (kg)	No. of lambs	Combined mean (kg)
(1)	Blackface	Blackface	Mid Finella	28.4	35	28.7
			West Finella	28.9	45	
(2)	Blackface	Border Leicester	Mid Finella	30.0	22	30.0
			West Finella	30.1	21	
(3)	Blackface	Texel	Mid Finella	27.6	33	27.5
			West Finella	27.3	22	
(4)	Blackface x Texel	Dorset Down	Mid Finella	31.3	46	30.6
			West Finella	29.9	49	
(5)	Blackface x Border Leicester	Dorset Down	Mid Finella	29.0	55	28.8
			West Finella	28.6	49	

Male lambs of the pure Blackface and of the two first-cross genotypes were taken at weaning for a continuation of the study of breed differences in carcase composition and feed efficiency (ref. p).

2. Voluntary intake, growth, body composition and carcass characteristics of pure Scottish Blackface, Texel x Blackface and Border Leicester x Blackface weaned lambs reared and finished under identical systems of management (01004/02001/02003).

J.Z. Foot, J.M. Doney, T.J. Maxwell and R.G. Gunn

The value of output from improved systems of hill sheep production may be increased if a breed of ram with preferred carcass traits is used on some of the hill ewes rather than the pure-bred hill ram on all of them.

Cross-bred lambs sired by rams of the Texel breed are recognised as having carcasses which are commercially desirable, and a limited amount of work has been carried out by the MLC to compare the progeny of the Texel sire out of hill ewes with other crosses from the same breed of ewes, and with pure-bred lambs. The current project is designed to extend this work to examine in detail the voluntary intake, growth, body composition, efficiency of food utilisation and carcass characteristics of Scottish Blackface, Texel x Blackface and Border Leicester x Blackface lambs. The plan is to carry out a series of comparisons under systems of management appropriate to hill and upland areas including, eventually, finishing on forage crops (e.g. rape and turnips).

The initial work has been with housed lambs. In the first year (1976) weaned male castrate lambs of the three genotypes were used. They were from the same Scottish Blackface ewe flock (Finella, Glensaugh) and had been reared to weaning under the same conditions of management. The lambs were finished in group pens on a pelleted dried grass and maize diet which was offered ad libitum and they were slaughtered 3, 6, 9 or 12 kg above their weaning weight. In that experiment the pure-bred Blackface lambs grew more slowly and at any given live weight had smaller carcasses than the cross-bred lambs. The Texel x Blackface lambs had more dissected muscle and less fat than lambs of the other two genotypes.

In 1977 the work was extended to include measurement of voluntary intake by individual lambs in order to determine whether any apparent differences in rate of gain and/or body composition were due mainly to differences in food intake.

Sixty-nine male castrate lambs from the same Blackface ewe flock were selected at weaning. There were twenty-three lambs of each genotype. The animals were kept indoors in individual pens, chopped dried grass was offered ad libitum and voluntary intakes were measured.

An initial slaughter group of four lambs of each genotype was taken at weaning. Subsequently lambs were slaughtered at 36, 39, 42, 45 or 48 kg live weight. There were usually four animals of each genotype slaughtered at each weight.

Lambs were shorn before slaughter and were starved for about seven hours. Carcasses were graded. One side of the carcass was divided into retail cuts and then boned out; muscle and fat were separated. After these had been weighed the various components of the dissected half carcasses were minced together, mixed and sampled for analysis. Analyses were carried out for water, fat, nitrogen, and ash. The non-carcass components for each animal (skin, head, feet, emptied alimentary tract, liver, heart and lungs) were minced together and analysed in the same way as the half carcass. The chemical composition of the carcass, the empty body and total body was calculated.

Lambs in the last two slaughter groups (45 and 48 kg killing weight) were infused with 33 µCi in 1.0 ml of tritiated water (TOH) at weaning and also when they reached their slaughter weight. Best-fit equations relating TOH space at slaughter to chemical composition of the body were calculated.

The mean rates of gain (g/day) for the lambs of each genotype are shown in Table 1. The relative differences in rate of gain of lambs of the three genotypes were not the same as those observed in the previous year. Rate of gain of Texel cross-bred lambs was not significantly higher than that of Blackfaces and was significantly lower ($P < 0.05$) than that of the Border Leicester cross-bred lambs; previously the mean daily gain of the two types of cross-bred lambs had been similar and significantly higher than that of the Blackface. The change in the relative growth rate of the Texel cross breed was due to a higher mean growth rate in the second year in lambs of the other two genotypes (Table 1).

Table 1

Rate of gain, voluntary intake and efficiency of feed use in weaned lambs of three genotypes.

Genotype (Number of lambs)	Weaning weight (kg) Mean (SD)	Rate of gain (g/day) Mean (SD)	1976	Daily dry matter intake (g) Mean (SD)	kg food dry matter/ kg gain Mean (SD)
Scottish Blackface (17)	26.9 (3.56)	171 (36.0)	139	1006 (106.7)	6.11 (1.27)
Texel x Blackface (18)	27.3 (4.11)	183 (41.3)	193	1045 (95.7)	5.87 (1.31)
Border Leicester x Blackface (15)	27.5 (2.67)	217[A] (43.0)	196	1161[B] (72.7)	5.55 (1.12)

[A]Rate of gain of Border Leicester x Blackface lambs significantly greater than that of Blackface lambs ($P < 0.01$) and Texel cross-bred lambs ($P < 0.05$).

[B]Intake of Border Leicester x Blackface lambs significantly greater than in the other two groups ($P < 0.001$).

Differences between genotypes in rate of gain were directly related to differences in voluntary intake; the Border Leicester cross-bred lambs had a significantly higher intake ($P < 0.001$) than lambs of the other two genotypes. There was no statistically significant difference in the efficiency of feed use for weight gain (Table 1). However, Blackface lambs used 62.3 g feed DM/g gain in body protein, significantly more than Texel cross-bred lambs (52.5 g) ($P < 0.05$) and tending to be more ($P < 0.1$) than Border Leicester cross-bred lambs (54.6 g). This was because the Texel cross-bred lambs, as in the previous year, tended to have a higher protein content than Blackface lambs in the total body. The Border Leicester cross-bred lambs were intermediate to the other two genotypes. (Table 1). Again as in the previous year, Texel cross-bred lambs tended to have less fat in the total body than the pure-bred Blackface lambs, but, in contrast to the previous year, the Border Leicester cross-bred lambs had as low fat content as the Texel cross-breeds (Table 2).

Differences between genotype in cold carcass weight at any one live weight were not apparent in the same way as in the previous year. Carcasses from Blackface lambs were just as heavy as those from Border Leicester cross-bred lambs of the same live weights, though they still tended to be lighter than those from Texel cross breds (Table 2).

Table 2

Equations relating cold carcass weight, total body fat and total body protein to slaughter weight in lambs of three genotypes.

Dependent variable	(A) Genotype	Regression coefficient for slaughter weight	Constant	R	SE of regression	Value of Y when X = 39 kg
Cold carcass weight	BF	0.518	-2.25	0.96	0.837	18.0
	GF	0.495	-1.54	0.94	1.055	17.8
	T	0.515	-1.38	0.95	0.941	18.7
Total fat	BF	0.326	-6.24	0.94	0.649	6.48
	GF	0.284	-5.68	0.85	0.985	5.40
	T	0.281	-5.12	0.90	0.767	5.83
Total protein	BF	0.118	+0.717	0.93	0.262	5.31
	GF	0.115	+0.89	0.91	0.288	5.38
	T	0.136	+0.40	0.92	0.313	5.70

(A) BF Blackface, GF Border Leicester and Blackface T Texel and Blackface

The difference in chemical composition between carcasses from lambs of the different genotypes were not great, although comparison of the carcasses from Blackface lambs with those from Texel cross-bred lambs showed the same tendency as previously for the pure-bred lambs to have somewhat fatter carcasses with a slightly lower protein content (Table 3). This time, though, carcasses of the Border Leicester cross-bred lambs contained the greatest amount of ether-extractable fat. On the other hand these animals did not have the most dissectable fatty tissue in their carcasses. The Blackface carcasses had the highest amount, about 13% more than in the carcasses from the Texel cross-bred lambs. The latter once more had the most dissectable muscle (Table 3).

Results from the TOH infusions are still being calculated.

The comparisons between lambs of these three genotypes will be continued with lambs at pasture.

Table 3

Equations relating chemically determined protein, water, fat and ash to carcass weight, and dissected muscle, fat and bone to carcass weight in lambs of three genotypes.

Dependent variable (Y)	(A) Genotype	Regression coefficient for carcass weight	Constant	R	SE of regression	Value of Y when X = 17.0
Protein	BF	0.127	0.664	0.951	0.147	2.82
	GF	0.116	0.817	0.898	0.147	2.79
	T	0.157	0.316	0.909	0.214	2.98
Water	BF	0.479	1.726	0.983	0.315	9.87
	GF	0.377	2.952	0.958	0.292	9.36
	T	0.449	2.242	0.966	0.359	9.88
Fat	BF	0.339	-2.119	0.950	0.394	3.64
	GF	0.468	-3.838	0.961	0.350	4.12
	T	0.374	-2.877	0.922	0.467	3.48
Ash	BF	0.033	0.114	0.903	0.056	0.68
	GF	0.038	0.114	0.810	0.071	0.76
	T	0.033	0.148	0.775	0.079	0.71
Muscle	BF	0.400	2.09	0.889	0.622	8.89
	GF	0.400	2.47	0.812	0.875	9.27
	T	0.436	2.16	0.893	0.650	9.57
Fat	BF	0.490	-3.21	0.942	0.527	5.12
	GF	0.501	-3.95	0.946	0.525	4.57
	T	0.416	-2.66	0.870	0.699	4.41
Bone	BF	0.118	0.96	0.774	0.291	2.97
	GF	0.086	1.45	0.610	0.339	2.91
	T	0.077	1.42	0.524	0.373	2.73

(A) BF Blackface, GF Border Leicester X Blackface, T Texel X Blackface

NUTRITION IN PREGNANCY

02002 : Nutritional physiology of the pregnant ewe

1. Late pregnancy nutrition in hill and upland sheep

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

Our earlier studies, with both Blackface and Greyface ewes, on the relationship between the severity of undernourishment and lamb birth weight have led to the formulation of what we regard as an acceptable nutritional state during late pregnancy. In general terms this can be described as a moderate degree of undernourishment, in which the ewe's energy intake is some 25% less than full requirements, but which results in only a small and acceptable reduction (less than 10%) in lamb birth weight. More specifically, this nutritional state is characterised by a plasma ketone concentration in individual ewes of 5 mg/100 ml, or a 3-hydroxybutyrate (3-OHB) value of 1.1 mmol/l.

We currently use plasma ketone or 3-OHB concentrations as a means of regulating inputs during late pregnancy, both in experimental work and in development projects. We consider, however, that there are two areas which require further investigation.

The first is the development of a wholly objective means of regulating food inputs during late pregnancy to achieve and then maintain a prescribed nutritional state. Despite our earlier attempts to derive and use a mathematical model as a basis for the adjustment of levels of supplementary feeding, it must be conceded that subjective judgements, based now on some considerable experience, have on occasion taken precedence over the wholly objective approach. Recent work here on the nutrition of pregnant upland sheep (Russel, Maxwell, Sibbald and Macdonald, 1977) and at the Rowett Research Institute on the growth of the products of conception (Robinson, McDonald, Fraser and Crofts, 1977) has provided additional information which we have incorporated in a modified programme for the computation of feed regulation, which is described below.

The second area in which further investigation is required is in the objective determination of the prescribed acceptable nutritional state applicable to the flock situation, in which ewes are fed as groups, and where foetal number and stage of pregnancy vary.

a) Late pregnancy ewe feed adjustment programme

A.J.F. Russel, A.R. Sibbald and T.J. Maxwell

Our first attempt to develop objective means of regulating quantities of supplementary feeding during late pregnancy was based on the relationship between plasma ketone concentration and energy status in Scottish Blackface ewes (Foot, Russel, Maxwell and Morris, 1973). From this relationship the quantity of feed required to change plasma ketones from the actual concentration to the prescribed level was calculated. To this was added an additional quantity of feed to meet the calculated increment in foetal growth over the period of time until the next ketone determination was made. Foetal weights were estimated from Donald and Russel's (1970) relationship between lamb birth weight and ewe mating weight, and linear foetal growth over the final weeks of pregnancy was assumed. Fuller details of this approach have been described by Russel (1978).

More recently derived estimates of foetal energy requirements in Greyface ewes (Russel et al, 1977) indicate appreciable changes with time when the additional energy costs of pregnancy are calculated per unit weight of foetus, increasing from 1.54 MJ ME/kg foetus/day one week before lambing to 2.22 MJ ME/kg foetus/day at five weeks prepartum (Table 1).

Table 1

Estimates of foetal and total conceptus energy requirements in late pregnancy

Weeks prepartum	Energy requirements (MJ ME/kg/day) Foetus	Conceptus
1	1.54	0.91
2	1.62	0.93
3	1.56	0.92
4	2.07	0.87
5	2.22	0.81

A new relationship between energy status and plasma 3-OHB concentration, which we now use in preference to total plasma ketones, has been derived from the results of the recent experiment with pregnant Greyface ewes. Estimates of energy status were calculated, using Robinson *et al*'s predictive equations and our actual lamb birth weights for each week of late pregnancy for each ewe. The relationship was:-

$$y = 0.5272 + 0.1616e^{-0.02123x}$$

where y is 3-OHB concentration and x is energy status (kJ ME/kg/day). This equation and that originally derived from data on Blackface ewes are illustrated in Fig. 1. The two relationships are clearly very similar when energy status is positive or slightly negative; at energy deficits in excess of 50 kJ ME/kg/day the more recent equation indicates a greater

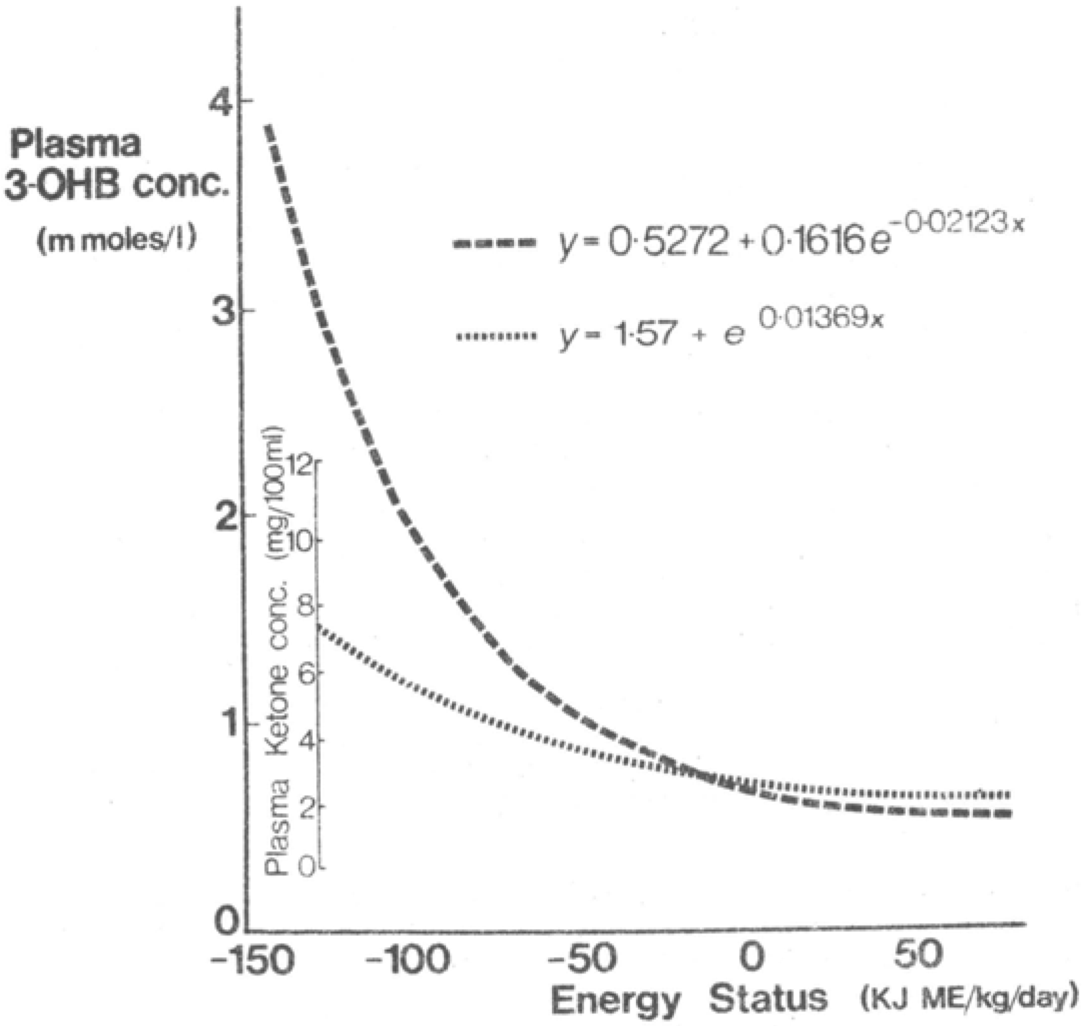

Figure 1

rate of change in 3-OHB concentration than did the original equation. Energy balances in the original and new equations are represented by 3-OHB concentrations of 0.71 and 0.69 mmol/l respectively.

Equation (1) can be rewritten as:-

$$y = 0.108W \log_{10} \frac{(x_1 - 0.5272)}{(x_2 - 0.5272)}$$

where y is the additional of energy (MJ ME/day) required to change plasma 3-OHB concentration (mmol/l) from x_1, the actual value, to x_2, the prescribed value, in ewes of Wkg live weight. To this is added a term to include the increment in energy requirement due to the increase in weight of the foetus during the subsequent week, thus giving an equation of the form:-

$$y = 0.108\ W \log_{10} \frac{(x_n - 0.5272)}{(x_{n+1} - 0.5272)} + (Ef_{n+1}Fw_{n+1} - Ef_n\ Fw_n)$$

where Ef is the foetal energy requirement (MJ ME/kg foetus/day), Fw is foetal weight (kg), and n is the number of weeks prior to parturition.

Equation (3) is used as the basis of a computer programme to calculate feed adjustments on either an individual or a flock basis for ewes varying in live weight, expected lambing percentage, current and prescribed 3-OHB concentrations, and date of lambing.

Having calculated the change in energy intake required to bring actual plasma 3-OHB concentrations to the prescribed level, the programme then uses the expected lambing percentage to determine the number of single-, twin- and triplet-bearing ewes in the flock. We find that the direct application of Robinson et al's equation for foetal weight provided birth weights which are too high for the situations with which we are dealing, and we prefer to use the equations of Donald and Russell (1970), relating the birth weights of single, twin and triplet lambs to ewe premating metabolic live weight, to calculate expected mean litter birth weights. Total foetal weight in any particular week is then determined by substituting this predicted litter birth weight in Robinson et al's equation. The weights of the other products of conception in the same week are calculated directly from Robinson et al's equations for placenta, fluids and empty uterus.

A similar calculation is performed to determine total conceptus weight in the following week, and an estimate of the energy required for the change in conceptus weight is then computed.

The two parts of equation (3) i.e. the energy required to change the plasma 3-OHB concentration and that needed to support the increment in conceptus weight, are summed and the result is printed as an energy change (MJ ME/head/day) and as its DOM equivalent (g/head/day).

It is planned to test this programme in two experiments during the next late pregnancy period. An outline of these experiments is given in sections b and c below.

b) <u>The determination of the amount and pattern of supplementary feeding during late pregnancy</u>

A.J.F. Russel and T.J. Maxwell

The two objectives of this experiment are (i) to test the model used to calculate changes in supplementary feeding during late pregnancy, and (ii) to measure the effect on lamb birth weight of the pattern of feeding during late pregnancy.

The design consists of three groups, each of twenty individually-fed pregnant Scottish Blackface ewes. The number of foetuses each ewe is carrying will have been determined radiographically.

The first group of ewes will receive amounts of feed calculated in advance to maintain the same constant nutritional state (characterised by plasma 3-OHB concentration of 1.1 mmol/l) in each animal. These allowances will be calculated on a weekly basis, taking account of ewe live weight, foetal number and time from parturition.

Ewes in the second group will receive allowances of food calculated in the same way as in the first group, but fed at a constant amount per day throughout late pregnancy.

The third group of ewes will be fed strictly according to the model described above on the basis of plasma 3-OHB concentrations, taking account again of foetal number, ewe live weight and time from parturition.

Plasma 3-OHB concentrations will be estimated weekly in all ewes as an index of energy status.

Comparisons of the nutritional states and amounts of food being given to ewes in the first and third groups will provide a test of the food adjustment model, and will also provide data from which any necessary modifications to the model may be made.

Feed inputs to ewes in the first and second groups will be the same, and a comparison of the birth weights of lambs will constitute a measure of the effectiveness of using an incremental pattern for supplementary feeding in late pregnancy.

c) <u>Studies in late pregnancy supplementation under field conditions</u>

A.J.F. Russel, T.J. Maxwell and J.A. Milne

In seeking to apply to the flock situation the approach of controlling nutritional state in late pregnancy developed with individually-fed sheep, it is necessary to alter the target or prescribed 3-OHB concentration.

In any flock there is likely to be considerable variation between individuals, both in energy intake and in energy requirements. Variation in requirements arises from differences in foetal numbers and stage of pregnancy. If the mean plasma 3-OHB concentration of a group of pregnant ewes is maintained at that level which is indicative of the nutritional state appropriate to the individual ewe, then a proportion of the ewes will inevitably be more severely undernourished. Gnerally, these will be the ewes with the higher requirements (i.e. those with the greater number of foetuses and those most advanced in pregnancy) and which have the greatest need of supplementary feeding. To keep the severity of undernourishment of such ewes within acceptable limits, the prescribed mean plasma 3-OHB concentration of the group or flock must be decreased i.e. the mean energy deficit must be reduced. At present we use an arbitrarily selected plasma 3-OHB concentration of 0.8 mmol/l (equivalent to a plasma ketone concentration of 3 mg/100 ml) in regulating inputs of supplementary feeding in the flock situation, but there is a need to determine the level appropriate to group-fed ewes more objectively.

An experiment will be conducted at Glensaugh in the 1978 late pregnancy period in which 3 different mean plasma 3-OHB concentrations will be maintained in separate groups each of 20 Greyface ewes. The three predetermined nutritional states will be characterised by mean plasma 3-OHB concentrations of (i) < 0.7 mmol/l (not measurably undernourished); (ii) 0.8 mmol/l (our currently used group-fed level) and (iii) 1.1 mmol/l (our current individually-fed level).

Intakes of roughage and supplementary concentrates will be measured at intervals using chromic oxide. The results of this study will provide information on the relationship between mean nutritional state and its associated variance in group-fed sheep maintained in different levels of undernourishment during late pregnancy. It will also be possible to determine the relative contributions of the variances in energy intake and energy requirements to the measure of variance in nutritional state.

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2. Effects 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

In the systems of hill sheep management being tested in the Organisation's development programme, increased numbers of ewes are grazed during the winter months on smaller areas of low quality indigenous hill pasture than was the case under traditional systems of management. The improved levels of spring, summer and autumn nutrition afforded by the use of better quality pastures in the new systems of management have resulted in the ewes being heavier and in better body condition at the beginning of winter. As ewe numbers have been increased, however, losses of weight and condition during winter, and particularly over the J nuary-February period prior to the beginning of the late pregnancy supplementary feeding, have also increased.

Experiments conducted in the animal house on the effects of different levels of nutrition during mid-pregnancy in adult ewes have not shown any effects on lamb birth weight. Nor is there evidence from the development studies, in which poor mid-pregnancy nutrition is assumed, of any reduction in lamb birth weight. In both situations, however, the nutritional state during late pregnancy has been controlled and maintained without adequate knowledge of what is acceptable at that time.

Despite the lack of evidence of any adverse effects of reduced levels of mid-pregnancy nutrition in ewes, there must obviously be a maximum rate of live-weight loss or a minimum level of body condition beyond which a production penalty in one form or another will be incurred. It would clearly be imprudent to await the manifestation of such a production penalty before embarking on an investigation of the effects of nutrition during mid-pregnancy. The importance of body condition in this context demands that the effects on production of the interaction between levels of "summer" and mid-pregnancy nutrition are also included in this investigation.

It is also clear that any such investigation must embrace the effects of mid-pregnancy nutrition on more than lamb birth weight; ewe milk production, lamb growth rate, and rate of ewe live-weight recovery both during and after lactation may also be affected by the extent of the loss in weight and condition earlier in the year. It is also possible that the input of supplementary feeding required to maintain an acceptable nutritional state in late pregnancy could be influenced by the level of nutrition during the preceding months.

In considering these factors, it became clear that the importance of the role of mid-pregnancy nutrition in overall production was more amenable to investigation in the field situation than under the constraints imposed by animal-house experimentation. It would not be possible, for example, to offer housed animals a diet changing in quality, and hence in intake, in a similar manner to that encountered in the field, particularly over the long period of time which would be required. This latter point is particularly important if it is considered that the depletion of body tissue during January and February may have an effect on the replenishment of these tissues in, say, September and October.

It was against this background that an experiment was initiated at Lephinmore in October, 1976. The objectives of this investigation are (i) 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 (ii) 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 - 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: to date the levels of feeding have been 100, 300 and 500 g/ewe/day to the Low, Medium and High mid-pregnancy groups respectively.

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 some time 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 heggs 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. To enable estimates to be made of the use and replenishment of body reserves throughout the year, detailed body composition studies are being conducted on an additional 70 ewes. These are being slaughtered over a period of two years to allow measurements of body condition to be related to directly measured body composition. The use of tritiated water in the indirect determination of body composition in grazing ewes is also being examined in these animals in collaboration with Dr Foot.

The pattern of live-weight changes of ewes in each of the six groups over the first year of the experiment is illustrated in Fig. 1. The high "summer" nutrition groups obtained a considerable live-weight advantage from the grazing of improved pasture over the pre-mating period, and this was maintained to the beginning of the mid-pregnancy period and indeed was still apparent at lambing time. The mid-pregnancy nutritional treatments were 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 9.5 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 (range = 1.5 kg). 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 the hill grazings available to these ewes.

Over the course of the first year mean ewe live weight increased by 5.2 kg. At the end of the year there was little evidence of any difference between groups which would be likely to result in production differences in the following year.

The quantities and costs of the concentrate inputs to the three winter nutrition groups during mid and late pregnancy are summarised in Table 1. Small quantities of hay were also used as storm feeding. Differences in the input of concentrates required to maintain the same prescribed nutritional state in the three groups during late pregnancy were small.

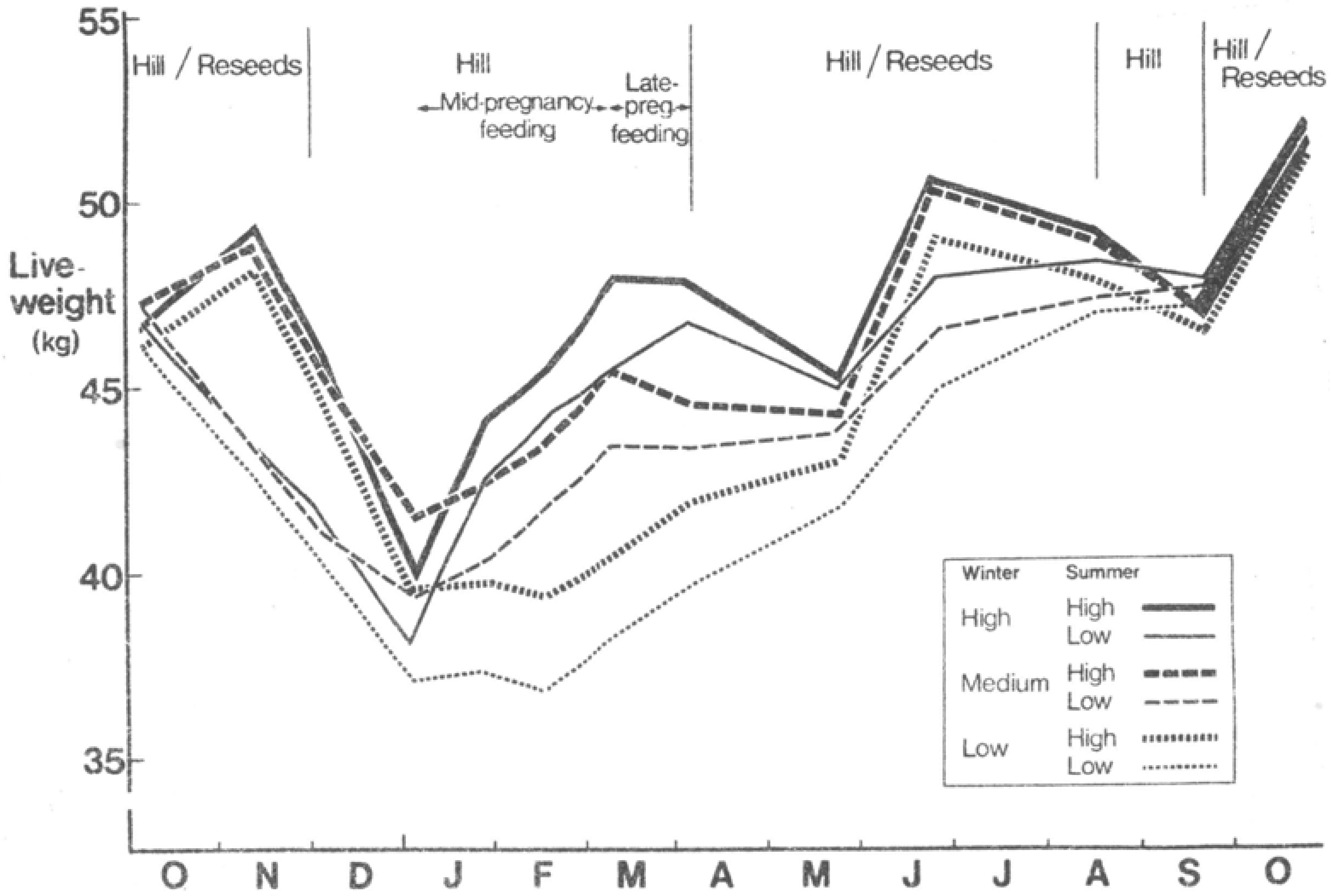
55
50
45
40
35
Live-weight (kg)
Hill / Reseeds
Hill
Mid-pregnancy feeding
Late-preg feeding
Hill / Reseeds
Hill
Hill / Reseeds
O N D J F M A M J J A S O
Winter
Summer
High
High
Low
Medium
High
Low
Low
High
Low

Figure 1

Table 1

Quantities and Costs of Mid and Late Pregnancy Concentrate Inputs

Winter Nutrition	High	Medium	Low
Mid-pregnancy			
(kg/ewe)	31.5	18.9	6.3
(£/ewe)	3.47	2.08	0.69
Late pregnancy			
(kg/ewe)	14.4	13.3	13.5
(£/ewe)	1.60	1.46	1.49
Total			
(kg/ewe)	45.9	32.2	19.8
(£/ewe)	5.07	3.54	2.18

The effect of the mid-pregnancy nutritional treatments on lamb birth weights (Table 2) are of interest. There were an insufficient number of twins born in any group for figures to be meaningful, and for this reason weights of only single lambs are presented here. Despite a small live-weight

Table 2

Mean Weights (kg) of Single Lambs from Ewes in the Six Treatment Groups, at Birth, Marking and Weaning

Summer Nutrition		Winter Nutrition			
		High	Medium	Low	Mean
High	Birth	4.1	4.1	3.6	3.93
	Marking	12.2	12.4	11.3	11.97
	Weaning	27.8	27.3	26.4	27.17
Low	Birth	3.9	3.9	3.6	3.80
	Marking	10.1	10.1	8.5	9.57
	Weaning	25.8	25.9	23.7	25.13
	Birth	4.00	4.00	3.60	3.87
	Marking	11.15	11.25	9.90	10.77
	Weaning	26.80	26.60	25.05	26.15

gain during late pregnancy in the Low mid-pregnancy nutrition group, the reason for which is not clear at this stage, but which contrasted with the pattern of live-weight change in the other two groups, the birth weights of single lambs from ewes in this low group were reduced by about 10%. There is no evidence that the late pregnancy nutrition of ewes in this group was poorer than in the other groups - indeed all the indications are to the contrary - and although it would be unwise to read too much into one year's results, it would appear that this effect of lamb birth weight must be attributed to the level of nutrition during mid-pregnancy.

The data in Table 2 show that the reduced birth weight 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.

The first year's production data are summarised in Table 3. Differences between the high and low summer nutrition treatment groups in the number

Table 3

Percentages of Lambs Born, Marked and Weaned, and Weight of Weaned Lamb Produced, from Ewes in the Six Treatment Groups

Summer nutrition		Winter Nutrition			Mean/total
		High	Medium	Low	
High	Lambing %	100.0	91.8	88.5	93.4
	Marking %	83.6	83.6	70.5	79.2
	Weaning %	83.6	77.0	70.5	77.0
	Total output weaned lamb (kg)	1418	1274	1135	3827
Low	Lambing %	82.0	80.3	77.0	79.8
	Marking %	68.9	68.9	54.1	64.0
	Weaning %	60.7	67.2	54.1	60.7
	Total output weaned lamb (kg)	966	1062	789	2817
Mean/total	Lambing %	91.0	86.1	82.8	86.6
	Marking %	76.3	76.3	62.3	71.6
	Weaning %	72.1	72.1	62.3	68.9
	Total output weaned lamb (kg)	2384	2336	1924	6644

of lambs born can be attributed to the use of improved pasture before and in the early part of the mating period. There is also, however, an indication of an effect of level of winter nutrition on lambing percentage, which, if confirmed by subsequent years' results, is considered to merit further investigation.

The major differences in production among treatment groups result from the two levels of summer nutrition. Ewes utilising improved pasture produced a 36% greater weight of lamb at weaning time than did those which were restricted to the hill grazings. There was no real difference in production between the high and medium levels of winter nutrition, but those on the low level suffered a production penalty of some 20% in weight of weaned lamb produced.

3. The evaluation of the possible use of plasma urea nitrogen concentration as an index of protein status in sheep

A.J.F. Russel and I.R. White (with I.F. Adu, National Animal Production Research Institute, Nigeria, and A.R. Egan, Waite Institute, Australia)

Other sections of this report deal with the use of blood metabolites as indices of energy status in sheep. The usefulness of assessments of energy status lies in the fact that we have some notion as to what constitutes an acceptable energy status at any particular stage of the annual cycle, and some knowledge of the effects on production of different nutritional states at various stages of the cycle.

Comparable quantitative relationships with respect to the assessment of protein status do not exist. In very general terms we can state from experience that plasma urea nitrogen (PUN) concentrations of less than 5 mg/100 ml probably indicate an unsatisfactory protein status, and that values of more than 10 mg/100 ml suggest that the animal is not in a serious negative nitrogen balance.

Analyses by Sykes (Animal Diseases Research Association), of data from joint HFRO-ADRA work on Scottish Blackface ewes at Glensaugh, suggest that PUN concentrations are reasonably closely related to protein status, defined as the difference between apparently digested nitrogen intake and nitrogen utilised for production (ADNI – N prod/$kg^{0.75}$). Sykes has also shown that data from the literature appear to conform to the same relationship. Data from experiments by MacRae and Milne, working with Agrostis-fescue diets, and by Tait, Milne and Russel, with heather diets, appear to support Sykes' hypothesis, although these results are all very much at the lower end of the range covered by the other workers' data.

An experiment was conducted late last year to evaluate the possible usefulness of PUN as an index of protein status in sheep. Twelve Scottish Blackface wether sheep were fed diets of chopped hay, chopped straw, starch and casein calculated to supply four levels of nitrogen intake (0.15, 0.325, 0.5 and 0.675 g ADN/$kg^{0.75}$/day) at each of three levels of energy intake (190, 320 and 450 kJ ME/$kg^{0.75}$/day). The different energy levels were included because of the known effects of energy on the efficiency of utilisation of nitrogen, and because there is reason to believe that the relationship between PUN concentration and nitrogen status may be affected by energy status.

The experiment comprised four 17-day periods. Measurements of urine output were made each day, faeces were collected for the final eight days of each period, and blood samples were taken on eight days throughout each period. To facilitate examination of the effects of changes in both energy and nitrogen intake on PUN concentration, the animals were moved in an orthogonal manner to new treatments each period, changing treatment by either one energy increment or two nitrogen increments.

The chemical analysis of the many samples collected during the course of the experiment are not yet completed. These analyses will include, in addition to concentrations of urea nitrogen in plasma and urine, and total nitrogen in urine and faeces, the estimation of plasma amino acids, in order that we may also evaluate the plasma glycine : total amino acid – glycine ratio which Egan has suggested as an index of protein status.

Urine samples are also being analysed for 3-methyl-histidine to evaluate the possible use of this metabolite as an index of the rate of breakdown of a major protein fraction in muscular tissue, which constitutes an important protein pool in the body.

Estimates were also made during the course of the experiment of urea entry rates, to provide information on urea production and recycling rates and so afford a better understanding of the dynamic state underlying responses in plasma urea concentration.

NUTRITION AND BODY COMPOSITION

02003 : Interactions between nutrition and body composition in sheep

1. Changes in body composition in lactating ewes

J.Z. Foot, E. Skedd and D.N. McFarlane

Much work has been done on lactation in hill or upland sheep, particularly on the nutrition and milk output of the ewe and on the growth of the lamb. However the ability of the ewe to draw on energy stored in the body when output exceeds the current intake of feed has received less attention. This needs to be taken into account if the partitioning of nutrients by the lactating ewe is to be understood, and if there is to be a logical basis for manipulation of the year-round nutrition of the ewes.

Until recently it has not been possible to assess the extent to which lactating ewes use body reserves during this period of peak nutrient requirements. Nor has it been possible to ascertain when the ewe starts to recover body reserves, although it is known that an inability to do so fast enough may jeopardise the outcome of the next mating.

Measurement of live weight alone during lactation is of little use as an indicator of changing body composition because variations in body water mask changes in other body components. Slaughter of animals give absolute values at one particular time but prevents sequential measurements being made in the same animals.

Changes in body composition require to be measured in the course of lactation experiments, where feed intake and milk yield are being monitored, in order to gain an understanding of the contribution of body reserves to lactational output.

Non-destructive measurements of body composition have been carried out in non-lactating ruminants using isotopes of water to measure body water by dilution, and subsequently body fat and other components, from relationships previously derived between these components and body water and live weight. However little work has been done with lactating animals, either in terms of absolute body composition measured by slaughter, or of sequential changes in body composition during lactation measured periodically using isotopes of water. Consequently, it was necessary to carry out some preliminary work to assess the range of fatness which might be expected in lactating ewes, and the accuracy with which this could be measured.

Previous work

A preliminary experiment was carried out in 1976 on 22 mature Scottish Blackface ewes which were infused with tritiated water (TOH) at two-week intervals, twice before lambing and throughout lactation. Ten were slaughtered five weeks after lambing, the rest were taken on through weaning and slaughtered at the next mating time (November).

The relationships shown in Table 1 indicate that the use of TOH

Table 1

Prediction of body fat (kg) in ten lactating ewes

REGRESSION COEFFICIENTS						
Live weight	Body water	TOH space	Difference between live weight at infusion and at slaughter	Constant	R	SD
0.567[A]				-24.40	0.899	2.731
0.920[A]	-1.207			1.91	0.997	0.516
0.896[A]		-1.168		1.82	0.993	0.767
0.942[B]		-1.296		0.36	0.995	0.658
0.928[B]		-1.253	-0.415	0.37	0.997	0.587

A : live weight at slaughter

B : live weight at infusion (7 h before slaughter)

increased the accuracy of prediction of body fat in lactating ewes (which ranged in fatness from 2.1 to 24.0% of live weight) when compared with the accuracy of prediction from live weight alone, and was potentially useful for nutrition experiments. An important factor in measurement of body fat in these lactating ewes was the increase in accuracy of prediction when the loss of weight between infusion and slaughter was included as a third variable (Table 1).

Additional information was obtained on rate of water turnover and half life of the marker which could be related to the number of lambs suckled and the nutrition of the ewe. An example is given in Table 2 which gives results of measurements made at about the time of peak lactation,

Table 2

Water turnover and half-life in lactating and dry ewes, measured using tritiated water

	Water turnover (kg/day)		Half life (days)	
Level of nutrition	High	Low	High	Low
Ewes suckling twin lambs	11.3 (4)[A]	6.4 (2)	2.6	4.4
Ewes suckling single lambs	8.2 (7)	6.3 (8)	3.3	3.8
Dry ewes	4.3 (2)	-	6.1	-

( )[A] number of ewes in treatment

approximately three weeks after lambing.

1977

Twenty-six mature Border Leicester and Blackface ewes, all bearing twin lambs were housed just before lambing. They were infused with 100 µCi TOH approximately one week after lambing. There was a second infusion four to five weeks later when nine animals which had been at pasture for three weeks were slaughtered. The remaining animals were put out to pasture and were infused just before slaughter at weaning, twelve weeks after lambing.

The TOH results are still being calculated. It appears, however that in these animals the nature of the sample militated against useful results being obtained from the use of TOH except in serial samples over a long period. All the animals were very thin (3.8% ± 2.73, mean ± SD of fat in total body), and were thus at the extreme end of the possible range so that there was little variation on which to base a scale relating fat to water. The standard deviation for the estimate of fat (% slaughter weight) from directly determined water (% slaughter weight) was 1.02%. This was similar to that obtained for the Blackface ewes in the previous year (0.99%) but the mean and range of fat had been much greater in the Blackfaces, 17.7% ± 8.68 (mean ± SD), providing a sound basis for estimation of body fat.

The extent to which these ewes suckling twin lambs drew on their body reserves was considerable and in some cases ewes must have been close to having only essential lipids remaining in the body (one ewe had only 350 g fat). This appears not to be unusual in lactating ewes. Similar results have been obtained recently from ewes suckling single lambs at Lephinmore. The results emphasise the importance to the lactating ewe of the mobility of body reserves. They also highlight the need for further work on the implications for subsequent production of such extensive withdrawal of body reserves for lactation.

NUTRITION : HEATHER

02004 : Nutritive value of heather to sheep

1. The effect of supplementation on the voluntary intake of diets containing proportions of heather and Agrostis/Festuca. The use of ^{103} Ruthenium Phenanthroline as a particulate marker

A.M. Spence and J.A. Milne

^{103}Ruthenium Phenanthroline (^{103}Ru P) meets some of the criteria of an adequate marker in digestive studies in that it is not absorbed from the digestive tract, does not affect the metabolism of rumen microorganisms at low concentrations (1.5 x 10^{5}M) and is associated with the particulate phase. We have used ^{103}Ru P to measure the mean retention time in the digestive tract of the undigested residue of poor quality roughages given to sheep and red deer (Milne, MacRae, Spence and Wilson, 1978) and may have a requirement for the measurement of mean retention time in the future. To satisfy the requirements of an adequate marker in such studies, ^{103}Ru P must (a) label the particulate phase of digesta uniformly on administration and (b) remain associated with those particles to which it initially adheres.

Both these requirements were tested with heather and a grass hay. In one experiment feeds with a range of particle sizes were added to 4 flasks with equal volumes of artificial saliva. Equal volumes of a solution containing ^{103}Ru P were added to the flasks which were incubated at 38°C. Duplicate flasks were removed at ½ h and 24 h after incubation, the contents freeze-dried and shaken through a bank of sieves for 30 minutes. The results for heather are given in Table 1. These show that

Table 1

Proportion of counts per unit mass expressed as a percentage found in feed particle fractions following incubation with ^{103}Ru P.

Particle size	½ h	24 h
> 1 mm	7.3	7.2
425μ - 1 mm	11.2	12.2
300μ - 425μ	18.8	22.3
< 300μ	62.8	58.3

most of the ^{103}Ru P was found to be associated with the smallest particles after ½ h and similarly after 24 h incubation. In a second experiment particles of a size which were retained on a 300μ sieve screen were labelled and mixed with particles of a range of sizes under similar conditions to that of the previous experiment. Duplicate flasks were removed at ½, 2, 5, 24 and 48 h after incubation. From Table 2 it can be seen that ^{103}Ru P did not remain associated with those particles to which it initially adhered, but became progressively associated with the smaller particles of heather. Similar results were found using hay particles.

Table 2

Proportion of counts per unit mass expressed as a percentage found in feed particle fractions following incubation with previously labelled particles in 300μ - 425μ fraction*

Particle size	0 h	½ h	2 h	5 h	24 h	48 h
> 1 mm	0	0.9	0.9	1.2	2.1	3.5
425μ - 1 mm	0	20.0	16.3	15.0	13.2	14.7
300μ - 425μ*	100.0	51.0	49.3	46.0	35.4	24.0
150μ - 300μ	0	15.8	18.5	19.7	23.0	26.3
< 150μ	0	12.3	15.5	18.3	26.3	31.5

The implications of these findings are that the mean retention time of ^{103}Ru P is unlikely to be the same value as that of the mean retention time of undigested feed residues, but is a complex function of it which will be related to the original particle size distribution of the feed and to its rate of breakdown to smaller particles in the rumen. Thus, in circumstances where different feeds were being compared, or where treatments which might influence the rate of breakdown of particles in the rumen were being studied, ^{103}Ru P cannot be used to measure the mean retention time of undigested residues in the digestive tract.

References

MILNE, J.A., MACRAE, J.C., SPENCE, A.M. and WILSON, S. (1978). A comparison of the voluntary intake and digestion of a range of forages at different times of the year by the sheep and the red deer (Cervus elaphus). Brit. J. Nutr. (In press).

UTILISATION : NUTRITION

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

1. The relationships among herbage weight per area, the amount of cereal-based concentrate offered and the herbage intakes of Greyface ewes in early lactation

J.A. Milne and T.J. Maxwell

In upland sheep flocks it is common practice to feed lactating ewes on cereal-based supplement until it is considered that the amounts of herbage are adequate. In these circumstances the amount of herbage per unit area and the amount of supplement given will determine the amount of herbage eaten and, consequently, the intakes of digestible organic matter (DOMI). Little is known of DOMI values under these conditions and Phase 2 of this experiment to be conducted in 1978 will examine the interrelationships between herbage weight, level of supplement and DOMI values of ewes nursing twin lambs in early lactation.

Measurement of DOMI at pasture when supplements are given poses certain problems which were examined in Phase 1 of this experiment. The measurement of intake requires the partition of faecal output into that of concentrate and that of grass origin. This involves the prediction of, or assumptions about, the digestibility of the supplement and of the grass. The preferred method for the measurement of digestibility of grass is its estimation from the in vitro digestibility of extrusa samples from oesophageal-fistulated sheep. The measurement of intake thus depends upon there being predictable associative effects of supplement and grass on total digestibility, a predictable effect of level of feeding on the digestibility of the grass and a close relationship between in vivo and in vitro digestibility of the grass.

These aspects were examined in an experiment in which 16 Greyface ewes with twin lambs were allocated at parturition to 4 treatments of 4 levels of a predominantly barley concentrate, viz. 0, 0.33, 0.66 and 1.00 kg/head/day, and offered freshly harvested herbage from a PRG sward ad libitum. This allowed an examination of possible associative effects on digestibility. A further 12 ewes with twin lambs (4 ewes/additional treatment) were offered the same amount of grass as the estimated mean intake of grass by the ewes on each of the supplemented treatments. These treatments together with the ad libitum grass treatment with zero concentrate were used to examine the effect of level of feeding on the digestibility of the grass. Oesophageal-fistulated Greyface barren ewes were also given the same herbage and extrusa samples were taken daily for in vitro digestibility determination. These values were then compared with in vivo digestibility values. Since there were no period x treatment interactions the results reported in Table 1 are the mean values of the final three 6-day periods in the first month of the experiment.

Table 1

The digestibility of OM and OM intakes of grass by Greyface ewes nursing twins in the first month of lactation, given cut herbage and/or concentrate (Means of 12 observations).

Ad libitum grass	Level of Concentrate (g/day)				SE of Mean
	0	400	800	1200	
OMI of grass (kg/day)	2.21	2.07	1.56	1.55	± 0.091
OM digestibility (%)	84.3	81.4	82.2	80.3	± 0.72
Fixed levels of grass intake					
OMI of grass (kg/day)	2.21	2.04	1.61	1.60	-
OM digestibility (%)	84.3	85.2	83.7	82.9	± 0.48

There was a significant ($P < 0.01$) depression of 0.75 (± 0.242) g OM of grass per additional g OM of concentrate given. Digestibility of OM declined with increasing level of concentrate but only the difference between the 0 and 1200 g/day concentrate treatments was significant ($P < 0.05$). No associative effects of concentrate and grass on total digestibility were demonstrated. Within the range of intakes studied, an increase in the level of feeding of grass did not result in a depression in the digestibility of OM. The mean in vitro digestibility of OM of extrusa samples was 82.1 (± 0.48) and this value was not significantly different from the mean in vivo digestibility of OM of the grass-only treatments.

The results of this experiment indicate that with the levels of supplementary feeding (0-1200 g/day) and with the quality of herbage likely to be ingested in Phase 2 of the experiment, measurement of the intake of grass can be made satisfactory by the partition of faecal output and by the use of an in vitro estimate of the digestibility of grass.

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 Armstrong, J Hodgson, T.G. Common, R.A. Hetherington and G.R. Bolton

The experiments in this series are intended primarily to complement the programme of grazing studies described on page A.43, and also to check the reliability of estimates of herbage intake derived from the predication of in vivo digestibility of the diet from in vitro determinations on sample of herbage collected from animals fistulated at the oesophagus.

1. The effect of freezing or drying on the digestibility of herbage

Italian ryegrass (R.V.P.) was harvested at three different qualities during the growing season. The chopped herbage was fed fresh, frozen (after storage at -20°C) or dried (at 45°C) to 12 Blackface wethers, i.e. 4 per treatment for each quality. Sheep were allocated to treatments in a changeover design according to voluntary intake 'classes' as assessed during the preliminary feeding period. Dried and frozen feeds were fed 4 days after fresh feeds. During digestibility periods, feeding was at 70%-80% of individual voluntary intakes.

Apparent Dry Matter Digestibility

Ryegrass Qualities (with cutting dates)

Treatment	RG 1 (22-29/5)	RG 2 (7-14/6)	RG 3 (11-18/7)	Mean
Fresh	82.13	73.01	58.13	71.09
Frozen	83.18	69.02	57.80	70.00
Dried	79.77	66.83	58.78	68.40
S.E. Diff.	2.007	2.007	2.007	0.898

The depression of digesbility consequent on drying is in accord with previous work. The effect of freezing is more important for our púrposes. The depression with RG 2, (which approaches significance at the 5% level) would in inself be biologically significant, but it is felt that any real effect would be more apparent with the highest quality herbage of which there is no evidence here.

Samples of these feeds have been fed to sheep fistulated at the oesophagus; the digestibility of the extrusa samples so obtained and of the feed will be determined in vitro to allow the creation of feed : extrusa relationships.

2. The relationships between in vivo and in vitro digestibility in a range of plant species.

The aim of this experiment is to create relationships between the in vivo and in vitro digestibilities of frozen feed, and the in vitro digestibility of freeze-dried samples of extrusa from oesophageal fistulates, for the prediction of diet digestibility in the investigation of diet selection and nutrient intake by cattle and sheep grazing a series of hill and upland pasture communities (see p. A.43). The hill herbages are those harvested from communities dominated by *Agrostis-Festuca*, *Nardus stricta*, *Molinia caerulea*, *Eriophorum vaginatum*, and *Trichophorum caespitosum*. *Loliún perenne* (S23) and *Trifolium repens* (Huia) are the upland species. Each of these seven species/communities have been or will be harvested at three stages of maturity; the herbage being fed frozen to sheep at approximately 70% of voluntary intake in three successive monthly periods in two successive years. The design is a cyclic partially balanced incomplete block with 2 sheep on a given feed for one month so that 6 sheep eat each feed.

The first years' work is nearing completion; indications are that the technique adopted has been largely successful and that the range of herbage digestibility is very close to that intended.

In vitro digestibility measurements will be made on samples of all feeds, and subsequently on extrusa samples from sheep and cattle to create relationships between in vivo and in vitro digestibility on feed extrusa.

The in vivo/in vitro relationships derived in this study will be based on measurements made with the least possible restriction of intake necessary to ensure complete consumption of the experimental feeds. Even this may not be enough to eliminate the bias which can be introduced by predicting in vivo digestibility in the field from relationships derived at controlled levels of feed intake indoors. Further trials are planned to evaluate the influence of level-of-intake on digestive efficiency using sheep and cattle, and herbages offering a contrast of species and stage of maturity.

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

J. Hodgson, Richard Armstrong, S.A. Grant, D. Suckling, G.R. Bolton, R.A. Hetherington and T.G. Common

The early systems development projects at HFRO were based largely on information about diet selection and nutrient intake by sheep grazing predominantly *Agrostis/Festuca* communities, and the influence of grazing management on herbage production from these pastures (J. Eadie (1967) and I.A. Nicholson (1967)). Recently information has become available from a Calluna-dominant community (J.A. Milne and Sheila A. Grant (1978)). However, there is little information for the poorer grass-heath and bog communities which occupy a large proportion of hill land in the UK. Furthermore, no comparative information exists on diet selection and nutrient intake by cattle and sheep on natural communities, so there is no objective basis for determining the appropriate balance between the two animal species for particular hill and upland pasture conditions.

This study was set up in 1977 to investigate diet selection and nutrient intake by cattle and sheep grazing a representative series of hill and upland plant communities at different seasons of the year. It is dependent upon the collaboration of members of both departments. Six communities were chosen originally, partly because of their importance in terms of the land area they occupy, and partly because of the range of opportunity offered for selective grazing. They are:-

1. Sown sward dominated by *Lolium perenne* (Glensaugh)
2. Dry heather moor dominated by *Calluna vulgaris* (Glensaugh)
3. Peat bog community dominated by *Calluna vulgaris* and *Eriophorum vaginatum* (Lephinmore)
4. Wet grass heath dominated by *Molinia caerulea*
5. Dry grass heath dominated by *Nardus stricta*
6. Agrostis/Festuca grassland

The Lolium sward was chosen primarily to act as a link with other work on sown swards at HFRO and elsewhere.

Grazing studies started on the first three communities in the summer of 1977. Suitable sites for the last three communities have been acquired recently from the Forestry Commission, and will come into use in the next two years.

The objectives of the study are:-

(a) To compare the selective grazing behaviour of cattle and sheep, and to relate this to detailed measurements of sward structure and botanical composition.

(b) To measure the potential nutrient intake of cattle and sheep at different seasons of the year.

(c) Subsequently to measure the impact of grazing management upon sward composition and herbage production, and upon nutrient intake by grazing animals.

Measurements will be made at each site on several occasions during the year, chosen to cover the main phases of the annual cycle from spring growth to winter senescence. They will be made initially with cattle and sheep grazing together at grazing pressures approximating to traditional levels - i.e. resulting in the removal of only 25-35% of annual production on the poorer communities - but in later phases grazing management will be manipulated to improve the floristic composition of each community, and the consequential changes in diet selection and nutrient intake measured.

Each site (except site 1) is 4-5 ha in area, and is grazed by 10-12 mature, barren suckler cows (Blue-Grey and Hereford x Friesian) and 10-12 hill ewes (Blackface) for 2-3 weeks on each occasion. Measurements of the botanical composition and *in vitro* digestibility of the diet are made on samples collected from 4-6 animals of each species fistulated at the oesphagus; estimates of herbage intake are derived from the digestibility estimates, and measurements of faecal output made on non-fistulated animals. The measurements of diet composition are related to parallel measurements of the botanical composition and structure of the sward, using a combination of point quadrats and stratified sampling. Measurements of grazing mechanics (biting rate, bite size and grazing time, and the depth within the canopy of the grazing horizon) are also made.

Essential background information for this study is provided from indoor trials with sheep to measure the voluntary intake and digestibility (*in vivo* and *in vitro*) of an extensive series of frozen herbages cut from indigenous and sown plant communities as several stages of maturity (see pA.41).

The study is still in its early stages, but preliminary information on diet selection on the *Calluna/Eriophorum* community and on the *Lolium* sward is given under Project 04010 on p C.60 .

References

EADIE, J. (1967). The nutrition of grazing hill sheep; improved utilisation of hill pastures. HFRO 4th Report, 38-45.

NICHOLSON, I.A. (1967). The grazing animal in vegetational control. HFRO 4th Report, 46-50.

MILNE, J.A. and GRANT, S.A. (1978). Better use of heather hills for sheep production. HFRO 7th Report (In press).

4. The influence of sward characteristics and grazing management on grazing behaviour, diet selection and herbage intake by grazing sheep. a. The effect of weight of herbage per unit area, allowance per animal and their interactions

J. Hodgson and J.A. Milne

A knowledge of the factors influencing diet selection and herbage intake by grazing animals, and the extent to which they can be manipulated, is a necessary background to the development of more efficient methods of grazing management. Herbage intake by sheep has been shown to be affected by weight of herbage per unit area and under strip-grazing conditions by allowance per animal but there is little information on the interaction between these two variables. Herbage intake may be mediated by limitations to grazing activity as well as by the mechanisms conventionally postulated for housed animals. Those aspects of grazing behaviour considered to be important are the time spent grazing, rate of biting and the size of individual bites.

To assess the influence of herbage weight per unit area and allowance per animal and their interactions on herbage intake and on grazing behaviour an experiment was conducted in 1976 with Scottish Blackface wether sheep grazing a series of vegetative perennial ryegrass swards. Nine vegetative swards were prepared differing in initial weight of herbage per unit area (1200 to 3600 kg OM/ha) and density (70 to 150 kg OM/ha/cm). The range in weight and density was obtained by varying the cutting regime and fertiliser application prior to the experimental grazing. Each sward was grazed at 3 initial allowances per animal, viz. 16, 32 and 64 kg OM/sheep. The plots thus formed were grazed by 4 sheep for a period of 12 days, divided into three 4-day sub-periods, and measurements of herbage intake (OMI), digestibility (OMD) and grazing behaviour were made in each sub-period.

There was a significant ($P < 0.05$) positive and rectilinear relationship between weight of herbage per unit area and OMI within 6 of the 9 swards studied. A similar relationship was found for the data pooled within sub-periods 1 and 3, and when all the data was pooled (see Fig. 1). There was also a significant ($P < 0.01$) positive relationship

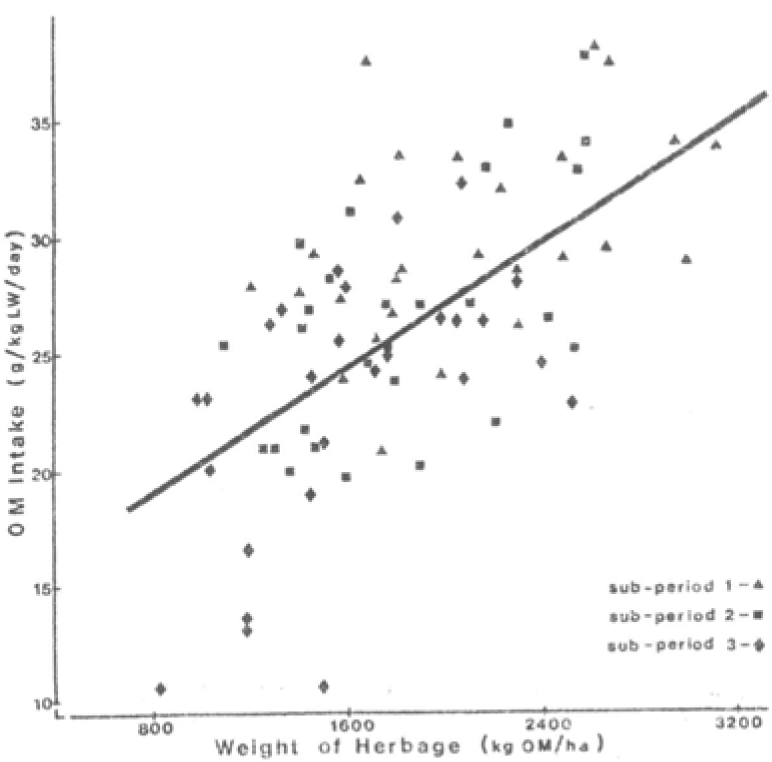

Figure 1 Relationship between intake of OM by sheep and weight of herbage per unit area.

between OMI and herbage allowance in 7 of the 9 swards, in pooled data for the third sub-period, and overall (see Table 1), but not in the first sub-period. Herbage weight and allowance were correlated except

Table 1

Relationships between intake and digestibility of OM, bite size and grazing time (Y) and weight of herbage per unit area (X_1) and per animal (X_2). Pooled data (n = 81 observations)

Y	Regression Equation	r	R.S.D.
	weight of herbage per unit area (X_1) (kgOM/ha)		
Organic Matter Intake (gOM/kgLW/day)	$Y = 0.0067(\pm 0.00103)X_1 + 14.1$	0.59	4.62
Organic Matter Digestibility (%)	$Y = 0.0026(\pm 0.00062)X_1 + 74.7$	0.42	2.79
Bite Size (mgDM/bite)	$Y = 0.020\ (\pm 0.0053)X_1 + 24.5$	0.39	23.0
Grazing Time (h)	$Y = -0.0015(\pm 0.00043)X_1 + 11.1$	0.36	1.94
	weight of herbage per animal (X_2) (kgOM/sheep)		
Organic Matter Intake (gOM/kgLW/day)	$Y = 0.099(\pm 0.0235)X_2 + 22.6$	0.43	5.10
Bite Size (mgDM/bite)	$Y = 0.56\ (\pm 0.097)X_2 + 39.1$	0.55	20.8

in the first sub-period. This evidence, together with the fact that the proportion of variation in OMI explained by regression was always higher for herbage weight/unit area than for allowance per animal, suggests that OMI was more closely related to herbage weight than to allowance.

OM digestibility was positively and linearly related ($P < 0.01$) to weight of herbage/unit area (see Table 1), and also to OMI. It is thus not possible to separate completely the effects of physical limits (related to the digestibility of the diet) and behavioural limitations to intake. However the fact that faecal output declined as the weight of herbage/unit area and diet digestibility decreased suggests that physical limits were unlikely to be important, thus emphasising the influence of aspects of grazing behaviour on the relationships between intake, weight of herbage/unit area and allowance per animal.

Of the three grazing behaviour variables measured, bite size was found to be the most important. In 6 of the 9 swards there were positive and rectilinear relationships between bite size and both herbage weight/unit area and allowance/animal, whilst a significant ($P < 0.05$) negative and rectilinear relationship between grazing time and herbage weight/unit area was found on only 3 of the 9 swards. Biting rate was related neither to herbage weight/unit area nor allowance/animal.

A preliminary report of the results of this experiment is included in the Proceedings of the 1978 Meeting of the European Grassland Federation.

4. <u>The influence of sward characteristics and grazing management on grazing behaviour, diet selection and herbage intake by grazing sheep. b. Studies of sward factors influencing diet selection and rate of herbage consumption by sheep grazing single-species grass swards</u>

J.A. Milne and J. Hodgson

Experiment 1 of this series demonstrated that both herbage intake and the digestibility of the diet were positively and linearly related to the weight of herbage per unit area. Herbage weight can be considered in relation to its components of height and density, particularly of the grazed horizon. Rate of intake may be limited by the density of herbage in the grazed horizon or by its proximity to ground level (Hodgson, 1977) but the relative importance of these variables in influencing rate of intake and diet selection is not well understood. Horizon density may influence diet selection.

An experiment was conducted in 1977 to examine the effect of 3 densities (mean densities approximately 100, 150 and 300 kg DM/ha/cm) and 5 overall heights (25, 50, 100, 150 and 200 mm) of a single species uniform P.R.G. sward on both short-term and daily rates of intake, and on bite size and diet selection using oesophageal-fistulated sheep. The different densities and heights were obtained by different patterns of grazing and of fertiliser application in a preliminary preparation phase. The treatments were replicated over time in July and September. Results of this experiment are not yet available.

Diet selection, as well as being affected by the height and density of the sward, is also likely to be influenced by the distribution of leaf and stem and live and dead material within the canopy, particularly in the top horizons. Two experiments were conducted to test the boundaries of the hypothesis that sheep grazing a uniform single-species sward do so by removing material nearest the top of the sward. A simple single-species grass sward was examined as a prelude to considering more complex swards where, for example, grass and clover are present.

In one experiment the relative composition of top horizons of the sward were altered in two ways (a) by the application of paraquat at low concentrations to produce mixtures of live and dead leaf in swards differing in initial height (50, 100 and 150 mm) and (b) by cutting predominantly reproductive swards to the above heights and regulating the amount of regrowth by varying fertiliser application and the length of the regrowth period. The second procedure produced a better range of treatments. In a second experiment the effects of varying stubble height and also the amount of regrowth above it were examined. Three base heights of swards with a preponderance of dead material (50, 100 and 150 mm in depth) were obtained by frequent cutting during the summer. Regrowth was allowed until new leaf had reached 25, 50 and 100 mm above each of the base heights. In both experiments observations were made on (a) the diet selected, using oesophageal-fistulated sheep, and (b) the sites of removal of different morphological components from within the sward. Results are not yet available.

Automatic equipment has been developed to measure biting rate and grazing time (see pC.91) and this equipment was tested in the above experiments.

<u>Reference</u>

HODGSON, J. (1977). Factors limiting herbage intake by the grazing animal. <u>Proc. Int. Meeting Animal Production from Temperate Grassland</u>, Dublin, June 1977, 70-75.

NUTRITION : METABOLISM

02009 : Mineral nutrition and animal performance

Introduction

The objectives of this project are:-

a) To investigate and quantify the effects of hill land improvement on trace element status and the availability of trace-elements to the grazing animal.

b) To establish satisfactory prophylactic measures which will remove adverse effects upon animal performance due to trace element deficiencies. To achieve these objectives an understanding of the factors involved is necessary.

Previous findings have established the existence of both cobalt and copper deficiencies in the animals grazing some improved pastures, in contrast to those grazing the unimproved hill, on HFRO experimental farms. Studies in cobalt deficiency have investigated the diagnosis and treatment of this condition with particular emphasis on the correlation of serum vitamin B_{12} concentrations and the excretion of a urinary metabolite, formiminoglutamic acid (Russel et al, 1975). Studies in copper deficiency have shown significant differences between copper sufficient and copper deficient twin lambs grazing improved hill pastures in terms of liveweight gains, wool quality, blood parameters and bone structure.

Reference

RUSSEL, A.J.F., WHITELAW, A., MOBERLY, Patricia and FAWCETT, A.R. (1975). Investigation into diagnosis and treatment of cobalt deficiency in lambs. Vet. Rec. 96, 194-198.

1. Copper

A. Whitelaw, R.H. Armstrong, A.R. Fawcett, C.C. Evans, A.J.F. Russel and P. Newbould

In previous studies it was demonstrated that the elevation of molybdenum and sulphur levels in the improved pasture were responsible for an induced copper deficiency in lambs (Whitelaw et al, 1977).

As in 1976, the Alderhope unit at Sourhope was used in these investigations. Two possible means of prophylaxis against the effects of copper deficiency were studied.

(1) The use of a copper injection given to ewes in mid pregnancy at a dosage calculated to elevate the plasma copper concentrations of these animals to the high level of the normal copper plasma range (60 - 160 μgs/ml). This would rely on boosting the foetal lamb's liver copper reserves to give it protection from birth onwards.

(2) The use of a copper injection given to ewes at parturition and, subsequently, to increase the copper content of the milk available to their lambs.

Three groups of ewes were formed.

Group I (17 ewes). 1974 age group ewes given copper in mid pregnancy.
Group II (25 ewes). Twin producing ewes drawn from the 1971, 1972 and 1973 age group ewes at random, and given copper at parturition and subsequently as required to maintain their copper plasma concentrations within the normal range.
Group III (23 ewes). The remainder of the twin producing ewes drawn at random from the 1971, 1972 and 1973 age groups. These acted as controls.

Blood samples from ewes and lambs were taken at fortnightly intervals when lambs were weighed. Milk samples were taken from representative numbers of ewes from each group. Lambs were kept worm free with routine anthelmintic dosage and were each given a cobalt bullet.

Results

Table 1 shows the mean plasma copper concentrations of the ewes pre and post copper injection and from parturition to the end of the study.

Table 2 shows the mean plasma copper concentrations of the lambs of group I and for comparison those of group III control lambs.

One of each pair of twin lambs in all treatment groups was maintained Cu sufficient; those in Group I and Group III from 11/5 and in Group II from 24/6.

Table 3 shows the mean weights of Group I and Group III lambs kept in copper sufficiency by an injection of copper based on plasma copper concentrations, and of the Group I and Group III lambs kept deficient.

These results indicate that the injection of copper to the Group I ewes did not significantly raise the plasma copper levels of the Group I lambs compared with the control lambs (Table 2) and did not show any significant advantages in weight changes for the Group I lambs compared with the control lambs (Table 3).

It is concluded that there is no prophylactic benefit from the use of a mid pregnancy injection of copper given to ewes.

Table 4 shows the mean plasma copper concentrations of the ewes of Groups II and III from birth to weaning. From this it can be seen that the Group II ewes maintained plasma copper concentrations within the normal range throughout the study, whereas those of the control group III ewes fell below the normal range and remained low thereafter. Table 5 shows the mean plasma copper levels of the twin lambs of both groups and includes the levels obtained subsequent to the division of the twin lambs of each group into two sub-groups, one kept 'sufficient' and the other left 'deficient'.

The plasma copper levels of the Group II lambs (from dams injected with copper at parturition) up to the point of division were double those of the control group. They maintained levels of sufficiency for four weeks longer than the control lambs. The plasma copper concentrations of group II lambs remaining deficient were significantly higher than those of the comparable group III deficient group. It is presumed that this was due to enhanced copper levels in the milk of their dams. The milk analysis results are not available at the time of writing.

Table 1

Group I ewes - Plasma Copper Concentrations (μg/100 ml)

28/1/77	15/2/77	INJECTION	3/3/77	29/3/77	PARTURITION	11/5/77	26/5/77	9/6/77	24/6/77	7/7/77	21/7/77	4/8/77	18/8/77	1/9/77	15/9/77
83.3	81.1	✓	109.7	78.1	68.3	54.7	30.4	28.3	22.2	21.9	23.5	21.7	22.3	21.1	21.0

Table 2

Group I lambs and Group III control lambs - Plasma Copper Concentrations (μg/100 ml)

	BIRTH	11/5/77	26/5/77	9/6/77	24/6/77	7/7/77	21/7/77	4/8/77	18/8/77	1/9/77	15/9/77
Group I Sufficient	46.9	50.4	77.0	43.6	57.2	80.3	61.2	53.7	63.4	51.0	51.4
Group I Deficient			30.3	19.5	15.6	14.8	9.9	17.5	18.0	21.5	24.3
Group III Deficient	42.1	43.7	21.7	15.5	19.6	15.0	10.2	13.7	17.6	18.0	23.5

Table 3

Lamb weights (kg)

	BIRTH	11/5/77	26/5/77	9/6/77	24/6/77	7/7/77	21/7/77	4/8/77	18/8/77	1/9/77	15/9/77
Group I Sufficient	3.35	7.67	10.50	14.37	18.59	21.73	25.50	27.59	30.85	29.68	32.16
Group III Sufficient	3.22	7.18	9.81	13.48	17.29	20.49	23.88	26.28	29.49	28.71	31.57
Group I Deficient	3.50	7.43	10.08	13.90	17.58	20.41	24.48	26.03	29.66	28.95	30.88
Group III Deficient	3.23	6.92	9.43	12.86	16.73	19.95	22.68	24.77	27.63	27.49	29.72

Table 4

Group II and Group III ewes - Plasma Copper Concentrations (µg/100 ml)

	PARTURITION	11/5/77	26/5/77	9/6/77	24/6/77	7/7/77	21/7/77	4/8/77	18/8/77	1/9/77	15/9/77
Group II	59.7	85.2	66.0	72.7	82.5	90.0	92.8	85.7	92.9	68.5	71.7
Group III	53.4	40.9	30.1	25.7	15.4	16.0	21.0	15.0	17.3	17.5	21.2

Table 5

Group II and Group III lambs - Plasma Copper Concentrations (µg/100 ml)

	BIRTH	11/5/77	26/5/77	9/6/77	24/6/77	7/7/77	21/7/77	4/8/77	18/8/77	1/9/77	15/9/77
Group II	50.7	88.5	52.6	33.1	20.0						
Sufficient						69.3	52.1	60.7	58.9	53.1	47.0
Deficient						20.7	20.7	23.3	24.0	27.5	29.7
Group III	42.1	43.7									
Sufficient			68.0	59.0	69.1	87.0	62.5	55.1	61.5	56.7	47.6
Deficient			21.7	15.5	19.6	15.0	10.2	13.7	17.6	18.0	23.5

Table 6

Weights - all available "paired twins". (1977)

		BIRTH	11/5	26/5	9/6	24/6	7/7	21/7	4/8	18/8	1/9	15/9	GAIN FROM SPLIT
Group 1 Lambs - dams mid preg.	S.	3.35	7.67	10.50	14.37	18.59	21.73	25.50	27.59	30.05*	29.68	32.16	24.49
	D.	3.50	7.43	10.00	13.90	17.58	20.41	24.40	26.03	29.66	28.95	30.08	23.45
Group III Lambs - dams no treat.	S.	3.22	7.18	9.81	13.40	17.29	20.49	23.83	26.28	29.49	28.71	31.57	24.39
	D.	3.23	6.92	9.43	12.86	16.73	19.95	22.68	24.77	27.63	27.49	29.72	22.00
Group III Lambs - Coprin at birth	S.	3.39	7.06	9.53	12.82	16.7	20.0	23.9	25.41	28.89	28.35	30.89	14.19
	D.	3.29	6.74	9.35	13.4	17.24	20.40	24.04	25.44	29.11	28.11	30.07	12.83

* Very Wet Day.

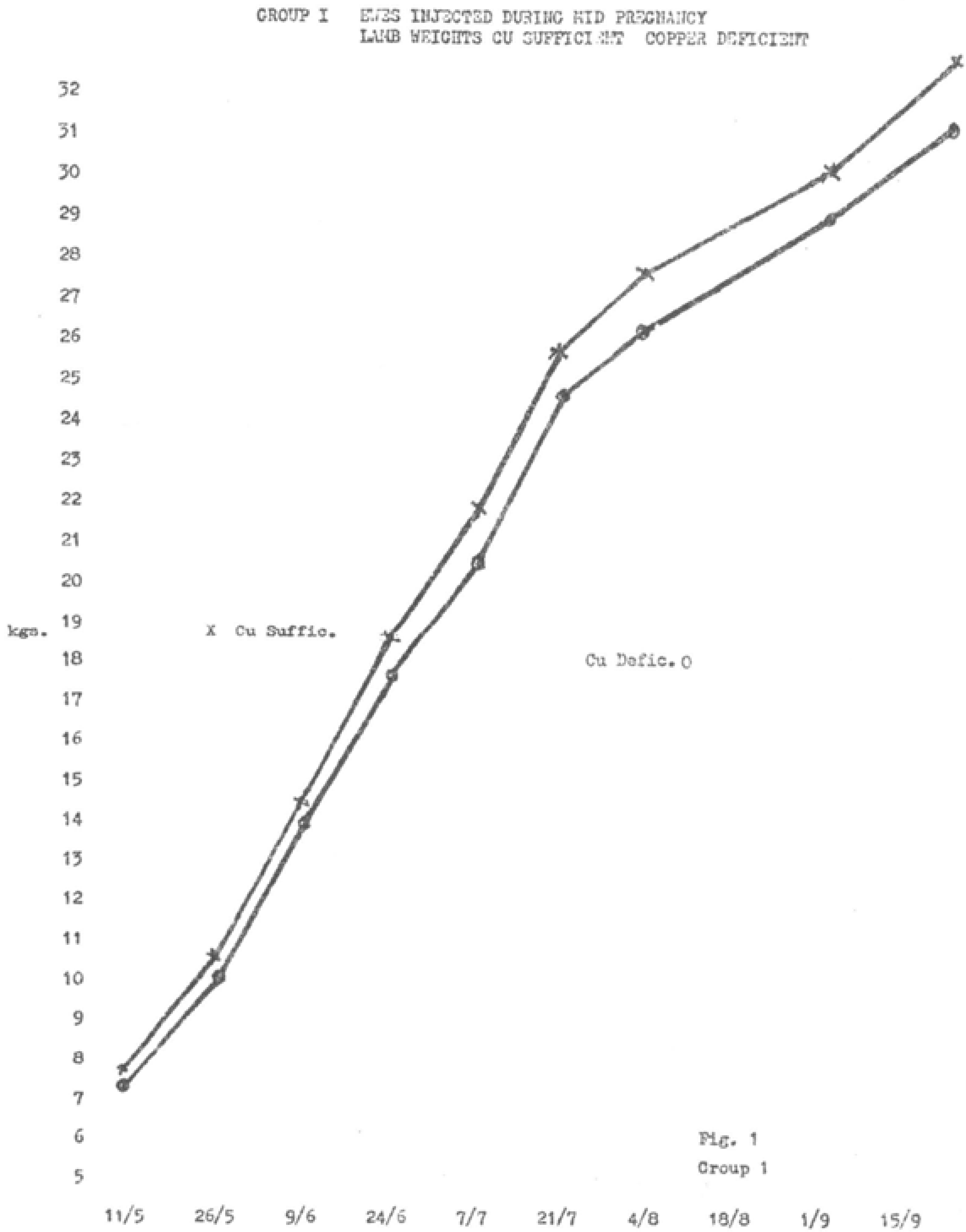
GROUP I EWES INJECTED DURING MID PREGNANCY
LAMB WEIGHTS CU SUFFICIENT COPPER DEFICIENT
kgs.
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
X Cu Suffic.
Cu Defic. O
Fig. 1
Group 1
11/5
26/5
9/6
24/6
7/7
21/7
4/8
18/8
1/9
15/9

Figure 1

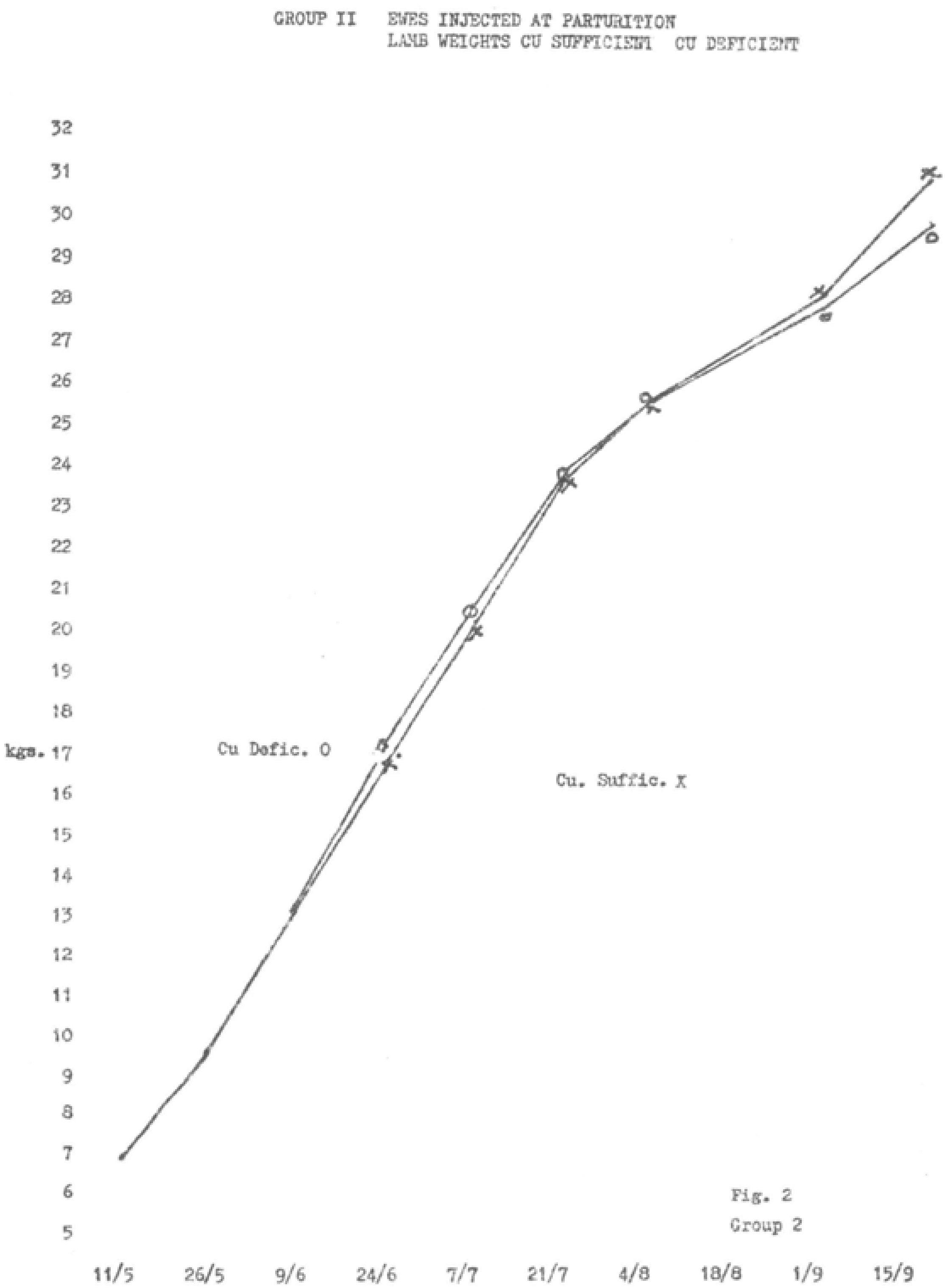
GROUP II EWES INJECTED AT PARTURITION
LAMB WEIGHTS CU SUFFICIENT CU DEFICIENT
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
kgs. 17
16
15
14
13
12
11
10
9
8
7
6
5
Cu Defic. O
Cu. Suffic. X
Fig. 2
Group 2
11/5
26/5
9/6
24/6
7/7
21/7
4/8
18/8
1/9
15/9

Figure 2

GROUP III CONTROL NO TREATMENT TO EWES
LAMB WEIGHTS CU SUFFICIENT CU DEFICIENT

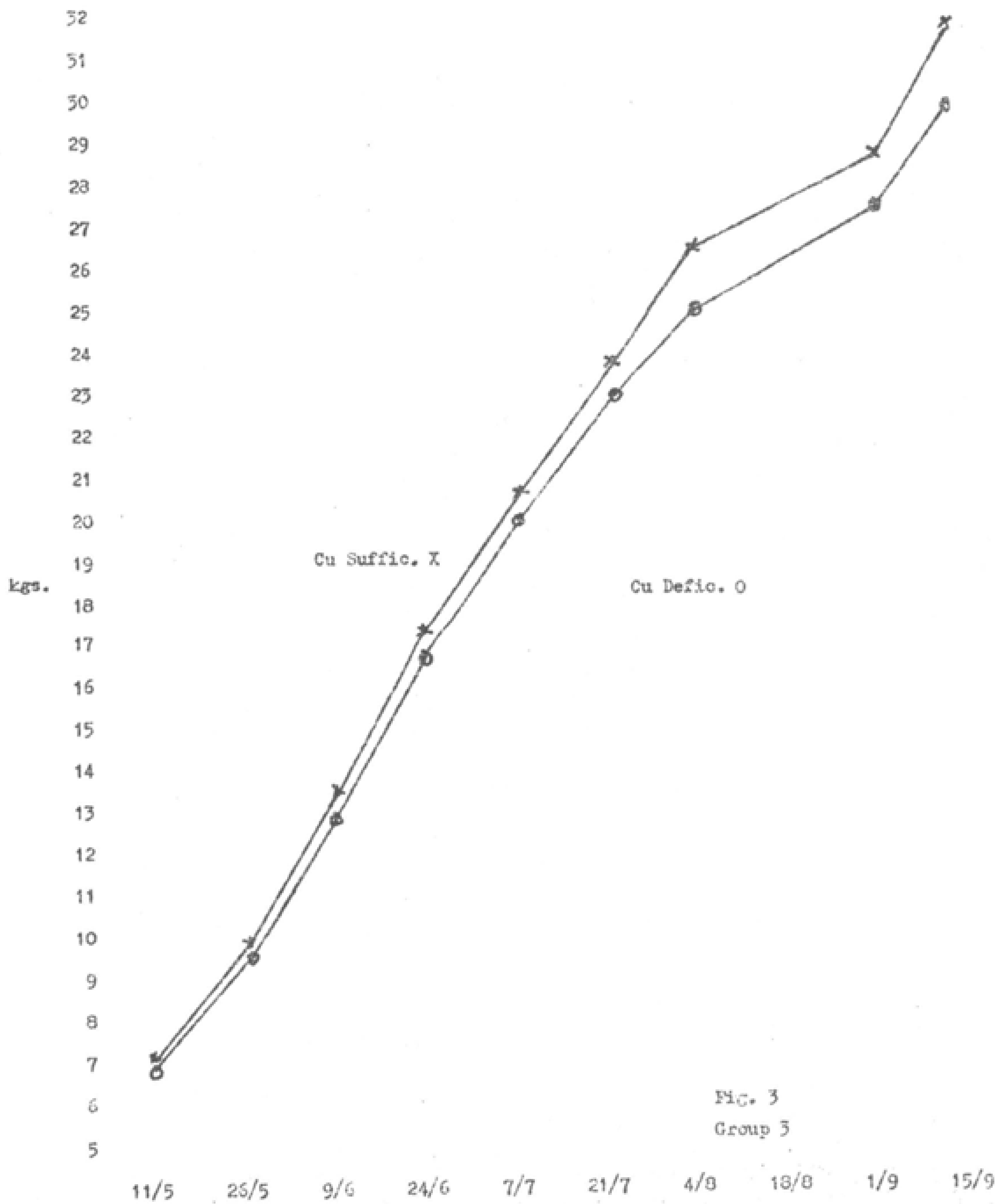

Figure 3

Table 6 shows the live weights of the twin lambs of Groups I, II and III and figures 1, 2 and 3 show plotted live weights of lambs in their groups. The differences between sufficient and deficient lambs were less than those obtained in 1976.

Radiographical examination of the bones of lambs showed that where there was a significant weight difference in favour of the "sufficient" lamb of a twin pair oesoeporosis was present in the "deficient" lamb but not in the "sufficient" lambs.

Discussion

In seeking an explanation for the lower weight differences obtained in the 1977 study compared with the 1976 study the suspicion lies with an unfortunate contamination of glassware. This resulted in plasma copper concentrations over a period of the study being accepted as higher than they actually were. This meant that supplementation of the "sufficient" lambs was not carried out when in retrospect it was desirable, and resulted in a period of six to eight weeks when plasma copper concentrations were below sufficiency in the "sufficient" lambs of all groups. Figures 1, 2 and 3 reflect the importance of this.

Analysis of the results shows that whilst the differences are not as significant as those obtained in 1976 the evidence does indicate that young lambs grazing reseeds between birth and weaning did not achieve optimum performance. The administration of copper to ewes in mid pregnancy does not prevent the plasma copper levels of their lambs deteriorating to low levels in the same way as do those of lambs whose dams received no mid pregnancy injection of copper, and this suggests that the administration of copper to ewes in mid pregnancy is of no prophylactic value. The injection of copper to ewes at parturition on the other hand shows a prophylactic benefit to their lambs of at least four weeks duration, and this is shown to be related to increased levels of copper in the milk of these dams compared with unsupplemented animals. Herbage analysis of samples from improved areas and adjacent non-improved hill pastures reinforces the findings of the 1976 study in that whilst the copper concentrations of the improved and non-improved pastures are of a similar order, the elevation of molybdenum and sulphur concentrations in the improved pasture are of extreme importance.

At the end of the study weaned lambs, ten pairs of twins, matched twin for twin and selected at random from sufficient and deficient lambs were fed dried grass pellets _ad lib_. for ten weeks beginning in October 1977.

At the commencement of the trial the Cu-sufficient lambs were on average 1.6 kgs heavier than their Cu deficient twins.

Mean liveweight gains were of the order 180-190 g/day and at the end of the trial there was a mean weight difference of 2.2 kgs in favour of the Cu sufficient lambs. There were no demonstrable differences between previously Cu "sufficient" and Cu "deficient" lambs during the trial in either food intake per unit live weight or in rate of liveweight gain. However when live-weight gain was plotted against intake (both expressed per kg live weight) the lambs did appear to fall into two distinct groups according to previous Cu status suggesting that the previously Cu sufficient lambs were apparently more efficient than the previously Cu deficient lambs. Approximate values for feed conversion efficiency were 6 and 4 g feed/g live weight gain for "deficient" and "sufficient" lambs respectively. Because a few individuals in both groups did not conform to the general pattern it was not possible to demonstrate any statistical difference in efficiency of food conversion.

There is evidence from the experiment that the Cu "deficient" lambs were in poorer body condition than their Cu "sufficient" twins. It might therefore not have been unreasonable to expect a better food conversion in the Cu "deficient" group on the basis that they would be putting on more muscular tissues and water, and less fat than the Cu sufficient lambs.

Subsequent experimentation with A.J.F. Russel will therefore involve an estimate of the composition of tissue gains, by direct measurement of body composition at the beginning and end of a similar trial.

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2. Cobalt

A. Whitelaw, A.J.F. Russel, C.C. Evans, E. Skedd, A.R. Fawcett and I.R. White

Introduction

Because the serum vitamin B_{12} estimations on samples taken between 1974 and 1977 have only become available in 1977, the results of studies in Cobalt deficiency have not been reported prior to this year.

The prevention and treatment of Cobalt deficiency in sheep can be achieved by the administration of cobalt, (a) as a top dressing, applied to pasture as a spray or as a dust, usually mixed with fertiliser; (b) as a drench of cobalt sulphate or cobalt chloride; (c) as a bullet of cobaltic oxide given per os to a ruminant, which lodges in the reticulum and gives a slow release of cobalt; or (d) as an injection of vitamin B_{12}, since cobalt deficiency produces its effects as a result of a deficiency of that vitamin.

In the diagnosis of cobalt deficiency, in the assessment of the cobalt status of sheep, and in monitoring the efficacy of preventive measures, whilst the subjective assessment of response to therapy is frequently used, laboratory techniques are essential. The clinical signs of cobalt deficiency are not pathognomic and the disease requires a differential diagnosis from other diseases producing similar clinical signs of inappetance, poor weight gains, debility etc. A range of laboratory techniques are available.

1. Cobalt content of pasture and soil.
2. Cobalt content of livers of suspect animals
3. Vitamin B_{12} contents of livers of suspect animals
4. Serum or plasma vitamin B_{12} estimations
5. Urinary metabolite concentrations - Methyl Malonic Acid - Formiminoglutamic Acid

The most convenient of these is the serum concentration of vitamin B_{12} on blood taken from the live animal. The use of this measurement has become well accepted (e.g. Findlay (1972)). Russel et al (1975) found serum vitamin B_{12} levels in lambs, both supplemented and non-supplemented with cobalt, to relate well with liveweight gains and the appearance of formiminoglutamic acid in the urine when these lambs grazed a known deficient pasture.

On the research farms of the Hill Farming Research Organisation it has been demonstrated that the liklihood of a cobalt deficiency is increased in animals grazing pastures improved by liming and reseeding. Investigations into cobalt and copper deficiencies occurring in sheep on these improved pastures are taking place to determine their extent, the factors concerned, and the means of prevention. This is a report of three small trials ancillary to these investigations.

In these trials, where the serum vitamin B_{12} levels exceeded 2000 pgs/ml and were not accurately estimated over that figure, the level of 2000 was taken to be the figure for purposes of calculation.

a) The long term effects of cobalt bullets on serum vitamin B_{12} concentrations in sheep grazing a hirsel with known areas of cobalt deficient pasture

In 1974 two groups of ewe lambs on the Park Law unit at Sourhope were selected at random from the 1973 age group of the North Country Cheviot flock grazing that unit. One group was given a cobalt bullet* whilst the other was left undosed. Blood samples were taken at intervals and serum vitamin B_{12} concentrations were estimated by a radio-immuno assay technique.

Results

Table 1 (see over) shows serum vitamin B_{12} concentrations of individuals and dates of sampling from 19.6.74 to 24.3.77. Means of groups and means of individuals are shown.

The mean serum vitamin B_{12} estimations of each group at each sampling date show that the serum vitamin B_{12} concentrations of the group given cobalt bullets were significantly higher than the groups not given bullets ($P = 0.01 - 0.002$). The overall means of individual sheep serum vitamin B_{12} concentrations showed that of the dosed group to be twice that of the undosed group.

Discussion

The cost of cobalt bullets as a means of preventing cobalt deficiency is such that long term efficacy is required. In older sheep this is more difficult to determine than in lambs, particularly because in older sheep the effects of deficiency are less severe than in lambs, where poor growth rates can accompany both clinical and sub-clinical disease. Dewey, Lee and Marston (1969) carried out an intensive study into the efficacy of cobalt bullets in penned sheep on a cobalt deficient diet and showed these to be as effective, over a period of five years, as a supplement of 1 mg of cobalt per day by mouth in maintaining health, body weight and adequate concentrations of vitamin B_{12} in liver and serum. In this small trial the cobalt bullets were effective in producing significantly higher concentrations of serum vitamin B_{12} over a period of three years when the animals were grazing a unit which had cobalt deficient areas within its total area. During periods prior to lambing when concentrates were being fed and any cobalt deficiency would be expected to be ameliorated the serum vitamin B_{12} concentrations of the sheep given bullets showed much higher levels than those not given bullets. In previous work (Russel, et al (1975)) it was shown that the concentrations of serum vitamin B_{12} after cobalt bullet administration were higher than those attained with conventional cobalt sulphate drenching, and that these levels were sustained, whereas those after drenching dropped after approximately three weeks. In practice on HFRO farms cobalt drenches are used in all lambs at monthly intervals prior to weaning; thereafter lambs retained for stock are dosed with cobalt bullets.

* Permaco (TVL)

Table 1. Cobalt Bullet Trial Park Law. 1973 Age Group

	19/6/74	25/7/74	9/8/74	22/8/74	10/9/74	20/11/74	27/5/75*	8/8/75	17/11/75	24/3/77*	Means	n̄ of n
COBALT BULLETED												
301	1590	770	-	540	300	380	920	730	560	> 2000	865	
304	1540	1850	640	820	310	1470	600	1500		> 2000	1248	
305	710	770	330	70	680	360	-	-	620	-	506	
306	1150	410	160	290	970	310	1065	530	-	-	611	
309	1270	380	730	230	480	610	1090	1170	-	-	745	
310	> 2000	> 2000	1910	1010	1790	1500	-	-	-	> 2000	1744	
312	660	650	380	190	230	60	515	-	90	> 2000	536	
316	1940	1210	1110	730	> 2000	1010	1315	-	770	> 2000	1348	
319	790	130	510	470	840	320	1100	560	-	> 2000	752	
322	900	70	550	300	1370	1010	680	-	-	-	697	
323	730	920	1600	600	1010	390	785	660	-	-	837	
325	1480	2000	1620	740	640	> 2000	1205	1350	-	> 2000	1448	
307	620	770	740	560	1620	1040	885	780	1160	1920	1009	
331	440	370	-	330	1520	1030	670	-	-	> 2000	909	
336	> 2000	1940	1730	760	1170	840	315	-	-	> 2000	1407	
n	1133	953	924	513	1032	822	396	910	640	1992	(977)	987
NON BULLETED												
302	0	0	0	0	0	0	365	-	-	70	54	
303	0	160	0	260	520	400	600	-	-	> 2000	492	
308	360	540	270	270	480	1030	630	-	640	> 2000	691	
311	200	410	530	270	750	840	690	-	-	> 2000	711	
313	10	50	220	120	0	0	875	-	-	-	182	
314	100	140	100	160	750	240	-	-	-	-	248	
315	0	20	30	10	0	0	805	-	-	80	118	
317	70	480	1380	650	520	630	1010	-	-	> 2000	842	
318	160	640	570	1130	1790	1110	1190	1670	-	-	1039	
320	0	480	590	170	0	770	995		-	> 2000	625	
321	0	0	20	0	0	10	455	40	-	40	63	
324	0	140	370	0	770	0	670	-	0	150	233	
326	160	480	670	150	1260	370	660	-	370	> 2000	680	
328	0	0	0	0	0	0	435	-	-	70	63	
332	30	730	940	400	270	120	-	350	-	> 2000	605	
333	0	60	-	-	-	-	-	-	-	-	30	
334	0	130	80	0	1080	110	715	0	-	> 2000	457	
335	0	20	20	0	420	270	290	-	430	-	181	
329	180	300	60	10	40	60	600	-	-	1300	319	
330	540	120	310	30	60	210	925	-	500	1460	462	
n	90	245	324	194	458	325	701	515	383	1278	(405)	452

* Periods of concentrate feeding

T TESTS

19.6.74 P = > 0.001

25.7.74 P = > 0.001

9.8.74 P = > 0.001

22.8.74 P = > 0.001

10.9.74 P = > 0.001

20.11.74 P = > 0.001

27.5.75 P = 0.05 - 0.02

8.8.75 NS) **
17.11.75 NS)

24.3.77 P = > 0.001

Means 0.01-0.002

** Because of small no. of samples

b) <u>The comparative efficacy of the administration of cobalt bullets and vitamin B_{12} injections in elevating serum vitamin B_{12} concentrations in lambs</u>.

In 1975 160 lambs from the Near End Hairney Law (NEHL) unit and 230 lambs from the Rigg unit at Sourhope were made available for a short term trial. The lambs from each unit were randomised into three groups.

(i) Group 1 - lambs used as controls
(ii) Group 2 - lambs each given one cobalt bullet* by mouth
(iii) Group 3 - lambs each given 2 mgs of hydroxycobalamin† by injection

Because of lamb sales the trial period was limited in duration.

Results

Table 2

NEHL lambs

Mean serum vitamin B_{12} concentrations (pgs/ml)

	1/7/75 (Predose) (sample)	23/7/75	11/9/75
Group 1	460	154	299
Group 2	260	1604	1610
Group 3	514	326	336

Table 3

Rigg lambs

Mean serum vitamin B_{12} concentrations (pgs/ml)

	26/6/75 (Predose) (sample)	23/7/75	10/9/75
Group 1	140	105	290
Group 2	251	1543	1257
Group 3	171	376	205

Whereas the cobalt bullets produced a marked elevation of the serum vitamin B_{12} concentrations in both NEHL (Table 2) and Rigg (Table 3) lambs the injection of vitamin B_{12} elevated levels in the Rigg lambs only at 30 days post injection, and these to a much lower level than did the cobalt bullets.

Discussion

Hogan <u>et al</u> (1973) injected vitamin B_{12} into lambs grazing cobalt deficient pasture at weaning and subsequently at monthly intervals, and showed this to be effective in preventing cobalt deficiency. In comparative measurements taken at 50 days, 5 lambs receiving an injection of 2 mgs of vitamin B_{12} in two doses of 1 mg 34 days apart showed mean plasma vitamin B_{12} concentrations of 510 pgs/ml compared with control lambs showing a mean concentration of 140 pgs/ml. Another 5 lambs receiving 3 mgs of vitamin B_{12} as 2 mgs followed by 1 mg 34 days later showed a mean concentration of 630 pgs/ml.

* Permaco S (TVL) † Neocytamen '1000' (Glaxo)

In the small study at Sourhope, in the [illegible] lambs, a predosing mean concentration of 514 pgs/ml serum vitamin B_{12} in the lambs given vitamin B_{12} by injection was followed by lower mean concentrations of serum vitamin B_{12} of 326 pgs/ml and 336 pgs/ml at one and two months respectively. This contrasted with mean concentrations of 464 pgs/ml predosing and 16[illegible]4 and 161[illegible] pgs/ml subsequently in the group given bullets. In the Rigg lambs, the mean serum vitamin B_{12} concentrations in the group given vitamin B_{12} injections rose from 171 pgs/ml to 376 pgs/ml (i.e. from a marginally deficient level to one of sufficiency) at the end of one month. At the end of approximately one further month the level of 2[illegible]5pgs/ml approached marginal status once more. On the other hand the comparable levels in the group given bullets were 252 pgs/ml predosing and 1543 pgs/ml and 1257 pgs/ml.

The trial period was of short duration and weight gain differences were not apparent. None of the mean concentrations in the [illegible] lambs at the time of dosing could be regarded as indicative of deficiency and only the mean concentration of serum vitamin B_{12} in the control lambs on the 23/7/75 could be regarded as marginal. Similarly in the Rigg lambs whilst the initial samples could be regarded as borderline only the level on 23/7/75 could be regarded as indicative of cobalt deficiency.

The results of this trial have limitations because of the short period involved, but do indicate strongly that cobalt bullets have a marked superiority in elevating serum vitamin B_{12} concentrations in sheep compared with injections of vitamin B_{12}.

c) <u>The effects of two levels of pasture application of cobalt upon serum vitamin B_{12} concentrations in sheep</u>

Following an investigation into the treatment and diagnosis of cobalt deficiency in lambs on a cobalt deficient pasture at Glensaugh (Russel <u>et al</u> (1975)) the pasture was divided into 12 plots (Figure 1).

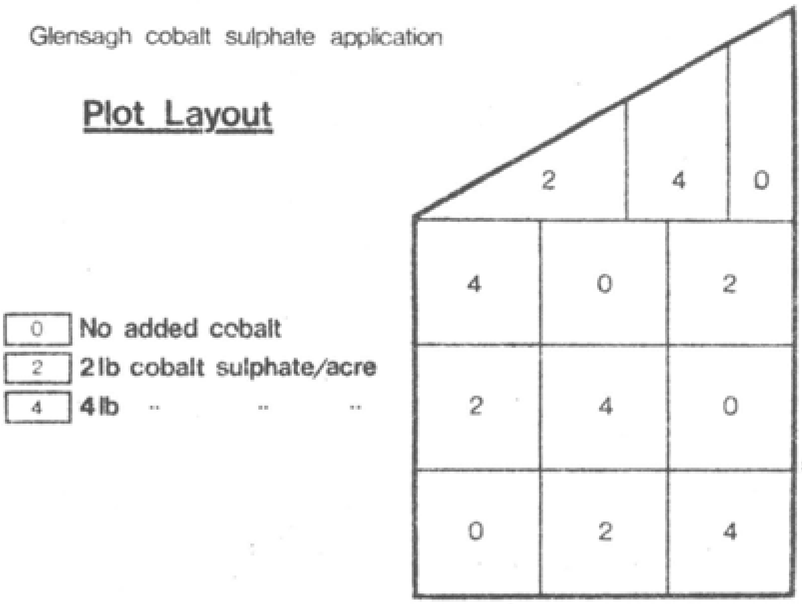

Figure 1

On 21 August 1974 a cobalt sulphate solution was applied at 2lbs per acre on 4 plots, and 4 lbs per acre on 4 plots. The remaining 4 plots were untreated and acted as controls. In 1974, lambs grazing these plots showed uniformly high serum vitamin B_{12} concentrations, and it was concluded that spray drift had occurred, depositing some cobalt on the herbage in the control plots.

In 1975, 48 lambs were randomised on a weight basis into three groups each of 16 lambs. One group was allocated to each of the treatment plots and one group to the control plots. Blood samples were taken for estimation of serum vitamin B_{12} concentrations at fortnightly intervals, when the lambs were also weighed. At the beginning of the experiment on 13 August 1975 samples taken showed the serum vitamin B_{12} concentrations to be in the range of deficiency (below 100 pgs/ml).

Results

Table 4 (see over) shows the serum vitamin B_{12} concentrations of each member of each group. Whilst all groups showed an elevation of serum vitamin B_{12} concentrations one week after introduction to the plots only the lambs on the treated plots showed a continuing elevation. It is clearly demonstrated that the cobalt sulphate spray produced very satisfactory increases in serum vitamin B_{12} concentrations which were significantly better at the higher rate of application (4 lbs/acre). It was disappointing that weight gain differences were not demonstrated. The control group however showed no evidence of serum vitamin B_{12} concentrations in the range associated with clinical deficiency (below 100 pgs/ml). This could be attributed to differences known to occur on a year to year basis, a factor which can affect field studies of cobalt deficiency where a pasture which produces a deficiency in one year may not do so in a subsequent year. Our conclusion is that spray drift in the previous year, 1974, at time of application applied cobalt to the foliage on the control plots. This was in the main removed by grazing, with sufficient reaching the pasture to alter the level of cobalt deficiency in the pasture from a real one to a borderline level.

It is known that lime reduces the availability of soil cobalt to plants, the availability at pH 5.8 being twice that of pH 7.2 (Young (1956)). Because the technique used in improving hill pastures include liming, reseeding, and application of fertiliser, subsequent studies should investigate the levels of top-dressing necessary to achieve satisfactory prophylaxis of cobalt deficiency.

This is especially important in circumstances where a susceptible class of stock, young lambs, may be confined in improved pastures from birth to weaning.

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Table 4

Serum vitamin B_{12} concentrations of lambs grazing 3 treatments with cobalt sulphate application (pgs/ml).

Treat. 0

No.	13/8	22/8	3/9	17/9	1/10	15/10	29/10
53	70	280	260	150	280	490	510
56	80	150	170	130	170	195	120
57	95	150	160	115	150	140	200
60	120	165	135	150	160	250	-
63	70	150	465	145	160	320	250
66	80	175	250	130	170	320	285
70	60	120	175	120	165	270	290
301	-	160	170	155	205	310	135
302	-	160	215	140	290	390	290
304	60	185	130	105	135	210	120
305	150	130	145	135	100	115	110
686	40	250	195	185	155	245	150
687	90	175	140	140	120	350	255
694	115	145	135	110	130	215	120
695	85	160	195	130	240	760	850
697		210	155	160	210	580	600
	85.8	172.8	193.4	137.5	177.5	322.5	292.3

Treat. 2 lb/ac.

No.	13/8	22/8	3/9	17/9	1/10	15/10	29/10
49	350	150	280	280	>2000	1040	1330
51	135	170	650	540	1150	1180	>2000
54	75	150	280	240	505	785	1380
61	130	180	480	540	910	1080	1690
64	130	180	415	445	655	1050	1410
65	50	120	210	160	390	310	870
71		140	185	200	500	940	1580
72	90	180	300	230	610	1255	1430
73	80	155	395	465	1110	1500	1890
307	20	170	240	225	385	1465	>2000
308	190	220	325	260	445	805	1215
688	40	125	140	150	465	980	1545
692	70	150	420	630	780	1690	1010
696	80	150	460	405	1015	1770	>2000
698	135	140	400	280	1280	1010	1450
	107.3	157.8	345	336	818.6	1124	1520

A.32

Treat. 4 lb/ac.

No.	13/8	22/8	3/9	17/9	1/10	15/10	29/10
50	90	170	425	440	1300	>2000	>2000
52	130	145	425	225	860	1455	1710
55	80	150	260	270	550	760	575
59	85	170	750	1280	>2000	>2000	>2000
62	100	220	420	350	850	1930	2000
67	230	145	780	770	1585	>2000	>2000
68	50	155	345	150	730	1110	1680
69	120	165	590	905	>2000	>2000	>2000
74	80	190	400	280	1000	1490	1790
75	-	240	545	570	1190	>2000	>2000
303	60	120	250	360	1820	>2000	1825
685	55	150	410	520	1050	>2000	1820
690	45	145	280	380	920	1600	2000
691	130	205	865	1235	>2000	>2000	>2000
693	90	165	1060	1095	>2000	>2000	>2000
699	60	160	270	210	650	>2000	1410
	93.7	168.4	504.6	565	1281.5	1771.5	1800

INPUT/OUTPUT

03002: The nutritional and productivity consequences of hill land improvement

1. The nutritional and production responses to a range of improvement techniques on a range of hill soils and pastures.

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

Introduction

In the Organisation hill sheep systems development programme upgraded pasture is used as a source of improved nutrition for the ewe at critical periods in the production cycle.

Increased pasture production and improved pasture quality may result from a variety of improvement methods which include enclosure by fencing, application of lime and phosphates to raise soil pH and enhance soil P status, correction of soil micro-element imbalances, drainage, weed control and the introduction of higher yielding pasture species. This range of treatment possibilities must be seen against the background of hill land resources which vary greatly in both soil and pasture quality. At the poorer end of the range, e.g. blanket bog, only a comprehensive range of inputs will produce herbage of acceptable quality and productivity, whereas, on land of better quality, e.g. Agrostis/Festuca pasture, the control of grazing associated with fencing alone may lead to greater output. The question arises as to which improvement pathway, or combination of inputs, will be the most appropriate in a particular situation.

Consequently, a series of trials was established at Sourhope (1969-1971) to examine the effect of a range of improvement treatments on pasture production on three hill land types representative of the better, medium and lower quality pasture types in the Cheviot environment. A further objective of these experiments was to study soil and vegetation changes in response to the applied treatments, and certain aspects of nutrient recycling. These studies are described elsewhere in this report (p. C.32).

Sites

1. Agrostis-Festuca

This was the best indigenous site chosen. Overlying a fairly deep Brown Forest soil of the Sourhope series (pH 5.0-5.5), plot size was limited to 0.1 ha due to lack of uniform soil and pasture conditions. The site is at 1000' elevation and slopes gently south-eastwards. Pre-treatment, before fencing, in 1969 included burning and removal of excess debris by forage harvester. Treatments were applied during the winter of 1969-70.

2. Molinia

On this site the soil type is a peaty podzolic soil of pH 4.0 (Cowie series). The peat layer is more than 10 cm deep and the site is on a westerly slope about 1200' above sea level. Application of treatments to the plots, each of 0.2 ha, began in the early summer of 1970 after burning and fencing.

3. Nardus

The soil type is again a peaty podzol of the Cowie series (5-10 cm thick) and the vegetation type was the poorest of the three sites, *Nardus stricta* comprising about 36% of the pasture. This area was fairly level at 1200' above sea level. Pre-treatment involved two separate sprayings of Dalapon a fortnight apart in mid 1971, followed by application of the treatments to the 0.2 ha plots.

Treatments

The treatments applied to each site were:-

1) Fencing (grazing control).
2) Fencing + lime.
3) Fencing + lime + slag.
4) Fencing + lime + slag + clover.
5) Fencing + lime + slag + clover + grass and nitrogen 'booster dose'.

Application rates

Lime: 5.02 tonnes/ha (Site 1); 6.28 tonnes/ha (sites 2 and 3).

Slag: 1.25 tonnes /ha (approx. 80 kg P per ha).

Clover: 2.25 kg/ha (1.40 kg S100 and 0.85 kg Kent).

Grass: 22.5 kg/ha S23 Perennial Ryegrass.

Nitrogen: 250 kg/ha 'Nitrochalk'.

All sites have been relimed and reslagged at original treatment rates after approximately six years.

Experimental

The context of the studies is grazed pasture and the grazing wether was chosen as the most suitable grazing animal and means of expressing the pasture response to treatment.

Extrapolation of results into the systems development context necessitated a grazing management regime, as closely related to that context as possible. As a result, there are three grazings per year at each site, the first two being of four weeks and the last being of three weeks duration, extending from mid-May to mid-June, mid-July to mid-August and mid-October to early November. All plots were grazed simultaneously and for the same length of time.

One major consideration is the allocation of sheep to each treatment. It is important that this should be done as objectively as possible and a procedure based on equating weight of standing crop of herbage per sheep has been used throughout the study. The quantity of herbage standing crop on each plot was established by a cutting technique on each plot prior to each grazing period. It was occasionally necessary to add or remove animals from plots to ensure a total herbage standing crop of 560 kg/ha on the plots at the end of each grazing period.

Grazing day totals and weekly bodyweight change on all plots in all years were measured. Total faecal collections four days per week on each site on one year in three were also made.

Herbage production was calculated from growth figures measured at sites during the same year as faecal collections were made. Dead:green herbage ratios and clover percentages from samples cut at the start of each period were obtained at these sites.

From faecal nitrogen values, ingested herbage digestibility and hence digestible organic matter intake were calculated using equations previously derived from digestibility trials.

Samples from herbage cut immediately prior to each grazing on all plots and sites each year were analysed for in vitro digestibility. From time to time complete botanical analysis of the plots on all sites were made.

Results

Grazing day totals for each plot on all three sites are shown in Table 1. In the interests of brevity figures are only presented for those years in which complete data including faecal output were collected, referred to as "total collection years".

Table 1. Grazing Days/ha

Sites		Treatments 1	2	3	4	5
Agrostis-Festuca	1971	2431	2609	2610	2610	3944
	1974	2649	3074	3114	3390	4112
Molinia	1972	1695	1868	1483	2095	2318
	1975	2699	2317	2698	3914	4048
Nardus	1973	2180	2525	2382	2762	2787
	1976	2396	2431	2946	2822	3731

The examination of figures for all years has shown that the treatments can be broadly divided into two groups, i.e. the non-reseed treatments and those where reseeding has been included. This has been substantiated by statistical analysis of the data on Table 1 in which treatment 5 was shown to be significantly greater ($P < 0.001$) than treatments 1, 2 and 3, none of which differed significantly, and also significantly greater than treatment 4 ($P < 0.001$) which, in turn, was significantly greater than treatments 1 and 2 ($P < 0.01$) and treatment 3 ($P < 0.05$). There was also a significant increase ($P < 0.01$) between the first and second "total collection" years. The site of best indigenous quality (Agrostis-Festuca) produced more grazing days than either of the others.

Live weights have shown a tendency to increase with "level of input" treatment though not generally significantly except at the highest treatment level.

A pattern, similar to that of grazing days, again prevails with herbage production (Table 2), treatment 5 being significantly higher than all others ($P < 0.001$ for 1, 2 and 3 and $P < 0.01$ for 4), while treatment 4 was significantly greater than treatments 1 ($P < 0.001$) and 2 and 3 ($P < 0.01$).

Table 2. Herbage Production (kg DM/ha)

Sites		Treatments 1	2	3	4	5
Agrostis/Festuca	1971	2586	3762	3399	3410	5277
	1974	2203	2992	3892	3484	4836
Molinia	1972	1920	1829	982	3835	3925
	1975	2591	3171	3065	5499	6250
Nardus	1973	2158	2582	1803	4169	3230
	1976	1655	3073	2983	3490	4532

Among the three lowest treatments, only treatment 2 was significantly higher than treatment 1. ($P < 0.05$). Again herbage production increased significantly between "total collection years" ($P < 0.05$). Although more herbage was produced on the Agrostis/Festuca site than on the other two, it was only significantly higher than that of the Nardus site.

Statistically, a somewhat similar result has emerged for organic matter intake, digestible organic matter intake and for herbage digestibility. 'Weighted' digestibility was found to be significantly lower on the Molinia site ($P < 0.01$ and $P < 0.05$ for the Agrostis/Festuca and Nardus sites respectively).

Herbage quality was reflected in the fact that the mean percentage of dead material over the three herbage cuts taken at the start of grazing periods in each "total collection year" was significantly less in treatment 5 than in treatments 1, 2, 3 ($P < 0.001$) and treatment 4 ($P < 0.01$), and treatment 4 was significantly less than treatments 1 and 3 ($P < 0.01$) and treatment 2 ($P < 0.05$).

From the data of all six total collection years, a highly significant ($P < 0.001$) relationship between grazing days and organic matter intake was established ($Y = 1.49X - 233$), where Y = grazing days and X = OMI in kg. Consequently, estimations of herbage production can be derived by regression from total grazing day values, for those years in which herbage growth estimates were made, thus allowing a better appraisal of herbage production trends over time.

Grazing days and liveweight change data for 1977 are given in Tables 3 and 4 respectively. The relatively poor performance of the Agrostis/Festuca and Nardus sites in 1976 and 1977 and of the Molinia site in 1977 may have been due to the exceptionally dry weather during the summer of 1976, the extra water-retention capacity of the peaty soil on the Molinia site delaying the effect of the drought there.

Interest now centres on when and at what level the effects of treatments will level off. Although faecal collections and growth estimations have ceased meanwhile, the work continues at a monitoring level with the collection of data on grazing days and liveweight change, with the intention that at some point in time, as yet undecided, total collection of data will be resumed.

Table 3. Grazing days/ha, 1977

Sites	Treatments 1	2	3	4	5
Agrostis/Festuca:					
Grazing Period 1	830	1067	830	1107	1146
Grazing Period 2	1107	1107	1107	1107	1522
Grazing Period 3	415	623	623	623	830
	2352	2797	2560	2837	3498
Molinia: Grazing Period 1	1067	1038	761	929	1181
Grazing Period 2	830	830	969	1181	1176
Grazing Period 3	588	450	415	553	588
	2485	2318	2145	2663	2945
Nardus: Grazing Period 1	430	499	430	722	959
Grazing Period 2	504	588	672	924	756
Grazing Period 3	346	346	484	415	623
	1280	1433	1586	2061	2338

Table 4. Sheep weight changes (kg)
(Sheep remaining on plots throughout grazings)

Sites		Treatments 1	2	3	4	5
Agrostis/Festuca:	Grazing Period 1	+ 3.7	+ 3.5	+ 4.7	+ 3.1	+ 5.8
	Grazing Period 2	- 2.9	+ 1.1	- 4.1	- 1.0	- 1.7
	Grazing Period 3	+ 4.0	+ 2.9	+ 1.5	+ 2.1	+ 3.6
		+ 4.8	+ 7.5	+ 2.1	+ 4.2	+ 7.7
Molinia:	Grazing Period 1	+ 2.9	+ 0.5	+ 2.7	+ 5.0	+ 3.5
	Grazing Period 2	- 2.1	- 1.5	- 2.1	- 2.6	- 3.3
	Grazing Period 3	+ 0.3	+ 2.6	+ 2.4	+ 3.9	+ 4.1
		+ 1.1	+ 1.6	+ 3.0	+ 6.3	+ 4.3
Nardus:	Grazing Period 1	+ 4.3	+ 0.6	+ 2.9	+ 4.8	+ 1.4
	Grazing Period 2	- 1.0	- 1.8	- 2.3	- 1.9	+ 0.1
	Grazing Period 3	+ 0.5	+ 1.6	+ 2.1	+ 4.3	+ 2.5
		+ 3.8	+ 0.4	+ 2.7	+ 7.2	+ 4.0

CATTLE

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

1. The influence of plane of nutrition in early lactation and on the performance of spring-calving suckler cows and their calves (1976 experiment)

J.N. Peart, A.J.F. Russel, J. Hodgson, A. Whitelaw and A.J. Macdonald

Earlier studies in this series showed that calf birth weight, milk yield and calf performance were apparently very insensitive to low levels of nutrition in late pregnancy. Furthermore, studies at other centres indicate that calf performance can be sustained despite low levels of nutrition of the cow in early lactation. This trial was carried out to examine the influence of prolonged under-nutrition of spring-calving cows in both late pregnancy and early lactation on cow and calf performance, and also to examine the ability of the cow to recover body condition and milk yield on transfer to a grazing regime allowing access to liberal quantities of high-quality herbage.

Twenty-four Hereford x Friesian and 24 Blue-Grey (Shorthorn x Galloway) cows, bred to a Charolais bull, calved between 11 February and 9 April. The cows were housed for the winter in individual stalls, and for the last 12 weeks of pregnancy were fed hay to supply 75% of estimated maternal maintenance energy requirements. After calving they were divided into two groups, balanced for genotype and calving date, and fed a maintenance diet of hay plus a balanced concentrate to supply the theoretical requirements for either 2.25 kg (L) or 9.0 kg (H) milk per day, until turned out to graze on 15 May. The calves were fed chopped hay to appetite from 6 weeks of age. From 15 May to weaning on 7 September the cows and calves grazed as a single herd in a paddock grazing system, at a controlled daily allowance of herbage DM equal to 5% of the total live weight of cows and calves. Cows and calves were weighed fortnightly, and half the cows on each treatment were used for measurements of milk production at fortnightly intervals throughout lactation, and of herbage intake on five occasions during the grazing season.

The results are shown in Table 1.

Table 1. The influence of plane of nutrition in early lactation, and genotype of cow, on cow and calf performance

	Treatment		Genotype		SE
	L	H	H/F	BG	
Cow weight (kg)					
12 weeks before calving	580	560	585	555	9
after calving	500	470	500	470	10
at turnout	415	425	425	415	9
at weaning	505	495	510	490	10
Cow condition score					
at calving	2.6	2.4	2.4	2.5	0.13
at turnout	2.2	2.4	2.3	2.3	0.14
at weaning	2.9	2.8	2.7	3.0	0.13
Cow weight change (g/day)					
before calving	-460	-520	-495	-485	38
calving to turnout	-1730	-1260	-1700	-1290	144
turnout to weaning	+355	+215	+245	+325	53
Milk yield (kg/day)					
first 6 weeks lactation	8.1	9.5	9.0	8.6	0.26
before turnout	7.2	9.4	8.7	7.8	0.43
2nd week after turnout	11.6	10.1	11.3	10.4	0.59
difference	3.8	1.4	2.7	2.5	0.39
during grazing season	11.7	10.8	12.0	10.4	0.60
Herbage intake (kg OM/day)					
during grazing season	14.1	13.6	14.7	12.9	0.33
Calf weight (kg)					
at birth	39	39	42	37	0.7
at turnout	80	86	87	79	1.7
at weaning	219	224	232	210	4.0
Calf weight gain (g/day)					
birth to turnout	770	930	875	820	38
turnout to weaning	1170	1145	1215	1095	24

Comparisons between genotypes are corrected for variations in date of calving and (for calf results) sex of calf; comparisons between early lactation treatments also include a correction for weight of cow immediately after calving, since there was a significant difference between treatments ($P < 0.05$) in this parameter. There were no significant interactions between treatment and genotype.

The cows lost weight at a mean rate of 490 ± 38 g/day over the last 12 weeks of pregnancy (NSD treatments or genotypes).

Plasma 3-hydroxybutyrate (3-OHB) concentrations were determined weekly for the last 12 weeks of pregnancy. The general pattern of change in this parameter over the late pregnancy period confirmed our previous observations of a progressively increasing concentration up to some 3 to 4 weeks prepartum, followed by a marked decline over the last few weeks. This pattern appears to be quite characteristic, but is difficult to interpret biologically. Where the level of feeding remains unchanged the plasma 3-OHB concentration would normally be expected to continue to rise until parturition. It is intended to examine this phenomenon in subsequent experiments.

Maximum plasma 3-OHB concentrations at 3 to 4 weeks prepartum were generally of the order of 3 mmol/l, but there was considerable variation between individuals, some animals attaining values in excess of 5 mol/l. Methods of describing the shape of the characteristic plasma 3-OHB response during late pregnancy, and of deriving relationships between integrated weekly values and calf birth weight, are currently being investigated.

Cows on Treatment L lost more weight between calving and turnout than those on Treatment H ($P < 0.05$), gave less milk in early lactation ($P < 0.01$), and their calves grew more slowly ($P < 0.001$) and were lighter at turnout ($P < 0.01$).

Milk yields increased substantially in the first two weeks after turnout, and to a much greater extent ($P < 0.001$) in cows from Treatment L than cows from Treatment H, so that by the milk measurement 10 days after turnout the previous difference in yield has disappeared. During the grazing season herbage intakes, milk yields and calf growth rates did not differ significantly between treatments, though all were marginally higher for animals previously on Treatment L. Calves from Treatment H were heavier at turnout ($P < 0.01$), but there were no differences between treatments in calf weight, cow weight or cow condition at weaning.

Calves from Hereford x Friesian (H/F) cows were heavier at birth, turnout and weaning (all $P < 0.001$) than calves from Blue-Grey (BG) cows; their growth rate was significantly greater after turnout ($P < 0.01$), but not before. Milk production was consistently higher in H/F than BG cows, but the differences were not significant. H/F cows were heavier than BG cows at the start of the experiment and at calving ($P < 0.05$), lost more weight in early lactation ($P < 0.05$), and gained weight more slowly (NS) during the grazing season. Genotypes did not differ in weight or condition at weaning.

The re-breeding results in response to oestrus synchronisation before or immediately after turn-out are reported on p. B.42.

Clearly, spring calving suckler cows which enter late pregnancy in good body condition can withstand a prolonged period of under-nutrition in late pregnancy and early lactation, with little detriment to ultimate calf growth or cow condition, if they are allowed access to a generous supply of high quality herbage during the grazing season. The rapid recovery in the milk yield of Treatment L cows and the increased growth of their calves following turnout were particularly striking. The Hereford x Friesian cows produced more milk than Blue-Grey cows and their calves were always heavier, but they required more food when indoors because of their greater weights, and their herbage intakes were higher.

2. <u>The effects of body condition and nutritional state in late pregnancy, nutrition during early lactation, and grazing treatment on the performance of spring-calving suckler cows and their calves (1977 experiment)</u>

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

Results of earlier experiments indicated that with cows in good body condition (condition score 3 or more) at the beginning of late pregnancy, severe undernourishment during the final 12 weeks of gestation had only a small and biologically inconsequential effect on calf birth weight and subsequent performance. The imposition of severe undernourishment in late pregnancy clearly entails a considerable degree of dependence on body reserves, and in this study one objective was to examine the interaction between the effects of body condition at 12 weeks prepartum and nutritional state during late pregnancy on subsequent performance. The levels of feeding in early lactation were the same as those used in 1976. In this trial grazing management was controlled in order to examine the effects on cow and calf performance of interactions between the planes of nutrition during the winter-feeding and grazing phases, and to test whether the marked improvements in milk yield and calf performance which occurred at turn-out in 1976 could be repeated under more stringent grazing management.

<u>Pregnancy</u>

In the pregnancy phase of the experiment there were three treatments each comprising 20 cows (10 Hereford x Friesian (H/F) and 10 Blue Gray (BG)).

Group TA: cows in poor body condition (score <2) at 12 weeks prepartum and fed to avoid significant undernourishment during late pregnancy (plasma 3-hydroxybutyrate (3-OHB) concentrations $<$ 0.6 mmol/l).

Group TU: as in TA but fed to induce a relatively severe degree of undernourishment (plasma 3-OHB concentration around 1.5 mmol/l).

Group FU: cows in good body condition (score >3) at 12 weeks prepartum and fed as in TU during late pregnancy.

Hay was fed to all cows throughout late pregnancy in quantities based initially on 12-week prepartum live weights. Thereafter the quantities were adjusted individually at weekly intervals according to plasma 3-OHB concentrations. Six H/F cows from treatment group TU were removed from the experiment in the weeks immediately before or after parturition, as it was considered that to persist with the treatment could have been injurious to their health. No Blue Grey cows were removed for this reason. Apart from this action, which was necessarily based on subjective assessments, there were no differences between breeds in their response to the pregnancy treatments. The main results of the pregnancy treatments are summarised in Table 1.

Table 1. <u>Mean plasma 3-OHB concentrations and feed intakes during late pregnancy of cows in the three treatment groups, and calf birth weights</u>

Body Condition	Thin (T)		Thin (T)		Fat (F)	
Nutritional State	Adequate Nourished (A)		Severely Undernourished (U)			
	H/F	BG	H/F	BG	H/F	BG
Plasma 3-OHB conc.						
9-12 weeks prepartum	0.43	0.50	0.72	0.87	0.53	0.48
5- 8 weeks prepartum	0.48	0.56	1.24	1.43	0.92	1.00
1- 4 weeks prepartum	0.42	0.54	0.89	0.94	0.85	0.90
Total feed intake (kg hay in 12 weeks)	523	582	303	341	352	342
(kg hay/kg live weight in 12 weeks)	1.17	1.18	0.73	0.77	0.62	0.62
Intakes as proportion of non-pregnant maintenance (%)	117.3	117.8	73.4	76.5	62.2	62.1
Calf birth weight (kg)	42.0	40.7	41.1	40.4	41.7	40.0

The prescribed plasma 3-OHB concentrations were not achieved in the two undernourished groups (TU and FU). Nonetheless, substantial differences in energy status as characterised by plasma 3-OHB concentrations were produced between treatment TA and treatments TU and FU, particularly during the period from 5 to 8 weeks prepartum. In the two undernourished groups, plasma 3-OHB concentrations more nearly approached the prescribed levels in the cows originally in poor body condition (TU); concentrations in the cows in good condition (FU) showed less elevated values, and consequently food adjustments were made less frequently in this group.

The quantities of food supplied to the adequately nourished group (TA) were considerably greater, both in absolute terms and on a body weight basis, than those given to each of the two undernourished groups. In the two undernourished groups (TU and FU) the absolute amounts of food supplied were virtually the same; on a body weight basis, however, the cows in good condition (FU) were given less food (and at the same time appeared to be less severely undernourished) than the cows in poor condition (TU). As proportions of theoretical non-pregnant maintenance requirements the quantities of food supplied to the cows in treatments TU and FU were 75 and 62% respectively (Table 1).

The statistical analysis of results is not complete, but it is clear that severe undernourishment in late pregnancy will not necessarily have an adverse effect on calf birth weight, and that within certain limits, the body condition of the cow at the beginning of late pregnancy is also unlikely to have a significant effect on calf birth weight. However, a certain minimum body condition, probably in the order of condition score 2 to 2.5, is necessary at the beginning of late pregnancy for the cow herself to successfully complete gestation on a low level of nutrition without excessive depletion or exhaustion of body reserves.

<u>Early lactation</u>

The cows calved between 24 January and 10 April. At parturition they were assigned from their pregnancy treatment groups to one of two nutritional levels which were continued until all the cows were turned out to graze on 23 May. The levels were either to provide maintenance of post partum live weight plus an allowance for 2.25 kg milk (L) or maintenance plus 9 kg milk (H). Hay was rationed to supply the maintenance allowance and a proprietary brand of dairy cubes was used to meet the allowance for milk production. Having regard to the poor condition of some of the H/F cows originally on treatment TU, all the remaining H/F and BG cows from this treatment were assigned to the high level of feeding in early lactation. The sequence of treatments in pregnancy and lactation is shown in Table 2 which summarises the uncorrected results for the first 8 weeks of lactation. (See over).

Because of the spread of calving dates, the period of treatment varied between individuals from 6 to 16 weeks. However, the majority of cows completed a minimum of 8 weeks treatment before turn-out. All cows and calves were weighed every 2 weeks, and the milk production of 4 cows of each of the first six treatments in Table 2 was measured at fortnightly intervals using an oxotycin-machine milking technique. There was little difference between breeds in mean daily milk production during the 0-8 week period. The higher plane of nutrition in both pregnancy and early lactation resulted in a higher level of milk production than higher nutrition in either phase alone.

Differences in the milk yield of cows from the TA and TU pregnancy groups were not reflected in calf growth rates, which were similar regardless of cow nutrition in early lactation (Table 2). The calves from three of the four groups of cows from pregnancy treatment FU had appreciably greater live-weight gains than calves from cows on other pregnancy treatments. The exception, BG cows on Treatment FU in pregnancy and H in lactation, had calves which grew

Table 2. Mean values of cow and calf data relating to the first 8 weeks of lactation 1977

Breed	Pregnancy Nutrition	Lactation Nutrition	No. of Cows	Post part. Weight (kg)	Post part. Condition	Weight at 8 weeks (kg)	Condition 8 weeks	Daily Milk Yield 0-8 weeks (kg)	Live weight Loss 0-8 weeks	Calf Birth Weight (kg)	Calf Daily Gain 0-8 wks (g)
Thin Groups:											
BG	TU	H	9	438	1.7	396	1.5	8.83	42	40.0	897
BG	TA	L	4	505	2.2	416	1.8	9.70	89	41.6	968
BG	TA	H	5	481	2.2	439	2.0	10.19	42	39.7	963
HF	TU	H	7	421	1.6	375	1.3	9.10	46	41.0	897
HF	TA	L	5	435	2.0	396	1.6	9.06	39	41.0	963
HF	TA	H	5	452	1.7	391	1.3	10.33	61	43.5	901
Fat Groups:											
BG	FU	L	7	533	2.9	439	2.0	NR	94	41.6	1023
BG	FU	H	7	503	3.0	488	2.8	NR	15	39.0	835
HF	FU	L	5	542	2.9	451	2.3	NR	91	41.5	1021
HF	FU	H	4	551	2.7	492	2.3	NR	59	42.0	1092

relatively slowly, suggesting that milk yields were poor. The cows in this group also lost little weight in early lactation, whereas cows in all other groups utilised body reserves in substantial quantities. Cows on treatment L in lactation lost approximately twice as much live weight as those on treatment H (89 v 48 kg). Patterns of change in body condition score were similar to patterns of live-weight loss.

Grazing

At turn-out on 23 May cows and calves were assigned to two groups balanced for calving date within sequences of pregnancy and lactation treatments, and the two groups grazed as "Leaders" and "Followers" in a rotational paddock grazing system. The daily herbage allowance was set at 40 g DM (measured to ground level) per kg of total cow and calf live weight. The period of grazing in a paddock required to meet this allowance was calculated to the nearest half day from estimates of herbage weight, the weight of the cows immediately after calving, and the latest weights of the calves. The Leaders grazed a paddock for half this period and the Followers for the second half. The paddocks received 75 kg N/ha in the spring, and 40 kg N/ha after each grazing. A Charolais bull ran with each group of cows for 6 weeks from the beginning of the grazing season.

Animals were weighed every two weeks. Estimates of milk production were continued at fortnightly intervals on 24 cows, and the same animals were used for estimates of herbage intake on five occasions. The experiment terminated when the calves were weaned on 1 September.

There was a substantial increase in milk production at turn-out in both the Leader and Follower groups and, as in 1976, the increase was greater in cows on the lower plane of nutrition in early lactation.

The results of statistical analyses are not yet available, but on average the Leader cows were heavier at weaning than the Follower cows (584 vs 526 kg), their milk yields were higher at peak (13-14 kg vs 11-12 kg) and at weaning (11-13 kg vs 7.5-8.5 kg), and their calves grew more quickly (1260 vs 1030 g/day) and were heavier at weaning (260 vs 237 kg).

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

This work has been primarily undertaken to provide a background of information for research and development purposes, at a level of detail not generally available hitherto.

The data used have been abstracted from the statistics of the Department of Agriculture and Fisheries, Scotland. Studies so far have concentrated on full time hill sheep farms, i.e. those with a minimum labour input of 250 standard man days/annum or more. There are 3,443 such hill farms in Scotland. The total area of land involved is 3.1 M hectares, including 2.8 M ha rough grazings, 0.19 M ha grass of which 0.05 M ha are mown and 0.14 M ha are in permanent ley; there are 0.03 ha in crop. On these farms, there is a livestock population of 1.88 M breeding ewes and 0.21 M hill beef cows.

From this basic information it is possible to construct a picture of the "average" full time hill sheep farm. It is 899 ha in size, comprising 826 ha rough grazing, 55.3 ha grassland of which 15 ha are mown annually and has a cropping area of 9.8 ha. The farm carries 548 ewes and gimmers, 62 hill beef cows and has a labour force of 2-3 men.

Relationships between sheep/cattle ratios and farm area devoted to crops and grass have been examined, as have relationships between farm size and stocking rate, and flock size and ratio of rough grazing to inbye land.

The analysis has also been carried out at the Regional level. As an illustration of the contrasts which are found, farms in the Highland area are extensive averaging 1883 ha, including 1820 ha rough grazing, 50 ha crop and grass, 511 breeding ewes stocked at 3.7 ha/ewe and a herd of 48 hill beef cows. In the Grampian region the average farm has 441 ha, of which 349 ha are rough grazing, 89 ha crop and grass, 270 ewes with a S.R. of 1.3 ha/ewe and 64 hill beef cows.

The data which has been analysed is being prepared for publication.

Other studies have been concerned with a detailed analysis of the intensity of land use based on the classification of hill farms by Winter Keep grades. A detailed study of flock size, distributions in hill sheep farming is under way.

Specific aspects of land use have also been examined to provide information for studies on the effect of forestry on agriculture.

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, 1 ha of *Agrostis/Festuca* within an existing paddock was enclosed and reseeded using different methods as a prelude to more extensive reseeding of that area. In preparation, the area of 18.2 ha received ground magnesium limestone at 7.5 tonnes per hectare.

Cattle

As previously 25 hill cows were carried from May 1st to the end of December.

Sheep Stocks and Livestock Reconciliation

The data for the Hairney Law and Auchope flocks have been combined. The breed differences between the two flocks that existed at the beginning of this project have been substantially reduced as a consequence of the breeding policy adopted.

Ewes and Gimmers Nov.1976	Cast	Deaths	Gimmers brought into flock	Hoggs born 1977	Ewes and Gimmers Nov.1977
621	126	14	142	150	623

Total Stock Numbers

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
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

Ewes and gimmers have increased in number by over 50%. Ewe mortality was 2.2%.

Sheep Year 1976/77

a) Winter Feeding

The young ewes and gimmers (336) were fed separately (Auchope) from the older ewes (285) (Hairney Law). 'Norbloc' cereal based feed blocks were made available from 6 January and 13 December respectively to the two groups and hay was given throughout the winter period as necessary.

Concentrate feeding commenced on the 10 January. The amounts given per ewe per day were as follows:-

	Auchope (g)	Hairney Law (g)
10 Jan. Whole oat cubes	223	207
8 Feb.	223	350
18 Feb.	372	
25 Feb. - 7 Mar. Changed over to Ewe Cobs	372	263
18 Mar. - 16 Apr.	372	300

Feeding was continued at these levels to ewes still to lamb.

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

	Ewes & Gimmers (kg)	Hoggs (kg)
Hay	24.7	12.6
Whole Oat Cubes	14.4	
Cereal Blocks	10.0	0.4
Ewe Cobs	23.0	4.1
Sugar Beet Pulp Cubes		13.4
Ewe Pencils		0.7
Grass Nuts		14.6
Ewe and Lamb Food		0.7
Total feed cost/hd.	£6.60	£3.54

b) Lambing Performance

Ewes to tup	621	
Tup eild	34	
Kebs	2	
Ewe losses to lambing	6	
Total lambs born (alive and dead)	754	(121.4%)
marked	674	(108.5%)
weaned	664	(106.9%)

c) Lamb Weights (kg)

Birth weights,	singles	4.1
	twins	3.3
Marking weights,	singles	9.1
	twins	7.4
Weaning weights,	singles	27.1
	twins	25.5
	All lambs	26.5

d) Wool Production (kg)

Age 4 crop	1.8
3 crop	1.8
2 crop	1.9
1 crop	2.1
Gimmers	2.1
All ages	2.0

e) Ewe Body Weights 1976/77

	Nos.	Pre-mating Nov.76	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.77	Nos.
4 Crop	110	58.7	56.3	59.6	50.5	58.6	63.9	119
3 Crop	130	58.5	56.5	59.8	51.3	59.1	61.7	124
2 Crop	131	53.8	52.8	56.6	49.8	58.2	59.0	123
1 Crop	129	50.3	48.8	53.2	48.7	55.7	54.7	115
Gimmers	121	46.7	42.6	47.6	43.5	50.1	50.4	142
All ages	621	53.6	51.3	55.3	48.8	56.3	57.7	623

Summary of Production and Performance 1969-1977

f) Premating Ewe Body Weight (November) (kg)

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
NCC	54.8	56.1	58.9	59.5	60.3	54.7	56.7	58.0	53.6	57.7
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
Stock Numbers	398	451	518	528	573	600	601	620	621
Weaning Percentage	84.7	86.7	102.5	104.7	99.5	91.5	102.7	108.5	106.9
Total Weight Lamb Weaned (kg)	7786	9188	14177	14046	14193	14329	16042	17902	17596
Total Weight Wool (kg)	850	1017	1253	1369	1561	1454	1535	1543	1503

h) Gross Margin (GM) Analysis

	1969	1970	1971	1972	1973	1974	1975	1976	1977
Income									
Lamb	1235.4	1329.6	2196.7	3070.6	4286.9	3576.1	4494.8	7667.9	9398.5
Wool	420.8	469.9	670.4	720.1	852.3	801.2	1011.6	1223.2	1653.3
Cast Ewes	228.8	176.4	533.0	391.3	1170.0	744.2	963.0	1660.8	2358.7
Gimmers								585.8	
Subsidy	489.5	554.7	828.8	871.2	945.5	1800.0	2163.6	2232.0	2235.6
Total	2374.5	2530.6	4228.9	5053.2	7254.7	6921.5	8633.0	13369.7	15646.1
Expenditure									
Feed	498.5	787.2	490.0	722.2	893.3	1492.1	1477.6	2296.6	4615.3
Grazing/Fertiliser	32.5	32.5	91.8	121.0	118.7	21.9	49.5	47.9	139.8
Other Costs	398.0	460.0	507.6	491.0	636.0	798.0	967.6	1178.0	1310.3
Total	929.0	1279.7	1089.4	1334.0	1648.0	2312.0	2494.7	3522.5	6065.4
Flock GM	1445.5	1250.9	3139.5	3719.0	5606.7	4609.5	6138.3	9847.2	9580.7
GM/Ewe	3.63	2.77	6.06	7.04	9.78	7.68	10.21	15.88	15.43

i) Net Annual Cash Flow

	1969	1970	1971	1972	1973	1974	1975	1976	1977
Change in GM	-677	-608	841	1029	2012	1441	2392	4423	3170
Less Capital:									
Reseeding						1792	337	268	539
Fencing	474	180			35				98
Interest Paid	36	192	321	229	92	134	25	20	48
Change in Tax		29	90	135	103	56	698	151	125
Total	-1187	-951	610	935	1988	-429	2728	4286	2610
Cumulative Balance	-1187	-2138	-1528	-593	+1398	+966	+3694	+7980	+10590
Valuation Extra Stock									

YRGS II. On blanket bog - Lephinmore/Midhill

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

Land Resources

The land consists of 444 ha of mainly blanket bog. Improved pasture falls into two categories - some 26 ha of grassy pasture, 14.3 of which was reseeded several years ago, and two larger areas (PI and PII) totalling 69 ha of unimproved *Calluna* and *Eriophorum* moorland, within which some 35% of the area has been surface seeded to give a mosaic of improved grassy pasture throughout the whole. Ten per cent of this area was created during 1973, 4.5 ha being established in PII and 5.5 ha in PI. The remaining 349 ha is 'open hill'. Further division fences in PI were erected during 1974 to increase the capacity to graze twin nursing ewes and gimmers separately during lactation on improved pasture.

Six hundred and ninety five metres of fencing was erected to enclose a 68 ha paddock (Hunts Bog) on the hill for the purposes of feeding gimmers prior to lambing. Eight hectares of reseed in PII created in 1973/74 received 350 kg/ha of fertiliser (15:15:21) in two equal applications (Autumn 1977, Spring 1978).

Sheep Stocks and Livestock Reconciliation

Stock numbers have been increased to a total of 454 Blackface ewes.

Ewes and Gimmers Nov.1976	Cast	Deaths	Gimmers brought in	Hoggs born 1977	Ewes and Gimmers Nov.1977
452	82	23(4*)	107	125	454

* Unspecified loss.

Sheep Year 1976/77

a) Winter Feed

Hay was used in the early part of the winter during a period of snow cover and frost.

Standard Rumevite blocks were provided from 10 January until 8 March. Consumption (g/head/day) was as follows:-

10-17 Jan.	91	1- 7 Feb.	177
18-24 Jan.	155	8-16 Feb.	132
25-31 Jan.	153	17 Feb- 8 Mar.	208

Concentrate feeding began on 8 March and the amounts given per ewe per day were as follows:-

8 March	Ewe Cobs	227 g
22 March		340 g
28 March		400 g
5 April		510 g

Feeding continued at these levels to ewes still to lamb until 1 May when it was reduced to 454 g.

A number of ewes were fed separately through the winter and given additional feed.

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

	Ewes and Gimmers (kg)	Hoggs (kg)
Hay	8.97	108.0
Ewe Cobs	12.60	
Ewe Pencils	4.76	17.7
Grass Nuts	0.20	
Rumevite	8.60	
Total feed cost per head	£3.33	£6.31

The hoggs were housed from 28 October until 7 April.

b) Lambing Performance

Ewes to tup	452	
Tup eild	26	
Kebs	2	
Ewe losses to lambing	11	
Total lambs born (alive and dead)	485	107.3%
marked	435	96.2%
weaned	420	92.9%

c) Lamb Weights (kg)

Birth weights,	Singles	3.9
	Twins	2.8
Marking weights,	Singles	11.6
	Twins	9.8
Weaning Weights,	Singles	25.2
	Twins	21.5

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.76	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.77	Nos.
4 crop	67	54.4	44.8	49.4	45.5	48.1	54.1	69
3 crop	78	52.4	43.0	47.2	44.0	46.9	50.8	61
2 crop	76	48.7	40.0	43.2	40.3	42.9	52.5	102
1 crop	110	48.1	39.7	43.1	41.4	45.1	48.8	115
Gimmers	121	45.6	36.7	41.8	39.3	41.6	44.6	107
All ages	452	49.2	40.3	44.4	41.7	44.5	49.8	454

Summary of Production and Performance 1969-77

f) Premating Ewe Body Weight (November) (kg)

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

g) Production Data

	1969	1970	1971	1972	1973	1974	1975	1976	1977
Stock Numbers	339	361	373	384	422	433	434	458	452
Weaning Percentage	85.0	92.5	103.5	103.6	103.3	98.2	91.0	91.3	92.9
Total weight Lamb weaned (kg)	7207	8500	10268	9924	10218	10870	9638	9701	10419
Total weight Wool (kg)	652	772	772	814	815	856	934	915	882

h) Gross Margin (GM) Analysis

	1969	1970	1971	1972	1973	1974	1975	1976	1977
Income									
Lamb	631	987	1347	1209	2225	1569	1621	1757	2938
Wool	326	355	394	391	416	402	504	631	776
Cast Ewes	252	244	340	390	747	264	365	808	1066
Subsidy	417	444	597	634	696	1299	1562	1649	1627
Total	1626	2030	2678	2624	4084	3534	4052	4845	6407
Expenditure									
Feed	388	411	427	502	741	884	1194	1452	2256
Fertiliser									158
Other Costs	536	639	660	733	810	1108	1171	1218	1252
Total	924	1050	1087	1235	1551	1992	2365	2670	3666
Flock Gross Margin	702	980	1591	1389	2553	1542	1687	2175	2741
Gross Margin/ Ewe	2.07	2.71	4.27	3.62	6.00	3.56	3.89	4.75	6.06

i) Net Annual Cash Flow

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Change in GM		102	376	801	642	1334	665	571	831	896
Less Capital										
Reseeding					100	624				
Fencing						60				449
Interest Paid					8	51				34
Change in Tax		-43	-12	-12	-12	-38	-238	-2	-2	-30
Total		145	388	813	546	637	903	573	833	443
Cumulative Balance	306	451	839	1652	2198	2835	3738	4311	5144	5587

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.

Sheep Stock and Livestock Reconciliation

The initial flock of 217 Scottish Blackface ewes has been increased.

Ewes and Gimmers Nov.1976	Cast	Deaths	Gimmers brought into flock	Hoggs born 1977	Ewes and Gimmers Nov.1977
272	55	18	60	63	259

Sheep Year 1976/77

a) Winter Feeding

Cereal feed blocks (Stockade-25.4 kg) were made available from 4 January. Hay was also given in varying amounts throughout the winter period as dictated by weather conditions.

From 12-20 January 158 g of whole oat cubes per ewe per day were given during a period of adverse weather.

Prepartum feeding proceeded as follows:-

31 January	Whole Oat Cubes	230 g/ewe/day
14 February	" " "	276 g " "
7 March	Change over to Cereal/Protein Ewe Cobs	276 g " "
5 April	Ewe Cobs	368 g " "

Hay feeding stopped

11 April	Ewe Cobs	183 g/ewe/day

Feeding stopped on 31 May.

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

	Ewes and Gimmers (kg)	Hoggs (kg)
Hay	14.8	13.7
Feed Blocks	4.6	
Ewe Cobs	15.8	1.0
Beet Pulp Cubes		10.3
Whole Oat Cubes	10.8	0.8
Grass Nuts		11.5
Ewe and Lamb Food		0.8
Total Cost per head	£4.04	£2.65

b) Lambing Performance

Ewes to tup	272	
Tup eild	10	
Kebs	0	
Ewe losses to lambing	6	
Total lambs born (alive and dead)	350	128.7%
marked	314	115.8%
weaned	307	112.9%

c) Lamb Weights (kg)

Birth weights, (alive & dead)	Singles	4.1
	Twins	3.3
Marking weights,	Singles	10.1
	Twins	7.3
Weaning weights,	Singles	29.5
	Twins	28.6
All lambs		29.1

d) Wool Production (kg)

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

e) Ewe Body Weights (kg)

Ages	Nos.	Pre-mating Nov.76	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.77	Nos.
4 Crop	41	56.9	51.8	55.8	48.4	54.2	61.0	37
3 Crop	51	58.7	53.5	58.4	50.7	57.4	59.1	44
2 Crop	54	56.9	52.8	58.4	50.6	56.6	56.6	60
1 Crop	66	52.7	49.5	54.6	47.7	53.0	54.8	58
Gimmers	60	52.7	48.2	51.4	46.1	50.2	54.5	60
All ages	272	55.3	50.9	55.5	48.6	54.0	56.8	259

Summary of Production and Performance 1972-1977

f) Premating Ewe Body Weight (November) (kg)

1972	1973	1974	1975	1976	1977
54.4	51.8	55.7	54.5	55.3	56.8

g) Production Data

	1973	1974	1975	1976	1977	1978
Stock Numbers	217	222	242	255	272	259
Weaning Percentage	112.9	109.0	116.6	106.3	112.9	
Total Weight Lamb Weaned (kg)	6615	6534	7981	7751	8934	
Total Weight Wool (kg)	493	490	560	542	536	

YRGS IV. On heather moor - Glensaugh, Cairn and Birnie

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.

For the sheep year 1972/73 the Redstones plot (12 ha) was integrated with the Cairn and the Upper and Lower Croft (7 ha) with the Birnie. In 1973/74 another improved enclosure was added to each hirsel, the Redstones reseed (11 ha) with the Cairn and the Upper and Lower Birnie reseeds ($7\frac{1}{2}$ ha) with the Birnie. Some years ago the Redstones plot was improved by grazing control and liming, with partial surface cultivation and seed application. The remaining enclosures were all reseeded some 20 years ago and have since been treated with lime and basic slag, but not after 1972.

Livestock Reconciliation

	Ewes and Gimmers Nov.1976	Cast	Dead	Gimmers brought into flock	Hoggs born 1977	Ewes and Gimmers Nov.1977
Cairn	198	57	23	51	50	177
Birnie	225	54	11	55	58	215

Sheep Year 1976/77

a) Winter Feeding

Concentrates:- Cairn

Dates	Ewes (g/hd)	Gimmers (g/hd)
10 Jan - 3 Feb.	127.5	127.5
4 Feb - 23 Mar.	113.0	169.0
24 Mar - 6 Apr.	225.0	338.0
7 Apr - 19 Apr.	352.0	469.0
20 Apr - 13 May	478.0	598.0
14 May - 17 May	255.0	255.0

Total consumption:- Ewes 28.94 kg/hd.
Gimmers 37.66 kg/hd.

Concentrates:- Birnie

Dates	Ewes and Gimmers (g/hd)
10 Jan - 23 Mar.	111.0
24 Mar - 6 Apr.	223.2
7 Apr - 19 Apr.	334.8
20 Apr - 13 May	446.0

Total consumption: 26.40 kg/hd.

Hay was fed from December 4 to May 6 as follows:-

	Cairn (g/hd/day)	Birnie (g/hd/day)
December	328	224
January	590	488
February	581	584
March	442	333
April	319	321
May	153	67

Total consumption:- Cairn 68.50 kg/hd.
Birnie 58.60 kg/hd.

Total feed per head:- kg.	Cairn,	cost	Birnie,	cost
Concentrate	31.25	£3.50	26.40	£2.96
Hay	68.50	4.11	58.60	3.52
Total cost		£7.61		£6.48

Hoggs

The Cairn and Birnie hoggs were fed concentrates outside from November 3 and hay from November 26. Both hefts were housed on January 11 and fed inside until turn-out on May 9.

Concentrate feeding was identical for both hefts.

Nov. 3 - 9	110 g/hd/day
Nov. 10 - May 9	220 " " "
Total consumption:-	40.46 kg/hd.

Hay was fed as follows:-

	Cairn (g/hd/day)	Birnie (g/hd/day)
Nov. 26 - Dec. 5	105	89
Dec. 6 - Jan. 10	219	89
Jan. 11 - May 9	658	636
Total consumption:-	87.89 kg/hd	80.34 kg/hd

Total feed per hd. (kg)	Cairn,	cost	Birnie,	cost
Concentrates	40.46	£4.53	40.46	£4.53
Hay	87.89	5.27	80.34	4.82
Total cost		£9.80		£9.35

b) Lambing Performance

	Cairn	Birnie
Ewes to tup	196	225
Ewes eild	31	31
Kebs	1	5
Ewe losses to lambing	3	5
Total lambs born	185 (94.38%)	226 (100.44%)
Total lambs marked	140 (71.42%)	188 (83.55%)
Total lambs weaned	132 (67.34%)	184 (81.77%)

c) Lamb Weights (kg)

	Cairn	Birnie
Birth, singles	3.6	3.8
twins	2.6	2.9
Marking, singles	14.1	14.1
twins	13.3	11.3
Weaning, singles	26.4	28.7
twins	24.8	24.1

d) Wool Production (kg)

	Cairn	Birnie
4 crop ewes	1.58	1.84
3 " "	1.78	1.87
2 " "	1.35	1.66
1 " "	1.62	2.11
Gimmers	1.57	1.84
All ewes and gimmers	1.57	1.84
Hoggs	1.92	1.95

e) Ewe Bodyweight Changes (kg):- Cairn

Age	Nos.	Pre-mating Nov.76	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.77	Nos.
4 crop	27	54.16	52.98	53.29	47.72	54.46	59.72	9
3 crop	28	54.46	51.92	52.78	49.04	54.35	53.74	25
2 crop	42	48.04	43.65	43.19	42.46	50.26	53.24	43
1 crop	47	45.92	43.36	43.54	41.59	50.36	50.83	48
Gimmers	52	41.14	37.31	38.20	39.93	46.72	47.28	51
All ages	196	47.45	44.36	44.74	43.63	50.67	51.26	176

Birnie

Age	Nos.	Pre-mating Nov.76	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.77	Nos.
4 crop	23	50.33	51.08	53.45	47.42	50.45	59.16	15
3 crop	36	50.63	52.32	54.24	47.56	53.73	55.38	36
2 crop	47	47.20	46.51	47.81	45.29	51.20	54.24	56
1 crop	60	44.01	45.76	46.87	44.30	51.17	52.58	52
Gimmers	58	38.94	36.22	37.08	39.82	49.09	47.17	53
All ages	225	44.98	45.11	46.42	44.46	51.0	52.78	212

Summary of Production and Performance 1972/77

f) Premating Ewe Bodyweights (kg) - November

	1972	1973	1974	1975	1976	1977
Cairn	52.8	51.8	55.8	50.0	47.5	51.26
Birnie	49.8	49.8	55.1	52.0	45.1	52.78

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
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

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 acquired for extraction.

The new 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 has been 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 will be 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 will be based, at least in the early years, 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

The unit is stocked with Scottish Blackface ewes.

Ewe Numbers Nov. 76	Cast	Deaths	Gimmers brought in	Hoggs purchased	Hoggs born 1977	Ewes and Gimmers Nov.1977
251	45	13*	63	-	77	256

* Unspecified losses 9 included.

Sheep Year 1976/77

a) Winter Feeding

Winterwell cereal based feed blocks were made available from 16 February. Consumption up to 15 March averaged 255 g/ewe/day which was greater than desired. Standard Rumevite blocks were subsequently used up to and during lambing. Consumption during this period was 170 g/ewe/day.

Total cost per ewe ..... £2.18.

Hoggs were inwintered from 8 November to 5 April.

Total consumption of feed per hogg during the winter was as follows:-

Hay	101 kg
Ewebol Pencils	36 kg

Total cost per head ..... £5.87.

b) Lambing Performance

Ewes to tup	251	
Tup eild) Kebs)	28	
Ewe losses to lambing	10	
Total lambs born (alive and dead)	227	90.4%
marked	200	79.4%
weaned	188	74.9%

c) Lamb Weights (kg)

Birth weights, (alive & dead)	Singles	4.0
	Twins	3.1
Marking weights,	Singles	10.5
	Twins	13.4
Weaning weights,	Singles	24.5
	Twins	29.7

d) Wool Production (kg)

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

e) Ewe Body Weights (kg)

Age	Nos.	Pre-Mating Nov.76	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.77	Nos.
4 Crop	20	48.6	44.3	46.6	48.5	50.8	51.8	29
3 Crop	39	52.4	47.4	50.4	49.4	52.2	48.8	38
2 Crop	40	48.7	44.7	47.7	46.6	48.5	47.5	49
1 Crop	60	46.5	42.1	45.2	44.6	47.2	43.8	77
Gimmers	92	42.8	37.6	39.3	40.2	43.3	40.6	63
All ages	251	46.6	41.8	44.4	44.4	47.1	45.4	256

Summary of Production and Performance 1975/77

f) Premating Ewe Body Weight (November) (kg)

1974	1975	1976	1977
47.7	45.4	46.6	45.4

g) Production Data

	1975	1976	1977	1978
Stock Numbers	227	243	251	256
Weaning Percentage	78.4	76.5	74.9	
Total Weight Lamb Weaned (kg)	4530	4652	4668	
Total Weight Wool (kg)	468	482	502	

OFF-WINTERING/INWINTERING SYSTEMS

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

Inwintering systems with and without land improvement

Introduction

In existing traditional systems of hill sheep farming stocking rates are set at levels determined by the need to maintain, from grazed pasture, certain minimum levels of winter nutrition. Stocking rates set in this way are low with respect to levels of summer pasture production, leading to a low efficiency of hill pasture utilisation. Systems based on off-wintering offer possibilities of substantial increases in output arising from the removal of the major constraint to increasing stocking rate.

In attempting to use this biological argument it has to be remembered that even if the capital cost of a wintering house could be avoided by off-wintering sheep (on an area of pasture or some form of hard standing), the increased cost of winter feeding has to be at least recouped if the new system is to be economically viable. Calculations of the output increase that is necessary to justify the expenditures involved usually produce figures in excess of 100%.

The large part of the output increase has to come from increases in stocking rate, since the limited number of studies of inwintering which have been carried out have tended to confirm the expectation that inwintering by itself will not lead to improvements in individual ewe performance. The contribution that improved individual ewe performance would make to output would, of course, reduce the stocking rate increase required to reach an economic break-even point but improvements in individual performance require improvements in summer and autumn nutrition.

The economic argument set the context within which the biological possibilities of off-wintering or inwintering were examined. It was necessary, therefore, to examine the inter-relationship of individual animal performance and stocking rate within the context of an inwintering system. It was anticipated that the results would indicate the expenditures that can be justified or, conversely, what levels of expenditure would be justified.

Arising out of the impact of increased individual ewe performance on the stocking rate increase required to justify any given level of expenditure, and since the extra costs of land improvement are small in terms of the output increases necessary to recoup them relative to those necessary to recoup the increased feed costs of off-wintering, it was relevant to examine the biological and economic consequences of a system based on the association of off-wintering with land improvement.

Since it was to be expected that the results would differ as between hill environments, two studies have been in progress since 1970, one at Sourhope and one at Lephinmore. Within each of these major studies the investigation of the systems possibilities of off-wintering on the one hand, and off-wintering together with land improvement on the other, has been linked together for interpretive reasons. This was done by setting them up side by side on similar sized areas of land of similar character by inwintering both sheep stocks similarly in the same house and by arranging for the stocking rate increases to proceed at the same rate. The improved pasture was integrated with the open hill in these studies in the same way as it has been in the year round grazing system studies.

Inwintering was chosen in each case as the method of off-wintering because of the control it allowed over winter nutrition and its mitigating effects on between year variation in winter weather conditions.

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.

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

Cattle

Up to the summer of 1977 a cattle stock numbering 24 was grazed in such a way as to equate the number of grazing days per month spent on the Gairs with the number of grazing days on the Rigg. They were maintained on these areas from 1 May to 31 December. In 1977 it no longer became possible to graze cattle on the Rigg on this basis because of inadequate pasture.

Sheep Stocks and Livestock Reconciliation

Both the Rigg and Gairs have carried South Country Cheviots. Stocking rate increases have been made equally on the two units by purchase of ewe lambs in late summer which were then wintered with those hoggs retained from that season's flock. In 1974 Blackface hoggs were purchased to replace the Cheviot hoggs on both units. It is intended to replace progressively both Cheviot ewe stocks by Scottish Blackfaces. For this reason the flock data is presented separately for the two breeds.

	Ewes and Gimmers Nov.1976	Cast	Deaths	Gimmers brought in	Hoggs born 1977	Hoggs bought	Ewes and Gimmers Nov.1977
Rigg:							
Cheviot	152	54	5				93
Blackface	138	5	1	59	32	26	191
Total	290	59	6	59	32	26	284
Gairs:							
Cheviot	165	46	8				111
Blackface	132	2	3	72	18	57	199
Total	297	48	11	72	18	57	310

Total Stock Numbers

	1969	1970	1971	1972	1973	1974		1975	1976	1977
Rigg	205	205	238	278	279	298	Cheviot	234	152	93
							B.F.	65	138	191
Gairs	209	207	233	260	279	297	Cheviot	240	165	111
							B.F.	65	132	199

Sheep Year 1976/77

a) Winter Feeding

The Rigg ewes were housed on 10 January and the Gairs on 11 January. Both flocks were given identical rations:-

	Concentrate (g/head/day)	Sugar Beet Pulp (g/head/day)	Hay (g/head/day)
11 January	114	227	568
21 January	114	170	568
1 February	114	227	568
2 March	114	227	605
7/8 March	227	227	756
22 March	170	227	681
31 March	227	227	681
8 April early lambing ewes only	284	227	681

11 April - early lambing ewes and gimmers out of shed and late lambing ewes out on 21st. Feeding continued through lambing.

Total feed per head (kg)	Concentrate	Sugar Beet Pulp	Hay	Ewe and Lamb Feed	Grass Nuts	Whole Oat Cubes	Cost
Ewes and Gimmers	19.7	20.8	63.7				6.75
Hoggs	11.9	22.4	38.1	0.8	3.5	0.4	5.33

b) Lambing Performance

	Ewes mated	Tup eild and Keb	Ewe losses to lambing	Total Lambs born	Marked	Weaned
Rigg:						
S.C.C.	152	7	4	170 (111.8%)	155(102.0%)	153(100.7%)
Blackface	138	8	-	171 (123.9%)	157(113.8%)	152(110.1%)
Gairs:						
S.C.C.	165	5	3	208 (126.1%)	179(108.5%)	181(109.7%)
Blackface	132	5	2	157 (118.9%)	151(114.4%)	144(109.1%)

c) Lamb Weights (kg)

		Rigg		Gairs	
		S.C.C.	Blackface	S.C.C.	Blackface
Birth weights,	Singles	4.4	4.9	4.6	5.2
	Twins	3.6	3.8	3.4	3.7
Marking weights,	Singles	9.1	10.8	10.4	11.6
	Twins	6.9	7.2	6.7	6.9
Weaning weights,	Singles	25.2	30.0	28.5	31.6
	Twins	24.1	27.1	26.0	25.6

d) Wool Production (kg)

	Rigg	Gairs
4 crop	1.7	1.9
3 crop	1.6	2.1
2 crop	2.0	2.0
1 crop	1.4	1.4
Gimmers	1.4	1.5
All ages	1.7	1.8

e) Ewe Body Weights (kg)

Rigg:

Ages	Nos.	Pre-Mating Nov.76	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-Mating Nov.77	Nos.
4 crop	54	54.3	52.4	55.2	46.5	53.6	56.0	46
3 crop	48	55.7	53.3	57.1	48.8	55.8	54.5	47
2 crop	50	52.9	49.7	53.6	46.2	54.8	56.1	60
1 crop	63	52.6	50.7	57.0	45.7	54.9	52.8	72
Gimmers	75	48.5	47.3	53.7	43.6	50.9	51.3	59
All ages	290	52.4	50.4	55.2	45.9	53.7	54.0	284

Gairs:

Ages	Nos.	Pre-Mating Nov.76	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-Mating Nov.77	Nos.
4 crop	44	58.3	56.4	59.7	52.2	58.8	57.1	51
3 crop	58	56.5	54.1	57.7	49.4	57.3	56.6	60
2 crop	63	56.5	52.6	56.4	49.2	57.2	56.7	61
1 crop	63	55.5	52.3	57.9	48.4	56.4	52.0	66
Gimmers	69	48.5	48.1	53.5	44.7	51.4	51.0	72
All ages	297	54.7	52.3	56.8	48.5	55.9	54.4	310

Summary of Production and Performance 1969/77

f) Prenating Ewe Body Weights (kg)

	1969	1970	1971	1972	1973	1974	1975	1976	1977
Rigg:									
S.C.C.	48.3	49.7	51.5	51.2	50.6	50.0	51.8	53.8	55.6
Blackface								48.5	52.1
								52.4	54.0
Gairs:									
S.C.C.	49.9	50.5	51.9	53.5	52.9	54.1	53.8	56.6	56.7
Blackface								48.5	51.5
								54.7	54.4

g) Production Data

	1970	1971	1972	1973	1974	1975	1976	1977
Rigg:								
Stock Numbers	205	205	238	278	279	311	299	290
Weaning Percentage	83.0	87.0	100.8	87.8	91.0	89.6	90.6	105.2
Total weight Lamb weaned(kg)	3706	4432	5712	5324	6155	6257	6640	8218
Total weight Wool (kg)	402	534	641	732	680	670	674	567
Gairs:								
Stock Numbers	209	207	233	260	279	305	305	297
Weaning Percentage	83.0	96.0	91.4	93.1	87.0	87.2	99.0	109.4
Total weight Lamb weaned(kg)	3581	5246	5176	5675	6394	6381	7943	9248
Total weight Wool (kg)	461	524	634	752	766	732	738	643

h) Gross Margin (GM) Analysis

	1970	1971	1972	1973	1974	1975	1976	1977
Rigg								
Income								
Lamb	414	507	1241	1563	2062	2346	3170	4682
Wool	186	286	337	400	375	434	513	567
Cast Ewes	113	206	285	556	224	222	902	820
Subsidy	252	328	393	459	837	1120	1076	1044
Less Hogg Purchase					671	827	594	641
Total	965	1327	2256	2978	2827	3295	5067	6472
Expenditure								
Feed	455	624	654	744	1029	1649	1854	2325
Grazing	3	12	21	16	23	29	40	116
Other Costs	166	174	202	284	374	563	589	612
Total	624	810	878	1044	1426	2241	2483	3053
Flock Gross Margin	341	517	1378	1934	1401	1054	2584	3419
G.M. per Ewe	1.7	2.5	5.8	7.0	5.0	3.4	8.6	11.8

i) Net Annual Cash Flow

	1970	1971	1972	1973	1974	1975	1976	1977
Rigg:								
Change in Gross Margin	-277	-232	411	776	354	-148	886	1407
Less Capital								
Reseeding								
Buildings	3348						2466	
Fencing								
Interest Paid	184	419	471	450	384	358	522	592
Change in Tax		-176	-256	-274	-267	-244	-236	-375
Total	-3809	-475	+196	+600	+237	-262	-1866	+1190
Cumulative Balance	-3809	-4284	-4088	-3488	-3251	-3513	-5379	-4189

j) Gross Margin Analysis

Gairs:

	1970	1971	1972	1973	1974	1975	1976	1977
Income								
Lamb	508	700	1053	1632	2142	2393	3859	5645
Wool	213	280	333	411	422	476	565	649
Cast Ewes	165	223	293	565	224	291	783	667
Subsidy	257	331	384	429	837	1098	1098	1069
Less Hogg Purchase					719	827	783	1406
Total	1143	1536	2063	3037	2906	3431	5522	6624
Expenditure								
Feed	470	624	634	704	1035	1639	1886	2358
Grazing	8	21	25	25	30	53	82	135
Other Costs	169	176	198	265	374	552	601	626
Total	647	821	857	994	1439	2244	2569	3119
Flock Gross Margin	496	714	1206	2043	1467	1187	2953	3505
Gross Margin per Ewe	2.4	3.5	5.2	7.9	3.9	3.9	9.7	11.8

k) Net Annual Cash Flow

	1970	1971	1972	1973	1974	1975	1976	1977
Gairs:								
Change in G.M.	-60	39	340	1012	526	106	1437	1708
Less: Capital								
Reseeding	224	426	63			711		351
Buildings	3348						2466	
Fencing	216	127					205	
Interest Paid	208	476	529	506	414	408	598	616
Change in Tax		-268	-432	-326	-298	-266	-506	-420
Total	-4056	-722	+180	+832	+410	-747	-1326	+1161
Cumulative Balance	-4056	-4778	-4598	-3766	-3356	-4103	-5429	-4268

IWS II. On blanket bog - Lephinmore/Low End

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

This study was terminated in 1975/76. A summary of the management and performance achieved during the period of the study (1970/76) follows.

Resources and Management

The land resource which was regarded as being 'poor' in terms of its vegetation and soil rises from near sea level to 680 m and receives an annual rainfall of 2000 mm. The unit carried 180 ewes which produced around an 80 per cent lamb crop at weaning of average weight 27.0 kg. Feed inputs were negligible at around 5-6 kg of a protein/cereal supplement per ewe.

In 1975 the hill was divided and fenced into two areas of 167 ha (north) and 157 ha (south).

The flock of Scottish Blackface ewes was divided equally and allocated by age and weight and to some extent in relation to their previous area of hill grazing to the northern and southern hill areas respectively. Associated with both hill units was an area of improved (i.e. reseeded) 'common' land of 14 ha. Associated with the southern hill two areas of improved, reseeded land were created. The first of 8 ha in 1969/70 at the start of the study and the second of 7 ha, alongside the first, in 1972. Both areas received 2 tonnes lime and 500 kg basic slag, after either being burned (7 ha) or grazed heavily with cattle (8 ha). The 8 ha reseed was sown with seed cleanings fortified with perennial ryegrass (S23) and white clover. A compound fertiliser providing some 150 units of N per hectare was applied at the time of seed sowing. The 7 ha area was sown in the summer of 1972 with perennial ryegrass (Barenza and Premo) and white clover. A compound fertiliser was also applied at the time of sowing.

In each year of the study both flocks were removed from their respective hill areas during the second week in January until lambing.

The flock grazing the southern hill area, the associated improved land, and the equivalent of half of the Common grazing, was designated the 'Inwintered + land improvement' (IN + LI) flock. That grazing the northern hill and the equivalent of half the Common grazing was designated the 'Inwintered' (IN) flock.

In the first four years of the study the ewes from both flocks were removed from the sheep house some seven days prior to lambing to the Common grazings. For the remaining three years of the study the ewes were lambed inside.

After lambing, ewes from both flocks nursing twins remained on the Common grazings up to weaning. A proportion of gimmers nursing single lambs from both flocks were also kept on the Common grazings up to weaning, the numbers from each flock being such as to give an equal number of ewes from each flock, i.e. (IN) and (IN + LI) on the Common grazings.

The remaining ewes from flock (IN) were put out to their respective hill area after 3-7 days. The remaining ewes from the (IN + LI) flock were grazed on the improved reseeded areas throughout the period of lactation except in 1976 when some 100 ewes with lambs grazed the hill for a period of three weeks in May during which time the improved land was free of sheep.

At weaning the lambs were removed from the units and the ewes from both flocks returned to their respective hills.

Before mating the ewes from the (IN + LI) flock were grazed for a short period (2-4 weeks depending on the autumn regrowth of pasture) on their improved land before joining the ewes from the (IN) flock at mating on the Common grazings. Mating proceeded on the Common grazing until such time as pasture was no longer available. The ewes were then returned to their respective hills, the (IN + LI) ewes grazing their improved land for a week to ten days before going out to their hill.

As stocking numbers increased it was not possible to accommodate all ewes on the Common grazings during mating. In the last two years some 60 ewes from each of both flocks have not been mated in the Common grazings. The 60 on the (IN) flock have returned to the hill and those on the (IN + LI) flock to the 15 ha of improved grazing.

During the second week in January the ewes from both flocks were housed and given a basal diet of 908 g hay and 114 g cereal/protein supplement. The levels of concentrate feed given during the last six to eight weeks of pregnancy were adjusted so as to maintain blood ketone levels below 3 mg%. The total amounts of feed given are presented in Table 1. The amounts of feed given to the ewes from both flocks were the same since there was no evidence in any year that one flock was more undernourished than the other.

Table 1.

	Hay (kg/hd)	Concentrate (kg/hd)
1969	96.5	26.2
1970	70.8	18.7
1971	71.0	17.6
1972	75.8	18.0*
1973	82.0	19.3
1974	82.0	26.1
1975	87.4	21.8

* Some Sugar Beet Pulp Cubes were included.

The hoggs from both flocks were also housed during the winter from the beginning of November until prior to lambing. They were given some supplementary feed on being returned to their respective hills for two to three weeks. They remained on the hill throughout the summer.

The amounts of feed given are presented in Table 2 (hoggs).

Table 2.

	Hay (kg/hd)	Concentrate (kg/hd)
1969	Away	Wintered
1970	68.1	14.1
1971	89.9	13.9
1972	74.9	14.8
1973	79.5	14.2
1974	83.2	19.3
1975	90.8	17.0

Stock Numbers

Part of the objective of removing ewes off their grazing areas during the winter is to facilitate an increase in stock numbers to levels which are more commensurate with summer pasture production. Consequently ewe numbers were progressively increased on both units (IN) and (IN + LI).

Ewe numbers were increased by the retention of extra ewe lambs, the purchase of ewe lambs on transfer from other flocks at Lephinmore and the retention of old "cast for age" ewes.

Results

a) Lamb and Wool Production, Stock Numbers and Weaning Percentage

	Stock Numbers	Weaning Percentage	Total Lamb (kg)	Per Ewe	Per Hectare	Total Wool (kg)
(IN)						
1970	107	80.0	2279	21.3	13.9	205
1971	115	93.0	2857	25.0	17.4	257
1972	143	103.5	3775	26.7	23.0	282
1973	166	92.8	3775	22.7	23.0	293
1974	176	78.4	3414	19.4	20.8	354
1975	174	82.2	3861	22.2	23.5	363
1976	192	90.6	4507	23.5	27.5	464
(IN + LI)						
1970	102	70.7	2015	19.8	11.6	179
1971	112	104.5	3324	29.7	19.1	246
1972	137	97.1	3511	25.6	20.2	274
1973	160	102.5	3800	23.8	21.8	304
1974	174	76.2	3232	18.6	18.6	328
1975	174	83.9	3825	22.0	22.0	356
1976	187	93.6	4602	24.6	26.4	433

b) Lambing Performance

	No. Ewes	Barren	Deaths to Lambing	Total lambs born	Lambs Marked	Lambs Weaned
(IN)						
1970	107	23(21.5)	4	97(91.5)	89(83.9)	85(80.1)
1971	114	9(7.9)	4	123(107.9)	107(93.9)	106(93.0)
1972	143	11(7.7)	2	175(122.4)	154(107.7)	148(103.5)
1973	166	16(9.6)	2	175(105.4)	154(92.8)	154(92.8)
1974	176	31(17.6)	1	155(88.1)	142(80.7)	138(78.4)
1975	174	21(12.1)	-	159(91.3)	147(84.5)	143(82.2)
1976	192	20(10.4)	-	197(102.6)	176(91.7)	174(90.6)
(IN + LI)						
1970	102	27(26.5)	4	94(87.7)	82(77.3)	75 (70.7)
1971	112	5(4.5)	2	135(120.5)	122(108.9)	117(104.5)
1972	137	14(10.2)	1	151(110.2)	136(99.3)	133(97.8)
1973	160	10(6.3)	2	204(127.5)	166(103.8)	164(102.5)
1974	172	39(22.7)	-	158(91.9)	134(77.9)	131(76.2)
1975	174	28(16.1)	-	166(95.4)	150(86.2)	146(83.9)
1976	187	17(9.1)	3	196(104.8)	178(95.2)	175(93.6)

c) Lamb Mortality - percentage of total lambs born

	Total live lambs born	Birth to Marking	Marking to Weaning	Birth to Weaning
(IN)				
1969-70	97	8.3	4.1	12.4
1970-71	123	13.0	0.8	13.8
1971-72	175	12.0	3.4	15.4
1972-73	175	12.0	0.0	12.0
1973-74	155	7.1	2.6	10.9
1974-75	156	6.1	0.0	6.1
1975-76	193	6.2	0.0	6.2
(IN + LI)				
1969-70	94	12.8	7.4	20.2
1970-71	135	9.6	3.7	13.3
1971-72	151	9.9	2.0	11.9
1972-73	204	18.6	1.0	19.6
1973-74	158	15.2	1.9	17.1
1974-75	166	8.4	0.0	8.4
1975-76	187	4.5	0.0	4.5

d) Lamb Body Weights (kg)

	Singles			Twins		
	Birth	Marking	Weaning	Birth	Marking	Weaning
(IN)						
1969/70	4.0	12.1	28.1	3.2	9.8	23.2
1970/71	4.0	13.1	28.1	2.9	10.9	23.4
1971/72	4.0	12.8	26.4	3.2	11.4	24.4
1972/73	4.1	12.6	25.6	3.0	10.7	21.3
1973/74	3.7	12.8	25.1	2.6	10.6	22.3
1974/75	4.0	11.9	27.2	3.0	10.9	24.6
1975/76	3.9	11.8	26.6	2.7	9.3	23.4
(IN + LI)						
1969/70	4.3	12.1	27.2	2.9	9.0	23.0
1970/71	4.3	13.6	30.3	3.2	10.5	24.1
1971/72	4.2	13.0	27.3	3.2	11.5	25.0
1972/73	4.2	13.0	25.0	2.9	11.8	21.2
1973/74	3.7	14.1	25.4	2.8	10.7	20.7
1974/75	4.1	13.2	26.8	3.0	10.8	23.8
1975/76	3.9	11.6	26.7	2.9	10.6	25.2

e) Lamb Growth Rates (g/day)

	Singles			Twins		
	Birth	Marking	Weaning	Birth	Marking	Weaning
(IN)						
1969/70	249	211	223	211	163	177
1970/71	264	199	219	206	156	172
1971/72	221	201	209	183	182	183
1972/73	239	172	193	203	130	154
1973/74	234	169	192	204	154	174
1974/75	257	193	210	207	181	184
1975/76	237	158	179	147	173	169

Lamb growth rates (cont'd).

	Singles			Twins		
	Birth	Marking	Weaning	Birth	Marking	Weaning
(IN + LI)						
1969/70	253	202	216	218	167	179
1970/71	285	219	239	219	168	183
1971/72	231	210	218	187	187	187
1972/73	240	157	183	205	135	158
1973/74	254	155	191	234	151	182
1974/75	276	176	205	207	165	177
1975/76	235	180	194	194	177	183

f) Ewe Body Weights (kg)

	Premating	Prefeeding	Prelambing	Marking	Weaning
(IN)					
1969/70	44.0	47.3	49.8	46.7	50.7
1970/71	49.3	47.1	50.4	47.5	51.0
1971/72	48.2	46.9	52.2	45.5	48.7
1972/73	47.2	46.2	48.2	46.5	47.4
1973/74	43.0	42.3	44.9	46.5	47.7
1974/75	44.8	43.2	48.0	46.8	47.0
1975/76	45.2	44.0	48.7	43.4	46.3
(IN + LI)					
1969/70	44.0	46.2	48.5	44.3	47.6
1970/71	49.4	47.9	51.9	45.4	51.1
1971/72	48.5	46.8	51.9	46.2	48.1
1972/73	49.2	47.8	49.7	46.6	47.2
1973/74	45.8	42.3	44.9	45.4	49.4
1974/75	48.0	43.6	48.6	48.1	48.6
1975/76	45.7	44.4	49.5	44.0	47.3

g) Gross Margin Analysis

(IN)	1970	1971	1972	1973	1974	1975	1976
Income							
Lamb	237	329	413	750	460	578	885
Cast Ewes	48	85	144	216	260	100	328
Wool	94	131	135	149	166	196	282
Subsidy	130	182	236	274	528	634	691
Total	509	727	928	1389	1414	1508	2186
Expenditure							
Feed: Ewes							
Concentrate	98	76	102	121	234	361	350
Sugar Beet Pulp				13			
Hay	151	119	170	209	567	568	743
Hogg Wintering	51	132	105	117	353	215	347
Other Costs	190	202	273	319	451	473	540
Total	489	529	650	779	1605	1617	1980
Gross Margin	20	198	278	610	-191	-109	206

Gross Margin Analysis (cont'd)

	1970	1971	1972	1973	1974	1975	1976
(IN + LI)							
Income							
Lamb	194	342	362	779	429	580	905
Cast Ewes	52	105	114	225	236	120	288
Wool	82	126	132	155	154	192	241
Subsidy	130	179	226	264	516	626	673
Total	458	752	834	1423	1335	1518	2107
Expenditure							
Feed: Ewes							
Concentrate	98	74	100	117	238	357	341
Sugar Beet Pulp				13			
Hay	151	117	163	202	554	561	724
Hoggs	50	132	105	117	353	215	347
Other Costs	190	198	262	307	440	468	526
Total	489	521	630	756	1575	1601	1938
Gross Margin	-31	231	204	667	-240	-83	169

h) Increase or Decrease in Gross Margin from Low End (£)

	1970	1971	1972	1973	1974	1975
Base Gross Margin	559	691	654	1124	775	1023
(IN) Gross Margin	20	198	278	610	-191	-109
(IN + LI) Gross Margin	-31	231	204	667	-240	- 83
Change	-548	-262	-172	153	-1206	-1215

At the beginning of the study the cost of buildings and the cost of 'bought-in' feed required that ewe numbers would have to be at least doubled and lamb weaning percentage increased to over 110 per cent to obtain economic viability. Though the output per unit area was more than doubled (stock numbers were increased by 90 per cent and lamb output per ewe was increased marginally), the increase in costs due to the increased 'bought-in' feed required to to maintain adequate levels of nutrition during the off-wintering period was greater than the income realised from the increased output. It was clear that the necessary improvement in individual ewe performance was unlikely to be forthcoming at the stocking rate achieved by 1976 and with the existing land resources.

The general conclusion in relation to animal performance was that even if summer nutrition had been improved by additional land improvement to achieve greater ewe body weight recovery and higher premating body weights to ultimately achieve an increased number of lambs weaned (110 per cent), a lamb price of 70p/kg liveweight would have had to be obtained to make the unit economically viable.

UPLAND

03008: Improved systems of sheep production from upland pastoral resources

Sheep production systems in the uplands

T.J. Maxwell, J. Eadie, R.D.M. Agnew and I. Stephen

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

Introduction

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

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

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

Previous investigations concerning the levels of output achieved from pastoral sheep systems have tended to be conducted as stocking rate experiments, the aim being to establish the effects of different stocking rates at various levels of pasture production on individual animal performance. Many of these experiments have lacked objectivity and have often been conducted without reference to the constraints that are a feature of pastorally based sheep production systems. The parameters used in deciding when to move sheep from one grazing to another are rarely defined. The conservation of surplus pasture is often an integral part of these systems but the area of pasture conserved is frequently unrelated either to the maintenance of adequate levels of nutrition from the remaining grazed area or to the amount of conserved feed required for the winter. Winter nutrition is set at a level which is often unrelated to the animal's performance at pasture during the grazing season. Furthermore, these experiments are invariably short term experiments lasting for one or two seasons. They, therefore, do not take account of the long term effects of the various treatments on animal performance.

The conduct of the systems experiment is carried out with reference to a number of management decision rules. The more important of these are concerned with the timing and application of fertilisers, the closing of areas of land for conservation, the movement and stocking of sheep, and the timing and level of feeding of ewes during gestation and lactation.

The measurements taken to assist in the implementation of these rules include 4" soil temperature, availability of pasture, and nutritional status of the ewe in terms of blood ketone analysis.

Four systems of production under study are as follows:-

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

Land Resources

In October 1973 an area of land was designated to the Greyface systems experiment. This consists of the Bowes Field, 5.11 ha (5-6 year ley), the Hard Park, 4.78 ha (1 year ley), the Hogg Park, 4.02 ha (2nd year ley), and the Forestry Park, 4.83 ha, which is permanent pasture, together with approximately 10 hectares of hill, the 'Loch Hills'. Each field was subdivided into four paddocks, each system having one paddock in each field. The areas of the respective systems were 5.13, 4.71, 4.47 and 4.43 hectares. The hill area (14.0 ha) was fenced to give wintering paddocks, two large paddocks for the high stocking rate and two small paddocks for the low stocking rate systems. Each pair of paddocks are alternated between the two 'early' and 'late' systems on an annual basis.

Sheep Stocks

Scottish Blackface x Border Leicester (Greyface) ewes are used and are mated with a Dorset Down ram.

Livestock Reconciliation 1976/77

System	Ewes and Gimmers Nov.1976	Cast	Deaths	Gimmers brought in	Ewes and Gimmers Nov.1977
1	51	8	3	29	69
2	72	11	4	13	70
3	44	16	3	23	48
4	66	16	5	12	57

The number of ewes for each system is up to the total required. Mortality averaged 6.4% for the four systems.

Sheep Year 1976/77

a) Winter feeding

Hay was provided for the early lambing systems and for the late lambers from 2nd November. Concentrates were fed to the early lambers from 19th January and to the late lambers from 4th February, approximately eight weeks prepartum in each case.

Prelambing concentrate feeding was based on ewe body weight and plasma B-hydroxybutyrate levels monitored fortnightly until approximately three weeks before lambing when weekly weighing and sampling was adopted.

Feeding continued into lactation until the 27th May for the low stocking rate and high stocking rate systems.

Mean plasma B-hydroxybutyrate levels and subsequently determined feeding
(Aim was to keep B-hydroxybutyrate levels between 0.6 and 0.7 mg%)

Number of weeks prepartum	9	8	7	6	5	4	3	2	1
EARLY LAMBERS									
Mean plasma hydroxybutyrate level (mg%)	0.37			0.48	0.58			0.63	1.08
Date of sampling	6/1			25/1	1/2			22/2	1/3
Feeding: Concentrate	–	–	113	113	227	340	454	567	567
Hay	938	938	938	938	938	938	938	938	930
(g/hd/day)									
LATE LAMBERS									
Mean plasma hydroxybutyrate level (mg%)	0.45			0.45	0.61	0.37	0.59		0.61
Date of sampling	1/2			22/2	1/3	8/3	15/3		29/3
Feeding: Concentrate	–	113	113	227	340	454	454	454	567
Hay	789	789	789	789	789	789	789	789	750
(g/hd/day)									

a) Total Feed Inputs and Cost per ewe

Systems 1 and 2

	Prelambing kg	Prelambing £	Lactation kg	Lactation £	Total kg	Total £
Concentrate	23.7	2.66	103.3	11.57	127.0	14.23
Hay	80.5	3.93	57.0	2.60	137.5	6.53
Total cost		6.59		14.17		20.76

Systems 3 and 4

	Prelambing kg	Prelambing £	Lactation kg	Lactation £	Total kg	Total £
Concentrate	24.2	2.71	56.4	6.31	80.6	9.02
Hay	93.0	4.55	26.9	1.32	119.9	5.87
Total cost		7.26		7.63		14.89

b) Lambing Performance

System	Ewes to tup	Eild	Ewe losses to lambing	Total lambs born alive	Total lambs marked	Total lambs weaned
1	51	0	1	89 (174.5%)	78 (152.9%)	77 (151.0%)
2	72	2	1	131 (181.9%)	112 (155.6%)	110 (152.8%)
3	44	0	0	71 (161.4%)	62 (140.9%)	62 (140.9%)
4	66	3	3	93 (140.9%)	82 (124.2%)	89 (121.2%)
	233	5	5	384 (164.8%)	334 (143.3%)	329 (142.6%)

Lamb types

System	No. ewes lambed	Ewes producing: Singles No.	%	Twins No.	%	Triplets No.	%
1	50	11	22.0	36	72.0	3	6.0
2	69	12	17.4	52	75.4	5	7.2
3	42	15	35.7	27	64.3	0	0
4	60	27	45.0	33	55.0	0	0
	221	65	29.4	148	67.0	8	3.6

c) Lamb weights (kg)

System	Birth Singles	Birth Twins + Mult.	Birth All	Marking Singles	Marking Twins + Mult.	Marking All	Weaning Singles	Weaning Twins + Mult.	Weaning All
1	4.8	4.1	4.2	21.3	15.2	16.1	36.1	30.3	31.1
2	5.3	3.9	4.0	17.9	13.8	14.3	34.3	27.9	28.6
3	5.3	4.2	4.5	23.6	18.7	19.8	40.8	32.6	34.4
4	5.3	4.1	4.5	20.2	17.9	18.7	35.5	32.4	33.5

Lamb mortality

System	Total lambs born	Born dead No.	%	Birth-Marking No.	%	Birth-Weaning No.	%
1	89	1	1.1	11	12.4	12	13.5
2	131	8	6.0	24	17.9	26	19.4
3	71	3	4.2	9	12.7	9	12.7
4	93	2	2.1	11	11.8	13	14.0

d) Wool production

System	Age of Ewe: 1 crop	2 crop	3 crop	4 crop	5 crop	Mean
1	3.0	2.9	2.3	2.4	-	2.7
2	2.8	2.9	2.7	2.4	-	2.7
3	3.3	2.4	2.5	2.2	-	2.5
4	2.7	2.4	2.6	2.3	-	2.5

e) Ewe body weight change 1976/77 (kg)

System	Pre-mating 8/10/76	Pre-feeding 6/1/77	Pre-lambing 4/5/77	Marking 29/4/77	Clipping 29/6/77	Weaning 12/7/77	13/9/77
1	68.5	69.0	72.7	64.0	61.1	63.9	75.0
2	65.6	68.4	71.8	62.2	58.2	60.0	68.6
	15/11/76	1/2/77	29/3/77	30/5/77	30/6/77	29/8/77	29/9/77
3	62.6	62.4	69.9	65.2	65.4	67.3	68.3
4	57.7	60.3	65.8	63.5	63.0	67.3	69.1

f) Total production data

System	Nos.	Weaning %	Total weight lamb weaned (kg)	Weight of lamb per ewe	Weight of lamb per hectare	Weight of wool
1	51	151.0	2398	47.0	467.4	127
2	72	152.8	3147	43.7	668.2	191
3	44	140.9	2136	48.5	477.8	106
4	66	121.2	2678	40.6	604.5	152

g) Fertiliser inputs

Nitrogen was applied to all treatments at the rate of 247 units per hectare per annum.

On April 26/27 the Bowes Field (A) and the Forestry Park (D) received 150 units of nitrogen per hectare, whilst the Hard Park (B) and the Hogg Park (C) received 140 units with a further 51 units on May 20 (early lambing paddocks) and June 13 (late lambing paddocks).

After conserved paddocks in A and D had been harvested on June 29, A and D received 46 units per hectare on July 5. On the same day paddocks 1 and 2 of the Hard and Hogg Parks received a final 56 units after weaning of the early lambs. After weaning of the late lambs, paddocks 3 and 4 received the final 56 units on August 10.

Estimate of hay production

The yield estimates are based on pasture sampling measurements taken on 26 June when the grass was at an optimum for cutting to achieve a high digestibility and high yield.

System	Area conserved	Total hay yield (tonnes)	Total yield (tonnes/hectare)
1	2.028	8.519	4.2
2	-	-	-
3	1.280	4.860	3.8
4	-	-	-
Total	3.310	13.380	4.0

The above estimates were obtained from herbage cut to a shorter stubble and dried to a greater degree than would be possible in practice.

Herbage Digestibility

A selection of herbage samples taken primarily for purposes of grazing allocation, was retained and subjected to dry matter digestibility analyses.

It will be possible to relate seasonal digestibility changes to pasture availability and botanical composition when the digestibility results become available.

Pasture Measurements - weight of herbage DM cut to ground level (kg per ewe)

	10/5	24/5	13/6	27/6	18/7	8/8	22/8	8/9	28/9	11/10	25/10	15/11	8/12
1	26.4	62.1	67.2	63.6	116.9	185.1	215.9	119.8	120.3	113.2	77.6	53.8	-
2	6.1	31.1	47.0	55.8	71.4	102.2	106.2	79.7	75.7	75.2	57.1	36.8	-
3	25.8	63.9	95.6	101.5	131.0	167.9	186.0	165.1	146.6	142.2	115.3	93.1	-
4	114.5	54.5	78.6	96.6	96.0	117.5	118.6	94.2	95.1	106.7	63.8	62.1	-

Pasture Measurements - weight of herbage DM cut to ground level (kg per hectare)

1	326	905	997	944	1058	1676	1955	2187	2196	2013	1416	783	-
2	115	443	649	782	1030	1476	1533	1577	1496	1487	1130	614	-
3	325	722	1229	1305	1129	1446	1602	2290	1991	1931	1567	1238	791
4	265	775	994	1199	1192	1617	1633	1715	1732	1943	1163	1139	899

SIMULATION

03009: Systems Modelling

1. Lactation Model

A.R. Sibbald and T.J. Maxwell

The sheep used in the Agrostis/Festuca grazing model, described in last year's Annual Report (pp 63-65) were non-breeding. The modelling of hill sheep production systems requires the use of breeding ewes and the modelling therefore of reproduction, pregnancy and lactation.

Lactation is of importance to both lamb growth and ewe body weight recovery and is considered to be the area which will cause the greatest modelling problems. The lactation of hill and upland sheep has received considerable attention within the research programme in HFRO. It therefore seemed appropriate to attempt to model the lactation of sheep.

Many factors are known to influence the level of lactation in sheep; these include breed, number of lambs suckled, condition of the ewe, quality of diet and the extent of appetite expansion during lactation. It is by no means clear from existing data which of these are the driving variables and the fact has greatly influenced the initial development of the model.

It has been assumed in the model that there is a maximum potential level of milk production related to breed of sheep and number of lambs suckled. Lactation curves of this type are described in the literature. Ewe maintenance must always be satisfied and, additionally, during early lactation, the model attempts to achieve full potential milk production, the constraining factors of level and rate of use of mobilisable ewe reserves operating when energy derived from herbage intake is less than adequate for both ewe maintenance and milk production. Energy derived from herbage is limited by the quality of herbage and the extent to which the ewe can expand its appetite above a level based on that of a dry ewe of similar body weight. When intake is restricted, reserves may be mobilised, the ewe accordingly may lose body weight, and milk production may be reduced.

As lactation proceeds the partitioning of energy, surplus to the ewe's maintenance requirement, is increasingly towards ewe body weight recovery. The representation of this partitioning of energy when intake is restricted, has, so far, caused the greatest problem in the development of the model since mobilisation of ewe reserves must again be taken into account. The development of the model has led to a deterministic partitioning procedure by which the rate of transfer of energy towards ewe body weight recovery after early lactation is controlled by a defined input of data. A flow chart of the model including the partitioning decisions is shown in Figure 1.

Testing the responses of the model against data from recent experimentation will provide a means of further verifying concepts and some of the functional relationships the model currently uses.

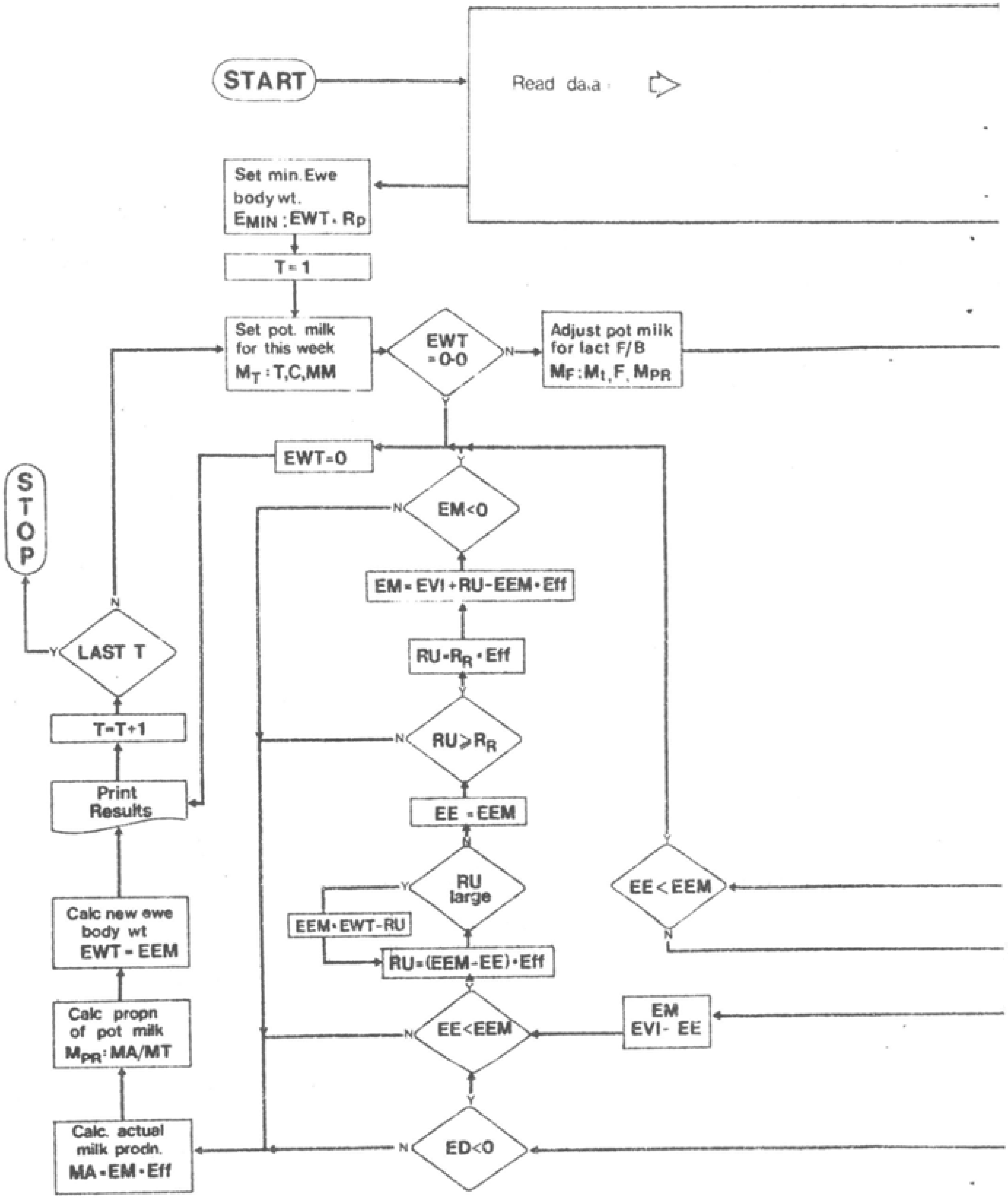
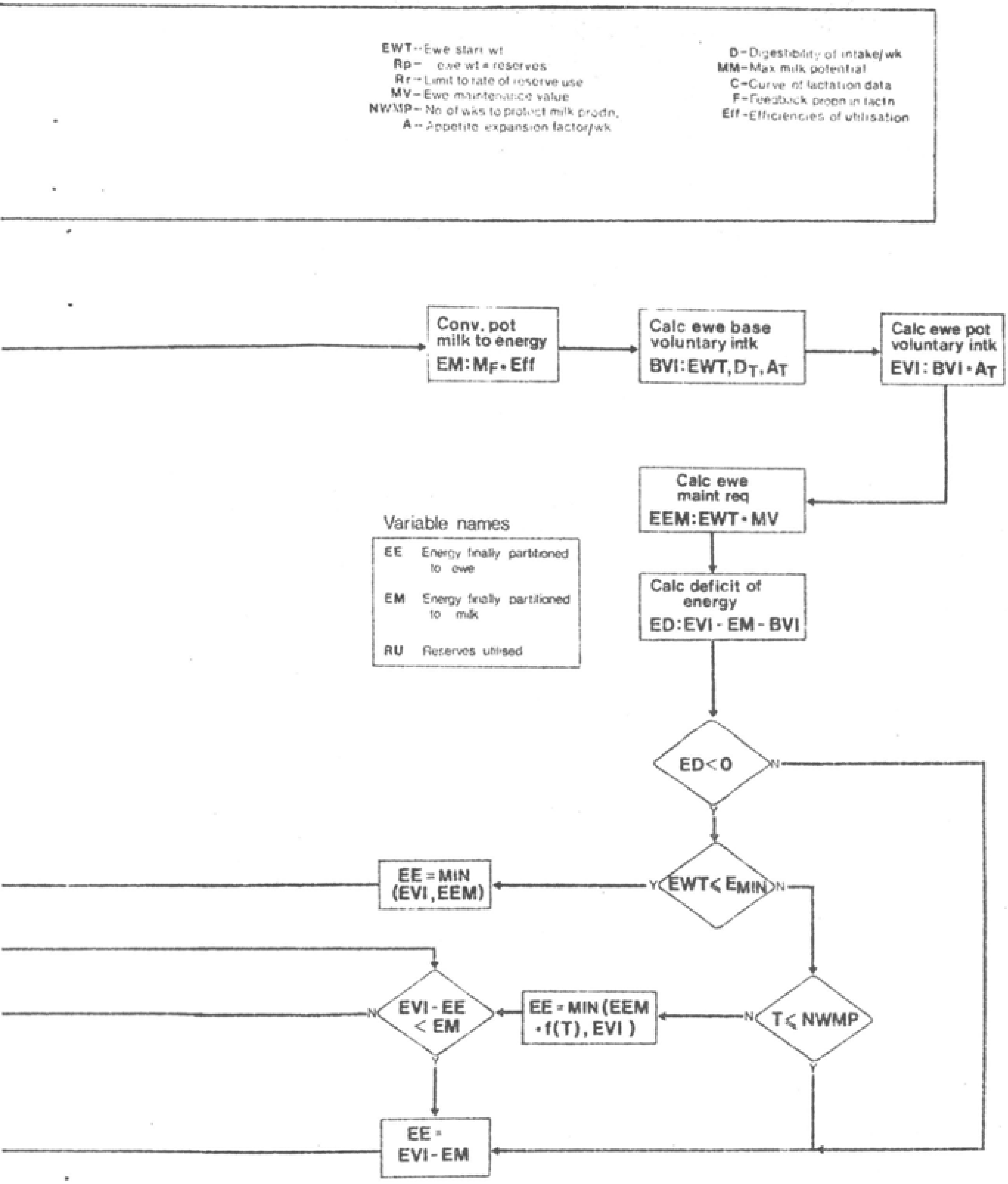


Fig. 1. Flow chart of Lactation Model



EWT – Ewe start wt
Rp – ewe wt = reserves
Rr – Limit to rate of reserve use
MV – Ewe maintenance value
NWMP – No of wks to protect milk prodn.
A – Appetite expansion factor/wk
D – Digestibility of intake/wk
MM – Max milk potential
C – Curve of lactation data
F – Feedback propn in lactn
Eff – Efficiencies of utilisation
Conv. pot milk to energy
EM: MF • Eff
Calc ewe base voluntary intk
BVI: EWT, DT, AT
Calc ewe pot voluntary intk
EVI: BVI • AT
Calc ewe maint req
EEM: EWT • MV
Variable names
EE Energy finally partitioned to ewe
EM Energy finally partitioned to milk
RU Reserves utilised
Calc deficit of energy
ED: EVI - EM - BVI
ED < 0
N
Y
EWT ≤ EMIN
EE = MIN (EVI, EEM)
T ≤ NWMP
EE = MIN (EEM • f(T), EVI)
EVI - EE < EM
EE = EVI - EM

2. Land Use - Agriculture and Forestry Integration

T.J. Maxwell and A.R. Sibbald

A modelling approach to the allocation of land as between forestry and agriculture in the context of hill and upland has been under investigation. The present version of the model can be used to examine objectively the outcome of the stated objectives and constraints concerned with integration.

The results of the various land allocations are examined in economic terms. However, the two activities, forestry and agriculture, have widely differing time production cycles. This difficulty is overcome by discounting all items of revenue and expenditure for both activities over the same period. Since a cycle of forestry production takes 60 years a period of that duration has been chosen as appropriate. The choice of discount rate, however, will influence the contribution that each activity makes to the total Net Present Value. This has been examined using two hypothetical examples, one on land of a type to be found in the Southern uplands and the other in the West of Scotland.

The 'best' solutions for these two examples (i.e. solutions which gave the highest Net Present Value when both forestry and agriculture (unimproved and improved) were using the area in planned integration) were examined over a range of discount rates from 3 to 7 per cent and compared with the area allocated wholly to either forestry or agriculture (unimproved or improved). Figures 1 and 2 show the responses of the alternatives to changing discount rate.

In general, agriculture ranks highest when discount rates are in excess of 5 per cent whereas forestry ranks highest at discount rates below 5 per cent; integrated solutions rank at intermediate levels over the range.

The nature of the relationships have an element of considerable uncertainty due to possible price and cost changes over a period of sixty years. Taking the view that relative real changes between prices and costs over a short, as opposed to a long, period of time are less likely, then one must conclude that agricultural solutions have a lower level of uncertainty than forestry solutions. Integrated solutions therefore have intermediate levels of uncertainty.

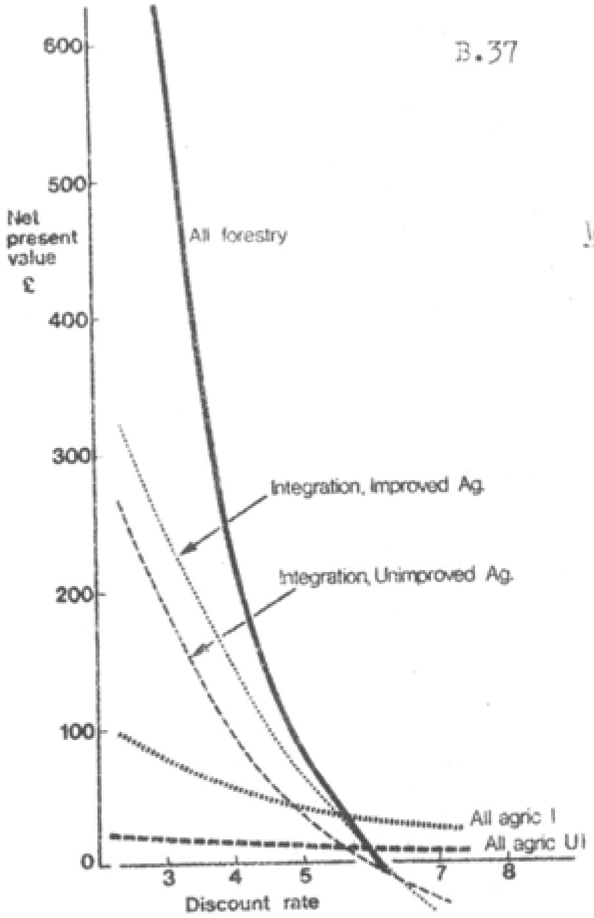
DATA HANDLING

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 continues to be summarised by computer, as does that from three other projects, viz. mid-pregnancy nutrition at Lephinmore, the Hill Sheep Development project in operation at commercial farms and at Kirkton Farm belonging to the West of Scotland College of Agriculture and the Gurkha Re-integration Training Scheme at Lumle in Nepal. The total number of records processed throughout the year was 10,602 ewes and gimmers, 9,910 lambs and 2,913 hoggs.

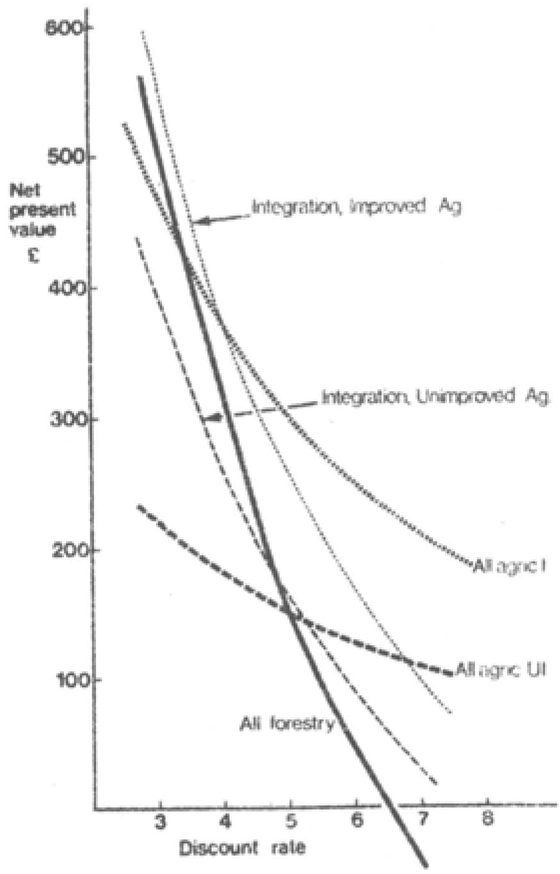
It was hoped that, by now, data would be processed by the ICL 2980 Computer housed in the new ERCC building on Bush Estate but the ICL System has not yet proved to be sufficiently satisfactory to warrant the transfer of work from the Newcastle based IBM 360 and 370 Computers. In view of this,



WEST OF SCOTLAND
(1500 ha)

Figs. 1 and 2

SOUTHERN UPLANDS
(1000 ha)



an extension in the period of time ARC users may continue to avail themselves of the Newcastle Service, has been negotiated. The processing of the data from the Hill Sheep Development project continues to be carried out on the PDP 11/20 Computer at SLAE.

In addition, during 1977, discussions were held at HFRO with two members of the Grasslands Trials Unit in the Falkland Islands with a view to our processing their data from a sheep experiment to be carried out in the Falklands and it is expected that this project will be well under way in 1978.

Nepali Migratory Flock Data Handling

Two complete years of data have now been collected from two migratory flocks of sheep run by the Gurkha Reintegration Training Scheme based at Lumle in Nepal under a scheme funded by the Overseas Development Ministry. In addition to producing standard summary tables of ewe and lamb data, a survey was conducted to investigate effects of data of lambing on production levels.

The migratory flock system, traditional to Nepal, allows uncastrated rams to run with the breeding flock at all times and consequently lambs are born throughout the year. The annual cycle of migration includes a trek up the mountains in April and May and another trek down in September and October. It was therefore important to establish the effect of lambing date on such factors as lamb birth weight and weight gain, lamb mortality and wool production.

The year was split into 12 periods of one month and it was found that 57% of all lambs were born in the two month period from mid-November to mid-January, indicating that the majority of ewes were pregnant during the trek down the mountain. The remaining lambs were, in the main, born either between mid-August and mid-November or mid-January and mid-March. There proved to be no significant differences between the birth weights of lambs born at different times, the mean birth weight of 3.0 kg being derived almost completely from single lambs since twins are an almost unknown occurrence. There were however significant differences between individuals born at different times, in their subsequent weight gains from birth to 16 weeks. The smallest gains were made by the lambs born in the period mid-December to mid-January when one third of all the lambs were born, the difference between this and the largest weight gains making a potential difference of as much as 10% in the 16 week body weight. There seemed to be no penalty, in terms of lamb mortality, incurred by a change in lambing date other than a higher percentage of lambs taken by leopards from the February/March period; this could be due to the fact that these lambs were still small at the start of the upward trek. There was no loss of wool production incurred by changing lambing date, each ewe on average produced 1.27 kg of wool from two clippings per year.

There was some evidence that ewes lambing in the mid-December to mid-January period were lighter at premating than ewes lambing at other times. Further investigation of this indicated that the lower weight was probably associated with the age distribution of the ewes at lambing, rather than with a lack of body weight recovery in these animals. It was shown that about 25% of the lambs born in the December/January period were born to first-time mothers which were presumably younger and lighter and this fact could also influence lamb weight gains through the lower milk production potential of these younger animals.

A further contributing factor could be pressure imposed on grazings by the larger number of lactating ewes and lambs beginning to graze, following the bulk of the lambings between mid-November and mid-January.

This would have a more serious effect on those lambs born later in that period (i.e. mid-December to mid-January) and could partly explain the lowest lamb weight gains which occur at that time. Additionally, the higher proportion of first-time, inexperienced mothers occurring during that period could suffer disproportionately through grazing pressure during their lactation.

In the light of this evidence, it has been proposed that consideration be given to the practical implications of spreading further the distribution of lambing date, particularly by restricting the lambing of first-time mothers to a February/March period.

PDP 11/03 Micro-computer System

During the year a PDP 11/03 micro-computer system was installed with the main purpose of capturing on-line, data from auto-analysers in the analytical laboratories and subsequently processing the data files created. The system has been expanded to the limit of 28K of memory imposed by the RT-11 operating system. The computer system also contains a mass-storage, dual floppy-disk drive, a 16-channel analog-to-digital converter for connection of the lines from the analytical equipment and a video console with graphics capability and hard-copy unit. Following the initial installation of the system extra peripheral interfaces were purchased and since then a fast character printer and a paper tape reader have been added as extra output and input devices.

The system will, when fully operational, capture simultaneously and at variable rates, data from a number of analytical processors including up to eight continuous flow analysers (CFA), two gas-liquid chromatographs (GLC) and a double channel amino-acid analyser (AAA). The software for the data capture phase has been written by Colin MacArthur of the Edinburgh Regional Computing Centre (ERCC). As a second phase, the system will analyse previously captured data by identifying peaks, estimating peak heights and allowing for base-line drifts for CFA's. The system will further integrate areas under peaks for analysis of GLC and AAA data. The software for this phase is currently being developed by Kathy Burgoyne of ERCC. The graphics capability of the video console will allow inspection of captured data as peaks for comparison with pen-trace recordings as a back-up safeguard.

The various features of the system have already been fully tested by the development locally of data capture and peak processing programs for one GLC application, namely the estimation of pesticide concentration in wool samples from sprayed sheep.

Additionally the computer system has been used for the local development of other programs. A program to process paper tapes from the scintillation counter has been written. Also a ewe pregnancy feeding adjustment program and a model of lactation, both described elsewhere in this Report, have been developed.

VETERINARY MONITORING (02008, 02009, 03004, 03005)

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

Laboratory

	1974	1975	1976	1977
Faecal worm egg counts	2600	3164	3566	5500
Pasture larvae counts	80	106	204	100
Tracer lamb post morten Total worm count	16	24	86	29
Snail counts	52	72	22	18
* Serum vitamin B_{12} estimations	300	1400	1045	910
* Plasma copper estimations	1000	1900	4050	4504
Milk copper estimations				416
Miscellaneous Haematology * Plasma Pepsinogens * Calcium, Magnesium and Phosphorus estimations ≠ Fleece samples	30	97	900	405
Post morten examinations Copper Experiment				73

* Carried out in the Biochemistry departments and Inorganic Chemistry Laboratories

≠ Carried out by W.F. Smith.

Records of ill health and deaths were provided by the Research Station O.I.C's. Post-morten reports from the Veterinary Investigation laboratories were collected and analysed.

LEPHINMORE

Sheep (03004, 02009)

General. The overall loss rate in ewes and gimmers excluding culled animals was 5.4% which is fairly low. Unfortunately, the cause of death was very rarely established in these animals either because of unsuitability for post-morten examination or because the distance to the nearest VI centre at Oban is such as to make the transport of single animals too demanding in cost and time.

However, it is felt that more information is required into causes of death at this farm and means of achieving this will be examined.

The weaning percentage of the Low End lambs is considerably lower than in previous years but there is a direct relationship in this to a current nutritional experiment.

Liver Fluke. The percentage of ewes showing a positive fluke egg count was further reduced in 1977 to a level of 0.3-0.4. In 1978 a further stage in the work in fascioliasis has been commenced. Treatment has ceased in the Midhill flock, Barnacarry has a much reduced dosing schedule and Low End continues on the strategic dosing programme. The objective of the work is to estimate how close to eradication the programme has come, to establish in time how long the flocks can retain freedom from liver fluke after an intensive dosing period, and to make recommendations of a practical nature to the farming areas where fascioliasis is a problem. This entails monitoring frequently, particularly in the Midhill flock which could be vulnerable.

Monitoring continues in the flocks in respect of trace-element deficiencies and parasitic roundworm infestations, and upon this the veterinary programmes are planned and adjusted regularly.

Cattle (02008)

There were no health problems in the herd.

SOURHOPE

Sheep (03004, 03005, 02009)

General. Sheep losses were low. Parasitism was low and, although the summer was not as dry as that of the previous years, monitoring showed that the anthelmintic programme was effective. In particular the use of the anthelmintic, Fenbendazole, in the housed ewes and hoggs (superseding Tetramisole) showed that the dose at housing resulted in almost 100% effectiveness in removing worm burdens on the basis of faecal egg counts taken from these animals at dates whilst still in the house.

A breakdown of the diseases reported is as follows:-

CNS lesions	3	
CCN	1	
Scrapie	4	
Coccidiosis	1	
Hypocuprosis	3	(Where no other findings were present and where hypocuprosis as ajudged by low liver copper values was found incidental to other findings)
Bowel Abscessation	1	
Spinal abscess	1	
Fractured spine	1	
Adder bite	1	
Ruptured bowel	1	
Pneumonia	13	

Scrapie. All suspicious cases are isolated and sent for post-mortem examination. If positive, all relatives are culled. The incidence this year is lower than in the previous year.

Pneumonia. In common with the picture on a national scale, Sourhope experienced an outbreak of pneumonia due to Pasteurella haemolytica in the autumn of this year. Because of the unsatisfactory position regarding current vaccines either prophylactically or therapeutically, individual clinical cases were treated and the other members of the group at risk were given long-acting penicillin which appeared to give satisfactory control of the outbreak.

Copper deficiency. Results of investigations in depth into this problem appear elsewhere in this report (p. A.48), but the indications are that this disease is associated with improved pastures where elevation of molybdenum and sulphur concentrations occurs as a consequence of the improvement.

Cobalt deficiency. This disease again is exacerbated on improved pastures and the results of studies appear elsewhere in the report (p. A.56). Monitoring of stock continues and means of prevention are included in the veterinary preventive programmes.

Cattle

The incidence of disease was very low. An infertility problem suspected of being linked to copper deficiency was found on investigation to be due to poor fertility in the Hereford bulls.

GLENSAUGH (02009, 02008, 03004)

Sheep

General. Overall losses were within the normal range. However high losses in the lambs of Birnie and E. Finella, whilst not due to a veterinary component, give cause for concern and it has been established that these related to climatic, nutritional and managemental factors. A breakdown of cases reported and investigated at the local VI centre is as follows:-

Meningitis	2	Cobalt deficiency	1
CCN	2	Bowel disorders (various)	4
Pneumonia	16	Enteritis	4
Jaagsiekte	8	Trauma	4
Hypocuprosis	3	Stillbirths	20 (A sample sent to the VI centre for examination and assessment of skeletal growth retardation.)

Pneumonia. The occurrence of pasteurella pneumonia type 2A was associated with a national prevalence of the disease and, as at Sourhope, long-acting antibiotic (penicillin) was administered to in-contact animals when an outbreak was indicated by the occurrence of a number of clinical cases in the group.

Jaagsiekte. Confined to the Greyface flock and the policy of segregation of this flock still applies.

Parasitic Gastro-enteritis. The incidence of this disease was low and in particular the routine use of anthelmintic in the Greyface lambs was shown to be beneficial.

Copper deficiency. Copper was administered to growing lambs where low plasma copper status indicated a need. Wider investigation of the extent of this problem included routine monitoring and herbage sampling at Glensaugh. Routine copper estimations are carried out on all animals sent for post-mortem.

Cattle

The incidence of disease was low in the cows.

Diarrhoea in calves. As in previous years an outbreak of scour in the calves had a high morbidity but a very low mortality. This year a single outbreak - with rapid spread and a uniform recovery pattern was seen - particularly in the younger calves of the later calving cows. Causative organisms implicated were rotavirus and E. coli.

BREEDING PROGRAMME 1977

In 1976 cows were split into two groups, 35 non-experimental cows being run with a bull for natural service, 48 experimental cows being synchronised with a progestagen implant and artificially inseminated. Depending on calving dates the synchronisation was carried out in batches so as to limit the returns to be handled by natural service. Synchronisation in the house was timed so that returns would occur after turn-out.

Breeding Performance. Total Herd.

	Total	Holding to 1st service	2nd service	3rd service	Eild	Aborted
Synchronised cows	48	13	23	7	4	1
Natural Service	35	28	4		3	
			By genotype (synchronised)			
Blue Grey	24	10	11	-	2	-
Hereford x	24	3	12	7	2	-
			By genotype and treatment (synchronised)			
Blue Grey M + $\frac{1}{2}$	12	5	7			
Hereford x M + $\frac{1}{2}$	12	2	5	4	1	-
Blue Grey M + 2	12	5	4	-	2	1
Hereford M + 2	12	1	7	3	1	
			By treatment			
Blue Grey M + $\frac{1}{2}$	12	5	7	-	-	-
Blue Grey M + 2	12	5	4	-	2	1
Hereford x M + $\frac{1}{2}$	12	2	5	4	1	
Hereford x M + 2	12	1	7	3	1	

Natural service was used in 1977 for the cows calving in 1978.

As stated previously, experimentation does impose constraints on rebreeding in that treatments and measurements which could influence conception rate take place at mating time.

SURGERY (01001, 02004, 02008)

	Sheep	Cattle
Rumen fistulation	23	
Oesophageal fistulation	36	7
Vasectomy	22	
Ovarohysterectomy	12	

Carried out as a service to other departments.

C. PLANTS AND SOILS

PASTURE ESTABLISHMENT

04002: Determine optimum conditions for germination, establishment and growth of white clover and grasses in hill soils

1. Dormancy of Clover Seeds

J.A. Rogers and D. Bruce

Many legumes, including white clover, experience a form of seed dormancy in which water is prevented from reaching the embryo by an impermeable testa. Experiments have demonstrated that, when sown under hill climatic conditions, a high proportion of these hard seeds lose their dormant condition over winter and germinate during the following spring. In one experiment, in which seeds of a number of species were sown in December, the clover cultivars all germinated more rapidly than any of the grasses, but those seedlings which germinated were killed off during the winter presumably by frost. There was a variation in the percentages of these seeds which germinated that was related to the proportion of non-hard seeds in the respective seed lots. In the following spring additional clover seedlings emerged from those seed lots in which there was a high proportion of hard seeds. The numbers of seedlings which emerged were equivalent to the percentage of hard seed present. In a further experiment seeds of Kent Wild White clover containing 39% hard seed were sown in a marked grid in boxes placed at 305 m at House o' Muir. Half of the seeds were scarified using concentrated sulphuric acid while the other half were untreated. Shortly after sowing seedlings emerged; 31% of the scarified seeds emerged during the winter months and during this period 30% died, a further 3% emerged in spring resulting in a final stand equivalent to 3% of the original seed sown. In the untreated seeds only 13% emerged during the winter and subsequently died. During the following spring 32% of seeds emerged and the final seedling count was equivalent to 26% of the seeds originally sown. From these data it is obvious that the high percentage of hard seed in the non-scarified treatment was of considerable advantage. In addition, both scarified and non-scarified seeds of the variety New Zealand Grasslands Huia were sown. In the original seed lot there were only 3% hard seeds and the scarification treatment had little effect on the final outcome.

In fact the scarified treatment resulted in a 1.7% survival rate while the non-scarified treatment resulted in a survival rate of 4.8%, the difference almost exactly equalling percentage of hard seed in the original lot.

It was apparent therefore that the hard seeded condition was lost during the winter period in the soil; this did not happen to seeds kept in store. Laboratory experiments are currently in progress in which hard seeds are being subjected to varying periods of cold (2°C) and freezing (-5°C) temperatures, both in soil and in damp filter paper sandwiches. So far, none of the treatments applied has resulted in a significant loss in dormancy. Temperatures of -20°C were found to kill the seeds. It would thus seem that some other factor or factors than temperature are responsible for softening the hard seeds in the soil. These might be microbial action or prolonged exposure to moisture or acids in the soil.

Work on the time of sowing of hill pasture species had indicated that late autumn may be a good time to sow certain grass species. Unfortunately, clover seedlings resulting from such sowing date did not prove to be frost hardy. If, therefore, such a sowing date were adopted for grasses the clover must either be sown at a different time or include a high proportion of hard seeds, which would remain in the soil until the following spring when they could germinate after the last severe frosts.

2. The Effects of Different Sowing Dates on Germination and Early Establishment

J.A. Rogers and D. Bruce

Perhaps one of the most critical factors in establishing hill pastures, particularly where cultivation is minimal, is the timing of the operation. This is mostly related to climatic conditions. For a successful establishment the ground must be warm and moist during the period immediately following sowing. In late spring these conditions are usually fulfilled, the temperature generally becoming more favourable as time progresses. However during the period June to July, or even to early August, periods of water deficit are likely to cause the soil to dry out sufficiently to impair the establishment of young seedlings. This is particularly the case in the east of the country. Such periods of drought are still likely during August and even early September. It was, therefore, decided to investigate the possibility of sowing pasture species during late autumn and early spring so as to avoid periods of drought during or immediately after sowing. Two experiments were carried out in boxes. In the first, four varieties of perennial ryegrass were sown in late autumn and spring. Seedling counts and dry matter yields were recorded. The two early heading varieties (Aberystwyth S24 and Dutch Grenie) were found to perform better following the autumn sowing than the spring sowing, and, following the autumn sowing, these two varieties gave better results than either of the two late heading varieties (Aberystwyth S23 and the Belgian variety Melle).

Table 1. Total yield of cuts made during the first production year

Cultivars	Autumn Sown	Spring Sown	Difference	P
S24	69.4	37.9	31.5	< 0.1%
Grenie	76.8	40.0	36.8	< 0.1%
S23	61.8	38.5	23.3	< 0.1%
Melle	58.2	43.3	14.9	< 5.0%

Table 2. Total dry matter yields from 2 harvests taken during first production year from site at 305 m. Grams per 100 viable seeds sown (Figures in parenthesis are approximate values for $kg ha^{-1}$)

	Late Autumn Sowing	Early Spring Sowing	Difference
Perennial Ryegrass (2n)			
Grenie	31.2 (7800)	13.0 (3250)	18.2 ***
Preno	13.9 (3475)	18.0 (4500)	-4.1 NS
S23	14.4 (3600)	18.3 (4575)	-3.9 NS
Lanora	12.7 (3175)	11.1 (2775)	1.6 NS
PRG (4n)			
Barvestra	10.4 (2600)	12.6 (3150)	-1.7 NS
Barpastra	10.8 (2700)	9.0 (2250)	1.8 NS
Italian Ryegrass			
S22	43.8 (10950)	44.1 (11025)	-0.3 NS
Lental	53.4 (13350)	24.9 (6225)	28.5 **
Timothy			
S48	13.1 (3275)	6.7 (1675)	6.4 NS
S352	11.9 (2975)	8.3 (2075)	3.6 NS

Table 2 (cont'd)

	Late Autumn Sowing	Early Spring Sowing	Difference
Red Fescue			
S59	13.1 (3275)	10.5 (2625)	2.6 NS
Novorubra	17.1 (4275)	15.3 (3825)	1.8 NS
Tall Fescue			
S170	14.9 (3725)	8.2 (2050)	6.7 **
Meadow Fescue			
S215	11.0 (2750)	9.4 (2350)	1.6 NS
Poa pratensis			
Delft	5.0 (1250)	9.4 (2350)	-4.4 **
Merion	5.3 (1325)	4.8 (1200)	0.5 NS

A second experiment was then set up in which a wider selection of varieties and species was grown at two altitudes (180 m and 305 m). Two of the varieties grown previously were included, Grenie and S23, and these gave similar results to the earlier experiment. The early heading variety Premo was intermediate in emergence rate to Grenie and S23 although the yield was similar to the late variety, while the late Dutch variety Lanora was much slower to emerge from the autumn sowing than the others. Two tetraploid perennial ryegrasses were also tested; both were unsuited to autumn sowing although they gave similar results to the diploid varieties after the early spring sowing. Timothy (S48 and S352), Red Fescue (S59 and Novarubra), Tall Fescue (S170) and Meadow Fescue (S215) all gave satisfactory results from autumn sowing. Smooth stalk meadow grass (Delft and Merion) was very slow to emerge from both late autumn and early spring sowings, and the yield from the autumn sowing was considerably lower than from the spring sowing.

Four varieties of clover were sown, Kent and S184 wild white, S100 and Kersey white. All germinated more rapidly than any of the grass species, but those sown in autumn were soon killed by frost. Three varieties, which contained high proportions of hard seeds, showed an increase in seedling numbers after the winter kill, presumably due to hitherto dormant seeds germinating during the following spring.

3. Temperature Studies

J.A. Rogers and D. Bruce

From the time of sowing experiments it was found that there may be some advantage in sowing hill pastures during the autumn period or early spring. During these periods, although drought is not likely to be an important hazard, low temperature is likely to be the principal limiting factor. The results from these experiments indicated that there were considerable differences between species and cultivars in their response to the sowing date. As it was probable that these differences were, at least in part, due to differences in the low temperature growth of the germinating seeds, experiments were carried out to investigate this possibility. Preliminary tests using incubators showed that, although germination rates of different cultivars showed little or no differences at 15°C or above, at lower temperature there were marked differences. As the temperatures of the incubators could only be controlled to within 1°C and only a single temperature regime could be maintained in each during the trial, it was decided to construct a temperature gradient bar (see Analytical Services, section 3(g)).

This was designed to maintain temperatures in the range 1-10°C with a precision of ≤ 1.0°C. A number of varieties and species have been germinated on this bar and the times taken for 50% germination are shown in Table 3.

Table 3. Lowest temperature at which 50% germination occurred and the time taken

	°C	Days
Perennial ryegrass, S24	4.6	28
Perennial ryegrass, Lanora	6.8	27
Perennial ryegrass, Grenie	5.7	26
Perennial ryegrass, S23	5.0	27
Italian ryegrass, S22	2.9	30
Red Fescue, S59	5.9	34
Red Fescue, Novorubra	4.6	28
Tall Fescue, S170	5.5	38
Timothy, S48	none germinated in range 2 - 7.5	
White Clover, Huia	4.9	21

Among the varieties of perennial ryegrass it will be seen that the slowest variety to emerge following the autumn sowing, namely Lanora, has the highest minimum temperature threshold for germination. Similarly, Poa pratensis also has a high threshold, whilst perennial ryegrass cultivar Grenie and the Italian ryegrasses (all rapid to emerge from autumn sowing) had low temperature thresholds.

4. Allelopathic Studies

J.A. Rogers and D. Bruce

Germination and establishment of herbage species is often prevented, particularly in direct drilling, by allelopathic action of the existing vegetation. This may be a cause of the grequent lack of success in establishing hill pasture in Agrostis/Festuca grassland or on ground occupied by Calluna. Since, under conditions of minimal cultivation, quantities of vegetation or plant matter are still likely to be present when the seed is sown, it is clear that further information on the influence of the former vegetation on the establishment of new reseeds is required.

Two series of experiments were set up. In the first, seeds of perennial ryegrass, white clover and red fescue were sown in petri dish cultures in which they were irrigated with leachate from entire leaves of the donor species, and with 'extracts' made from shredding the donor plants in water and separating the supernatant fluid by centrifuging.

In the second series, seeds of clover and perennial ryegrass were sown on agar slopes made up from leachate and extracts as above, and the early growth of the seedlings was assessed. A nutrient medium was included as some of the extracts were found to enhance growth, and it was thought that this may have been due to mineral nutrients contained in the extracts. The root lengths obtained in two experiments are given in Table 4.

Table 4. Effect of leachate from different plant shoots on the growth of the seminal roots of white clover and perennial ryegrass on agar slope culture

a) White Clover

Donor	Root Length (mm)	
Nardus stricta	20.00)	
Nutrient control	19.61)	
Juncus squarrosus	14.39))	LSD = 7.33 (P = 5.0%)
Calluna vulgaris	14.25))	
Plain water control	13.98))	
Festuca rubra	11.08)	
Pteridium aquilinum	10.92))	
Eriophorum vaginatum	3.75)	

b) Perennial Ryegrass

Donor	Root Length (mm)	
Juncus squarrosus	52.25)	
Nardus stricta	44.92)	
Plain water control	41.92)	
Nutrient control	41.74)	LSD = 13.74 (P = 5.0%)
Calluna vulgaris	41.50)	
Pteridium aquilinum	40.56)	
Eriophorum vaginatum	40.50)	
Festuca rubra	26.25	

) Brackets enclose those values which do not differ significantly, one from another. (P >5.0%)

In both, extracts from Festuca rubra, Eriophorum vaginatum and Pteridium aquilinum were found to reduce root length while those from the other species had little or no effect. Shoot length was only slightly affected by the leachates and extracts.

PLANT NUTRITION

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

1. Comparison of methods for the assessment of soil-P status

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

Early attempts to characterise soil-P status in hill soils, which range in pH from less than 4.0 to more than 5.5 and in organic matter from 10-90%, showed up a number of problems:-

a) Organic soils gave values of "available" P by conventional extraction procedures which were high or very high by advisory service standards, and which did not correlate with plant growth.

b) Soils known to have been treated with P fertilizers and improved with re-seeded grass and clover, frequently gave "available" P values less than adjacent untreated soils with indigenous vegetation.

c) The relative ranking of soils, based on P uptake by test crops in glasshouse experiments, was radically altered in successive trials conducted in summer and winter (Floate and Pimplaskar, 1976).

We have selected nine representative hill soils, including Brown Forest soils, Podzols, Peaty Podzols, and Peat, and measured extractable-P by five methods. In addition, four of the soils were used in a greenhouse trial to compare grass and clover DM yield and P-uptake with other estimates of P status, which included sorption values, anion exchange-P, isotopic exchange-P, "L" values by isotopic dilution, as well as total and organic-P contents.

Results from the latter experiment are summarised in Table 1 which gives the values for correlation coefficients and significance levels (P) between grass and clover P-uptake, and the P-status values derived from eleven methods expressed as mg P/pot. These data show that three of the extraction methods gave negative correlation between P-uptake (for both grass and clover) and estimates of soil P status, largely because of high 'available' P values for the peaty organic soils which were at variance with low uptake of P by plants from these soils.

Table 1. Correlation coefficients for regression of soil-P status by eleven methods (y) on P-uptake by ryegrass and clover (x) in glasshouse trials

Analysis	Grass P-uptake		Clover P-uptake	
	correlation coeff. (x)	significance (P)	correlation coeff. (y)	significance (P)
Truog-P	.313	.343	- .464	.268
Morgan-P	- .541	.229	- .836	.082
Bray-P	.704	.148	- .091	.455
Olsen-P	- .460	.269	- .823	.088
Acetic-P	- .347	.326	- .847	.076
Anion Exch-P	- .246	.377	- .894	.053
I/S value	- .371	.314	- .654	.173
"E" value	- .897	.051	- .883	.058
"L" value	.514	.243	.899	.050
Total-P	.902	.049	.897	.052
Organic-P	.862	.069	.924	.038

The remaining extraction methods also gave negative correlations for clover P-uptake and positive (but low and non-significant) correlation values for grass P-uptake. We concluded, although the number of samples was small, that the correlations were so poor as to indicate that none of these methods was suitable for the whole range of hill soils.

Phosphorus supply for plant growth is controlled by intensity, capacity, and rate factors of which intensity may be of major importance in arable soils where extraction methods have been successfully used to assess P-status. In hill soils the intensity of supply is very low and plant P-uptake depends heavily upon capacity and rate factors to maintain any supply of P for plant growth. Alternative methods employing sorption and exchange reactions should account for some aspects of capacity and rate factors of supply from the labile soil P reserves. However, Anion exchange, inverse sorption, and isotopically exchangeable-P values also gave negative correlations with P-uptake by both grass and clover. Only "L" values obtained by isotopic dilution gave significant positive correlation with P-uptake by clover but this method is not suitable for routine use. Both Total-P and Organic-P gave significant positive correlations with grass and clover P uptake and the amounts of P taken up were in every case between 1 and 2 per cent of the organic P despite wide variation in the content of organic matter in the soils tested (10-80%).

These results suggest that in those soils in which 80-90% of the total-P is in organic forms this source may be important in maintaining the continuity of supply of P for plant growth.

We conclude that Total-P may give a convenient measure of soil-P status for grassland on hill soils but are aware that some soils may contain such large amounts of inorganic fixed-P that the usefulness of this value may be limited. Organic-P, while being less convenient to measure in the laboratory, may be more widely applicable to hill soils. Organic-P has been found to give good correlations with crop response in soils from the Kenya Highlands, and on grassland soils in New Zealand, and organic-P has been found to be the best predictor of available-P in the soils of southern Nigeria.

The anomalous results for apparently low "available" P in fertilized soils under improved grass/clover at Lephinmore, compared with higher values for untreated soils under adjacent indigenous vegetation has been explained as follows. The low values for Morgan-P (means of six pairs of samples) under improved pasture may reflect the depleted state of soil-P where plant-P uptake has been greater than by the indigenous vegetation, and the balance between rate of uptake and rate of release of "available"-P from other sources is higher where uptake has been less (Table 2).

Table 2. Mean values for plant and soil phosphorus in six pairs of adjacent indigenous and improved pastures at Lephinmore (units - g/m^2)

Plant or Soil component	Improved Pasture	Indigenous Pasture (Untreated)
1. Available-P in soil (Morgan)	1.03	1.20
2. Total herbage DM yield	521.3	353.9
3. P uptake by pasture crop	1.64	0.54
4. Total labile-P in plant/soil system (1 + 3)	2.67	1.77
5. Total-P in soil	44.7	40.8

A better assessment of the P-status of the soil/plant system under improved pasture may be given by the sum of 1 + 3 which is described as total labile P in the soil/plant system. These values show the improved pasture system to have 1.5 times more P in this category than the untreated indigenous system.

Total-P values also show a higher P-status in all the improved members of the six pairs of samples examined, and again provide a better assessment than conventional extraction methods for these hill soils.

This work is currently being written up as a paper which it is intended to submit to J. Sci. Fd. Agric.

References

FLOATE, M.J.S. and PIMPLASKAR, Meera S. (1976). Some anomalous results for available-P in hill soils, and experimental attempts towards their resolution. J. Sci. Fd. Agric. 27, 591.

2. The effectiveness of different forms of P fertilizers (Expt. 200)

M.S. Pimplaskar, M.J.S. Floate, P. Newbould and A.D. Ironside

A new series of experiments were started in 1977 to assess the effectiveness of different forms of P fertilizers as alternatives to basic slag. The materials tested in the present trials were Superphosphate (Super-P), Ground Mineral Phosphate (GMP), and a mixture of Super-P and GMP containing equal parts of P.

Factors which affect the production of DM and the amount of P taken up by plants from the different P sources include soil type and pH, and time and rate of P application, so the following treatments were included in a glasshouse trial using ryegrass as test plant:-

3 storage periods	0, 3, 6 months in Phases I and II of the trial.
3 rates of P	0, 20, 80 kg/ha P. (P_0 P_{20} P_{80}).
2 lime levels	0, 1.25 tonne/ha. (L_0 L_1).
3 forms of P	Super-P, GMP, and Super-P/GMP at 1:1 P.
2 soils	Linhope and Darleith Brown Forest Soils. (Some properties of the 2 soils are given in Table 1).

Table 1. Properties of 2 Brown forest soils used in pot experiment to test the effectiveness of different forms of P fertilizer

Soil Series (Location)	Parent Material	pH (.01 M $CaCl_2$)	% C	P sorption index	Exch. Al^{3+} meq/100g	Total P mg/100g	Anion Exch.P mg/100g
LINHOPE (Stanhope)	Silurian Greywacke	4.2	2.61	27	3.2	65	2.3
DARLEITH (Carron Valley)	Basalt	3.9	4.61	240	15.1	214	1.1

The soils were mixed individually with the chemicals needed for each treatment together with basal treatments of N and K. Soils were wetted and maintained at 60% field capacity in the dark for 3 and 6 months from April to July and from April to September respectively. After the appropriate storage periods pots were seeded with ryegrass and harvest cuts were taken at intervals between mid July and October (Phase I) and between October and January (Phase II): total growth period in both Phases I and II was 13 weeks. In Phase II the ambient temperatures in the glasshouse were lower, and supplementary light was provided to give 14 h day length.

An extra (fifth) replicate of each treatment was provided for soil analysis prior to, during the growth phase, and after the end of the trial. These replicates were uncropped and to date only the samples prior to the start of growth and after the end of the trial have been analysed. The results will be considered after the data on herbage DM production and P-uptake.

Total herbage DM yield is given for Phase I and Phase II in Tables 2 and 3 respectively.

Table 2. Total herbage DM yields of ryegrass from P-treated soils stored for 0 and 3 months (Phase I) (g/pot)

P-Fertilizer	0-Months				3-Months			
	L_0		L_1		L_0		L_1	
	P_{20}	P_{80}	P_{20}	P_{80}	P_{20}	P_{80}	P_{20}	P_{80}
Linhope Soil								
Superphosphate	3.83	4.21	3.51	4.16	3.69	4.96	3.39	4.57
GMP	3.22	4.38	1.46	2.94	3.39	4.72	1.95	3.54
Super/GMP	3.53	4.35	2.91	4.32	3.41	4.96	2.95	4.22
P_0 Control	-	-	-	-	0.95		0.81	
LSD:	5% : 0.31		1% : 0.41		0.1% : 0.53			
Darleith Soil								
Superphosphate	0.42	1.40	2.60	4.05	0.35	0.90	2.00	4.12
GMP	0.51	1.35	1.75	3.32	0.31	1.48	1.90	3.36
Super/GMP	0.39	1.41	2.33	3.85	0.32	1.34	1.97	3.72
P_0 Control	-	-	-	-	0.26		1.00	
LSD:	5% : 0.26		1% : 0.34		0.1% : 0.44			

Table 3. Total herbage DM yields of ryegrass from P-treated soils stored for 0 and 6 months (Phase II) (g/pot)

P-Fertilizer	0-Months				6-Months			
	L_0		L_1		L_0		L_1	
	P_{20}	P_{80}	P_{20}	P_{80}	P_{20}	P_{80}	P_{20}	P_{80}
Linhope Soil								
Superphosphate	3.63	3.81	2.31	3.40	1.94	3.20	1.90	3.64
GMP	2.34	3.50	1.28	2.13	2.12	3.27	1.86	2.87
Super/GMP	2.65	3.74	1.72	3.37	2.01	3.41	2.06	3.19
P_0 Control	0.67		.56		-	-	-	-
LSD:	5% : 0.22		1% : 0.29		0.1% : 0.38			
Darleith Soil								
Superphosphate	0.27	0.44	1.71	2.41	0.29	0.81	1.17	2.33
GMP	0.24	0.52	1.28	2.14	0.27	0.52	1.00	1.95
Super/GMP	0.25	0.56	1.57	2.56	0.27	0.61	0.98	2.23
P_0 Control	0.20		0.69		-	-	-	-
LSD:	5% : 0.28		1% : 0.37		0.1% : 0.48			

The results may be summarised as follows:-

1. Effect of lime on P_0 treated soils: lime significantly increased yield on Darleith soil from 0.26 to 1.00 g/pot and from 0.20 to 0.69 g/pot in Phases I and II respectively. Lime treatments gave a small but insignificant reduction in yield from 0.95 to 0.81 g/pot and from 0.67 to 0.56 g/pot in Phases I and II on Linhope soil.

2. Effect of lime on P-treated soils: Lime significantly increased overall mean yield on Darleith soil from 0.85 to 2.91 g/pot ($P < 0.01$), but reduced mean yield (particularly on GMP treatments) from 4.05 to 3.33 g/pot on Linhope soil.

3. Effect of P fertilizer rate: Both P_{20} and P_{80} treatments gave significant increases over P_0 on both soils although on Darleith soil a marked response was only obtained when lime and P were applied together (see also Project 04011/04003, p. C.83). The mean increase in DM yield from P_{20} to P_{80} was significant ($P < .001$) from 3.10 to 4.28 g/pot on Linhope soil and from 1.24 to 2.53 g/pot on Darleith soil.

4. Effect of form of P-fertilizer: There were small but significant differences in DM yield between P fertilizer treatments on both soils in Phases I and II of the trials. In general the ranking of materials was:

   Super-P > Super-P/GMP > GMP on Linhope soil and Super-P ≥ Super-P/GMP > GMP

   on Darleith soil where all differences were significant ($P < .001$) except Super-P ≥ Super-P/GMP on Darleith soil.

5. Effect of period of storage of soil with treatment: The mean effect of increasing the duration of soil:fertilizer contact was different between the 2 soils. On Darleith soil the overall effect of increasing the duration was to reduce DM yield. In Phase I yield was significantly ($P < .001$) reduced from 1.95 to 1.81 g/pot after 3 months, and in Phase II the reduction from 1.16 to 1.04 g/pot after 6 months was also significant ($P < 0.01$). On Linhope soil yields increased with duration of storage from 3.57 to 3.81 g/pot after 3 months (Phase I) but after 6 months yield was less than from treatments seeded immediately after fertilizers were applied.

The following general conclusions can be drawn from these results: Herbage DM yields were low (equivalent to less than 1250 kg/ha) on all P_0 treatments on both soils, and P fertilizer treatments gave large responses (up to 6300 kg/ha on Linhope, and up to 5250 kg/ha on Darleith soils). The mixture of super-P and GMP with equal parts of P was almost as effective as superphosphate alone and both were superior to GMP on both soils. There were indications that the effectiveness of GMP increased with duration of the period of contact between soil and fertilizer prior to seeding.

Data for herbage P content are not yet available so interpretation based on P-uptake by ryegrass cannot be discussed.

Fertilizer analysis

Laboratory evaluation of P-fertilizers was made by the following chemical tests using the standard methods (AOAC 1960, and MAFF 1960):

1) Total P content
2) Water soluble-P
3) 2% citric acid soluble-P

The amount of available P present in fertilizers was also determined by 2.5% acetic acid as this extractant has been used as a standard method of soil analysis. The fertilizer analysis data in Table 4 show that the water solubility of P in superphosphate is high but in GMP is very low. As expected citric and acetic acid soluble-P are high in superphosphate and, although citric acid soluble-P is almost half the total-P in GMP, its acetic acid solubility is low.

Table 4. Chemical analysis of P-fertilizers (% P)

Chemical Analysis	Superphosphate	GMP	Basic Slag
Total-P	9.5	12.1	3.6
Water soluble-P	8.3	0.4 mg/100 g	N.D.
2% Citric acid Soluble-P	8.9	5.6	3.1
2.5% Acetic acid Soluble-P	7.9	0.9	1.2

Soil analysis

In order to investigate the changes in the chemical behaviour of P in the soil as affected by the nature of fertilizer materials, soil characteristics, and by the duration of fertilizer/soil contact, a series of 48 uncropped incubation pots were analysed. These incubation pots represented all soil and fertilizer treatments. The samples were taken immediately after fertilization and periodically after each harvest.

The sub-samples were analysed for pH, total P and available P by the same extraction procedures mentioned for fertilizer analysis.

The objectives of the soil analysis of the uncropped incubation pots were:-

1) To measure available P using a range of extraction procedures at 0, 1, 2, 3, 4, 5, 6 months after the soils were fertilized with super-P, GMP and super-P/GMP mixture.

2) To correlate the amount of available P extracted by various extractants with total-P uptake from 3 harvests, with a view to selecting an appropriate method for assessing the residual value of fertilizer P in soil.

3) To measure any changes in fertilizer solubility in the soil with time.

Results for water soluble and acetic acid soluble P at 0 and 3 months storage (referred to as pre-treatment) and after the growth experiment (referred to as post-treatment) have been completed (Table 5) but results for other analysis are not yet available.

Table 5. Water soluble and acetic acid soluble-P in P-treated soils after different storage periods, before and after growth of ryegrass (mg/100 g)

P-Fertilizer	Treatment	0-Months				3-Months			
		Water Soluble-P		Acetic Soluble-P		Water Soluble-P		Acetic Soluble-P	
		Pre-t.	Post-t.	Pre-t.	Post-t	Pre-t.	Post-t.	Pre-t.	Post-t
Linhope Soil									
Superphosphate	L_0 P_{20}	0.35	0.25	1.56	0.40	0.25	0.25	0.96	0.38
	L_1 P_{20}	0.25	0.30	1.39	0.53	0.35	0.34	1.00	0.43
	L_0 P_{80}	1.18	0.50	7.75	2.34	0.75	0.30	5.50	2.13
	L_1 P_{80}	0.90	0.58	6.70	2.87	0.60	0.47	6.10	2.18
GMP	L_0 P_{20}	0.70	0.13	5.15	0.53	0.25	0.12	1.00	0.60
	L_1 P_{20}	0.20	0.15	1.28	1.32	0.20	0.15	1.40	1.00
	L_0 P_{80}	0.98	0.30	8.20	2.40	0.65	0.23	8.40	3.60
	L_1 P_{80}	0.25	0.15	8.60	6.90	0.30	0.15	9.25	6.40
Super-P/GMP	L_0 P_{20}	0.35	0.25	1.64	0.67	0.25	0.25	1.09	0.45
	L_1 P_{20}	0.25	0.18	1.94	0.89	0.20	0.15	1.10	0.84
	L_0 P_{80}	1.00	0.30	8.40	2.61	0.30	0.25	1.47	2.67
	L_1 P_{80}	0.45	0.20	8.15	6.40	0.50	0.20	7.55	4.85
Darleith Soil									
Superphosphate	L_0 P_{20}	0.10	0.10	0.64	0.54	0.10	0.10	0.54	0.51
	L_1 P_{20}	0.15	0.15	0.59	0.40	0.15	0.20	0.44	0.39
	L_0 P_{80}	0.15	0.15	1.86	1.38	0.15	0.10	1.40	1.40
	L_1 P_{80}	0.15	0.15	1.99	1.13	0.15	0.20	1.38	1.18
GMP	L_0 P_{20}	0.15	0.10	0.72	0.55	0.10	0.10	0.42	0.43
	L_1 P_{20}	0.53	0.10	0.54	0.42	0.10	0.10	0.38	0.40
	L_0 P_{80}	0.25	0.12	1.76	1.59	0.10	0.10	1.30	1.18
	L_1 P_{80}	0.51	0.10	3.50	1.64	0.10	0.10	2.44	1.45
Super-P/GMP	L_0 P_{20}	0.15	0.12	0.54	0.53	0.10	0.23	0.64	0.53
	L_1 P_{20}	0.20	0.12	0.54	0.39	0.10	0.11	0.60	0.37
	L_0 P_{80}	0.20	0.11	1.62	1.28	0.10	0.10	1.47	1.29
	L_1 P_{80}	0.20	0.10	1.70	1.35	0.10	0.15	1.74	1.44

Pre-treatment water soluble-P in Linhope soil was higher in P_{80} treated soils than P_{20}, and this remained about the same in the P_{20} post-treatment samples, but was reduced to about half its starting level in P_{80} treatments. This may have been due to the greater uptake of P by ryegrass under these treatments.

Pre-treatment water soluble-P in Darleith soil was less than in Linhope, and was not higher in P_{80} treatments than P_{20} treated soils. There was little change in the amounts extracted post-treatment. Acetic acid soluble-P in Linhope soil was affected by level of P treatment and time of sampling in a similar way to water soluble-P but the amounts extracted were greater.

Acetic acid soluble-P in Darleith soil was also greater than water soluble-P in almost all samples. In contrast to water soluble-P, there were larger amounts of acetic acid soluble-P in this soil at the P_{80} level than at the P_{20} level. Although lime treatments produced significantly different DM yield results on this soil, there appeared to be little difference in extractable P attributable to lime treatments.

Correlation between values for extractable-P in soils and P-uptake by ryegrass will be calculated when data are available.

References

1) Association of Official Agricultural Chemists (1960). Official Methods of Analysis p.11. 9th ed. Washington.

2) Ministry of Agriculture, Fisheries and Food (1960). Statutory Instrument 1960 No. 1165. The Fertilizers and Feeding Stuffs Regulations.

3. Effects of soil type and location on effectiveness of different forms of P fertilizer (Expt. 700)

M.J.S. Floate, A.D. Ironside and G.R. Bolton

Practical farming experience, and some evidence from ADAS field experiments, suggest that as an alternative to basic slag, ground mineral phosphate (GMP) may be more effective on acid soils in the wetter Western regions than on less acid soils in the drier East. A pilot experiment was carried out in 1977 to test a field pot technique in an attempt to quantify these effects.

Two Brown Forest soils - Darleith series (pH 4.4) from Carron Valley on Basalt and Linhope series (pH 5.0) from Stanhope on Greywacke were used at two locations - Stanhope in the Borders, and Lephinmore in Argyll. Pots, each containing 300 g soil were prepared with the following treatments at HQ in April. They were then placed up to rim level in the ground for the three months mid April to mid July. It was intended that pots be seeded with ryegrass in mid July and growth measurements taken until the end of September.

Unfortunately, at one location (Stanhope) many pots were destroyed when sheep invaded the enclosure at the beginning of July. However, at least one replicate of each treatment survived. For uniformity between sites and to provide more than one replicate for growth data, one replicate of each treatment was brought back to the laboratory, diluted with two volumes of vermiculite (negligible P content) and remixed to provide three new diluted replicates which were returned to the field and seeded in mid July.

Data for herbage DM produced during the period 18 July to 26 September from the various treatments are given in Tables 1 and 2. Although statistical analysis of these data has not yet been completed, the following observations can be made:-

Stanhope site:

1. Yields on Linhope soil are consistently higher than Darleith.
2. Yields on P-treated soils are consistently higher than P_0 treatments on both soils: there is probably a significant response to 80 kg/ha P with all forms of P fertilizer.
3. There appears to be little difference on Darleith soil attributable to form of P fertilizer or to lime application.
4. On Linhope soil there is also little difference between treatments except that lime + GMP appears to suppress the response to P.

Lephinmore site:

1. Yields on Linhope soil may not be significantly different from Darleith.
2. Yields on P-treated soils are consistently higher than P_0 treatments on both soils: this response may be significant.
3. On Darleith soil, lime and P treatment differences may not be significant.
4. On Linhope soil, as at the Stanhope site, there appears to be a real suppression of the response to P applied as GMP, in presence of lime.
5. The single replicate results for undiluted soil, i.e. without added vermiculite (in brackets in Table 2), are markedly different from the diluted soils in some important respects.

Table 1. Herbage DM production from ryegrass in pots at Stanhope (Border Region): (g/pot July-Sept.)

Soil Type	TREATMENT							
	P_0		Superphosphate		Ground Mineral Phosphate		Basic Slag	
	L_0	L_1	L_0	L_1	L_0	L_1	L_0	L_1
Basalt Carron Valley Darleith Series	0.86	0.73	1.27	1.32	1.19	1.22	1.32	1.14
Greywacke Stanhope Linhope Series	0.82	1.05	1.75	1.79	1.81	1.25	1.69	1.77

Table 2. Herbage DM production from ryegrass in pots at Lephinmore (W. Scotland): (g/pot July-Sept.)

Soil Type	TREATMENT							
	P_0		Superphosphate		Ground Mineral Phosphate		Basic Slag	
	L_0	L_1	L_0	L_1	L_0	L_1	L_0	L_1
Basalt Carron Valley Darleith Series	0.37 (0.11)*	0.47 (0.19)	0.77 (0.15)	0.52 (0.55)	0.60 (0.11)	0.70 (0.60)	0.57 (0.46)	0.60 (0.67)
Greywacke Stanhope Linhope Series	0.34 (0.16)*	0.34 (0.25)	0.82 (0.41)	0.75 (0.36)	0.71 (0.43)	0.38 (0.42)	0.73 (0.36)	0.59 (0.43)

* Results in brackets are for undiluted soils (i.e. without added vermiculite)

The differences between plant growth on undiluted soils and on soils with added vermiculite, and some possible reasons for these results will now be considered. On Linhope soil, yields are lower than on diluted soil, but in the main the treatment effects are similar with only two exceptions - the response to added P seems to be less, and the suppression of P resonse from GMP in the presence of lime is not apparent on the undiluted soils. On Darleith soil, the yields from P_0L_0, P_0L_1, Super-P-L_0, and GMP-L_0 are much lower than on diluted soil. In every pair of L_0-L_1 treatments there is a marked response to lime on the undiluted Darleith soils; this result is in agreement with the results of a glasshouse pot experiment in which similar treatments were included (see Projects 04011/04003, p. C.33). The yields from Super-P-L_0, and GMP-L_0 may not be significantly greater than from control treatment.

Our interpretation is that at the low pH of these soils (4.1-4.3), and with high levels of exchangeable aluminium, P-uptake by ryegrass from both native and added sources of P is inhibited. When soil pH is increased, and when exchangeable aluminium is also diminished, either by application of lime or addition of vermiculite (which has pH = 8.4), P uptake from both native and applied sources is enhanced. It appears that P applied as basic slag, even without lime, may be more available for plant growth than other forms of P fertilizer on this soil type because of the liming effect of the basic slag.

Mean DM production values for ryegrass on each of the two soils at each location are summarised in Table 3. These show that yields at Stanhope were approximately double the yields at Lephinmore during the same growth period July to September.

Table 3. Mean ryegrass DM yield on two soils at two sites in 1977 (g/pot)

Soil Type	Stanhope	L_0P_0	Lephinmore	L_0P_0
Darleith Series (Carron Valley)	1.13	.86	0.58	.37
Linhope Series (Stanhope)	1.49	.82	0.58	.34

One of the objectives of this experiment was to examine possible interactions between climate and fertilizer treatment and for this reason climatic data have been collected for both sites during the storage period April to July and during the growth period July to September 1977. Data for soil moisture has been calculated as the running net total of rainfall minus potential evaporation at weekly intervals. These data, together with accumulated temperature (day $^{\circ}C > 6^{\circ}$), are presented in Table 4. (See over).

These data suggest that the treatment pots at Lephinmore did not suffer moisture limitations at any stage during the season, while at Stanhope there may have been a moisture deficiency during July and August. However, the pots were brought back to the laboratory, diluted with vermiculite and rewetted before seeding on 18 July. The moisture deficiency may not, therefore, have been as great as the data suggest. It seems that the differences in climate during the storage period may not have had much influence on soil-fertiliser interaction.

Table 4. Calculated net soil moisture status, and accumulated day degrees temperatures for Stanhope and Lephinmore, 1977.

Week ending	Soil moisture (mm) Stanhope	Soil moisture (mm) Lephinmore	*Day degrees ($^{\circ}C > 6^{\circ}$) (accumulated) Stanhope	*Day degrees ($^{\circ}C > 6^{\circ}$) (accumulated) Lephinmore
26.4.77	+ 25.9	+ 99.5	9.5	3.4
3.5.77	+ 62.7	+126.5	15.6	5.3
10.5.77	+ 74.9	+145.5	25.6	8.0
17.5.77	+ 79.3	+147.5	36.9	12.8
24.5.77	+ 57.3	+127.5	68.1	40.1
31.5.77	+ 34.3	+100.5	106.7	73.2
7.6.77	+ 40.7	+128.5	142.4	88.6
14.6.77	+ 61.4	+136.5	162.7	99.0
21.6.77	+ 41.4	+113.5	199.7	131.3
28.6.77	+ 18.5	+ 98.0	249.0	163.1
5.7.77	- 2.1	+ 87.5	311.4	207.2
12.7.77	- 29.1	+ 56.5	378.9	269.4
Sub Total for storage period			378.9	269.4
26.7.77	- 35.3	+122.5	60.2	30.6
2.8.77	- 55.8	+142.0	110.2	56.2
9.8.77	- 55.6	+142.0	149.9	81.0
16.8.77	- 72.5	+147.0	209.1	126.3
23.8.77	- 79.4	+141.0	259.2	154.9
30.8.77	- 28.1	+144.0	300.7	175.4
6.9.77	+ 5.5	+198.5	343.9	193.3
13.9.77	+ 23.0	+310.5	374.6	208.1
20.9.77	+ 14.7	+307.5	399.1	220.0
27.9.77	+ 43.7	+333.5	425.6	228.9
Sub Total for growth period			425.6	228.9

* Calculated as described in Met. O. leaflet No. 10 (1965).

It is, however, clear that there is a large site difference in amount of DM production which may be due to climatic differences. The treatment pots at Stanhope may have suffered minor moisture deficiencies in July/August but growth at Stanhope was more than double that at Lephinmore where there was no moisture limitation. The accumulated day-degrees data suggest that the greater production at Stanhope is related to the much greater heat input at this site compared with Lephinmore during the same period. This suggests that DM production on hill land may be more dependent upon temperature regimes than soil moisture availability.

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

C.C. Evans and P. Newbould

Observations of hypocupraemia in lambs grazed on recently improved pasture at Sourhope (see Whitelaw p. A.48) gave rise to the need for data on the trace element content of herbage from the Alderhope reseeds, and from the unimproved vegetation.

The initial objectives of this work are twofold:-

1. To provide evidence of the dietary causality of the hypocupraenia found in ewes and lambs which graze reseeded pasture, and

2. As a pilot investigation prior to detailed experimentation to understand the uptake of Cu, Mo and S and the subsequent availability of Cu to animals grazing improved pastures so as to prescribe appropriate remedial strategies of grazing or soil/plant treatments.

During 1977 an investigatory approach of sequential harvesting of herbage and soil from all four reseeds and adjacent unimproved areas was carried out. Particular reference was made to the A1 and A2 paddocks in which ewes with twin lambs were mainly confined. Samples were taken at approximately 3-4 weekly intervals from mid-April to the end of October by random replicated harvesting of both herbage and soil (0-15 cm). A limited number of samples were separated into their clover and grass fa ctions.

It was apparent from the 1976 chemical data for herbage from other reseeds at Sourhope (Gairs E2) that a possible cause of sheep hypocupraenia at this Station involved the enhanced uptake of Mo and S and a consequent reduction in dietary Cu availability to the grazing animal. While chemical data is still awaited from the bulk of samples harvested during 1977 the analyses of those taken in early spring substantially confirm the 1976 Gairs E2 results, i.e. the concentration of Mo in herbage from reseeded areas was 3-4 times greater and of S approximately twice as large as in herbage from adjacent unimproved areas. The level of copper was approximately the same in both types of herbage.

During August, samples of herbage from the Birnie and West Finella reseeds at Glensaugh and adjacent heather dominated unimproved pasture were taken; chemical analysis is still in progress.

5. <u>The effects of lime, magnesium and potassium on the growth of white clover in a glasshouse experiment</u> - <u>a preliminary report</u>

A. Rangeley and P. Newbould

A factorial experiment, in a randomised block design, was planned to elucidate the main effects of, and interactions between, lime, magnesium and potassium on the growth of white clover.

The levels of nutrients were:-

Lime	(as $CaCO_3$)	0, 1, 2, 4 g/pot
Magnesium	(as $MgSO_4.4H_2O$)	0, 27, 55, 109 mg Mg/pot
Potassium	(as KCl)	0, 52, 105, 210 mg K/pot
Phosphorus	(as $Ca_3(PO_4)2$)	100 mg P/pot 196 mg Ca/pot

The chemicals were mixed into a shredded deep peat soil. At the beginning of the experiment the four levels of calcium carbonate gave pH's of 3.9, 4.9, 5.6 and 6.9. Each 4" pot was sown with 40 seeds of white clover "Grasslands Huia" and one week after germination each received a solution containing three strains of Rhizobium. Trace elements in solution were applied after a further week.

The experiment was harvested after twelve weeks of growth, the shoots were cut off 1 cm above soil level for any weight measurements. A second harvest will be taken 10-12 weeks after the first and measurements will include dry weight of shoots and roots, nutrient content of shoots, nodule size and number and the pH of the soil.

The main effects of each nutrient, for shoot dry weight at the first harvest, are given in Table 1. With lime, shoot dry weight was greater than the control only with the addition of 1 $gCaCO_3$/pot. With 2 $gCaCO_3$/pot growth was the same as in pots which did not receive calcium carbonate and with 4 $gCaCO_3$/pot growth was less. There should not have been calcium deficiency with any treatment because 196 mgCa/pot was added as tricalcium phosphate. The response of white clover to calcium carbonate seems to be related to the percentage of $H_2PO^-_4$ ions in pure solutions at different pH values. At pH 4.9 where there was most growth, more than 90% of phosphate ions are present in the $H_2PO^-_4$ form and at pH 6.9 where there was least growth, only 20% of ions are present as $H_2PO^-_4$. The validity of this relationship is being investigated. There was no response in shoot dry weight to applications of magnesium (Table 1).

Table 1. The main effects of calcium, magnesium and potassium on the shoot dry weight of white clover at the first harvest

Calcium		Magnesium		Potassium	
Level mg/pot	Dry Weight g/pot	Level mg/pot	Dry Weight g/pot	Level mg/pot	Dry Weight g/pot
0	1.58	0	1.53	0	0.90
400	2.28	27	1.58	52	1.66
800	1.66	55	1.57	105	1.86
1600	0.73	109	1.59	210	1.84
LSD	5% = 0.106		1% = 0.126	0.1% = 0.180	

Applications of 52 and 105 mg potassium/pot increased shoot dry weight over the control but there was no further response with 210 mg K/pot. Figure 1 illustrates that the response to potassium is dependent upon the response to calcium and, if the relationship is true, the availability of $H_2PO^-_4$ ions.

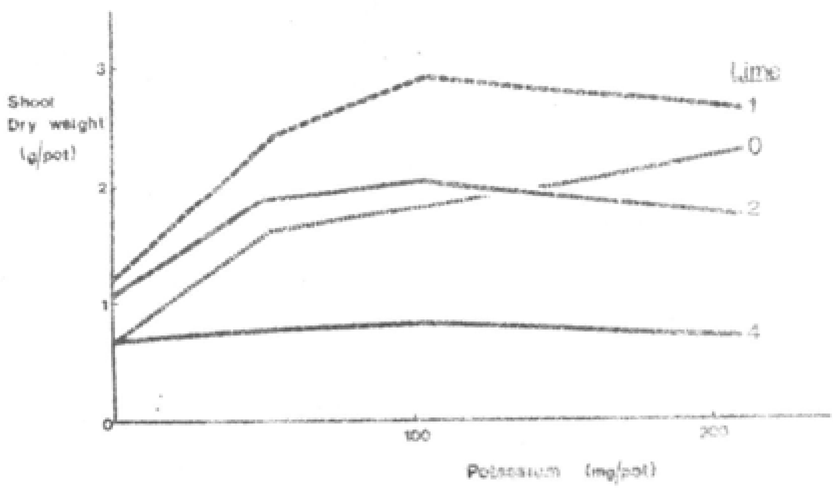


Fig. 1. The response, in shoot dry weight, to potassium in the presence of lime.

PASTURE ESTABLISHMENT: BRACKEN CONTROL

04004: Determination of effect of bracken control on herbage production and pasture formation

1. The effect of a reduction in bracken density on the production of underlying grass

G.E. Davies and G.J. Baillie

Although a great deal of work has been done on methods of controlling bracken, little attention has been given to the effect of treatment on the underlying vegetation, whether in terms of quality or quantity. Experiments set up at Sourhope in 1973 were designed to study both these aspects. A brief description of these experiments, a summary of results up to 1977 and conclusions reached are given below.

For this work two bracken dominated sites, which are fairly typical of the hilly regions of the SE of Scotland, were chosen. Both sites were at an altitude of 335 m, with one site (Site 1) facing due South and the other site (Site 2) due West. The soil was a well drained brown earth of the Sourhope series. Bracken cover was more dense and vigorous at Site 1 and was associated with a greater depth of soil and a greater abundance of broad-leaved grasses. Each site measured 60 x 60 m and consisted of six replicated blocks with control and herbicide treatments randomized within each block. The herbicide applied was asulam at the commercial rate of 11.2 l ha^{-1} with 448 l ha^{-1} water. Spraying took place in mid-July 1973 at about full frond development. In order to estimate yields and to ensure that at least part of the area be subjected to normal grazing pressure every year, each site was divided into two halves. Blocks 1-3 were fenced and recorded in 1974 and 1976 and grazed in 1975 and 1977. Blocks 4-6 were fenced and recorded in 1975 and 1977 and grazed in 1974 and 1976. Grazing was controlled and there were no fertilizer applications until the spring of 1977. At this date each main treatment was split, with one half receiving the equivalent of 628 $Kgha^{-1}$ granulated mineral phosphate.

Records taken during the experimental period consisted of bracken frond counts and height measurements, botanical composition of the underlying sward and estimates of accumulative dry matter yields taken at four harvest dates between late May and the beginning of November.

Results

Bracken cover

The degree of control obtained during four years after spraying in 1973 and the seasonal fluctuations in the number and height of fronds in the control plots are given in Table 1.

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

	Year	Control		Sprayed		% reduction	
		No.	Height	No.	Height	No.	Height
Site 1	1973	33	73	33	77	-	-
	1974	39	67	1	35	97.9	47.8
	1975	34	56	1	28	97.4	51.1
	1976	40	59	1	30	97.6	49.6
	1977	32	51	1	33	95.9	34.5
Site 2	1973	28	59	26	58	-	-
	1974	34	57	<1	28	98.6	50.6
	1975	33	49	1	28	98.2	41.9
	1976	41	51	1	30	98.0	38.0
	1977	34	44	1	28	95.8	35.5

Results showed that for both sites the reduction of approximately 98% in frond numbers achieved in 1974 was maintained into 1976. In 1977, however, the reduction was approximately 2% less and was associated with not such a great reduction in height of the remaining fronds. Frond numbers and height fluctuated on the control plots from 1973 to 1977. This was probably due to several factors such as the lack of grazing during recording years, the summer droughts of 1975 and 1976 together with the dying off of some of the older bracken stands within the sites.

Botanical composition

Only species that play a major part in changes in sward composition are given in Table 2.

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

Percentage cover assessed using a 10 point quadrat (1200 points per treatment with the exception of Blocks 1-3, 1975, and Blocks 1-6, 1977, where 600 points were used) * P< 5.0% ** P < 1.0%

Key to Species: At = *Agrostis tenuis*; Ac = *Agrostis canina*; Pp = *Poa pratensis*; Fo = *Festuca ovina*; Df = *Deschampsia flexuosa*

Site 1

Blocks	Year	Grazing	Treatment	Bare Ground	At.Ac.Pp.	Fo.Df.	Herbs
1-3	1974	Ungrazed	Control	11.1	42.2	14.7	9.6
			Spray	22.7*	18.9*	25.1*	5.4
	1975	Grazed	Control	2.9	44.4	17.9	16.2
			Spray	8.8	29.4**	33.2	6.1**
	1976	Ungrazed	Control	1.0	43.0	16.7	18.6
			Spray	0.7	34.6	21.8	19.6
	1977	Grazed	Control	0.2	42.2	19.1	18.1
			Spray	0.1	41.2	25.5	16.0
4-6	1974	Grazed	-	-	-	-	-
	1975	Ungrazed	Control	5.3	42.5	9.0	12.3
			Spray	2.0	46.8	4.0	9.3
	1976	Grazed	Control	2.5	41.6	10.5	14.4
			Spray	0.4	48.4	5.1	14.6
	1977	Ungrazed	Control	0.2	42.6	10.3	16.6
			Spray	0.1	49.1	3.3	14.0

Site 2

Blocks	Year	Grazing	Treatment	Bare Ground	At.Ac.Pp.	Fo.Df.	Herbs
1-3	1974	Ungrazed	Control	3.0	30.5	42.1	11.2
			Spray	11.2	10.2*	56.5	4.8
	1975	Grazed	Control	1.2	27.5	41.7	17.1
			Spray	1.9	21.2	52.4	9.3**
	1976	Ungrazed	Control	0.5	29.9	30.1	24.5
			Spray	0.4	21.4	45.1	16.7**
	1977	Grazed	Control	0.3	23.8	39.5	19.7
			Spray	0.3	19.1	42.1	21.7
4-6	1974	Grazed	-	-	-	-	-
	1975	Ungrazed	Control	10.2	15.0	50.1	13.3
			Spray	3.8	18.6	44.3	11.1
	1976	Grazed	Control	1.7	21.2	41.1	22.0
			Spray	0.5	23.6	35.5	19.1
	1977	Ungrazed	Control	0.5	24.0	38.8	23.2
			Spray	1.1	25.1	32.7	20.7

An assessment of the botanical composition of the underlying sward made in 1974 showed that _Agrostis tenuis_, _Agrostis canina_ and _Poa pratensis_ were severely reduced on the sprayed plots at both sites. This resulted in an increase of bare ground with _Festuca ovina_ and _Deschampsia flexuosa_ taking advantage of this and consequently increasing their cover. This increase, however, only partially compensated for the loss of the broad-leaved grasses. There was thus an increase in bare ground at both sites. Reduction in the cover of herbs also contributed to this.

By 1975 blocks 1-3 showed a marked reduction in bare ground at both sites. In Site 1 the decrease was due mainly to the recovery of the broad-leaved species and the still increasing cover of the fine-leaved ones, and in Site 2 by the recovery of the broad-leaved species. Herbs increased in cover at both sites but to a greater extent on the control plots. This increase was responsible for reducing the amount of bare ground on these plots. Blocks 4-6 differed slightly from blocks 1-3 at both sites. However it did seem that in these plots, which were grazed in 1974, there was little difference between treatments. The apparent treatment differences at Site 1 for the fine-leaved grasses were not due to treatment but location and are also shown in the 1976 and 1977 data. The reduction in bare ground on the sprayed treatment at Site 2 is explained by an increase in _Anthoxanthum odoratum_, _Deschampsia caespitosa_ and _Carex_ species.

In 1976 there were indications that on blocks 1-3 the change towards the original sward composition was being slowed down by a rapid increase in herbs at both sites. Their cover also increased on the control plots. Herbs also increased on all plots at both sites in blocks 4-6 and there was some indication at Site 2 that this increase was at the expense of the fine-leaved grasses.

Changes in botanical composition were minimal in 1977 with the exception of Site 1 (blocks 1-3) where the broad-leaved grasses increased and attained their original cover. Thus within four years after spraying there was little difference between treatments whilst the cover of herbs had increased considerably on all plots but showed no treatment differences.

Accumulative dry matter yields of underlying vegetation

Table 3. _Accumulative dry matter yields (Kg ha^{-1}), 1974-77_

Year	Blocks	Control				Sprayed				% increase	Sig.
		May	July	Aug.	Nov.	May	July	Aug.	Nov.		
Site 1											
1974	1-3	855	1210	1518	1817	1034	1202	1457	1401	-	NS
1975	4-6	917	1400	1353	2073	808	1967	1979	3039	47	P 10%
1976	1-3	979	1275	1285	1749	1582	1753	1768	2588	48	P 5%
1977	4-6	1016	1349	1772	2272	1410	2309	2528	3439	51	NS
Site 2											
1974	1-3	1050	1251	1451	1807	913	1376	1686	1719	-	NS
1975	4-6	897	906	1327	1750	1016	1337	1818	2069	18	P 10%
1976	1-3	913	863	1086	1620	1125	1392	1776	2510	55	P 10%
1977	4-6	581	687	978	1809	881	1320	1192	2233	23	NS

Because it had previously been under the bracken canopy the top soil horizon on the sprayed treatments in 1974 remained very loose and 'puffy' in texture and this was especially true of Site 1 which originally had the more dense bracken cover. Thus puffiness combined with the loss of broad-leaved species, due to the direct effects, of asulan, apparently contributed to comparatively poor yields. The final yield in November on Site 1 was approximately 400 Kgha^{-1} less than on the control whilst Site 2 showed a lesser decrease. The higher rate of growth on the control plots at both sites in the period between August and November can probably be attributed to the sheltering effect of the bracken canopy during a cold and wet autumn.

In 1975 the top soil on the sprayed treatment was far more consolidated due to grazing and treading by stock in the previous year and bare ground had been considerably reduced at both sites by the recovery of species affected in 1974 combined with an increase in cover of some of the other species. At both sites the rate of growth between May and July was much greater on the sprayed treatment than on the control. Lack of growth between July and August at Site 1 on both treatments was explained by drought conditions during this period. Site 2 was apparently less affected due probably to aspect (West facing) and the dominance of fine-leaved grasses, generally regarded as more drought resistant than the broad-leaved grasses that dominated Site 1. Between August and November growth was poor on Site 2. The final yield on the sprayed treatment in November of 2000 Kgha^{-1} showed only an increase of 18% on the control. Growth rates for both treatments were higher on Site 1 with the sprayed treatment giving the higher rate. The November yield of 3039 Kgha^{-1} showed an increase of 47% on the control.

In 1976 the final yields on the sprayed treatments at both sites were little different. Site 1 gave a yield of 2588 Kgha^{-1} and Site 2, 2510 Kgha^{-1}, giving increases over the control of 48 and 55% respectively. Growth at the two sites was affected by drought in mid-summer in similar fashion to that in 1975. The exceptionally large yield in May on the sprayed treatment at Site 1 was probably due to the site's favourable aspect (South facing) and above average rainfall combined with warm weather in the weeks prior to harvesting.

For purposes of comparison with previous years and because there were no significant interactions between the two main treatments and added phosphate, the results given for 1977 in Table 3 are for main treatments only. The results of phosphate application are given separately. Main treatment results confirmed the 1975 results when the same blocks were sampled (blocks 4-6). In November the sprayed treatment at Site 1 gave an increase in yield of 51% over the control and Site 2 an increase of 23% whilst in 1975 the increases were 47 and 18% respectively. However, the yields in 1977 at the two sites and for both treatments were greater than those of 1975. These increases were probably largely due to the adequate summer rainfall of 1977 compared to drought conditions prevailing in 1975.

Conclusions

It is evident that in the year following spraying little increase in yield can be expected. An unstable top soil and a reduction in cover of the more productive species by asulan, associated with a considerable increase in bare ground, appear to be the main reasons. In later years bare ground is reduced and the sward becomes more consolidated. Results in 1975 for blocks 4-6 also indicate that fairly intensive grazing in the first year after treatment hastens this process.

Provided that the original sward has an abundance of the more productive grasses, as in Site 1, yields of between 2600 Kgha^{-1} and 3400 Kgha^{-1} are possible on the sprayed areas. When the cover of these species is poor, as at Site 2, lower yields ranging between 2000 and 2500 Kgha^{-1} can be expected.

Aspect also plays an important part in determining the degree of increase, thus the lower yield in each of the two ranges is due to steeper slopes and hence shallower soils on these areas.

The low yields on Site 2 in 1975 and 1977 reflect adverse soil conditions and poor botanical composition and it is doubtful if these areas are suitable for spraying.

On areas such as Site 1 (blocks 1-6) and Site 2 (blocks 1-3) there is little doubt that provided control of bracken is sufficiently effective to maintain the increased yields, spraying is economically justified and that the treated areas, if used fairly intensively, could be of considerable benefit to the farmer.

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

G.E. Davies and G.J. Baillie

At present, the use of asulam with a 'follow up' treatment on classified hill land is eligible for a grant of up to 50% of the total costs. A minimum application of 628 $Kgha^{-1}$ (5 cwt/acre) of either ground or unground mineral phosphate is required to qualify. As considerable doubts exist as to the benefits, if any, of this treatment it was decided to test its effectiveness on the trials already described.

In the spring of 1977 one half of each main treatment, i.e. control and sprayed, received the equivalent of 628 $Kgha^{-1}$ of granulated mineral phosphate (27% P_2O_5). In agricultural practice the fertilizer would have been applied in the year following spray treatment. It was decided, however, that its inclusion in the trials at an earlier date, because of envisaged large sampling and experimental errors, would have made the interpretation of results difficult.

Results

There was no evidence at Site 1 to suggest that the addition of phosphate increased growth on either the control or sprayed treatment. At Site 2 varying degrees of increase were apparent at the four harvest dates for both treatments but with the exception of the third harvest (August) were not significant. The interaction with control and sprayed treatment was not significant at this date.

At the two sites the proportion of green herbage was greater on the phosphate treated plots at all harvests and for both treatments. There were no significant interactions with main treatment effects, therefore the results shown below are given for the P_0 and P_1 treatments only.

Harvest Date	Site 1			Site 2		
	P_0	P_1	Sig.	P_0	P_1	Sig.
May	62.1	70.3	NS	44.4	56.3	*
July	74.6	80.6	NS	64.7	80.5	**
Aug.	60.0	84.5	***	65.2	79.3	**
Nov.	45.5	75.7	**	57.0	75.3	**

Results are not yet complete and plant and soil analysis have still to be made, therefore no attempt is made at this stage to interpret these results. The trials continue.

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

G.E. Davies and G.J. Baillie

The question of whether any appreciable increase in pasture growth occurs after the application of lime and phosphate to indigenous swards, especially in the absence of clover, is one of considerable dispute. Recently, the widespread use of asulam and the uncertainty of what 'follow-up' treatment to apply has highlighted this problem. In 1977, therefore, a trial was established at House o' Muir incorporating both bracken control and fertilizer treatments.

The area (0.42 ha, 1.03 acres) is dominated by very vigorous growing bracken. Frond counts and height measurements made in 1977 gave a mean frond count of 36 fronds/sq m and mean height of 100 cm. The underlying vegetation is of the "dry heath" type with a few areas dominated by *Vaccinium myrtillus*.

Asulam was applied at the beginning of August 1977 at the commercial rate of 11.2 l ha^{-1} and 448 l ha^{-1} water. No deleterious effect on the grass cover was observed but on some of the more vigorous stands of bracken scorching of the growing tips of the bracken fronds occurred.

During 1978 records taken will be similar to the ones taken on the Sourhope trials. Lime and phosphate will be applied in the late autumn of 1978 or early in 1979.

EFFECTS OF UTILISATION: MOORLAND

04005: The effects of seasonal patterns and different intensities of utilisation on the growth of heather

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

S.A. Grant, G.R. Bolton and L. Torvell

Grazing treatments were continued in this long term experiment which was set up at Lephinmore in 1971 to investigate the effects of increasing stock numbers on blanket bog vegetation. There were three sites and at each site three stocking rates were provided. The lowest rate (1.5 ha/sheep) results in the utilisation of about 15% of the annual production of the vegetation and is equivalent to the average for the Cowal peninsula. The intermediate and high rates are two and three times this rate respectively.

In the first three years of the experiment the pattern and levels of use of the species comprising the bog vegetation were studied. The methods used involved observation of the vegetation in permanent quadrats and examination of cuticle fragments in faeces. In summer the sheep grazed *Trichophorum caespitosum*, *Molinia caerulea*, and scattered plants of *Deschampsia flexuosa*, *Agrostis canina* and *Carex* species. In autumn, as availability of these plants became reduced, *Eriophorum vaginatum*, *E. angustifolium* and *Calluna vulgaris* were also grazed. In winter *Eriophorum vaginatum* and *Calluna vulgaris* formed the bulk of the diet (Grant et al, 1976). The results show excellent agreement with results obtained to date in project 04010 (see p. C.63).

The effects of grazing on the productivity and floristic composition of the vegetation are being monitored using both harvesting and point quadrat procedures. Harvests were made in 1971 prior to grazing, in 1974 after three years of grazing, and in 1977 after six years of grazing. Changes in standing crop and green dry matter yield (green leaves of sedges and grasses and current shoots of heath species) are summarised in the table below.

	Stocking Rate		
	Low	Intermediate	High
Standing crop (kg/ha)			
1971: prior to grazing	2780	2720	2977
1974: after 3 years grazing	4157	4235	3362
1977: after 6 years grazing	6508	6106	3629
Green Dry Matter yield (kg/ha)			
1971	1543	1508	1655
1974	1469	1487	1146
1977	1572	1645	1170

In both 1974 and 1977 the reduction in standing crop and green dry matter yield at the high stocking rate was significant. The reduction in standing crop was due to a decrease in the build up of woody stems of heather, a decrease in accumulated, uneaten, dead Eriophorum, reduced current production, and reduced vascular plant cover. In 1977, for example, percentage ground cover due to bare ground or Sphagnum averaged 9.0% for plots at the low stocking rate compared with 25.0% for plots at the high rate.

The species under stress differed among the sites. Two sites were wetter and more recently burned. The vegetation was more mixed. Heather was the species most under stress at these sites; during 1972/76 heather cover increased from 20-25% to 30-35% on the low and intermediate stocked plots but remained at 20-25% on the high stocked plots. In 1977 the heather grew exceptionally well and increased its cover on all plots. At the drier site there were fewer species; heather had had a high cover initially; there was less Eriophorum and no Molinia or Trichophorum. At this site both the floristic analyses and the harvest data indicated a steady decline in Eriophorum vaginatum and Erica tetralix under high stocking. Erica is not grazed to any extent but appears to be very susceptible to damage by treading.

Reference

GRANT, Sheila A., LAMB, W.I.C., KERR, C.D. and BOLTON, G.R. (1976). The utilisation of blanket bog vegetation by grazing sheep. J. appl. Ecol. 13, 857-869.

2. The effects of utilisation by grazing hill sheep on the morphology, productivity and nutritive value of heather (04005/02004)

S.A. Grant, J.A. Milne, G.T. Barthram and W.G. Souter

To examine the effect of season and level of shoot removal on the morphology, productivity, and nutritive value to sheep of heather, a long term experiment was set up in 1973. Plots were grazed in June/July and September/October and sheep numbers were adjusted to remove 0, 40 or 80% of the dry matter of the current season's shoots at any one grazing.

After three years of grazing, standing crop was reduced by both levels of grazing whether in summer or autumn. New shoot production was unaffected on plots which had had the 40% level of shoot removal but was reduced on plots which had had the 80% level of shoot removal whether in summer or autumn.

Grazing behaviour of sheep within a plot was affected by variation in heather cover, with the sheep showing a preference to graze near bare areas.

The siting of new season's shoots was influenced by the amount of shoot length grazed in the previous season; a high incidence of shoots grazed down to the previous season's wood (as with heavy autumn grazing) being associated with regrowth from the shoot bases.

In both summer and autumn at the beginning of the grazing period there was little effect of level of removal on intake and digestibility of the diet selected. However by the end of the grazing period, particularly in the autumn, both intake and digestibility were reduced as level of grazing increased. There was a decline in intake and digestibility between the beginning and end of the grazing period.

These results have been written up and submitted for publication (Grant et al, 1978; Milne et al, 1978).

Differences in sward morphology have increased with time and the longer term effects on intake and diet selection were studied in 1977, the final grazing year of the experiment. To obtain further information on the grazing behaviour of the sheep with respect to variation in heather cover, time lapse photography was used. Assessment of the longer term effects of grazing on productivity, floristic composition and recovery of the swards will be made in 1978.

References:

GRANT, Sheila A., BARTHRAM, G.T., LAMB, W.I.C. and MILNE, J.A. (1978). Effect of season and level of grazing on the utilisation of heather by sheep. I. Responses of the sward. J. Brit. Grassld. Soc. (submitted).

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EFFECTS OF UTILISATION: PASTURE

04006: Effect of pattern and intensity of use on growth and regrowth of native and improved hill swards

1. Regrowth of defoliated pasture

J. King, W.I.C. Lamb and E. Smith

The work on the effect of defoliation regime on regrowth of ryegrass swards is being prepared for publication. The results have been applied to data obtained from grazed, set-stocked swards from which it is evident that an inverse relationship exists between stocking rate and primary production.

Using net canopy photosynthesis (Pnc dm^{-2}) as a measure of primary production, data obtained from ryegrass swards set-stocked at high, medium and low stocking rate show that production increased with leaf area index (LAI) in an almost linear manner up to LAI 6.0. The highest rates of photosynthesis and therefore of dry matter production occurred on the swards subject to the lowest stocking rate.

The relationships measured at two levels of light intensity were as follows:-

Stocking rate	Low	Medium	High
Stocking Rate			
D. wt. of standing green crop ($kg\ ha^{-1}$)	3112	2250	1680
LAI	4.3	2.9	1.6
Pnc dm^{-2} mg CO_2 dm^{-2} min^{-1}			
at 410 Wm^{-2}	1.12	0.87	0.43
at 97 Wm^{-2}	0.49	0.38	0.24

The relationship between Pnc dm^{-2} and LAI are such that increasing LAI from 2 to 4 by reducing stocking rate could lead to an increase in production of between 29 and 74%. While these conclusions appear unexceptional they are of interest for two reasons. Firstly, they are not wholly in accordance with other published data although this may be due to interactions arising from moisture stress and the reproductive phase of growth. Secondly, the association of high growth rate with high LAI and therefore with low stocking rate, indicates that the relationship between utilised dry matter production and stocking rate may be curvilinear with maximum utilised yields at intermediate stocking rates.

This question and the relationship between utilised and primary pasture production seems to merit further work being carried out and the technical requirements are currently being assessed jointly with Dr. Hodgson.

2. Differences in productivity between grass species

J. King, W.I.C. Lamb and E. Smith

Two experiments are in progress. Both are concerned with possible differences in growth rate which might arise from differences in assimilation rate or partitioning between canopy and root.

In one experiment four grasses (Ryegrass, *Poa pratensis*, *Cynosurus*, *Agrostis tenuis*) have been grown in microswards, subject to the same defoliation regime, at two N levels. The swards can adapt their growth form to the cutting regime so that differences in productivity could arise from variation in residual LAI after cutting.

Measurements will be made of crop growth rate and associated parameters, such as LAI, and canopy photosynthesis during a period of uninterrupted regrowth.

A second experiment uses six grass species, the four mentioned above together with *Holcus lanatus* and *Festuca rubra*.

Seedling plants are grown in vermiculite, supplied with nutrient solution and subjected to growth analysis. Particular importance is being attached to partitioning of assimilate between root and shoot.

If possible, measurements will also be made of whole plant photosynthesis, respiration and single leaf photosynthesis.

3. Apparatus

J. King, W.I.C. Lamb and E. Smith

During the year the apparatus for measuring CO_2 exchange of plants and swards has been rebuilt and given a more efficient temperature control system.

The apparatus can now measure canopy photosynthesis and respiration of plants in pots, swards in larger containers or turf samples from the field. It is also possible to measure CO_2 in syringe samples taken from root respiration chambers.

A single leaf cuvette system with a limited range of temperature control has also been constructed.

NUTRIENT CYCLING

04007: Cycling of nutrients in grazed hill pastures and its influence on requirements for lime and fertilisers

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

1. Input-output studies and nutrient cycling, Lephinmore

M.J.S. Floate, G.R. Bolton and J. Eadie

A field plot grazing experiment (Le 1) of the Input-Output series (see p.A.(3)) was established on peat at Lephinmore in 1972. The main objectives of this experiment were to determine the output responses from different rates of lime and P fertiliser application on surface-seeded ryegrass/clover. However in 1973 on those plots with the lower lime rate (2.5 tonne/ha) patches began to develop where the sown species became very scarce or died out altogether. This was at first thought to be due to inadequate (and uneven) lime spreading and low soil pH. Analysis of both peat and herbage samples failed to show significant differences in pH or Ca status between normal and abnormal areas within the affected plots. Furthermore, there were no differences in chemical composition of herbage for a number of other elements and only K showed lower (but not significant) values for the abnormal areas.

Against this background, two new experiments were started: (a) a lime response experiment (Le 3) which is described on page C(5) and (b) a nutrient deficiency diagnosis trial (Le 5) conducted in micro-plots (plastic rings imbedded in situ into peat). Approximate calculations of elements present in peat, added in lime and fertilisers, and removed in crop or by leaching, suggested that the following elements could decline to low levels in a few years: Ca, Mg, K, B, S, Mo.

A deficiency trial using a method similar to that described by Middleton and Toxopeus (1973) was laid out in 1975. There were eight replicates of control treatments which were watered twice weekly with a complete nutrient solution, and four replicates of each of five test treatments which were similarly watered with solutions omitting one element each: -K, -Mg, -B, -S, -Mo. All treatments were surface sown with ryegrass + clover and included three lime levels: 0, 2.5 and 5.0 tonne/ha, but the sown species failed within a few weeks of germination in the absence of lime. Results for the remaining two lime levels are presented in Table 1.

Table 1. Annual grass and clover DM production from reseeded micro-plots on peat, 1975-77 (g/m²)

Treatment			Complete Nutrients	- K	- Mg	- B	- S	- Mo
1975	Grass	L 2.5	16.0	20.0	18.0	14.0	16.0	14.0
		L 5.0	22.0	28.0	22.0	24.0	20.0	22.0
	Clover	L 2.5	25.0	11.6***	27.6	27.0	22.0	15.0**
		L 5.0	25.2	19.6	27.6	23.6	18.6	15.6
1976	Grass	L 2.5	181.0	168.6	186.6	184.0	165.4	166.6
		L 5.0	196.0	175.0	184.0	191.0	166.5	171.6
	Clover	L 2.5	218.0	109.6**	212.0	184.6	164.0	180.0
		L 5.0	205.6	192.6	158.0	144.6	179.0	144.6
*1977	Grass	L 2.5	124.0	88	154	120	94	116
		L 5.0	220.0	242	156	192	240	236
	Clover	L 2.5	124	74	92	54	72	86
		L 5.0	328	406	398	450	368	394

* Data for first 3 cuts to 29.7.77

These show that there were no significant grass yield depressions due to nutrient treatments although in most cases yields were less than for the complete nutrient control. Clover yields were significantly reduced below control on both - K and - Mo treatments in the first year and on - K treatment in the second year. These effects were only found at the lower lime level and, in this sense, as well as the reduced numbers of viable plants on these treatments, the effects were similar to those originally observed in the field grazing trial. Results are not yet complete for the third year but the depression of clover yield on - K treatment does not seem to be so marked. A notable result in the third year is the much higher yield of both grass and especially clover at the higher lime level. These results may be related to pH differences between different lime levels and samples will be taken at the termination of the experiment.

It was concluded that the most significant reduction in plant numbers and clover yields could be attributed to K deficiency and that this was a likely explanation for the observations in the field grazing trial where the lower rate of lime had been applied. Complementary K responses by clover on peat soils have been found by Anne Rangeley in both glasshouse pot experiments (Rangeley, A. and Newbould, P. (1975)) and in a small plot cut-herbage field experiment at Lephinmore (Rangeley, A. et al 1975).

As a consequence of these findings, a large scale pilot trial on the original grazed plots at Lephinmore was carried out in 1977. The treatments and DM yields are presented in Table 2.

Table 2. Herbage DM production from top-dressing treatments applied in 1977 to reseeded pasture established on peat in 1972 (kg/ha)

Treatment		First Grazing Period: DM at 26.7.77	First Grazing Period: Grazing Days	Second Grazing Period: DM at 5.10.77	Second Grazing Period: Grazing Days
Control	L 0	517 ± 70	40	625 ± 47	34
	L 2.5	542 ± 90		608 ± 25	
P_0K_{100}	L 0	684 ± 51	44	585 ± 43	50
	L 2.5	727 ± 30		842 ± 79	
$P_{80}K_{100}$	L 0	1814 ± 198	149	1893 ± 96	164
	L 2.5	1812 ± 161		1636 ± 97	

The most striking result from this trial was the very highly significant response to the combined PK treatment which gave a three-fold increase in production on both occasions. Total production for the year for these plots exceeded 5000 kg/ha, which was about double the previous maximum yields from the same plots. Unlike cut-herbage experiments in which only clover showed significant effects of K treatments, in this grazing trial the production increase was due more to grass than to clover. Data presented in Table 3 for grass and clover production at 5.10.77 illustrate the very highly significant responses of both species to PK treatment.

Table 3. Grass and clover DM production responses to top-dressing treatments (kg/ha at 5.10.77)

Treatment		Grass DM	Clover DM
Control	L 0	438 ± 33	41 ± 3
	L 2.5	451 ± 18	50 ± 2
P_0K_{100}	L 0	334 ± 25	55 ± 4
	L 2.5	648 ± 61	54 ± 5
$P_{30}K_{100}$	L 0	1601 ± 82	273 ± 14
	L 2.5	1242 ± 73	349 ± 21

The very marked grass and clover responses recorded here in grazing trials, are of great interest in relation to nutrient recycling via the grazing animal, and to the transfer of clover fixed-N to grass. It is possible that some of the grass response was due to a direct effect of the PK treatment but an additional indirect effect is also probable. It is suggested that the PK treatment stimulated the clover which fixed more N which may then have been transferred to grass via sheep excreta, and resulted in a very marked grass DM response to the additional N. These possibilities need experimental verification and it is hoped to initiate work in 1978. Some preliminary studies of the amounts of nutrients transferred in urine were conducted in 1977.

During the July grazing period UMASE urine sampling devices were fitted to two ewes on each of the control and PK plots of the grazing trial. Twenty-four hour urine volume output was calculated from daily meter readings for four days and K concentrations in the urine sub-samples were determined. Results were incomplete due to problems of using the UMASE devices in the field, but some interesting results were obtained: for one sheep, on a control plot, K concentration increased progressively from 1650 to 5600 ppm from day 1 to day 4, urine volumes varied widely between 2.8 and 7.8 litres for 24 hours, and daily K output ranged from 2.7 to 27.2 g K per sheep per day. Mean values were 8.7 g K and 23.5 g K per sheep per day for control and PK plots respectively. Using these mean values it has been calculated that some 2.6 kg/ha K may have been recycled in urine on the control plots compared with 25.9 kg/ha K on the PK treated plots. Alternative calculations based on standing herbage DM at the beginning of the grazing period estimated herbage production and consumption during grazing, the measured K concentration in the herbage, and an assumed 85% excretion of K in urine suggest that 3-13 g K per sheep per day may be excreted on the control plots compared with 16-27 g K per sheep per day on the PK treated plots. In view of the difficulties encountered in UMASE collections, and the assumptions made in the latter calculations, these estimates are in remarkably good agreement.

Because of the increasing K concentrations noted for some sheep, and large variations in urine volume and daily K output, as well as missing values, the sampling was repeated for four days during conditioning and grazing periods in October. During the conditioning period K concentration ranged from 1900 to over 8000 ppm but there was no indication of daily increase in concentration. Mean values for individual sheep ranged only from 3350 to 4050 ppm K. Urine volume per 24 h varied from 2.1 to 7.3 l and daily K output varied between 11.5 and 29.8 g per sheep per day.

During the second week of the plot grazing period again two ewes on each of control and PK plots were sampled for 4 days. K concentration in urine ranged from 1750-6300 ppm on control plots and from 2450-4650 ppm on PK plots. Mean values for individual sheep were very similar (3260-3435 ppm K) regardless of plot treatment. Urine volumes were more variable: from 1.7 to 3.1 l/day on control plots and from 1.9-5.5 l/day on PK plots. There were again some missing values due to problems with sampling devices but mean values for daily K output per sheep were 8.6 g and 19.6 g for control and PK plots respectively. Given the sheep grazing days per plot from Table 2 it can be calculated that these amounts are equivalent to 2.2 and 23.9 kg/ha K for control and PK plots respectively. Alternative calculations based on herbage consumption and composition, as described previously, lead to values of 2.4 and 27.6 kg/ha K respectively which are again in good agreement with the measured amounts.

These preliminary trials have therefore provided evidence that the calculated values for recycled K agree closely with measured values and may be sufficiently accurate for practical purposes. They indicate that the amounts of recycled K on treated plots are some 10 times greater than on control plots.

Urine samples were also analysed for N content and the amounts of N recycled in urine have also been calculated. N concentration ranged from 2000 to 7250 ppm during the conditioning period and from 4500-7000 ppm on control and 3750-11750 ppm on PK plots during the grazing period. Mean values for daily urine-N output were 12.6 g and 18.9 g/day for control and PK plots respectively which leads to the conclusion that some 3.2 kg/ha and 23.0 kg/ha N may be recycled in urine on these contrasted plots during a two week grazing period in October.

This suggests that during a whole season with perhaps 10 weeks of grazing, over 200 kg/ha N could be recycled via sheep urine and this might lead to the production of some 3000 kg/ha grass DM. Such calculations lend support to the hypothesis put forward earlier to explain the difference between the results of cut and grazed experiments and emphasises the need for further experimentation.

Although we have now demonstrated that greatly increased yields of grass and clover DM can be attained on deep peat through the use of PK fertiliser, the amounts and frequency of fertiliser required to maintain these production levels remains to be determined. A combined series of cut and grazed plot experiments to meet these needs is planned to start in 1978.

Grateful acknowledgement is given to AJFR, GJD, IRW, ARMC, CCE, HAF, JMcK and ADI who assisted at various stages in this project.

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2. Input-Output studies and Nutrient Cycling, Sourhope

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

The objectives, location, design and some production results for the Input-Output series of experiments at Sourhope has been described in section 03002 of this report (p. A.3). A further objective of these experiments was to study soil and vegetation changes in response to applied treatments and certain aspects of nutrient recycling in a series of closed systems on different soil types.

The supplies of nitrogen and phosphorus in the soils of these experimental sites are, like most hill soils, dominated by the very large amounts in organic form and the very small amounts present at any one time in forms available for plant growth. One of the objectives in land improvement should be to mobilise more of these organic nutrient reserves, to maintain the continuity of supply of available nutrients, and so to make more effective use of the limited nutrient supplies in the production of improved pasture.

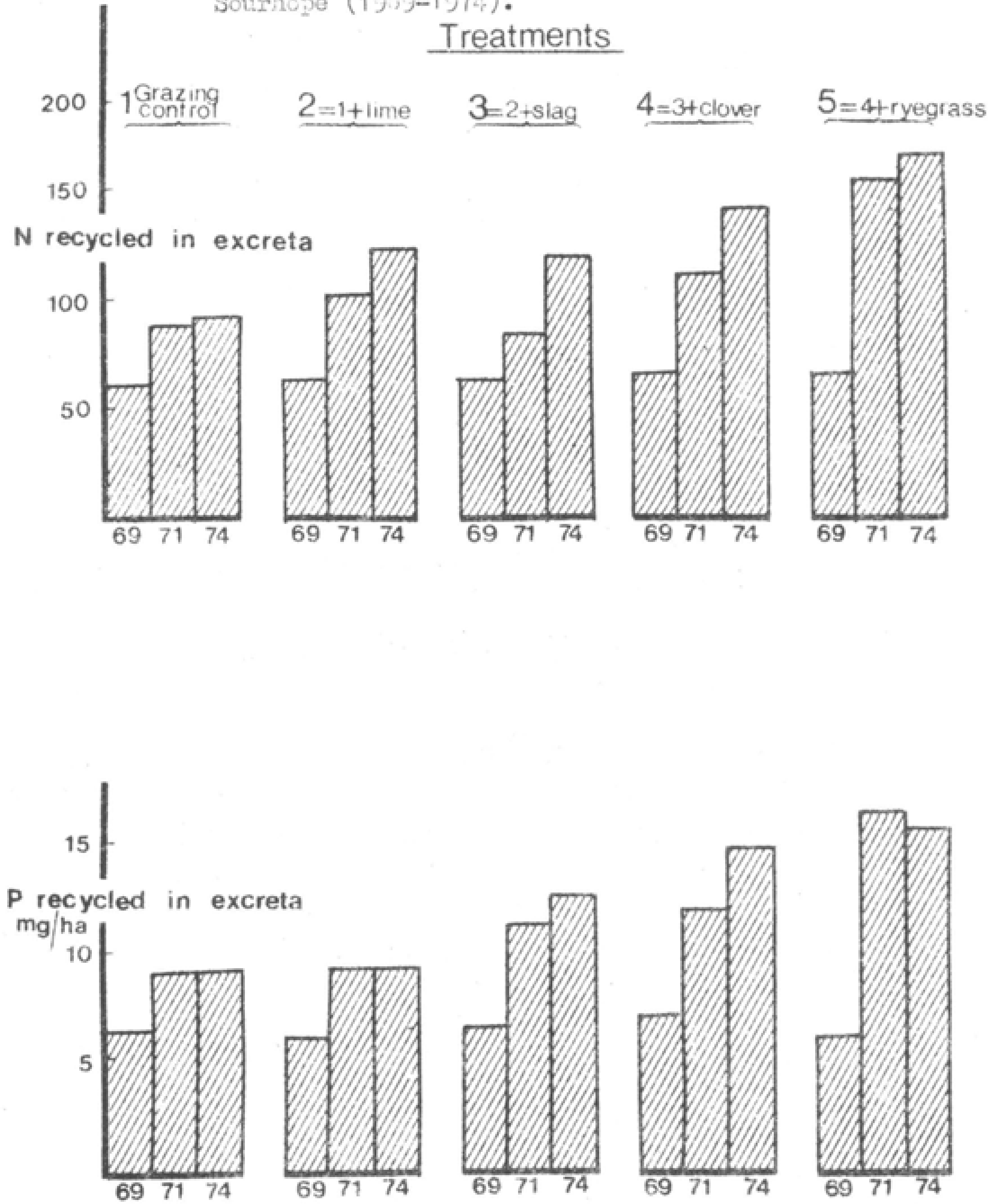
In this project we have, therefore, attempted to quantify nutrient cycling under different improvement treatments and to assess the changing efficiency with which soil nutrient supplies are used in pasture production. A great deal of data has been collected over the years and written up in previous annual reports. A review of herbage production, soil changes and nutrient recycling was undertaken by Carlos Gomez during his tenure of a Scholarship from INIA (Spain) but unfortunately his report remains uncompleted. However, in 1978, Dr. P.J. Vickery from CSIRO Pastoral Research Laboratory, Armidale, will be spending six months at HFRO during which time he will be using data from these Input-Output sites to develop a phosphorus cycle model. Because of this need to review the data in detail at that time, no up-to-date comprehensive review will be presented here but instead some examples will be given of the effects of time and treatment upon amounts of nutrients in recirculation.

Data for the amounts of N and P recycled as excreta for the range of five improvement treatments for 1969-74 on the Agrostis/Festuca (F-2) site at Sourhope are given in Fig. 1 (see opposite). These show that the amounts of N recycled via excreta increase progressively with time within each treatments, and that across the range of treatments the amounts increase with degree of intensity of treatment. These amounts can be expressed as a percentage of the total soil pool and these data are given in Table 1. In the pretreatment year about 1.7% of the soil N was recirculated in excreta and this increased to 2.3 and 4.3% of the soil pool after five years in treatments 1 and 5 respectively.

Table 1. Amounts of N and P recycled via excreta on a range of improved pasture treatments on Agrostis/Festuca expressed as % of total soil pool

Treatment		1	2	3	4	5
Nitrogen:	1969	1.51	1.64	1.65	1.78	1.75
	1971	2.18	2.62	2.19	2.99	4.04
	1974	2.28	3.18	3.11	3.77	4.30
Phosphorus:	1969	1.03	0.96	0.93	1.05	0.89
	1971	1.49	1.46	1.41	1.58	2.14
	1974	1.47	1.44	1.57	1.98	2.02

Fig. 1. Amounts of N and P recycled in excreta on a range of improved pasture treatments: *Agrostis Fescue* site (F-2) Sourhope (1969-1974).



The amounts of P recycled via excreta also increase with time within each treatment although there are indications that this may be reaching a plateau on the lower intensity treatments. The amounts of P recycled also increased across the range of treatments and, expressed as percentage of the soil pool, this represented an increase from about 1.0 to 1.5 on the lower treatments and up to 2.0 of the total soil pool on treatment 5.

For the Molinia/Nardus site (G-3) similar trends are emerging from the data which have been calculated and these suggest that up to 6% of the soil N pool may be recirculated after five years on treatment 5.

Thus, evidence is accumulating to suggest that not only are soil nutrient pools increased by treatments but also that an increasingly large proportion of the soil nutrient pool is being recycled and utilised for enhanced production.

NITROGEN FIXATION

04008: Factors affecting the fixation of nitrogen by white clover in hill pastures

1. Starter dressing of nitrogen in hill pasture improvement schemes

A. Haystead and C. Marriott

The application of combined nitrogen fertiliser to surface sown hill reseeds represents a major expenditure to the farmer. The effect of such dressings can be critical to the short and long term productivity of the improved swards. The advisory literature available to the farmer and current agricultural practice do not provide a logical basis for the new-comer to land improvement in deciding how much, in what form, and when, relative to sowing, to apply fertiliser nitrogen. The spectrum of recommended application rates is wide, ranging from a single application of 30-40 units of N to an initial dressing of 100 units followed by two annual dressings of 60 units. In 1976 a series of experiments was initiated to determine the effect of different levels of fertiliser nitrogen (0, 30, 60, 90, and 120 kg/ha^{-1} ammonium nitrogen) applied at three different times relative to sowing. The rationale behind the three sowing times was as follows:-

a) Fertilising several weeks before a spring sowing may stimulate N-mineralisation in the soil.

b) The traditional approach, fertilising at sowing time, ensures that the N is in the soil to give good seedling (particularly grass) establishment.

c) Applying after legume nodulation may give better legume growth and nitrogen fixation.

Preliminary work in the glasshouse demonstrated that it was possible to improve legume establishment, both in terms of total dry matter production, and the legume content of the sward, when quite high rates of nitrogen were applied after nodulation had taken place. The field trial was replicated on three soil types: an acid brown earth, a dry peaty podsol, and a deep peat. The extremely dry summer of 1976 gave very poor seedling establishments on the brown earth and peaty podsol so the results obtained at these sites cannot be considered to be typical. Seedling establishment on the deep peat was good, the sward overwintered well, and grew vigorously throughout the 1977 season. Table 1 shows the clover germination counts one month after sowing the experiment on 8.7.76. The trial was carried out using a randomised block design with 3 times 5 nitrogen levels (including 0) arranged factorially into 13 treatments, replicated four times. The plots were 4 x 2 m with 2 m dividing paths. The whole trial area was limed (7.5 tonnes ha^{-1}) and fertilised with superphosphate (30 kg P ha^{-1}), ground mineral-P (30 kg P ha^{-1}), muriate of potash (60 kg K ha^{-1}), and a trace element mixture containing Co, Mo, Cu, B and Zn.

Table 1. Effect of five levels of application and three application times of fertiliser-N on clover germination (plants m^{-2})

Application time	Fertiliser-N level (kg ha^{-1}) 0	30	60	90	120	
40 days before sowing	402	542	494	329	472	nsd
Sowing time 8.7.76		349	392	426	409	nsd
75 days after sowing+		364	419	357	394	nsd
		*	nsd	nsd	nsd	

Each value is the mean of 20 determinations (25 x 25 cm quadrats) per treatment.

\+ This treatment was not imposed at the time these data were obtained

There were no significant treatment effects on germination at this stage of sward establishment except the early application of 30 units which just reaches 5% significance with respect to the other two sowing times. Table 2 shows the percentage ground cover of clover ten weeks after sowing and again there is no evidence of treatment effects.

Table 2. Effect of five levels of application and three application times of nitrogen fertiliser on clover ground cover (%)

Application time	Fertiliser-N level (kg ha^{-1})				
	0	30	60	90	120
40 days before sowing	39	27	28	22	26
Sowing time 8.7.76		27	34	35	35
75 days after sowing*		23	22	23	30

Each value is the mean of 40 determinations per treatment made using 25 x 25 cm quadrats divided into 2.5 x 2.5 cm squares. Each square was scored plus or minus clover.

* This treatment was not imposed at the time these data were obtained.

Later in the year the plots were harvested by clipping to 1 cm above ground level with hand shears (10 x 25 x 25 cm quadrats per plot) and the whole plot cut with an Allen autoscythe. At the same time (13.10.77) a turf 20 x 20 x 15 cm deep was cut from each plot and placed in an airtight box for a 24 h acetylene reduction assay. After the assay was completed, the root soil mass was dissected and the nodules examined and counted. The data obtained in these assessments have been presented in detail in a previous report so are summarised here. No significant effect of nitrogen application before sowing or at sowing was observable in either DM yield, nodule numbers, or nitrogen fixing capacity at any of the levels, excluding the control (0 kgN ha^{-1}) which was lower ($P<0.05$) in all measured parameters. The late application, however, had a marked effect on nodule numbers, particularly large and multilobed nodule numbers, and on acetylene reducing activity of the sample turves. These data are summarised in Table 3.

Table 3. Effect of five different levels of fertiliser-N applied to an establishing grass/clover sward after nodulation had taken place on acetylene reduction ($nM\ C_2H_4\ m^{-2}\ day^{-1}$), and nodule numbers (nodules m^{-2})

	Applied level of fertiliser-N (kg NH_4-N ha^{-1}) 0	30	60	90	120	
C_2H_2 reduction	1.1	2.1	1.4	0.9	0.7	$P<0.01$
Total nodules	7500	6625	5125	5750	2625	$P<0.05$
Large nodules	600	625	275	313	125	$P<0.01$
Multilobed nodules	175	250	125	100	75	$P<0.01$

The effects of increasing combined nitrogen supply are most marked in the largest multilobed nodules which, by inference, are those contributing most fixed nitrogen to the clover plant, since the correlation between C_2H_2 and multilobed nodules is quite striking.

DM production of indigenous species is not markedly affected by nitrogen fertiliser application.

Table 4. Effect of five levels and three application times of fertiliser N on DM production of ryegrass, clover and indigenous species (gDM m^{-2})

Applied level of fertiliser-N (kg ha^{-1})		Application time: 40 days before sowing	Sowing time	75 days after sowing
0	I	125		
	RG	10.1		
	WC	6.9		
30	I	153	149	133
	RG	6.7	6.6	17.1
	WC	7.5	6.6	5.3
60	I	154	115	134
	RG	6.6	8.7	19.2
	WC	5.2	6.0	6.5
90	I	151	127	153
	RG	7.9	13.3	17.9
	WC	7.6	7.7	10.8
120	I	140	123	143
	RG	14.8	16.1	44.5
	WC	6.7	14.6	7.0

LSD (5%) Indigenous spp. (I), 29; Ryegrass (RG), 4.2; White clover (WC), 3.1.

Clover production is not affected by nitrogen up to 120 kg ha^{-1} when applied before sowing, but is increased by 120 kg ha^{-1} applied with the seed, and by 30, 60 and 90 kg ha-1 applied after nodulation. No increase is apparent when 120 kg ha^{-1} is applied after nodulation, presumably because of intense competition from the ryegrass. Grass production is stimulated by 90 and 120 kg ha^{-1} applied with the seed, and by 30, 60, 90 and 120 kg ha^{-1} applied after nodulation. The response to nitrogen at the late application is, however, not linear, the response at 120 kg ha^{-1} being disproportionately large, production being increased four-fold as opposed to almost doubled at 30, 60, and 90 kg ha^{-1}.

Harvests were taken from the plots during the growing season of 1977 but the results have not yet been fully analysed. Table 5 shows the contribution of indigenous species, ryegrass and white clover to the total DM yield of the sward in early summer 1977.

Table 5. Effect of 5 levels of application and 3 application times of fertiliser nitrogen on the proportion of indigenous species, ryegrass and white clover in early summer 1977 (% total DM)

Applied level of fertiliser-N (kg ha^{-1})		Application time: 40 days before sowing	Sowing time	75 days after sowing
0	I	30		
	RG	12		
	WC	58		
30	I	33	45	38
	RG	9	9	15
	WC	58	46	47
60	I	44	26	32
	RG	9	12	13
	WC	47	62	55
90	I	37	34	31
	RG	15	13	23
	WC	48	53	46
120	I	33	28	37
	RG	12	11	28
	WC	55	61	35

Ryegrass 95%, 11.0
99%, 15.4 Clover 95%, 24 Indigenous n.s.d.

Acetylene reduction assays were performed on 20 x 20 x 15 cm deep cores taken from the plots in spring 1977. One core was taken from each plot on three consecutive days; the rate of ethylene production over a 24 h period was measured on each core. No treatment effects were detectable in the measured rates of acetylene reduction at this sampling. In agreement with previous experience (Haystead and Lowe, 1977) and that of other workers (Goh et al, 1978), we found the acetylene reduction assay to be a poor estimator of white clover nitrogen fixation in an established sward because of the large differences between replicated treatments and, in this case, between consecutive assay days. This variation is undoubtedly due to the uneven distribution of clover in the sward.

The analysis of material taken from the experiment in 1977 continues and further measurements will be taken in 1978.

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GOH, K.M., EDMEADES, D.C. and ROBINSON, B.W. (1978). Field measurements of symbiotic nitrogen fixation in an established pasture using acetylene reduction and a ^{15}N method. Soil Biol. Biochem. 10 (1), 13-20.

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2. Nitrogen economy of white clover plants

C. Marriott

The effect of defoliation on the nitrogen economy of white clover plants is currently under investigation. Nitrogen uptake and assimilation depends on a continued supply of photosynthates, and this supply is severely reduced by defoliation of mature leaves, the major photosynthetic organs. A preliminary experiment was designed to:-

1) determine the capacity of plants to supply already assimilated nitrogen to new leaves in defoliated and non-defoliated control plants;

2) monitor nitrogen accretion in plant organs following defoliation and compare this with control plants, and

3) investigate the differences when nitrogen in the rooting medium is supplied as ammonium or nitrate nitrogen. Ammonium ions can be assimilated directly into nitrogenous compounds whereas nitrate ions must first be reduced to ammonium, and there is evidence that ammonium ions are less inhibitory to nitrogen fixation (Gibson, 1976).

S184 white clover plants were grown from stolon cuttings in sand in 10 cm pots in the glasshouse. The pots were inoculated with an effective strain of Rhizobium (HFRO strain 35) to ensure nodulation, watered as required with $\frac{1}{4}$ strength Dart and Pate's nutrient solution (1959), and given a weekly feed of 0.5 mg ^{15}N per pot, supplied in solution as either $(^{15}NH_4)_2SO_4$ or $Na^{15}NO_3$ (10 mg $^{15}N l^{-1}$). This was the sole supply of mineral nitrogen and it was estimated that this would supply about one fifth of the plants' nitrogen, thus labelling plant nitrogen but not suppressing nitrogen fixation. After a growth period of 12 weeks half the plants in each nitrogen regime were defoliated, by removing all fully expanded leaves. The labelled nitrogen supply was replaced with a weekly feed of unlabelled nitrogen for all plants. Control and defoliated plants were harvested at defoliation and 3, 7, 10, 14 and 21 days later, and dissected into component parts. These will be analysed for total nitrogen and ^{15}N content.

Data so far indicate that defoliation has a depressant effect on nodule numbers (just failing to reach significance in ammonium nitrogen regime), nodule dry weight (in ammonium nitrogen regime) and root dry weight (Tables 1-3). Root growth in the presence of ammonium nitrogen appears to stop completely following defoliation.

Table 1. Nodule numbers/plant

	Days after defoliation					
	0	3	7	10	14	21
CONTROL						
NH_4	198	238	502	464	508	577
NO_3	272	401	477	505	565	664
DEFOLIATED						
NH_4	-	236	379	243	345	489
NO_3	-	378	443	438	449	596
LSD 5%	220	106	150	224	164	304

Table 2. Dry weight of nodules/plant (mg)

	Days after defoliation					
	0	3	7	10	14	21
CONTROL						
NH_4	30.1	43.7	55.5	55.8	54.4	88.4
NO_3	44.4	47.6	48.7	59.4	79.1	79.7
DEFOLIATED						
NH_4	-	45.8	40.1	41.0	46.9	56.9
NO_3	-	47.1	48.4	49.2	71.1	89.7
LSD 5%	40.8	15.5	13.5	28.4	38.6	37.0

Table 3. Root dry weight (mg)

	Days after defoliation					
	0	3	7	10	14	21
CONTROL						
NH_4	233.3	357.3	356.8	316.3	439.3	515.3
NO_3	347.7	312.4	361.1	350.5	544.5	647.7
DEFOLIATED						
NH_4	-	399.5	279.4	272.4	316.9	401.2
NO_3	-	297.4	295.4	319.6	477.0	549.1
LSD 5%	93.3	41.0	137.7	199.8	164.7	119.7

Increase in total plant nitrogen in the post-defoliation period is due to either fixation of atmospheric nitrogen or uptake of nitrogen from the rooting medium. These would not be distinguished between in the above experiment. A second experiment is proposed using labelled nitrogen supplied during the post-defoliation period only, to differentiate between fixed and combined nitrogen.

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3. Fixation and transfer of nitrogen in white clover - ryegrass swards and lotus - ryegrass swards on deep peat.

A. Haystead and C. Marriott

Previous work has demonstrated that in grazed field situations quite severe defoliation of clover-grass swards has a limited effect on nitrogen fixation and root and nodule breakdown in the early part of the annual growth cycle of the pasture. This finding is in marked contrast to the data obtained in glasshouse and cut field-plot experiments reported by a number of authors (Muostafa et al, 1969; Chu and Robertson, 1974; Halliday and Pate, 1976; Haystead and Marriott, 1978). A series of experiments has been conducted during 1977 to determine seasonal profiles of N_2-fixation and underground transfer of legume nitrogen in repeatedly defoliated (cut) clover-grass and lotus-grass swards. The two sward types, both in their third year of establishment, were harvested by clipping during 1977. Harvest times were determined by the regrowth rate of the swards giving three cuts on both the clover experiment and the lotus plots. At each harvest the nitrogen fixing activity of the legume component was assessed (C_2H_2-reduction) before cutting, one day after cutting, and after approximately 10 days regrowth. In the interharvest periods the ^{15}N technique of Haystead and Lowe (1977) was used to determine N_2-fixation and underground nitrogen transfer. Roots and soil were sampled at each harvest and about ten days after harvest to determine seasonal and defoliation induced changes in soil extractable ammonia and nitrate, rhizosphere biomass, and nodulated root morphology.

Table 1 shows the effect of defoliation on nitrogen fixing activity in the two sward types at each harvest.

Table 1. N_2-fixing activity (C_2H_2-reduction) on clover and lotus containing swards under a system of periodic defoliation ($nMC_2H_4m^{-1}$ days^{-1})

	White Clover/Ryegrass		Lotus/Ryegrass
Harvest 1:	8.6.77	Harvest 1:	15.6.77
Before cut	19.0±.91 (n=32)		21.3±1.34 (n=62)
After cut (1 day)	4.7±.24 (n=32)		2.9± .17 (n=64)
(10 days)	2.4±.28 (n=32)		1.3± .14 (n=30)
Harvest 2:	21.7.77	Harvest 2:	11.8.77
Before cut	4.3±.25 (n=32)		6.5±.63 (n=30)
After cut (1 day)	2.8±.15 (n=32)		1.4±.27 (n=32)
(10 days)	7.9±.40 (n=32)		1.2±.24 (n=32)
Harvest 3:	29.9.77	Harvest 3:	3.10.77
Before cut	2.9±.17 (n=32)		No significant fixation
After cut (1 day)	.35±.04 (n=32)		
(10 days)	.73±.09 (n=16)		

Table 2 shows the dry matter yields of legume and grass determined by cutting the 2 m x 1 m microplots.

Table 2. DM yields of legume and grass during the two regrowth periods (Harvest 1 to 2 and Harvest 2 to 3. $gDM.m^{-2}$)

	White Clover/Ryegrass	Lotus/Ryegrass
Harvest 1-2:	8.6.77 - 21.7.77	15.6.77 - 11.8.77
Legume	33.5 ± 5.3	81.4 ± 9.2
Grass	52.5 ± 2.6	120.4 ± 8.6
Total	86.0 ± 6.1	201.8 ±12.5
% legume	38.9	40.3
Harvest 2-3:	21.7.77 - 29.9.77	11.8.77 - 3.10.77
Legume	59.1 ± 3.5	18.1 ± 2.2
Grass	116.3 ± 12.9	84.9 ± 5.6
Total	175.4 ± 14.1	103.0 ± 6.0
% legume	33.7	17.6
	(n = 16)	(n = 15)

Total nitrogen determinations of harvested herbage and roots, isotope ratio determinations, soil extractable nitrogen analyses, and soil microflora biomass determinations are currently in hand. The microplot ^{15}N method has been employed to determine fixation and transfer of fixed nitrogen over the winter and early spring regrowth period (October 1977 to April 1978). The data available at the present time demonstrate a marked depression of nitrogen fixing activity in response to defoliation superimposed on a characteristic seasonal pattern (Newbould and Haystead, 1978) of nitrogen fixation in both white clover and lotus swards. The effect of cutting was more marked in lotus swards both at individual harvests and as the season progressed. It was not possible to determine quantitative differences in nodule numbers at each harvest and, surprisingly, there was no evidence of nodule breakdown even at the autumn sampling (c.f. Young, 1958). These studies continue.

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4. Photosynthesis, respiration and nitrogen fixation in white clover (04008/04006)

A. Haystead, J. King, W.I.C. Lamb and E. Smith

It is frequently difficult to explain data obtained in field trials and glasshouse experiments because the response of nodulated white clover plants to changes in environmental conditions is not adequately described in the literature. An example of such a problem is the apparent absence of response to inoculation observed in a number of field trials carried out at HFRO. In situations where it can be demonstrated that indigenous rhizobia are either ineffective or absent, large responses to inoculation are obtained. In situations where indigenous populations of rhizobia are moderately effective no increases in clover production are obtained when seed is inoculated with highly effective rhizobia, even when it can be shown that the inoculum strains are present in a large proportion of the nodules formed. In the glasshouse using the same soil, freshly dug and stored under conditions designed to maintain rhizobium viability, increases in DM production rates of up to 30% can be obtained. A possible explanation for these contradictory results is that the limitation to clover growth in hill situations is not the rate of supply of symbiotically fixed nitrogen but the rate of photosynthate production in the shoots. Hardy and Havelka (1976) have demonstrated that under agricultural conditions the production of soybean is limited by the plants' ability to fix CO_2 not N_2. To predict the response of white clover to a given set of environmental conditions and to determine how establishment and production might be improved requires a detailed knowledge of the interrelationships between primary assimilatory and dissimilatory processes in the nodulated clover plant under different growth conditions. An apparatus has been designed in which clonal plants of white clover can be grown under sterile conditions and inoculated with specific rhizobium strains, and in which canopy photosynthesis and respiration can be measured simultaneously with acetylene reduction and nodulated root respiration.

Fig. 1 is a diagrammatic representation of the apparatus.

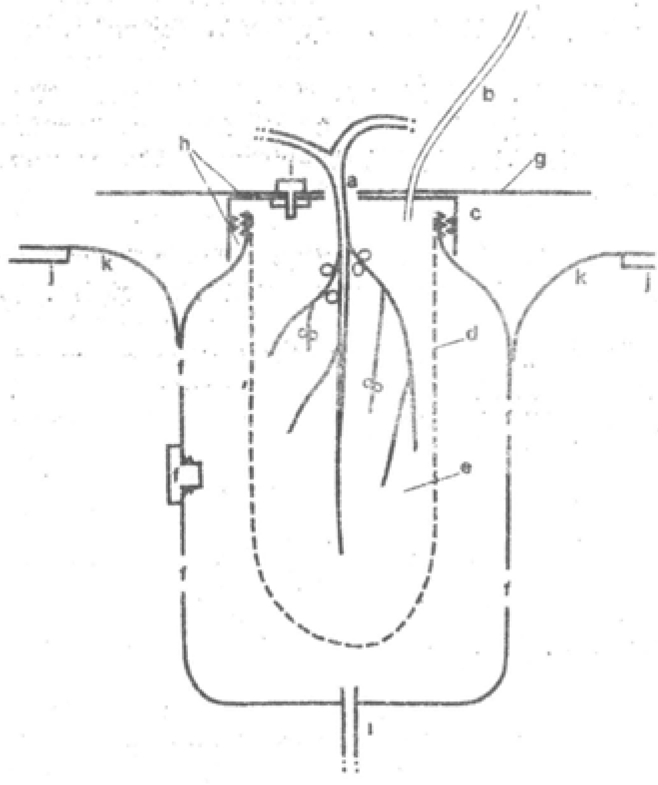

Fig. 1. Diagrammatic representation of the container in which plants are grown and in which root metabolism measurements are made.
Key to Fig. 1.
a) Silastic seal; b) Nutrient solution supply; c) Plastic screw top; d) Nylon mesh sock; e) Vermiculite; f) Vent hole with suba-seal closure; g) Aluminium plate; h) Silicone rubber seal; i) Bolt; j) Cuvette base; k) Neoprene rubber seal for cuvette system; l) Drain.

A preliminary series of experiments has been performed to determine the effect of changes in the rate of photosynthate supply on symbiotic nitrogen fixation and nodulated root respiration in effectively nodulated clover plants. Figure 2 shows the time course of nodulated root respiration and acetylene reduction in three sterile plants of white clover.

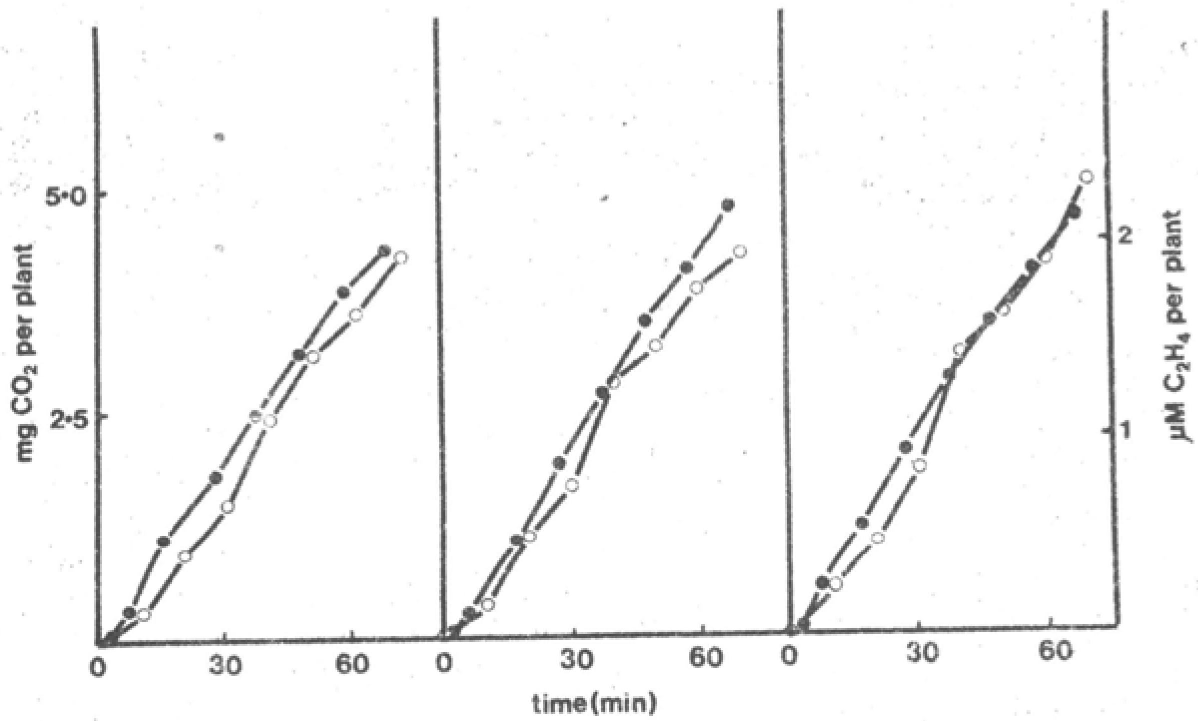

Fig. 2. Rates of nodulated root respiration (O —— O) and acetylene reduction (● —— ●) by three individual white clover plants. In each case linear regression accounts for over 99% of the variance.

Table 1 demonstrates the relationship between canopy net photosynthesis, dark canopy respiration, nodulated root respiration, and acetylene reduction in three plants of varying root/shoot ratio.

Table 1. Photosynthesis, shoot and root respiration and acetylene reduction of individual white clover plants

	Plant Number		
	1	2	3
Net canopy photosynthesis (mg CO_2 hour^{-1} per plant)	15.40	16.65	13.40
Dark canopy respiration (mg CO_2 hour^{-1} per plant)	6.16	7.27	4.14
Nodulated root respiration (mg CO_2 hour^{-1} per plant)	4.50	4.79	5.07
Acetylene reduction (µM C_2H_4 hour^{-1} per plant)	1.92	2.15	2.02
Canopy dry weight (g)	12.07	10.54	7.69
Root dry weight (g)	1.836	1.430	1.364

Figure 3 shows the variation in the ratio between nitrogenase activity (C_2H_2-reduction) and nodulated root respiration observed when plants are assayed on consecutive days.

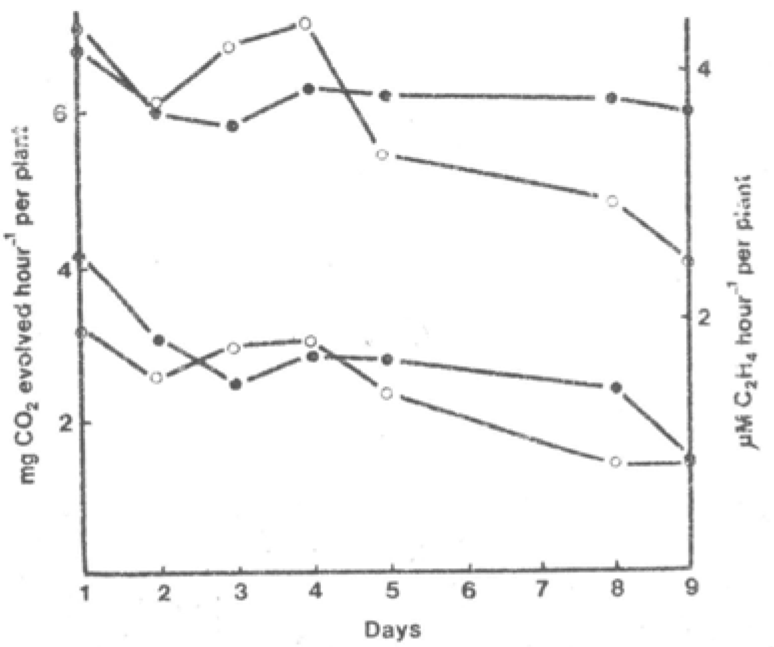

Fig. 3. Root respiration (0 —— 0) and acetylene reduction (● —— ●) by two white clover plants measured over an 8 day period.

A variation of this type has been reported by Mederski and Streeter (1977) in pea plants assayed continuously during the light period of a 12 h/12 h light/dark cycle. These authors attribute such variation to an autonomous regulation of nitrogen fixing activity by the symbiosis. The plants used in this experiment had reached a limiting leaf area index so do not show an overall increase in activity during the 9 days of the experiment. The significant decrease in acetylene reducing activity observed over the last four days of the experiment is probably induced by prolonged exposure to acetylene and has been observed by Mederski and Streeter (1977) and by David and Fay (1977).

Figure 4 shows the different response of nodulated root respiration and acetylene reduction to prolonged darkness.

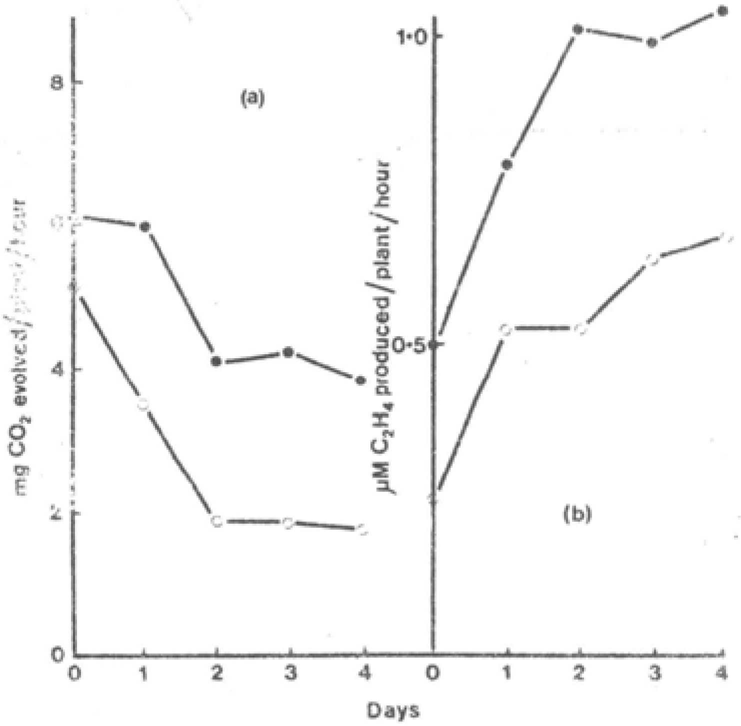

Fig. 4. Effect of irradiance changes on root respiration (O —— O) and acetylene reduction (● —— ●); (a) high to low light intensity, (b) low to high light intensity. Each value is the mean of 3 plants.

At the end of the normal 12 h dark period root respiration falls quite rapidly whilst C_2H_2-reduction continues at an unimpaired rate. This observation is probably a reflection of the high sink strength of the symbiotic system and may account for the absence of an irradiance determined diurnal rhythm in nitrogenase activity observed by a number of authors (Masterson and Murphy, 1976; Haystead and Marriott, 1978) in stolonating white clover.

Figure 5 shows the response of nodulated root respiration and nitrogenase activity to changes in irradiance.

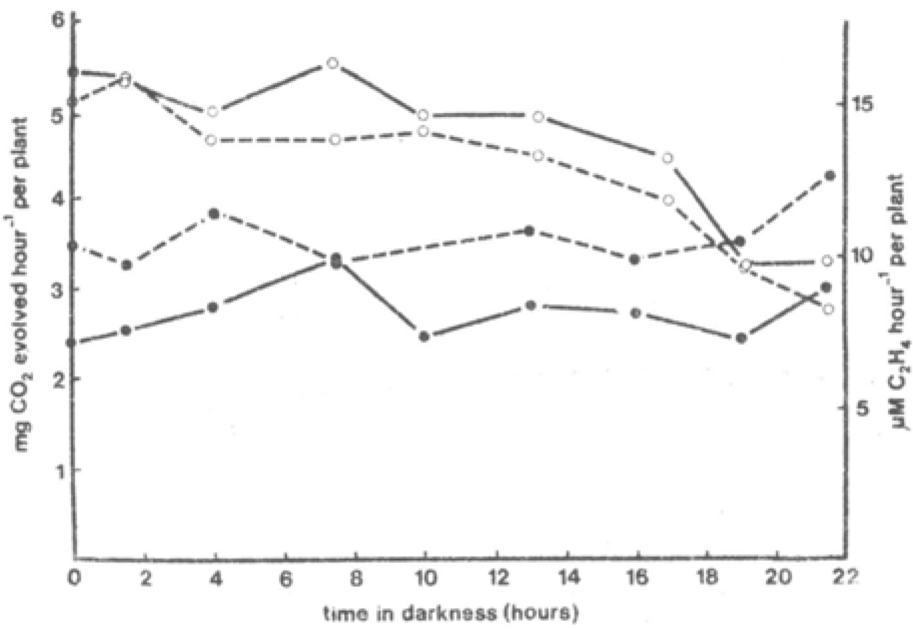

Fig. 5. Effect of darkness on root respiration (O) and acetylene reduction (●) by two white clover plants (——, - - - -) over a 22 hour period.

In the high to low light treatment (a) the plants were equilibrated at 160 Wm^2 and transferred to 40 Wm^2. The (b) treatment plants were equilibrated to 40 Wm^2 and transferred to 160 Wm^2. Again, the results demonstrate a more rapid response in root respiration than nitrogenase activity to a reduction of photosynthate production. An increase in the rate of supply to the roots and nodules produces an equally rapid response in both processes.

In addition to the long term depressant effect of acetylene on nitrogenase activity, it has been demonstrated that exposure of nodulated clover roots to acetylene reduced the steady state respiration extremely rapidly. This effect (shown in Figure 6) can be attributed to the reduction in energy requirement of the nodules in the presence of acetylene since the product of the nitrogenase reaction, ethylene, is not assimilated by the plant. The reduction in respiration can tentatively be equated with the energy requirement of ammonia assimilation and export in the nodule.

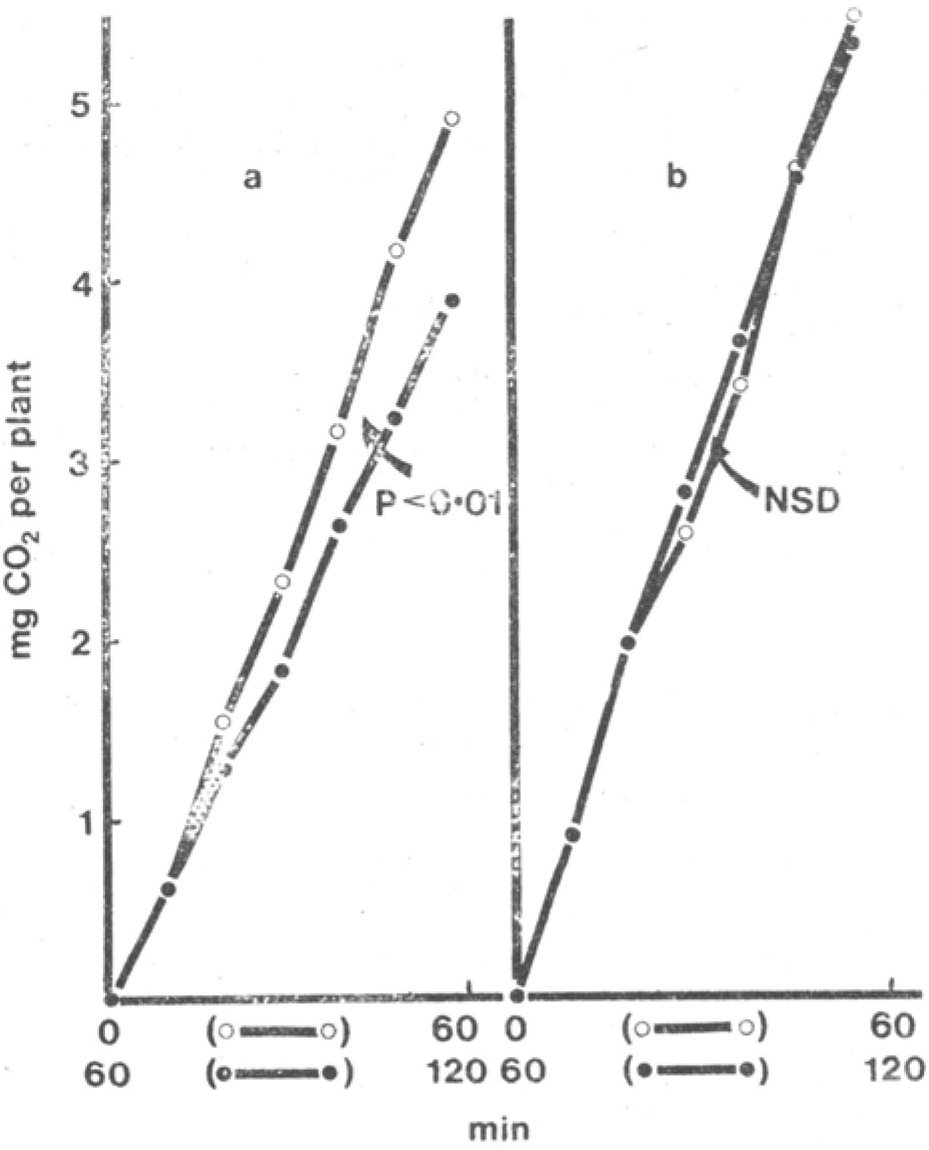

Fig. 6. Effect of acetylene on nodulated root respiration. 0–60 min. (0 0) and 60–120 min. (0 0). Acetylene added at 60 min. (a), no acetylene added (b).

This project is being continued vigorously; experiments currently in hand are designed to determine:

1) The role of the stolons as carbohydrate storage organs and the dynamics of reserve 'pool' filling in conditions of changing irradiance.

2. The partitioning of energy supply in N_2 fixing and NO_3 reducing clover plants during the 24 hour light/dark cycle.

3. Energy partitioning in limiting light of clover plants nodulated with rhizobia of high and moderate effectiveness.

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5. Transfer of symbiotically fixed nitrogen from white clover to a companion grass species in a fertilised hill soil

A. Haystead and C. Marriott

Previous experimentation (Haystead and Marriott, 1978a) has shown that under conditions where clover nodule senescence occurs there can be a considerable delay before isotopically labelled clover nitrogen can be detected in a companion grass species. A possible explanation for this phenomenon is that a rapid biological immobilisation of the nitrogen released from senescing nodules occurs (Haystead and Marriott, 1978b).

Figures 1 and 2 show the effect of defoliation on the rhizosphere microflora of white clover. Under identical growth and defoliation conditions the potential release of nitrogen to the soil per cut is around 13 mg of N per pot. It can be calculated that the nitrogen immobilised into the rhizosphere bacteria is equivalent to just under 20% of the released nitrogen in the first five days after cutting. The estimate of immobilised nitrogen is based on measurements of rhizosphere bacteria and no account is taken of either bulk soil mirco-organisms or of non-bacterial components of the rhizosphere microflora. For this reason the 20% immobilisation can be regarded as a minimum. The rate of nitrogen transfer from the microflora nitrogen pool into other soil fractions and, ultimately, into the companion grass is a function of the rate at which the bacterial protein is mineralised. Two experiments have been performed to determine the rate of bacterial nitrogen mineralisation and subsequent uptake by perennial ryegrass seedlings. In the first experiment, consecutive sowings of pre-germinated ryegrass seedlings were made into soil amended with ^{15}N labelled cells of Pseudomonas fluorescens, an ubiquitous soil micro-organism isolated from an agricultural soil.

Each set of plants was harvested seven days after sowing and analysed for total nitrogen yield and ^{15}N content (Figure 3).

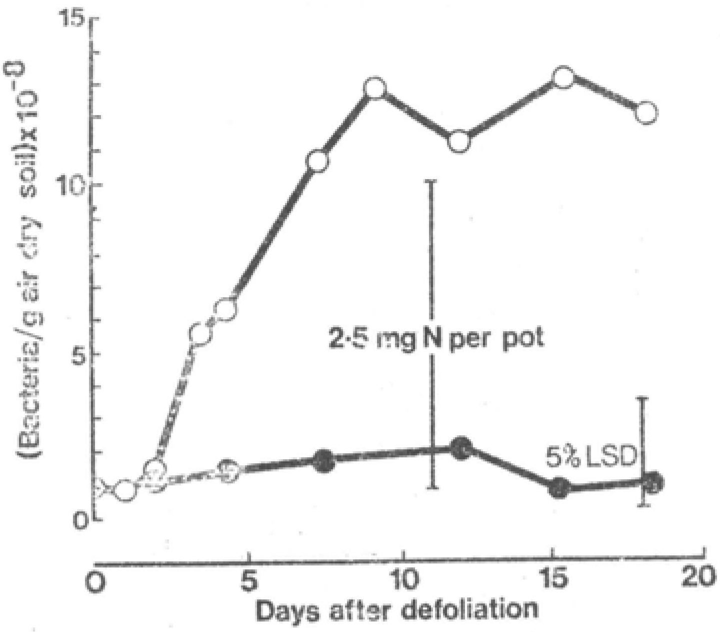

Fig. 1. Effect of defoliation on numbers of bacteria in rhizosphere. Soil of cut (O) and uncut (●) clover plants.
Bar indicates equivalent bacterial nitrogen increase per pot or per 80-100 g air dry peat. Each point represents the mean of 200 fields of view counted.

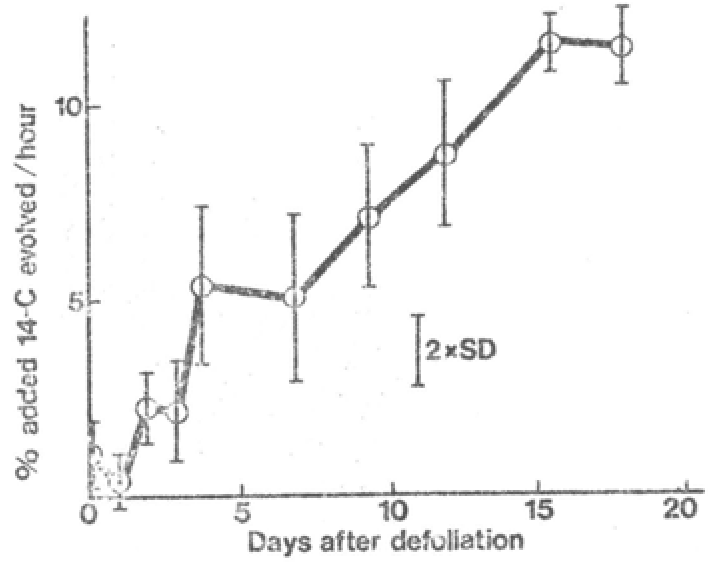

Fig. 2. Effect of defoliation on clover rhizosphere soil respiration.

The second experiment differed in that labelled bacteria and germinated ryegrass seedlings were simultaneously added to the soil and the plants were allowed to grow for 17 days, 25 plants being harvested and analysed for total nitrogen yield and ^{15}N content at 4, 7, 11, 14 and 17 days (Figure 4).

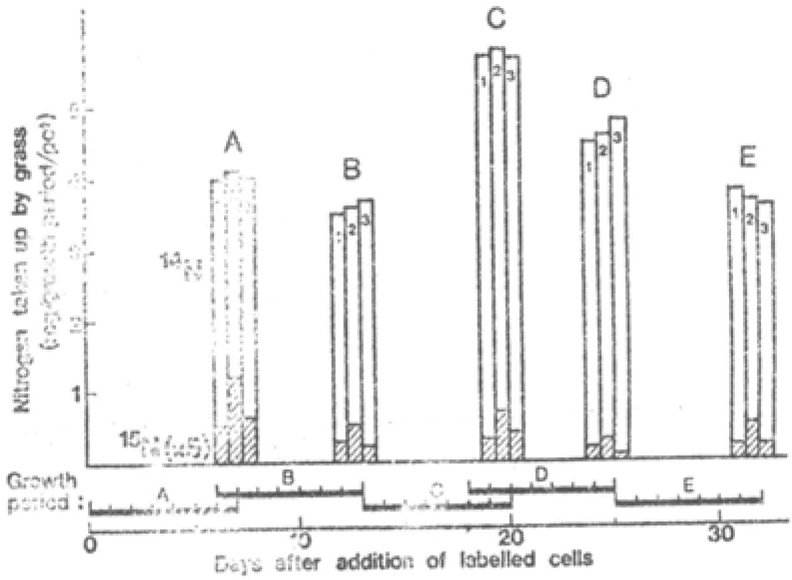

Fig. 3. Uptake of nitrogen by ryegrass seedlings sown successionally into three fertilised hill soils amended with ^{15}N-labelled bacterial nitrogen (36 Atom %-^{15}N). Brown earth (Sourhope), 1; Peat (Lephinmore), 2; Brown earth (House o' Muir), 3.

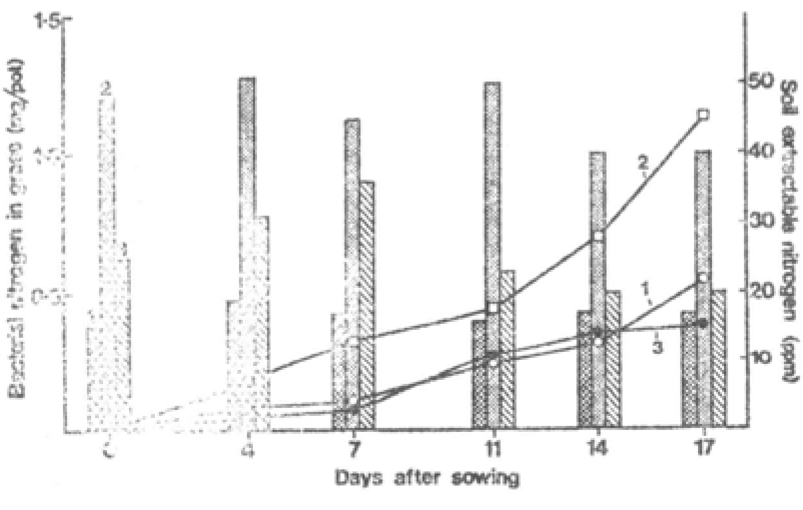

Fig. 4. Accumulated uptake of mineralised bacterial nitrogen by ryegrass seedlings in three hill soils. Brown earth (Sourhope), 1; Peat (Lephinmore), 2; Brown earth (House o' Muir), 3.

The histograms show the extractable ammonium nitrogen pool at each harvest.

It was thought that in the second experiment the more extensive exploitation of the soil by the grass roots may affect the rate or the pattern of bacterial nitrogen mineralisation. The data from both experiments demonstrate a rapid mobilisation of the bacterial nitrogen and consequent uptake by the grass roots, label being detectable in the grass after 4 days in experiment 2. Bacterial nitrogen is transferred at a different rate in the three soils examined in a way which is unrelated to the size of the extractable nitrogen pool into which the nitrogen is mineralised, the peat soil apparently providing a more favourable medium than the two brown earths. The conclusion one must draw from these results is that the observed delay in the transfer of fixed nitrogen from clover to grass is not simply a function of biological immobilisation; and that, whilst the microflora is certainly a soil fraction through which a substantial portion of nitrogen released in the breakdown of roots and nodules must pass, the transfer process is quite complex involving perhaps a number of interacting processes in the soil. Work is continuing to further describe the overall mechanism of legume-grass nitrogen transfer in hill soil.

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6. Heavy isotope analysis using the AEI MS10S mass spectrometer

A. Haystead

A stainless steel gas handling system has been designed and built for the MS10S mass spectrometer. The apparatus has been constructed to withstand the rigours of routine use by non-expert personnel in the Organisation. This need has arisen because the instrument is to be used by both the nitrogen fixation group (04008) and the ruminant nutritionists (02005). The system is complete and working to specification. Combined with the automated output analyser designed and manufactured at HFRO the system provides an efficient procedure capable of analysing nitrogen samples down to 10 μg at a rate of 25 samples per hour.

WHITE CLOVER SYMBIOSIS

04009: Microbiological requirements of white clover growing in hill soils

1. The response of white clover to inoculation with effective strains of Rhizobium trifolii in a range of soils and environments - collaborative series of field trials

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A series of experiments which began in 1975 to investigate the response of white clover to inoculation with Rhizobium have been carried out in collaboration with the three Scottish Colleges of Agriculture, the Microbiological Department of the Edinburgh School of Agriculture, the Welsh Plant Breeding Station, the Agricultural Development and Advisory Service and the ARC Unit of Statistics.

In the first phase, started in 1975, there were four treatments comparing two levels (0 and 30 kg/ha) of nitrogen fertiliser with and without inoculation. Three strains of Rhizobium isolated by Dr. Holding at the Edinburgh School of Agriculture were used and the seed was inoculated using the peat inoculum technique. Mutants of the strains with the ability to grow and form colonies on agar containing antibiotic, were selected so that each strain forming a nodule could be identified and differentiated from indigenous organisms. Significant responses in dry matter yield were observed only on the deep peat sites, and then only in the establishment year and at the first sampling in the second season. Although only a small amount of nitrogen fertiliser was added, this either caused poor clover establishment in the sowing year or decreased the contribution of clover to total yield in the second and third years after sowing at several sites. The cause of these long lasting effects of small levels of fertiliser nitrogen is not fully understood and other work by A. Haystead and C. Marriott which is in progress may help understanding.

In the following year, 1976, a further series of trials were started, mainly on brown earth and dry peaty podzol soils in the absence of starter nitrogen fertiliser, in which two varieties of white clover (S184 and New Zealand Grasslands Huia) were compared with and without inoculant. Although the microbiological data indicated that effective strains of Rhizobium were established on white clover plants at all sites, there was no significant agronomic response.

While most of the trials sown in 1975 and 1976 were continued throughout 1977, a further series of three trials were sown. These were planned to follow up the use of a technique which involved spraying inoculant on to already germinated white clover seedlings. This method had been successful on two mineral soils in 1976 (A. Rangeley et al, 1976) and to appraise a new commercial peat inoculant recently introduced for sale in this country (Nitragin). Two of the experiments were conducted by HFRO at Baddinsgill, West Linton and the other was carried out by NSCA at Riveach, Glenrinnes, Banffshire. The following four treatments were compared:-

		KEY
1.	Uninoculated seed	O
2.	Seed inoculated with peat inoculum and Edinburgh strains of rhizobia as in the earlier trials	EP
3.	Seed inoculated with peat inoculum and strains provided by the Nitragin Company	NP
4.	Untreated seed which was allowed to germinate before spraying on the inoculum with Edinburgh strains of rhizobia in pure water	ES

The microbiological data (Table 1) indicates that, on the two peat sites, a higher percentage of the nodules contained mutants after spraying inoculum than any other treatment. However, on the more mineral peaty podzol site at Baddinsgill very few mutant strains were established and the percentage of nodulated plants was the lowest seen in any of the trials. There were no significant agronomic differences between the inoculated treatments, although at Riveach all three inoculation treatments gave significantly higher percentages of clover cover than the control plots.

Table 1. Comparison of four methods of inoculation at three sites

	Treatment***	BADDINSGILL Peaty Podzol	BADDINSGILL Peat	RIVEACH Peat
Germination ($Plts/m^2$) 3-4 wks after sowing	0	128	227	540
	EP	125	192	574
	NP	129	214	681
	ES	128	238	572
Significant effects		NS	NS	* (LSD = 70)
Ground cover %	0	32	144	45
	EP	21	147	70
	NP	27	152	72
	ES	32	132	69
Significant effects		NS	NS	**(LSD = 8)
% Nodulated Plants	0	18	50	80
	EP	21	76	92
	NP	25	61	100
	ES	41	74	100
Significant effects		NS	NS	* (LSD = 10)
% Mutants in Isolated Rhizobia	0	13	11	0
	EP	7	31	2
	NP	0	7	1
	ES	2	89	55
Significant effects		NS	NS	**(LSD = 20)

*** See text for description of treatments

It was not possible to take samples for dry matter yield at all the sites during 1977 and it will be interesting to see if the significant difference in ground cover between inoculated and uninoculated treatments at Riveach persist over winter and are reflected in dry matter yield differences when samples can be taken in 1978.

Most of the trials in this series have now been discontinued, although the fences are being maintained around some so that the persistence of the introduced strains of *Rhizobium* can be followed for a further one or two years. The results were described to a joint AAB/BGS meeting at Brighton in 1977 and are presently being prepared for publication.

Reference:

RANGELEY, Anne, NEWBOULD, P., HOLDING, A.J. (ESCA) and ROBERTSON, N.G. (1976). Preliminary field test to compare methods for inoculation of white clover. HFRO Ann. Rept. (HFRO 217), 103-105.

2. Studies on the specificity of symbiosis between strains of *Rhizobium trifolii* and cultivars of *Trifolium repens* growing in hill soils

D.M. Vernon and P. Newbould

Earlier work has enabled a small number of highly effective *Rhizobium* strains to be selected from about 60 strains collected from white clover plants growing at altitude on the hills of the United Kingdom and Europe. Since the aim is to find strains that are effective at low temperature, so enabling symbiotic nitrogen fixation to start early in spring, the performance of some of the selected strains was compared at two temperatures (7 and 15°C) both alone and in competition with indigenous strains.

Effect of low temperature on symbiosis

Three strains (31, 35 and 42) which performed well at 15°C in the screening tests described in earlier reports were compared with a strain (61) recently provided from New Zealand; the latter strain originated from 8000 feet high in the Swiss Alps. A set of plants without inoculation was also included. All the plants were grown in controlled environment rooms with 100 W/m^{-2} of photosynthetically active radiation with a 16 hour day; temperature was not varied between day and night periods. To investigate the effect of low temperature on the different stages of forming an effective symbiosis the following experimental design was used. White clover plants (NZ Grasslands Huia) were grown from sterilised seeds in Gibson tubes at 15°C with 0.6 mg/plant of nitrogen as NH_4NO_3 until the first trifoliate leaf was fully expanded. The plants were then divided into four groups each of 60 plants with 12 plants for each inoculation treatment and the following conditions were applied:-

Plants in Group I were inoculated and kept at 15°C, those in Group II were inoculated and kept at 15°C until 3 days after the nodules of individual plants had turned red (days 19-26 approx.) when they were transferred to 7°C, those in Group III were inoculated and kept at 15°C until infection had occurred and on day 6 all the plants were transferred to 7°C, plants in Group IV were transferred immediately into a growth chamber at 7°C and inoculated.

This arrangement permits the effect of low temperature on infection, nodulation and fixation (Group IV), on nodulation and fixation (Group II) and on fixation (Group IV) to be investigated and determined separately. The experiment was concluded after 42 days by which time some of the plants inoculated with strains 35, 42 or 61 at 7°C had no red nodules. The group of uninoculated plants was given additional nitrogen (1 mg/plant) on the 24th day making a total of 1.6 mg/plant over the whole growth period.

The dates when the first nodule appeared and when nodules turned red owing to leghaemoglobin production, in addition to a determination of the total (shoot and root) dry weight of plants and their content of nitrogen after 42 days growth, were recorded. (Table 1).

Table 1. The effect of strain of Rhizobium and varying periods of low temperature (7 rather than 15°C) on nodulation, fixation, growth and nitrogen content of white clover (var. NZ G Huia) in Gibson tubes

STRAIN	Group I DAYS: 1-42 at 15°C	Group II 1-22* at 15°C 23*-42 at 7°C	Group III 1-6 at 15°C 7-42 at 7°C	Group IV 1-42 at 7°C
DAYS TO NODULATION (Inoculation = Day 0)				
31	8.2	8.2	8.0	21.2
35	12.6	12.6	18.1	28.4
42	16.3	16.3	15.5	24.4
61	13.8	13.8	16.5	27.2
LSD (P = 0.05)	3.8	3.8	6.9	5.8
DAYS TO APPEARANCE OF LEGHAEMOGLOBIN (Inoculation = Day 0)				
31	16.0	16.0	20.4	36.1
35	17.8	17.8	26.5	42.0
42	23.4	23.4	27.7	41.4
61	18.6	18.6	28.0	38.9
LSD (P = 0.05)	4.3	4.3	7.1	3.2
TOTAL DRY WEIGHT (mg)				
31	191.0	44.1	33.7	33.4
35	171.7	41.1	30.2	29.6
42	86.9	42.4	30.9	30.6
61	371.8	48.2	39.0	27.9
None (+N)	106.4	52.3	51.2	45.4
LSD (P = 0.05)	114.0	8.9	6.3	5.3
NITROGEN CONTENT (%)				
31	2.17	2.52	2.42	1.81
35	2.26	2.48	1.98	1.60
42	1.88	2.05	1.86	1.66
61	2.60	2.60	2.15	1.91
None (+N)	1.24	2.54	2.54	3.02
LSD (P = 0.05)	0.48	0.59	0.47	0.33
NITROGEN YIELD (mg)				
31	5.06	1.10	0.84	0.59
35	4.46	1.07	0.58	0.47
42	1.73	0.90	0.57	0.50
61	10.65	1.26	0.84	0.53
None (+N)	1.30	1.31	1.27	1.31
LSD (P = 0.05)	3.59	0.40	0.22	0.09

Strain 31 took just over 8 days to form a nodule at 15°C compared with 21 days at 7°C; by contrast the remaining strains took an average of about 14 days at 15°C and 27 days at 7°C. At 15°C a further 5-8 days were needed for the nodules to become red; strain 61 taking the least time (5 days) and strain 31 the longest (8 days).

The dry weight of the inoculated plants grown at 15°C (Group I) was greater than for uninoculated plants given mineral nitrogen, strain 61 producing the largest and strain 42 the smallest plants. All plants grown at 7°C for any length of time were smaller than those at 15°C; the uninoculated plants were significantly larger than those which were inoculated, and there was little difference between strains except for Group III plants, where those inoculated with strain 61 produced significantly more dry weight than those with strains 35 and 42.

A period of time at 7°C reduced the nitrogen yield of the inoculated plants but that of the N treated plants was unaffected. However N treated plants at 7°C were small plants with a high concentration of nitrogen. It appears that uptake of mineral nitrogen by the uninoculated plants was able to proceed at 7°C, and other factors must have limited growth. By contrast, fixation of nitrogen by all the inoculated plants irrespective of strain of Rhizobium was depressed by low temperature, approximately in proportion to the length of time of exposure; plants treated in this way contained a low percentage of nitrogen and were small suggesting that lack of nitrogen may have been the limiting factor to growth.

At the conclusion of the experiment three replicate whole plants from each treatment were incubated with acetylene gas for 90 minutes at 7 or 15°C and reduction of C_2H_2 to C_2H_4 was measured as an estimate of nitrogenase activity. Statistical analysis is still in progress but the preliminary results suggest that the activity of the enzyme was greater at 15 than 7°C and that there was little difference due to rhizobium strain or to the temperature of growth of the plants.

Effect of low temperature on competition between strains

a) In solution culture (Gibson tubes)

Two experiments were carried out. In both, white clover plants were growan at 15°C with 0.6 mgN/plant until the first trifoliate leaf was fully expanded. The following strain combinations were used in 12-fold replication at both 7 and 15°C:-

Treatment	Experiment 1	Experiment 2
1	P3/4	31
2	1DL/1	P3/4
3	FA6/4	FA6/4
4	P3/4 + 1DL/1	31 + P3/4
5	P3/4 + FA6/4	31 + FA6/4
6	1DL/1 + FA6/4	31 + P3/4 + FA6/4

Equal numbers of cells were supplied to each plant. Strains P3/4, 1DL/1 and FA6/4 were provided by Dr. A.J. Holding, ESA, and were the same as those used in the collaborative field trials (see p.C51). Each of the Holding strains was selected for its ability to grow on agar containing an antibiotic; the antibiotic differed for each strain so that the strain forming each nodule could be identified. Ten nodules, or as many as possible up to this number, were taken from each plant, surface sterilised in 25% Chloros for 5 minutes, washed five times in deionised water, bisected, and the cut surfaces streaked across Yeast Mannitol Agar either alone or incorporating 50 mg/l spectinomycin or 100 mg/l rifampicin.

In the second experiment strain 31 formed no nodules at either temperature. The reasons for this failure after the striking effectiveness of this strain in earlier experiments are under investigation. Thus it was only possible to compare the performance of Dr. Holding's strains when placed in pairs (Table 2).

Table 2. The effect of temperature on the number of nodules and the proportion of each of three strains of Rhizobium when inoculated in pairs on white clover

Experiment No.		15°C	7°C	Significance
1	Nodules sampled	102	47	
	Ratio: strains P3/1DL	0.08	0.07	NS
1	Nodules sampled	119	93	
	Ratio: strains P3/FA6	0.14	1.45	***
2	Nodules sampled	110	61	
	Ratio: strains P3/FA6	0.17	2.05	***
1	Nodules sampled	115	59	
	Ratio: strains 1DL/FA6	0.72	1.95	**

Irrespective of strain, the total number of nodules was greater at 15°C than 7°C; an indication of this difference is given by the number of nodules sampled, the maximum number could be 10 nodules x 12 plants = 120. A striking observation in both experiments was that, in P3/FA6 mixtures, strain P3 formed a larger proportion of the nodules at 7 than 15°C. 1DL also formed a greater proportion of nodules than FA6 at the lower temperature. However when P3 and 1DL were inoculated together, 1DL outcompeted P3 consistently at both temperatures.

b) <u>In soil</u> (pots)

To complete the screening of strains, which performed well at low temperatures in the artificial medium of Gibson tubes, it was necessary to carry out experiments in soil. Two soil were used: the peat from Lephinmore with few or no indigenous rhizobia, and the brown earth from Sourhope with small numbers of largely ineffective rhizobia. The sterile pot technique with five white clover plants per pot as described by Vernon and Newbould (1976) was used; three inoculation treatments with strains P3, FA6 and 42 respectively and one uninoculated treatment were applied in six-fold replication, and the plants were grown at either 7 or 15°C.

No nodules were observed in any treatment at 7°C. With plants grown in the peat at 15°C there were no nodules on the uninoculated treatment but all the inoculated plants were well nodulated and each strain was responsible for nodules formed in its respective treatment. By contrast the uninoculated plants on the Brown Earth bore a large number of minute white nodules scattered throughout the root system. The introduced strains of <u>Rhizobium</u> all formed large red nodules indicating that they had competed successfully with the indigenous strains at this temperature.

All the plants grown at 7°C were small but extremely high in nitrogen (Table 3). The treatment with strain 42 produced significantly bigger plants on the peat and the largest nitrogen yield, but, since none of the plants was nodulated, the reason for this effect is difficult to find. At 15°C, strain 42 applied to plants on the peat produced the smallest plants and the lowest yield of nitrogen when compared with the other strains. Strain FA6 produced a significantly higher yield of nitrogen than the uninoculated plants on both soils while strain P3 did the same on the peat soil only.

Table 3. The effect of temperature and strain of *Rhizobium* on dry weight, and content and yield of nitrogen of white clover in two soils

Strain	15°C Peat	15°C Brown Earth	7°C Peat	7°C Brown Earth
Total Plant Dry Wt. (g at 15°C, mg at 7°C)				
P3	2.43	1.56	22.8	17.6
FA6	2.51	2.08	22.5	21.6
42	1.63	2.05	37.1	22.0
None	2.37	1.49	24.3	17.8
LSD (P = 0.05)	0.70		10.8	
Nitrogen Content (%)				
P3	2.16	2.47	7.77	5.89
FA6	2.31	2.33	7.55	5.68
42	2.60	2.02	7.19	6.07
None	1.29	1.84	6.60	5.97
LSD (P = 0.05)	0.30		0.90	
Nitrogen Yield (mg)				
P3	53.6	34.0	1.77	1.03
FA6	55.3	46.3	1.66	1.22
42	32.7	37.8	2.63	1.34
None	27.2	25.6	1.53	1.06
LSD (P = 0.05)	16.8		0.67	

These preliminary results indicate that there may well be strains of *Rhizobium* to suit cultivar of white clover, soil type, and low temperature conditions. Further work is needed to confirm and expand these observations but they encourage the view that it may be possible and practicable to find (or breed) elite strains of *Rhizobium* that will be more competitive and effective at low temperatures than existing strains.

References:

VERNON, Dorothy and NEWBOULD, P. (1976). Studies on the specificity of symbiosis between strains of *Rhizobium trifolii* and cultivars of *Trifolium repens* growing on hill soil. HFRO Ann. Rept. (HFRO 217), 105-112).

3. The Mycorrhizal association in White Clover

A. Rangeley and P. Newbould

A series of pot experiments in 1975 established that white clover had a high requirement for phosphorus, and that there was little available phosphorus in hill soils. The mycorrhizal symbiosis (between most green plants and a fungus from the family endogonaceae) provides benefit to the plant mainly through additional absorption of phosphorus by fungal hyphae which explore regions of the soil outside the zone of root hairs. Efficient symbiosis, if established in hill pastures, may lead to more efficient use of phosphorus fertilizers. It may also enhance the speed with which nodules are formed on the roots of white clover seedlings since an adequate phosphorus supply is needed for this process.

Indigenous fungi were multiplied and inoculated onto white clover in a preliminary pot experiment. Plants inoculated with mycorrhizal fungi and given a low agricultural level of phosphorus (40 kg P/ha) grew as well as uninoculated plants given four times more phosphorus (160 kg P/ha). Nitrogen, phosphorus, calcium and magnesium absorption was enhanced, as was nodulation and nitrogen fixation (measured by acetylene reduction) (Table 1).

Table 1. The effects of a mycorrhizal fungal association on the growth of white clover at two levels of phosphorus fertilizer

Measurement	Treatment				LSD (5%)
	M-:P40	M+:P40	M-:P160	M+:P160	
Dry weight (g/pot)					
Shoot	0.73	1.78	1.96	2.29	0.25
Root	0.31	0.81	0.67	0.86	0.12
Total	1.04	2.59	2.63	3.15	0.35
% Mycorrhizal infection	13.4	53.9	3.2	46.9	10.8
Nodulation (per pot)					
1 mm	204	375	637	711	124
1 mm	14	131	191	225	61
Acetylene reduction (μmoles/pot/h)	1.5	19.0	33.3	33.5	6.6
Total nutrient in shoots (mg/pot)					
Nitrogen	38.5	69.4	78.7	82.1	9.9
Phosphorus	2.1	3.8	7.5	9.4	1.3
Potassium	18.8	18.2	17.9	18.8	2.3
Calcium	21.4	43.5	68.1	76.9	8.5
Magnesium	2.8	5.8	9.6	10.9	0.9

Two strains of mycorrhizal fungi, which are commonly used in mycorrhizal experiments, were tested on two cultivars of white clover. The strains of fungi were Glomus fasciculatus E3 (Rothamsted Experimental Station) and Glomus mosseae L1 (University of Dundee), and the two cultivars of white clover were Grasslands Huia and Aberystwyth S184. At a meeting, in July 1977, of groups in the UK interested in mycorrhizal effects on white clover in relation to hill land improvement, it was agreed that where possible S184 and E3 should be the standard cultivar and endophyte for simplification of comparison between experiments. Clover was sown into sand, either sterile or infected with E3 or L1. When the seedlings were mycorrhizal they were transplanted into shredded deep peat which had received a basal dressing of lime and potassium. Half the plants received gafsa phosphate at the equivalent of 13 kgP/ha. The seedlings were inoculated with Rhizobium at transplanting. There was one plant per 3" pot anf five replicates of twelve treatments:-

+ P Huia E3	- P Huia E3
+ P Huia L1	- P Huia L1
+ P Huia Control	- P Huia Control
+ P S184 E3	- P S184 E3
+ P S184 L1	- P S184 L1
+ P S184 Control	- P S184 Control

Measurements were made of leaf, stem, and root dry weight, leaf number, length of central leaflet, stolon number, nodule number, and acetylene reduction. Root samples were stained for assessment of fungal infection, but the measurements have not been completed and comparisons of effectiveness between strains cannot be made.

Only three out of twenty of the control seedings grew after transplanting, two were Huia and one was S184; they probably became infected with indigenous fungi after transplanting. Plants infected with both endophytes grew well and S184 responded to the application of gafsa phosphate. This was the case for all characteristics measured, but Table 2 presents the results for leaf, stem and root dry weight only.

Table 2. The effect of mycorrhizal infection, cultivar and gafsa phosphate on leaf, stem and root dry weight of white clover

	LEAF (mg/pot)	STEM (mg/pot)	ROOT (mg/pot)
+ P Huia E3	267	50	137
+ P Huia L1	218	47	110
+ P Huia Uninf.	11	0	4
+ P S184 E3	352	115	154
+ P S184 L1	376	114	170
+ P S184 Uninf.	6	1	2
- P Huia E3	210	36	92
- P Huia L1	244	45	118
- P Huia Uninf.	3	0	0
- P S184 E3	216	51	102
- P S184 L1	112	56	47
- P S184 Uninf.	7	1	3
LSD (5%)	74	35	41

A pot experiment is in progress to investigate the response of white clover to inoculation by E3 in three hill soils, a deep peat (as in previous experiments), a dry peat and a brown earth.

In 1977 a field trial (in collaboration with Dr. M. Daft, Dundee University was set up on the blanket bog at Lephinmore. The indigenous vegetation was cut, the area was limed, and given potassium, and phosphate as superphosphate at 20 kgP/ha. In early August 1977, pre-inoculated and uninoculated seedlings of S184 and Huia were transplanted into the bog and infected sand and seed were broadcast onto the surface. There was no effect of treatment in autumn 1977 and sampling will begin when there is sufficient growth in 1978.

A field trial is planned for the spring of 1978 on a brown earth at Sourhope. It is hoped to do a survey of hill soils and vegetation in Scotland for levels of infection of indigenous species and the number of spores in the soil. Laboratory work will include development of methods of inoculation and assessment of suitable strains of fungus.

EFFECTS OF UTILISATION

04010: Effects of utilisation by grazing hill sheep and beef cattle on growth and production of hill 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, D. Suckling, L. Torvell, D. Forbes and J. Hodgson

The statement of objectives, list of pasture types included, and approach adopted in this study are summarised under project 03003 (p. A.43).

Three of the six plant communities included in the study were grazed in both summer and autumn in 1977. These were a sown sward dominated by Lolium perenne, a blanket bog community dominated by Calluna vulgaris and Eriophorum vaginatum, and a dry heather moor dominated by Calluna vulgaris. Detailed sward measurements were made during each period of grazing. A combination of simple harvests and layer harvests, height measurements, and point quadrat data were used to obtain descriptions of herbage weight, sward height, floristic composition, and sward structure.

Extrusa samples were collected from each of four sheep and four cows, fistulated at the oesophagus, on at least three occasions during each grazing period. Samples from the summer grazing period of the ryegrass site and from both summer and autumn grazing periods of the blanket bog site have been examined. Thin suspensions of the extrusa samples were placed in petri plates and examined under a low power stereoscopic microscope fitted with a gridded eyepiece. The nature (species and morphological unit) of fragments occurring under the grid intersections were noted. In addition the length of twenty randomly selected fragments was recorded from each sample.

Sown Ryegrass Sward

This sward was grazed during the last week of June. Prior to grazing the herbage weight was 3054 kg/ha DM and the mean sward heights (measured from point of first contact in stratified point quadrats) were 9.6 ± 0.6 cm. At the close of grazing the herbage weight was 2076 kg/ha DM and height was reduced to 4.3 ± 0.3 cm. The sward was composed of 82% Lolium perenne, 13% Poa annua, 3% Trifolium repens, and 2% miscellaneous herbs. The sward was leafy, flowerheads and stems were still green and selection opportunity was relatively small. The morphological composition of the sward and that of ingested material (extrusa samples) are summarised in Table 1, (see over).

Frequencies of sheaths and flowerstems in the swards and extrusa samples are not really comparable. In the sward strikes were recorded against vegetative stems, which are bundles of sheaths, and in the extrusa samples strikes were against individual leaf sheaths; similarly, in the sward a flower-stem was composed of an intact stem, often surrounded by sheath, while in the extrusa samples stems were fragmented, hollow stem sheaths being frequent and often split into longitudinal sections. Bearing these points in mind the main findings were:-

(1) The percentage of green leaf (grass, clover, and herbs) in material ingested by both sheep and cattle was higher than its percentage frequency in the sward.

(2) The percentage dead leaf and vegetative sheath ingested was much less than that occurring in the sward.

(3) Sheep ingested less grass flower-stem than the cattle.

(4) Sheep ingested more clover and miscellaneous herbs (Cerastium arvense Ranunculus repens, Bellis perennis, and Rumex crispus) than did the cattle.

(5) Morphological units occurring in the upper horizons of the sward were more frequent, or as frequent in the ingesta, and those confined to the lower horizons less frequent than their percentage occurrence in the sward as a whole. For example, green leaf occurred mainly between 2-8 cm above ground, flowerheads from 5 cm upwards while dead leaf, and vegetative stems were mostly below 4 cm. The non-selective grazing of the upper horizons could have resulted in the diet composition found for cattle. The lower percentage stem and higher percentage of herbs in the sheep's diet suggests that sheep were exercising some degree of selectivity when grazing.

Table 1. Morphological composition of a grazed ryegrass sward and of material ingested by grazing sheep and cattle during 24 June to 1 July. Results are expressed as percentage frequencies of point contacts

	SWARD		SHEEP				CATTLE		
	23 June	30 June	27 June	28 June	30 June	1 July	27 June	30 June	1 July
GRASS									
green leaf	53.7	43.1	51.0	60.0	62.3	63.0	60.5	63.0	57.7
dead leaf	8.2	22.2	0.7	1.3	0.8	4.0	0.3	1.5	6.3
green veg. stem/sheath	16.4	22.2	12.3	10.3	15.8	8.8	8.5	11.8	10.0
dead veg. stem/sheath	–	–	–	1.3	3.8	0.3	0.8	1.8	2.3
green fl'hd	7.0	3.7	7.7	5.7	4.3	2.5	7.0	4.0	3.3
dead fl'hd	–	–	–	–	–	–	–	+	+
green fl'stem	5.2	5.8	13.0	12.0	11.5	12.5	21.3	16.0	13.7
dead fl'stem	–	–	0.3	0.6	+	0.3	0.3	1.5	1.0
CLOVER									
green leaf	3.0	3.1	1.3	1.7	2.3	0.5	–	0.3	–
dead leaf			–	0.3	–	–	–	–	–
HERBS									
green leaf	1.8	1.2	12.7	5.7	0.3	1.5	–	–	0.3
dead leaf			0.3	–	–	0.3	–	–	–
stem			0.7	0.3	–	0.5	–	–	–

+ Presence less than 0.1

(6) Mean fragment length in the extrusa samples was surprisingly similar for sheep and cattle. The four sheep had average fragment lengths of 12.0, 9.5, 12.4 and 11.1 mm and the four cattle 12.7, 8.8, 11.3 and 9.1 mm. The samples were well masticated and these measurements were not taken to indicate bite size but rather average fragment size of particles entering the rumen.

Blanket Bog Community

This community was grazed from 25-29 July and from 12-16 September. Standing crop was around 6000 kg/ha and green dry matter (green leaves of grasses and sedges and current season's shoots of heaths) 1500-1800 kg/ha. *Eriophorum vaginatum* and *Calluna vulgaris* were co-dominant and were growing together in fairly even and intimate admixture. Projecting leaves of *Eriophorum* gave a visual impression that this species was more frequent than in reality. Mean sward height of well developed tussocks was 29.4 cm ± 0.9 and of inter-tussock vegetation 15.7 cm ± 1.2. The percentage specific frequency (point contacts against a particular morphological unit of a species expressed as a percentage of total contacts) of some of the species in the sward as a whole, at the sward surface, and in the extrusa samples of grazing sheep and cattle, are shown in Table 2 (see over).

The main findings were:-

(1) Both sheep and cattle were grazing selectively. For example, apart from individual animals on isolated occasions, the heath species *Calluna vulgaris*, *Erica tetralix* and *Empetrum nigrum* were avoided.

(2) On all occasions the percentage green leaf in samples of ingesta from sheep was higher than that of cattle.

(3) Sheep were able to substantially improve the percentage green in their diet compared with that on offer. Cattle diets represented a marginal improvement only.

(4) The percentage dead leaf in the ingesta was higher at the end of each grazing period and was higher in autumn than in summer.

(5) Species preferred by sheep were the grasses and *Carex* spp, *Trichophorum caespitosum*, *Narthecium ossifragum* and *Juncus effusus* (see Table 2). Apart from Molinia at 21%, *Deschampsia flexuosa*, other grasses and *Carex* spp accounted for 19%. 3% and 15% of the diet respectively.

(6) With the exception of *Narthecium* the above species were also preferred by cattle but cattle were less efficient as selective grazers.

(7) *Eriophorum vaginatum* was avoided by sheep in July; in September it was avoided at first but increased to reach a similar level in the ingesta as in the sward at the close of the grazing period.

(8) Cattle did not avoid *Eriophorum vaginatum*. Apart from the first grazing date in July, when its frequency was lower than that at the sward surface, it occurred with similar frequencies in the diet and at the sward surface at the beginning, and slightly higher frequency in the diet than at the sward surface at the close, of each grazing period.

Table 2. Selected data illustrating the percentage specific frequency of green leaf of species in a grazed blanket bog community and in oesophageal fistula extrusa samples (mean of four animals for each date)

	SWARD		SHEEP			CATTLE		
	whole sward	sward surface	25/26 July	27/28 July	28/29 July	25 July	28 July	29 July
JULY								
Eriophorum vaginatum	10.4	19.8	4.3	5.3	5.0	15.0	24.5	29.0
Calluna vulgaris	15.6	18.9	0	[9.5]*	+	0.3	1.3	+
Trichophorum caespitosum	1.1	1.8	9.0	15.3	36.5	14.0	11.3	3.0
Molinia caerulea	0.2	0.4	20.7	5.0	5.8	3.8	0.3	+
Narthecium ossifragum	0.5	-	0.7	25.0	22.3	-	0.3	-
Juncus effusus	+	+	0.3	0.3	3.0	13.3	2.5	0.7
Juncus squarrosus	0.1	-	0.3	0.5	2.8	3.3	2.5	2.7
Dead sedge leaf								
(a) as percentage of sward	35.5	26.9	11.6	16.3	13.5	36.8	40.0	43.7
(b) as percentage of sedges	70.0	51.3						
SEPTEMBER			12 Sept	14 Sept	15 Sept	12 Sept	14 Sept	15 Sept
Eriophorum vaginatum	13.8	22.9	5.8	10.8	20.3	24.5	25.5	32.0
Calluna vulgaris	17.2	25.0	2.0	2.0	1.5	4.3	7.3	0.8
Trichophorum caespitosum	0.3	0.8	17.0	22.5	11.0	5.3	6.0	7.0
Molinia caerulea	0.1	-	11.3	6.3	3.5	1.0	0.3	0.3
Narthecium ossifragum	0.4	0.8	4.0	3.3	10.0	+	+	-
Juncus effusus	+	+	29.3	7.5	2.0	0.3	0.5	0.3
Juncus squarrosus	1.1	0.9	0.5	0.3	1.5	2.8	2.5	0.8
Dead sedge leaf								
(a) as percentage of sward	27.0	21.1	19.3	33.0	35.3	41.8	44.0	48.5
(b) as percentage of sedges	51.7	42.1						

\+ presence less than 0.1

* This figure is due to one sheep eating a largely heather diet - see text.

(9) Mean fragment size in the extrusa samples was marginally longer for sheep than cattle and little affected by season. In July mean fragment length for the four sheep was 11.7, 8.5, 11.8 and 11.9 mm and for the four cattle 9.8, 8.0, 9.6 and 8.8 mm. In September the mean lengths for sheep were:- 10.4, 11.4, 10.6 and 9.1 mm and for cattle were:- 7.9, 8.5, 8.6 and 8.3 mm.

(10) Mean fragment sizes were remarkably similar to those of the ryegrass site.

2. Investigation of the nature of defoliation of individual ryegrass tillers in swards of different structure grazed by sheep to remove different amounts of herbage

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

Very little information exists on the nature of defoliation of tillers in grazed swards. Such information is necessary to plan and to interpret studies investigating defoliation and regrowth. This is particularly true if cutting trials which afford both more controllable and manipulable conditions, are to be used to aid progress. The present experiment was set up to collect information on the proportion of tillers grazed, the extent to which leaves of different age on a tiller were defoliated, and whether grazing was distributed at random or concentrated in patches.

Four swards, involving a combination of two densities and two heights, were prepared in each of two randomly arranged blocks by manipulating cutting frequency and fertiliser application during the period from mid-April until the end of June. A regrowth period of three weeks was allowed after the last cut.

Pre-grazing measurements were then made to describe the sward in terms of herbage weight, sward structure, morphological composition, and tiller dimensions. The swards were then divided to give two sub-plots and grazing treatments, namely removal of 30% or 60% of the herbage weight over a period of 24 hours, were applied. The treatments were based on herbage allowance (1.2 kg/sheep) and sheep numbers were calculated to achieve an anticipated 30% or 60% herbage removal.

After grazing the sward measurements were repeated. Tiller measurements were made by recording ten vegetative tillers at 10 cm intervals in each of six randomly placed transects, point quadrat frames being used to locate the tillers. Tiller measurements included sheath tube height and sheath tube length, computed tiller angle, a note of the state of the sheath tube (sheaths loose or tightly imbricated, decapitated or entire) and the length and status (grazed or entire, live/dead score) of up to four leaves per tiller. The mean height of grazing (vertical distance above the ground of the grazed leaf tip) was also recorded in separate random transects.

As floral tillers were frequent on all plots and their presence could be expected to greatly modify grazing behaviour, measurements were repeated on two of the sward types in September.

Difficulties were encountered in imposing the treatments - intake of the sheep was very variable among the plots and some sheep jumped fences overnight. Sward structure was affected by the trampling of pregrazing recorders and grazing was patchy. Results were too variable to learn much about defoliation of individual tillers as affected by the interaction of sward structure and amount of herbage grazed. However, several general observations concerning the grazing of tillers were apparent.

The table below shows the mean height of green leaf prior to grazing, the mean height of the vegetative tiller sheath tubes and the mean height of grazed leaf tips.

Sward		Height green leaf (n = 12)	Height vegetative stems (n = mean of six transects, each of ten tillers)	Height of Grazing Notional utilisation 30% (n = 100)	60%
D_1H_1	rep 1	9.4 ± 0.5	2.5 ± 0.1	5.6 ± 0.1	4.8 ± 0.1
	rep 2	10.7 ± 1.2	2.9 ± 0.2	3.6 ± 0.1	4.2 ± 0.2
D_2H_1	rep 1	8.0 ± 0.8	2.3 ± 0.1	3.6 ± 0.1	3.4 ± 0.1
	rep 2	12.5 ± 0.8	2.1 ± 0.1	5.0 ± 0.2	3.0 ± 0.1
D_1H_2	rep 1	13.1 ± 1.1	3.3 ± 0.3	5.3 ± 0.1	5.3 ± 0.1
	rep 2	12.5 ± 0.8	3.3 ± 0.2	5.4 ± 0.1	4.0 ± 0.1
D_2H_2	rep 1	15.0 ± 1.7	3.2 ± 0.2	4.9 ± 0.2	3.8 ± 0.1
	rep 2	13.3 ± 1.0	3.5 ± 0.2	4.7 ± 0.2	4.8 ± 0.2

Mean grazing height was above that of mean vegetative tiller sheath tube height (vegetative stem) on all plots. However, some of the sixty measured tillers per plot were decapitated by grazing. Such tillers were more frequent on plots where the level of herbage removal was high. For example, where herbage removal was in the region of 20-30% of the initial weight, 0-2 tillers (0-3%) were decapitated; where removal approached 40%, 4-8 tillers (7-13%) were decapitated.

The individual tiller measurements were made to see whether the likelihood, and/or extent, of grazing differed for leaves of different age on the tiller. A comparison of pre- and post-grazing records from July of percentages of leaves of different age with cut or grazed edges* was as follows:- youngest leaves 1.1% before and 55.6% after grazing, second youngest leaves 6.5% before and 87.0% after grazing and third youngest leaves 35.9% before and 85.1% after grazing. The increment (of leaves with cut or grazed edges) was much higher for second leaves than for first or third leaves.

Percentage reduction in mean leaf length of leaves of different age as a result of grazing differed with season. In July the average percentage reduction in length of first, second and third leaves was 53.9%, 67.3% and 57.3% respectively. In September the reductions were 54.4%, 56.2% and 23.7%.

Trampling of the swards affected both tiller angle and sheath tube height. Vulnerability to damage by trampling was increased in tall compared with short swards, and, to a lesser extent, in swards of lower density compared with higher density. For example, mean tiller angle in the tall swards was reduced from 60.5° to 53.4° by trampling while in the short swards the change was from 54.9° to 53.9°. In low density swards, tiller angle changed from 61.2° to 56.2°, and, in high density swards, from 53.4° to 51.2°. Changes in sheath tube heights showed similar patterns.

Trampling and/or grazing caused another change to tiller state which could affect their subsequent tillering rates. Davies (private communication) has shown that the tillering rate of tillers with sheaths torn back is higher than that of intact tillers. The number of tillers with loosened as opposed to closely imbricated sheaths was increased at the close of the grazing period. Before grazing in July, 3.5% of tillers had loose sheaths; after grazing, the proportion had risen to 15%. In September, more tillers had loose sheaths prior to grazing than in July, as many as 13%, and after grazing the proportion had risen to 20%.

* Swards were prepared by pretreatment cutting management - a few second and many third youngest leaves had cut edges before grazing.

3. <u>A study of growth and senescence of individual tillers and of changes in herbage weight and morphological composition in four swards allowed to regrow at two light levels after cutting to two different heights</u>

S.A. Grant and L. Torvell

This experiment was set up partly to evaluate the tiller measurement technique for monitoring pasture growth and partly to study the interaction between defoliation and sward structure in its effects on the different components of growth (leaf appearance, leaf extension, specific leaf weight etc.).

S23 Ryegrass was sown on soil in boxes in April under uniform conditions. Cutting pretreatments were given to achieve a range of four sward structures, composed of vegetative tillers for treatment cuts and regrowth studies in September. A starter dressing of compound fertiliser was given at the time of sowing and extra nitrogen was added at intervals after cutting. Total nitrogen given was equivalent to 250 kgN/ha.

Uniform cuts were given during the establishment phase, between April and June, and pretreatment cuts were begun on 13 June. Two cutting heights (2 cm and 6 cm) and two cutting frequencies (2 weeks and 4 weeks) were used, which allowed three complete cycles before the treatment phase started on 5 September.

Eight boxes of each of the four sward types were cut back to 2 cm and eight boxes to 6 cm. Half the boxes in each group were then allocated to regrow in full daylight and half under muslin tents which reduced light to 50% of daylight. A split plot design was used with four replicate blocks split for full light or shade conditions.

At the time of the cutting treatment a further four boxes of each of the four sward types were destructively harvested to allow description of the swards in terms of herbage weight and morphological composition at the start of the regrowth period. A strip, 8 cm wide around the edge of each box, was cut and discarded to avoid edge effects. A quadrat whose basal area was measured accurately (average dimensions 24 x 16 cm), was layer harvested, material above 6 cm from 2-6 cm, and from ground level to 2 cm, being bagged separately for later sorting into morphological components. Samples were also cut to ground level to record tiller densities and weights per tiller and to measure water soluble carbohydrate reserve levels.

Measurements in the boxes during the regrowth period included: frequent sampling for light interception using tube solarimeters; automatic temperature monitoring; the measurement of leaf appearance, leaf extension rates, leaf senescence rates, sheath tube heights, and tiller production at weekly intervals on marked tillers; the measurement of weight per unit leaf area of the first (youngest), second, and third leaves separately; weight per unit leaf length of the first leaves; and the collection of samples to measure carbohydrate reserves and describe morphological composition. After four weeks of regrowth all the boxes were sampled to determine herbage weight, weight per tiller, morphological composition, and carbohydrate reserve level.

Samples are still being processed and the data are only partly available.

The data in Table 1 (see over) show the sward weights and composition immediately after cutting (start of the regrowth period) and final sward weights after four weeks of regrowth. The net gain in weight (difference between starting and finishing weights) was remarkably similar for the different cutting heights, the average for the 2 cm boxes being 167.4, and the 6 cm boxes 165.6. Pre-treatment cuts (sward types) showed a trend for lowest weight gains for boxes with a prehistory of low cutting heights to highest

Table 1. Sward weight (g/m) and composition at the time of cutting (September 6) and weight after four weeks regrowth, Lolium perenne 1st year swards

	SWARD 1	SWARD 2	SWARD 3	SWARD 4
2 cm cut				
Initial Weight	219.0 ± 14.9	201.5 ± 29.4	201.2 ± 14.7	161.1 ± 15.6
% Green leaf	14.1 ± 0.7	13.3 ± 1.8	5.0 ± 0.3	2.5 ± 0.5
% Dead leaf	41.2 ± 1.4	26.6 ± 1.6	25.3 ± 2.3	19.1 ± 1.4
% Vegetative stem	44.4 ± 1.5	59.0 ± 2.9	67.7 ± 2.3	78.1 ± 1.7
Final Weight	Light Shade	Light Shade	Light Shade	Light Shade
	375.7±7.4 294.1±17.3	407.0±31.1 334.8±16.0	378.5±10.3 350.8±17.1	382.0±14.2 372.1±7.3
6 cm cut				
Initial Weight	274.8±17.9	297.5±40.2	392.7±23.9	394.6±18.3
% Green leaf	29.4± 1.0	39.2± 2.7	30.6± 1.2	28.7± 1.4
% Dead leaf	33.9± 0.9	19.2± 0.6	30.4± 0.8	27.4± 1.7
% Vegetative stem	36.4± 1.4	40.9± 2.9	38.4± 1.8	43.8± 2.9
Final Weight	Light Shade	Light Shade	Light Shade	Light Shade
	452.9±11.0 377.0±21.5	486.1±15.3 432.1±13.8	602.4±18.3 560.2±17.2	603.7±8.9 524.5±22.6

gains for those with a prehistory of less frequent high cutting. Shaded boxes in general grew less well than those in full light, though the 2 cm cut of swards 3 and 4, which were reduced to a leafless stubble at the start of the growing period, showed little effect of shading.

Rates of leaf extension were analysed for each week of the regrowth period as also were rates of leaf senescence. The main effects are summarised in Table 2.

Table 2. Rates of leaf extension and rates of senescence expressed as mm per tiller per day. Summary of main effects

	LIGHT LEVEL			CUTTING HEIGHT			SWARD TYPE				
							Sward				
Rates of extension	Full light	Shade	Sig.*	2 cm cut	6 cm cut	Sig.	1	2	3	4	Sig.
Week 1	9.8	9.6	NS	8.9	10.6	***	8.5	10.1	10.0	10.3	**
2	11.2	10.9	NS	10.4	11.8	*	11.3	11.4	11.3	10.3	NS
3	9.9	9.7	NS	8.9	10.6	***	10.0	9.6	10.0	9.4	NS
4	8.6	9.7	*	8.5	9.7	**	9.3	9.3	9.0	8.9	NS
Rates of senescence											
Week 1	0.6	1.0	NS	0.3	1.4	***	0.6	0.9	1.2	0.6	NS
2	1.3	1.7	NS	0.5	2.5	***	1.1	1.6	1.5	1.8	NS
3	2.0	1.9	NS	0.5	3.5	***	1.5	2.1	2.3	1.9	NS
4	2.1	2.4	NS	1.4	3.1	***	2.2	3.1	1.8	1.9	NS

* 'Sig' - probability of the difference between means being of significance:-

NS = not significant
* = $P \leq .05$
** = $P \leq .01$
*** = $P \leq .001$

There was a significant reduction in the rate of leaf extension of the low cut treatment group in all four weeks; in the first week swards with a prehistory of frequent low cutting also had a reduced extension rate. In week four, extension rates were faster in the plants grown in shade. Rate of senescence was significantly higher in swards cut to 6 cm in all four weeks, and there was also a significant interaction between height of cut and sward type (not shown in Table 2). Rates of senescence were negligible in low cut boxes of swards 3 and 4 and high in tall cut boxes of the same sward types.

Data on leaf appearance, weight per unit leaf area, water soluble carbohydrate levels, and sward composition at the final harvest are still being processed but the information available suggests that the trends reported in Table 1 are the result of faster rates of senescence counteracting faster growth of tall compared with short swards. Light levels were very low during the period of regrowth, the average watt hours/m^2/day for weeks 1-4 being 1255, 1100, 624 and 1103 respectively. Light interception varied from 20-35% for the 2 cm cut swards and 50-75% for the 6 cm cut swards at the start of regrowth to 70-75% for the 2 cm and 80-100% for the 6 cm swards at the close of the regrowth period. Perhaps because of the remarkably dull weather, daughter tillers were not formed in any of the swards during the period of regrowth.

SOIL CHEMISTRY

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

Soil chemistry and acidity

1. Relationships between soil properties and lime requirements

M.J.S. Floate

Hill soils range in acidity from pH 5.5 to less than 4.0: Brown Forest soils pH 5.5–4.5, Podzols and Peaty Podzols pH 4.5–4.0 and Peat <4.0. This strong acidity is caused by high rainfall, strong leaching, low base content of many soil parent materials, and the accumulation of peaty organic matter. The acidity must be at least partially corrected if satisfactory levels of herbage production are to be attained.

Associated with low soil pH are high levels of exchangeable acidity and aluminium, high organic matter content, high cation exchange capacity, and consequently low base saturation. Different combinations of these associated properties occur in different kinds of soils and, consequently, the amounts of lime required to raise soil pH to satisfactory levels also vary among the different kinds of hill soils.

Because there is a very wide range in the above properties among hill soils it is difficult to find a method of determining "lime requirement" which is universally applicable. The buffer titration method (Woodruff 1948) is employed throughout ADAS, but local modifications employ pH and organic matter content to modify the interpretation of results. The Scottish Colleges employ a variety of methods. We have found that the conventional methods are not universally applicable to hill soils and particular problems arise with highly organic soils.

We have examined the relationships between pH, organic matter, exchangeable acidity and aluminium, and cation exchange capacity for some 50 hill soils in the pH range 3.9 to 5.5. We have also compared the prediction of lime requirement (based on a number of different soil parameters) and the measured pH response of different soils to unit increments of lime.

For 52 hill soils, ranging in pH from 3.9 to 5.5, and in organic matter content from 5 to 99%, we have shown that Total Exchangeable Acidity decreases as pH increases: $A = 262.7 - 48.5\,(\text{pH})$ $r = .78^{***}$ $(P < .001)$. There was no significant correlation between Exchangeable Aluminium and soil pH for the whole group of soils ($r = .10$ NS), nor for organic soils ($r = .15$ NS) or mineral soils ($r = .24$ NS), although there was a tendency for Al to decrease with increasing pH in the mineral soil group: at pH 4.0 the Exchangeable Aluminium ranged from 4–17 meq/100 g, at pH 4.5 from 6–15 meq/100 g, and at pH 5.0 from 2–10 meq/100 g. Exchangeable Aluminium was usually lower in organic than mineral soils at the same pH.

Because Total Exchangeable Acidity is inversely proportional to pH, Exchangeable Aluminium will only behave similarly if there is a constant percentage of Al^{3+} in the Total Exchangeable Acidity. This is not so, and we have shown a highly significant decrease in % Al as a component of acidity as organic matter increases (Fig. 1).

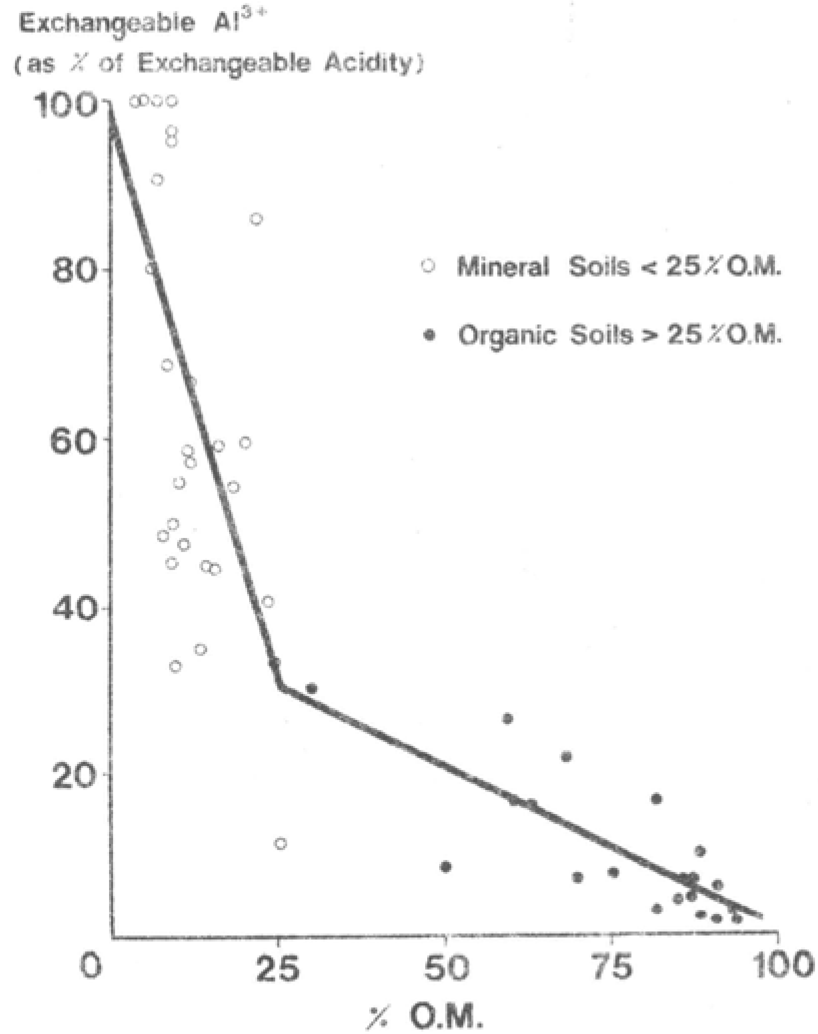

Fig. 1. Relationships between exchangeable aluminium as per cent of exchangeable acidity, and the organic matter content of 50 hill soils.

For mineral soils %Al decreases from 100% to 30% as organic matter increases up to 25% ($r = .64^{***}$ $P < .001$) and for organic soils % Al decreases from 30% to 1% as organic matter increases from 25% to 100% ($r = .80^{***}$ $P < .001$).

It can also be shown that Total Cation Exchange Capacity (CEC) is significantly correlated with organic matter ($r = 0.87^{***}$ $P < .001$) because Exchange Acidity and Exchange Capacity are closely related when base saturation is very low (< 10%) in all these soils.

We can conclude that when base saturation is low and exchangeable acidity is high in hill soils, the balance of the exchange capacity is satisfied by acidic H^+ or Al^{3+} ions, where Al^{3+} dominates in mineral soils and H^+ in the organic soils. It is this acidity which must be at least partially neutralised by liming.

The response of selected soils to unit rates of $CaCO_3$ has been examined. Two mineral and two organic soils were selected so that in each pair one soil had a low level (< 5 meq/100 g) and the other a higher level (10-20 meq/100 g) of exchangeable aluminium. The response of these soils to lime up to the equivalent of 12.5 tonnes/ha is shown in Fig. 2.

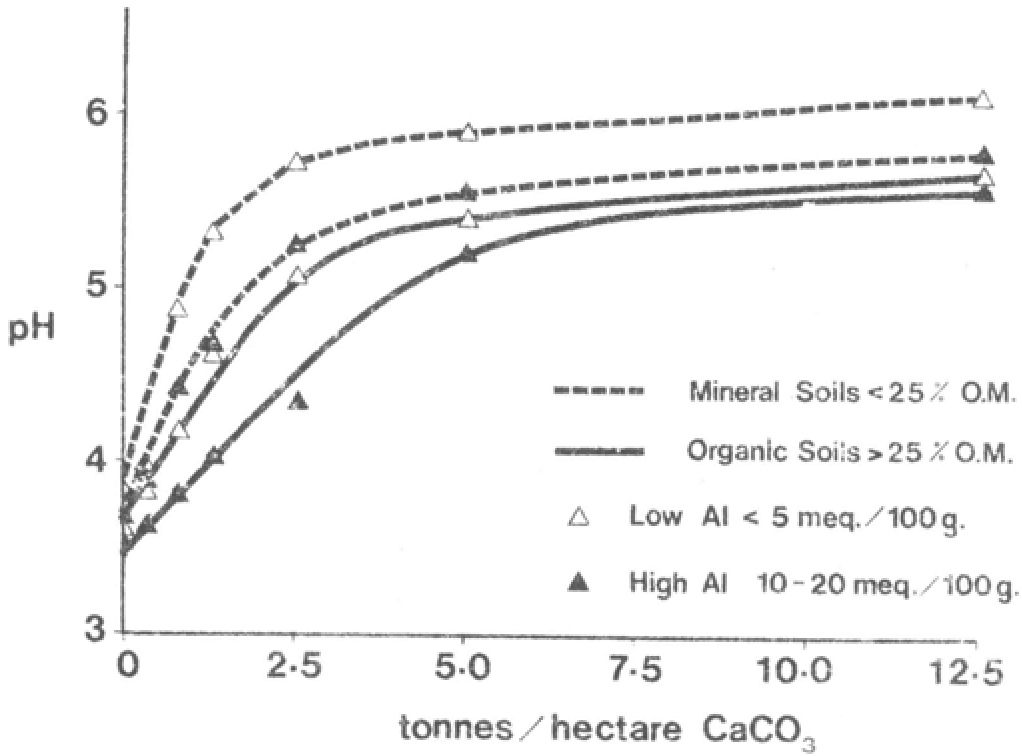

Fig. 2. Effects of high and low exchangeable aluminium on the pH response of organic and mineral soils to added lime.

There was considerable variation in response to unit rates of lime and, it was shown that within each pair, the soil with the higher exchangeable aluminium required more lime to attain a given pH. The results also show that the organic soils had a higher lime requirement than the mineral soils.

Nine soils, ranging in pH from 3.5 to 4.3, and in organic matter content from 10-30%, were selected to compare the prediction of lime requirement from a number of soil parameters, with the measured pH response to unit rates of $CaCO_3$.

These comparisons are summarised in Table 1 and illustrated in Figs. 3a, 3b where y is the predicted amount of Ca^{2+}(meq/m^2) based on calculations from different soil parameters, and x is the measured amount of Ca^{2+}(meq/m^2) required to raise the soil pH to 5.0 in the laboratory. The results show that the amount of Ca^{2+} calculated from the buffer method usually exceeds the measured amount required and that the correlation is not significant because less than 30% of the variance is explained by the regression.

Table 1. Correlation between measured and predicted amounts of lime required to raise soil pH to 5.0

Soil Parameter	Regression Equation	P	r	% Variance explained
Buffer titration	y = 0.43x + 4287	.129	.55	29.7
Exchangeable Al^{3+}	y = 0.168x + 511	.391	.33	10.7
Exchangeable acidity	y = 0.298x + 804	.302	.39	15.1
100% CEC	y = 1.60x + 3022	.001	.89	73.6
50% CEC	y = 0.301x + 1513	.001	.89	73.6

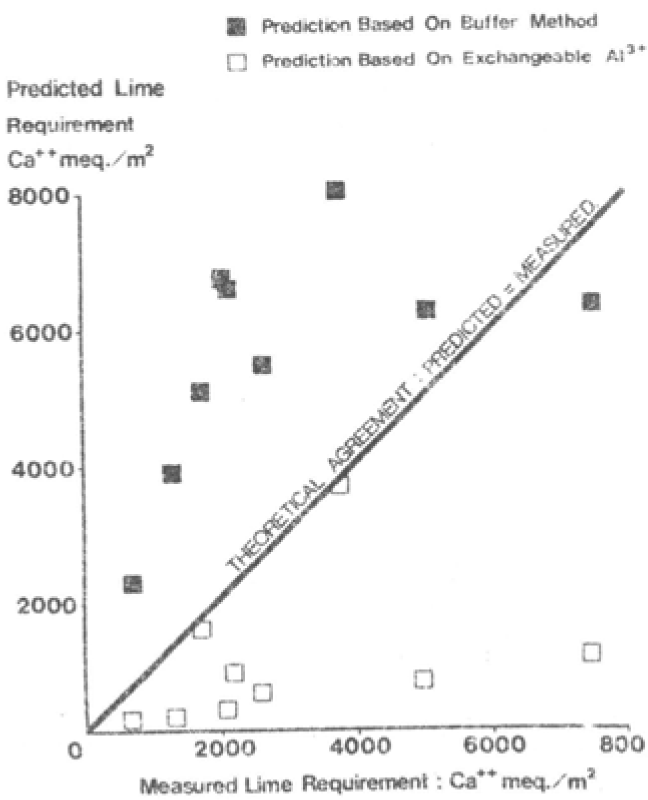

Fig. 3a. Relationships between lime requirement predicted from buffer titration and exchangeable aluminium, and measured lime response.

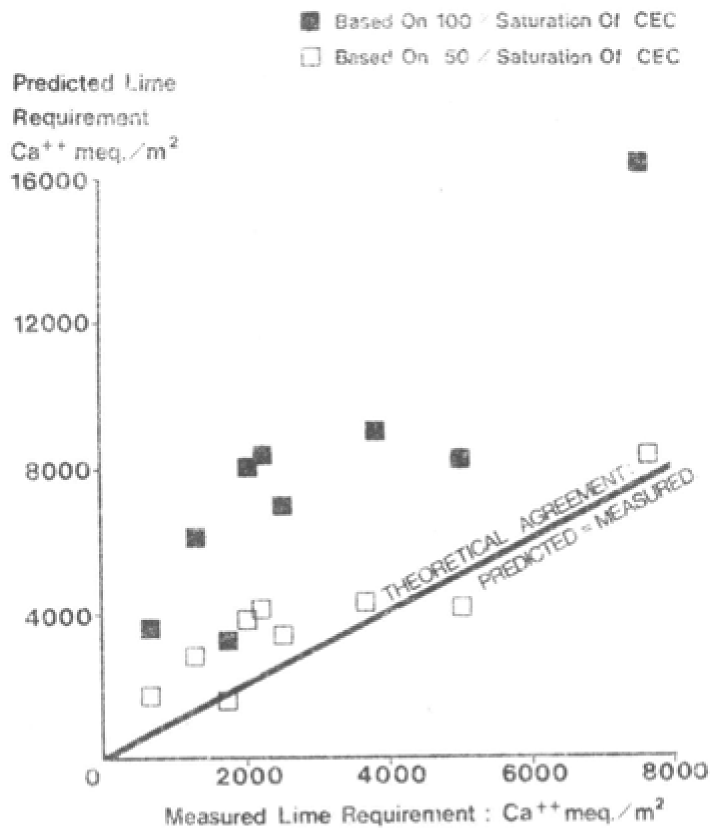

Fig. 3b. Relationships between lime requirement predicted from 50% and 100% saturation of CEC and measured lime response

A large part of the remaining variance is due to two soils and if these are omitted the correlation is improved but the calculated amounts are then more divergent from the line showing agreement with measured amount.

The predictions based on Exchangeable Aluminium and Exchangeable Acidity are both significantly lower than the measured amounts required and again the correlations are poor, only 10% and 15% of the variance respectively being explained by the regression equations.

By contrast, the calculated amount of Ca^{2+} based on CEC is highly significantly correlated with the measured amount required and almost 80% of the variance is explained. However, the calculated amount based on total CEC is almost double the measured amount required, whereas the calculated amount based on 50% CEC shows close agreement with the measured amount required.

It is concluded that, of the parameters tested, the amount of lime required to raise soil pH to a predetermined level is best predicted using the calculation based on 50% CEC. One of the reasons for the promising success of this prediction is that it takes account of the wide range in organic matter content in hill soils (5-100%) and the relationships with CEC and exchangeable acidity in these soils.

This work has been written up in a paper which has been accepted for presentation to the International Congress of Soil Science, Edmonton, 1978.

Reference:

WOODRUFF, C.M. (1948). Testing soils for lime requirement by means of a buffered solution and the glass electrode. Soil Sci. 66, 53-63.

2. Lime response on Peat

M.J.S. Floate, G.R. Bolton and A.D. Ironside

Two field experiments to study the effects of lime treatment (on Brown Forest soil at Stanhope, and on Deep Peat at Lephinmore) were established in 1974. The objectives of these experiments were:-

a) to provide soil for laboratory studies on the distribution of exchangeable Al^{3+} and H^{+} in relation to soil pH;

b) to measure soil pH response to increments of lime applied in the field;

c) to observe the establishment and survival of improved pasture species over a range of soil pH conditions.

Previously reported results have shown that exchangeable acidity in the peat does not exceed 6 meq/100 g at pH 4.0 and falls to less than 2 meq/100 g at pH 5.5. Similar results were obtained both for laboratory treated and field-limed samples. Exchangeable Al^{3+} levels in these soils were low: less than 2 meq/100 g at pH 4.0 and negligible amounts at pH 5.5. These very low levels of Al^{3+} in peat soils are thought to have little influence on P availability or uptake (see project 04003, p.C.5) and not to be a limitation on plant **regrowth on peat.**

Soil pH response to increments of applied lime have also been previously reported and show that 2.5 tonne/ha causes pH to increase from 4.2 to 5.0, and that 5.0 tonne/ha gives a further small response to 5.2. Soil pH values fall progressively with time after liming as a result of leaching, and maintenance treatments are clearly necessary to maintain satisfactory conditions for the growth of improved pasture species.

Establishment and survival of reseeded ryegrass and white clover has been studied for three years and the results have been reported. Because of large variations in soil pH between replicate plots at the same lime level, curvilinear analysis of individual plot pH values against plant numbers and dry matter production was carried out in 1976. This analysis suggested critical pH values of about 4.5 and 5.0 for ryegrass and white clover respectively.

Peat soil pH was measured in January 1977 and values are shown in Table 1.

Table 1. Original, and maintenance lime treatments, and corresponding soil pH values on reseeded pasture plots at Lephinmore

	L0	L1	L2	L3	L4	L5
Original lime rate August 1974	0	0.625	1.25	1.875	2.5	5.0 tonnes/ha
Peat pH January 1977	4.2	4.5	4.3	4.5	4.5	5.1
Maintenance lime rate Feb. 1977	0	4.375	3.75	3.125	2.5	0 tonne/ha
Total lime added	0	5.0	5.0	5.0	5.0	5.0 tonnes/ha
Peat pH April 1977	4.3	5.7	5.5	5.4	5.4	5.1

These suggest that on most treatments soil pH has fallen below the critical level for clover, and may be very close to the critical levels for ryegrass.

Because of these results, and because field observations also confirmed that the reseeded species were declining in numbers and production, a modified experimental design was incorporated in 1977. Maintenance top dressing treatments of lime were applied in February 1977 as indicated in Table 1. The objectives were to determine whether maintenance treatments (in amounts necessary to bring all plots up to the total equivalent of 5.0 tonne/ha) would restore the production levels of the lower yielding plots to that of the highest lime level.

Results for total DM, grass DM and clover DM for 1977, which are the sum of four harvests in May, July, August and October, are given in Table 2.

Table 2. Total, grass, and clover DM yields from reseeded ryegrass and white clover on peat in response to a range of initial and maintenance lime treatments (g/m^2 in 1977)

Treatment	L0	L1	L2	L3	L4	L5
Lime rate Aug. 1974	0	.625	1.25	1.875	2.5	5.0
Lime rate Feb. 1977	0	4.375	3.75	3.125	2.5	0.0
Lime total	0	5.0	5.0	5.0	5.0	5.0
Total DM	65.1	80.7	72.9	76.5	85.6	94.3
Grass DM	44.0	52.5	50.6	48.3	47.9	55.5
Clover DM	7.8	18.3	13.4	20.9	27.7	36.4
Clover as % of Total	11.9	22.6	18.3	27.3	32.3	38.6

Although statistical analysis of these data have not yet been carried out the following observations can be made:-

1. Total DM yields are low and do not exceed 1000 kg/ha. Yields from some maintenance plots approach, but do not exceed, original L5 treatment.

2. Grass DM yield differences are not great, but L0 is least and L5 is greatest. For those plots with maintenance lime treatments in 1977 there appears to be a closer relationship with the amount of this maintenance treatment, than with soil pH before liming: differences may not be significant.

3. Clover DM yields range from less than 100 kg/ha to almost 400 kg/ha, and represent between about 10 and 40% of the total DM yields on plots L0 and L5 respectively. Clover DM yield on those plots receiving maintenance treatments in 1977 appear to be more closely related to soil pH before liming, than to amount of maintenance applied.

These observations suggest that where the soil pH before liming was about 4.5 (the suggested critical values for ryegrass) the application of additional lime may have had a small effect on grass production; this pH is considerably below the suggested critical level for clover and this species may have been suppressed to an extent from which it has not been able to recover, by the restoration of pH to levels in excess of 5.0, through lime maintenance treatments.

The original 5.0 tonnes/ha lime on plot L5 appears to have been adequate to maintain soil pH at a satisfactory level for three years at least.

3. Lime response on Mineral Soils

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

The objectives of the field lime response experiments were outlined in section 04011 - Peat (p.C.75) and in this section the responses on Linhope series Brown Forest soil are described.

Results reported in detail in past annual reports have shown that after initial treatment with increments of lime up to 5.0 tonnes/ha, soil pH increased from 4.4 to 5.4. In subsequent years pH has changed little but exchangeable acidity and exchangeable Al^{3+} in the surface soil were further reduced in 1976. These values are not high and range from 2.99 meq/100 g exchangeable acidity and 2.52 meq/100 g exchangeable Al^{3+} in the control soil to 0.87 meq/100 g and 0.48 meq/100 g, exchangeable acidity and Al^{3+} respectively, in the soil of the highest lime treatment.

Perhaps because of the relatively narrow pH range across the treatments (pH 4.5-5.5), and perhaps because of the tolerance of the sown species of ryegrass and white clover, there has so far not been any marked effects on vegetation composition of the treated plots. There was some evidence in 1976 that the proportion of clover on the lower lime treated plots was decreasing more rapidly than on the higher lime treatments but this appears to have stabilised. The only noticeable treatment effect is the higher percentage cover of clover on the 5.0 tonnes/ha lime plots.

Yield differences between treatments are also small and only the highest lime rate is noticeably higher than any other treatment. Statistical analysis has not been carried out on these data because a complete analysis of grass and clover yield components must await the completion of herbage separations. Data for total herbage DM yield are given in Table 1.

Table 1. Herbage DM yields from reseeded ryegrass/clover on Linhope soil in response to lime treatments (g/m^2)

Year \ Treatment tonne/ha lime	0	0.625	1.25	1.875	2.5	5.0
1975 (one cut only)	21.9	31.5	27.8	23.2	25.9	31.7
1976	461.9	435.6	380.7	474.0	476.3	510.1
1977 (two cuts only)	256.8	273.3	271.3	292.9	280.4	316.0

The results for 1975 are difficult to interpret because only one cut was possible and, similarly, in 1977 interpretation is complicated by the loss of the largest component of total yield when the plots were accidentally grazed by sheep in July. Data for 1976 are more reliable and show that total production ranged from about 4000 to 5000 kg/ha. Differences between treatments may not be significant.

It is perhaps remarkable that on this site, which was originally heather covered and carried a mor humus layer with pH 4.0–4.5, improvement treatments with little or no lime have been capable of sustaining production from ryegrass and white clover for three years. It is perhaps less remarkable when these results are related to the low levels of exchangeable acidity and exchangeable Al^{3+} in the soil, and to the low cation exchange capacity (CEC = 7.8 meq/100 g) of this Linhope soil. It has been shown elsewhere in this report (04011, p.C.79)that laboratory studies suggested that 50% saturation of CEC might be a suitable basis for predicting lime requirement. This technique would suggest that only some 1.01 tonne/ha (≡ 1010 meq/Ca^{2+}/m^2) would be required, and this could nearly be supplied by the basal treatment of 1.25 tonnes/ha basic slag applied to all plots (1.25 tonnes slag ≡ 0.6 to 0.8 tonnes $CaCO_3$).

It may be concluded that the lime requirement predicted from 50% CEC has been shown at one field site to give satisfactory results, and that the amounts of lime required to attain greatly increased levels of improved herbage production from this soil are very small.

Soil Chemistry and Plant Nutrition (04011/04003)

4. Preliminary study of soil properties associated with acidity and phosphorus fixation in a range of Brown Forest soils

L.J. Mitchell and M.J.S. Floate

The specification of the improvement needs of Brown Forest soils is important because these soils are likely to have a high potential for improved pasture production. Their requirements for improvement may vary dependent upon inherent characteristics. Phosphorus requirements may depend in the short and long term upon P-status, P-fixing capacity and some properties associated with acidity which may be related to P-fixation and reduced P-availability. Exchangeable aluminium and its relationships with exchangeable calcium are likely to be important, so a preliminary study has been made of eight soils covering a wide range of Al-levels, and representing Brown Forest soils from East and West Scotland developed on a variety of different parent materials.

Phosphorus retention by soils has been shown to be correlated with Tamm extractable sesquioxides (Bromfield, 1965, and Halstead, 1967) and Williams et al (1958) showed that removal of sesquioxide reduced P-retention by 5-20% of that of the original soil. Attempts have been made to measure the degree of saturation of the anion exchange capacity but this is difficult on practical and theoretical grounds. As an approximation, Bache and Sharp (1974) have suggested an index value referred to here as Bache Sorption Index (BSI). The sorption index characterizes northern slopes for different soils measured at a single phosphate addition. This is measured by shaking soil with a known amount of P in solution, measuring the P remaining in solution after 18 hours equilibration (≡ c) and calculating the sorption index

$$= \frac{\text{mg P absorbed/100 g soil}}{\log_c}$$

This value has been measured for the eight soils studied here and in Tables 1 and 2 (see overleaf) are presented the data for individual soils, and the significance of the correlations between various properties. These results show a highly significant correlation between BSI and both extractable ($NH_4OA\bar{c}$) and exchangeable (KCl) aluminium. The correlations between BSI and pH and Fe (Tamm's extractant) were also significant.

P sorption characteristics of the soil are important with regard to the fate of added-P, but it is also important to assess the supply of native P from the soil which may be available for plant growth. Anion-exchange P was used as an improvement over conventional extraction methods which have been shown to be unreliable for some hill soils (see section 04003, p. C.5).

Sorption index was significantly and inversely correlated with Anion Exchange-P (r = -0.667) but the inverse correlation between Anion Exchange-P and $NH_4OA\bar{c}$-Al was more highly significant ($P < 0.1$). Because of the significant relationships between $NH_4OA\bar{c}$-Al and both BSI, and Anion Exchange-P, it is suggested that aluminium may play a dominant part in determining the availability of both native and added-P in these soils.

Exchangeable aluminium was not significantly related to soil pH for this group of soils and an examination of individual values (Table 1) suggests that this may be because the parent materials with different Al content give rise to soils with different levels of Exchangeable Al at similar pH values.

Table 1. Soil organic matter, pH, acidity, exchangeable cations, and phosphorus properties of eight soils

Soil Series (Classification)	Location (Parent material)	pH .01M $CaCl_2$	C %	Total P mg/100 g	Organic P mg/100g (% of Tot. P)	Anion Exch. P mg/100 g (% Tot. P)	Bache Sorption Index (BSI)	Cation Exch. Cap. meq/100 g	Exch. Acidity meq/100 g	Exch. Al^{3+} (NH_4OAc) meq/100g (pH 4.6)	Exch. Al^{3+} meq/100 g (soil pH)	Al. fraction	Exch. Ca meq/100 g	Exch. Mg meq/100 g	Tamm Fe %	10* AR Actvty Ratio
Minchmoor A Peaty Podzol	Minchmoor Greywacke	3.1	3.9	69.4	45.0 (78.0)	0.87 (1.3)	37	8.77	11.0	5.0	5.1	6.7	0.21	0.46	1.60	0.117
Sourhope Brown Forest	Sourhope Andesite	3.6	8.7	176.9	166.3 (87.0)	6.1 (3.6)	37	13.49	10.5	5.0	7.6	10.5	1.63	2.24	0.30	0.141
Linhope Brown Forest	Stanhope Greywacke	3.4	9.8	290.0	187.5 (60.0)	12.90 (4.4)	39	10.10	10.5	6.6	6.7	10.2	0.54	0.94	1.20	0.729
Fungarth Brown Forest	Lephinmore Schist	4.0	4.9	30.0	38.8 (66.0)	1.04 (1.3)	44	5.31	7.4	5.0	3.5	7.4	0.69	0.39	0.93	3.201
Hiraethog Peaty Podzol	Llansannan Shale/Slate	3.2	8.3	40.6	31.3 (93.0)	0.90 (2.2)	43	13.87	15.1	5.0	12.7	15.6	0.77	0.58	0.53	0.153
Minchmoor B Peaty Podzol	Minchmoor Greywacke	3.7	2.9	75.6	37.5 (62.0)	Tr -	61	7.84	10.8	5.6	7.9	10.8	0.13	0.18	3.30	0.008
Darleith Brown Forest	Carter Bar Basalt	3.8	13.2	278.3	98.8 (88.0)	0.62 (0.2)	102	14.58	14.1	13.8	10.4	12.8	0.52	0.56	4.10	0.116
Darleith Brown Forest	Mull Basalt	4.5	9.6	120.6	297.5 (92.0)	Tr -	128	11.08	11.6	15.7	7.5	11.6	0.71	1.14	4.40	0.126

Table 2. Probability values for significance of correlations between soil organic matter, pH, acidity, exchangeable cations, and soil phosphorus properties for eight soils

	1 pH	2 % C	3 Tot. P	4 Org. P	5 Anion Exch. P	6 BSI	7 CEC	8 Exch. Acidity	9 NH_4OAc Exch. Al^{3+}	10 Exch. Al^{3+}	11 Al fraction	12 Exch. Ca^{2+}	13 Exch. Mg^{2+}	14 Tamm Fe	15 10* AR
1 pH	0														
2 % C	–**	0													
3 Total P	–	0.02	0												
4 Organic P	–	0.05	–	0											
5 Anion Ex P	–	–	–	–	0										
6 BSI	0.01	–	–	–	0.03	0									
7 CEC	–	0.01	–	0.01	–	–	0								
8 Exch Acidity	–	–	–	0.03	Ex	–	0.1	0							
9 $NH_4OAcExAl^{3+}$	0.01	0.07	–	0.04	0.05	0.01	–	–	0						
10 Exch Al^{3+}	–	0.07	–	–	Ex	0.01	–	–	–	0					
11 Al fraction	–	–	–	–	–	–	–	0.01	–	–	0				
12 Exch Ca^{2+}	–	–	–	–	–	–	–	–	–	–	–	0			
13 Exch Mg^{2+}	–	–	–	–	–	–	–	–	–	–	–	0.01	0		
14 Tamm Fe	0.05	–	–	–	0.01	0.01	–	–	0.01	–	–	–	–	0	
15 10* AR	–	–	–	–	–	–	Ex	–	–	–	–	0.01	–	–	0

** Indicates non-significant correlation.

There are a series of interesting significant correlations between %C ↔ CEC ↔ Exchangeable Acidity ↔ Al fraction (exchangeable Al^{3+} expressed as % of exchangeable acidity), which is in agreement with, and perhaps help to explain, the correlation between OM, Al, P sorption observed by Williams et al (1958). It is also of interest in relation to the data presented under Project 04011 (p. C.70). The results for this group of eight soils - ranging in organic matter content from 3-13% C - suggests that %Al saturation of CEC might be related to lime requirement: when a wider range of soils covering 10-90% organic matter (04011) is included, CEC seems to be the more important determinant of lime requirement.

Bache and Sharp (1974) suggested that the ratio of divalent to trivalent ions on the exchange sites was important in controlling the activity of Al^{3+} in the soil solution. Amounts of exchangeable Al^{3+}, Ca^{2+} and Mg^{2+} have been measured and the ratio of acid to base ions calculated. The value of these measurements in calculating Activity Ratios and the interpretation of such results with regard to the behaviour of ions in solution as single ionic species or in the presence of other ions, viz. soil solution, has not yet been reconciled with Bache and Sharp's technique.

These observations emphasise the differences between soils on different parent materials which may appear similar but which may require different treatments to establish and maintain improved pastures.

References

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5. Interactions between soil acidity and the availability of native and added phosphorus

Lucy J. Mitchell and M.J.S. Floate

Preliminary studies with eight Brown Forest soils described in the previous section showed that P-sorption index (Bache and Williams, 1971) was significantly correlated with certain soil properties including exchangeable Al^{3+}, and that some measurements of "available"-P were inversely related to the same properties.

The results suggested that plant growth experiments with calcium and phosphorus treatments applied to different soils would be of value in studying the factors affecting the availability of native and added P.

Four soils were selected for use in a pot experiment in which the main objectives were to examine the effects of a range of Ca and P treatments on soil properties, plant DM production, and P-uptake. A further objective was to compare the availability of P measured by various laboratory procedures with the availability of P to ryegrass grown in pots. Some properties of the four soils are given in Table 1.

Table 1. Properties of four Brown forest soils used in pot experiment to investigate the availability of native and added P

Soil Series (Location)	Parent Material	pH (.01 M) ($CaCl_2$)	% C	P Sorption Index	Exch Al^{3+} meq/100g	Total P mg/100g	Anion Exchange P mg/100g
Linhope (Stanhope)	Silurian Greywacke	4.2	2.6	27	3.2	65	2.3
Fungarth (Lephinmore)	Highland Schist	4.2	3.2	44	3.2	75	2.0
Sourhope (Sourhope)	Andesite	3.5	5.3	45	8.4	118	2.5
Darleith (Carron Valley)	Basalt	3.9	4.6	240	15.1	214	1.1

Treatments included two rates of lime (L_0 and L_1 where L_1 = 1.25 tonnes/ha Ca CO_3), two rates of gypsum (G_0 and G_1 where G_1 = Ca^{2+} equivalent to L_1) and two levels of superphosphate (P_0 and P_{80} where P_{80} = 80 kg/ha P), and basal treatments of N and K. These treatments were mixed with five replicates of 300 g of each soil, wetted and maintained at 60% field capacity during storage in pots in the dark from April to mid July. After three months the pots were seeded with ryegrass and harvest cuts were taken at intervals until the end of September. At the end of the growth period roots were separated, weighed and analysed.

Total dry matter production data are presented in Table 2, and P-uptake data for some treatments on two soils are shown in Fig. 1. (see over). These data show that, for the control treatments, yields were low on all soils (not greater than 1500 kg/ha) compared with almost 9000 kg/ha on highest yielding treatments.

Table 2. Total ryegrass DM production from four soils with applied Ca and P treatments (g/pot)

n = 4
cv = 9.5%

$\sum H_1 + H_2 + H_3$ + stubble

	Sourhope	Fungarth	Linhope	Darleith
L_0 P_0 G_0	1.05	0.79	1.17	0.38
L_1 P_0 G_0	1.34	0.82	0.97	1.15
L_1 P_0 G_1	1.54	0.94	1.00	1.14
L_0 P_0 G_1	0.63	1.11	1.34	0.40
L_1 P_1 G_0	6.38	5.72	6.50	5.10
L_0 P_1 G_1	5.46	6.83	6.98	1.34
L_0 P_1 G_0	6.30	6.55	6.95	6.55
L_1 P_1 G_1	6.66	5.66	6.67	5.36

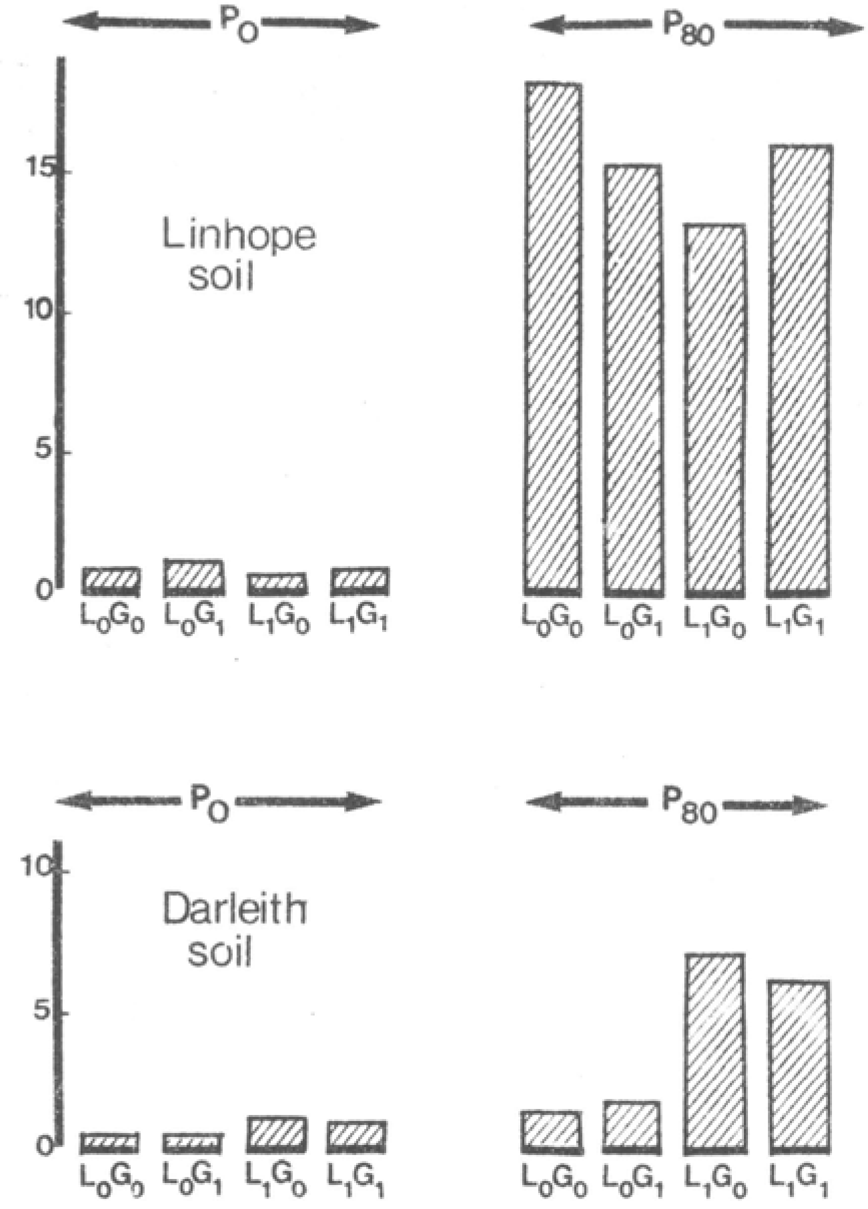

Fig. 1. P-uptake by ryegrass (mg/pot) on Linhope and Darleith soils.

The soils were ranked in the following order:

Linhope (Lp) ≫ Sourhope (Sh) > Fungarth (Fu) ≫ Barleith (Bl).

Lime added at the equivalent of 1.25 tonne/ha doubled yield and increased P-uptake on Barleith, and slightly increased yield on Sourhope but had no significant effect on the other soils. As an alternative source of calcium, gypsum gave no response on Barleith and reduced yield on Sourhope soil. Added phosphorus alone produced a very large response on three soils (Sh, Lp, Fu) (including a 10-fold increase in P-uptake on Linhope, but gave very little response on Darleith. Lime together with superphosphate gave similar yields to P alone on these 3 soils (Sh, Lp and Fu)) and produced a highly significant increase in DM yield and P-uptake on Darleith soil. Addition of gypsum together with P on this soil gave DM yield and P-uptake not significantly different from P alone. Lime and gypsum together with P on the other three soils gave evidence of depressed yields in some cases. (For other examples of Lime x P negative interactions see Project 04003, p. C.8).

Root DM yields gave results broadly similar to those reported above for shoot DM.

These results suggest that the availability of native P is low in all four soils, and, despite the much higher total P content of Darleith soil, its availability to ryegrass is less than in all other soils. Lime increased the availability of native P on Darleith soil, but had little effect on DM yield on the other soils. Addition of superphosphate increased the available P content (as estimated by laboratory techniques) of all four soils but DM yield and P uptake was not significantly increased on Darleith soil. P together with lime gave a highly significant positive interaction on this soil. This was the major difference between soils observed in the pot experiment.

In an attempt to explain these differences a comparison has been made of soil properties before and after treatment in Linhope and Darleith soils. Before treatment differences may be summarised: Darleith soil had a high cation exchange capacity, 85% saturated by exchangeable Al^{3+} compared with lower CEC and exch. Al^{3+} in Linhope; P sorption index in Darleith was very much higher than any other soil and although its total-P content was also higher, both amount and proportion of anion exchangeable-P were lower than in any other soil. Addition of lime to Darleith soil gave a pH increase of 0.5 unit compared with 1.0 unit increase on Linhope soil and this was associated with a reduction in amount of exchangeable Al^{3+} from 9 to 2 meq/100 g, and from 15 to 8 meq/100 g on Linhope and Darleith soils respectively. It seems likely that some or all of these changes associated with the addition of Ca^{2+} as $CaCO_3$ but not as $CaSO_4$, provide an explanation for the observed increase in DM yield and P-uptake on Darleith soil with added lime + P, and for the failure of ryegrass to respond to applied P in the absence of lime. However, Bache sorption index was only reduced by a small amount by lime whereas P treatments caused a very significant reduction in all soils. The reasons for this observation and the reasons why Ca^{2+} as $CaCO_3$ but not as $CaSO_4$ are effective in increasing P uptake remain to be explained. Further research is required for a proper understanding of these effects and to quantify the relationships described above.

High levels of exchangeable Al^{3+} in soils could lead to high concentrations in solution (at low soil pH) and to aluminium toxicity in plants but one reported sympton of this condition is a shortened and malformed root system which was not observed in our experiments. The symptoms of leaf-tip browning and die back observed in the lowest yielding treatments on Darleith soil were more characteristic of P-deficiency and it is suggested that the cause might be aluminium induced P-deficiency.

Plant shoots and roots from the Linhope and Darleith soils have been analysed for Ca, Al and P content and some results are given in Table 3. These data show that the aluminium content of roots are much higher than leaves and exceeds 4000 ppm in one treatment on Darleith soil. The ratio of P:Al is also lower in roots than in leaves and, on Darleith soil, root ratios are all less than 1.0 due to the high content of aluminium.

Table 3. Root and shoot Al and P content for some treatments applied to Linhope and Darleith soils

Soil	Linhope				Darleith			
Treatment	L_0P_0	L_1P_0	L_0P_{80}	L_1P_{80}	L_0P_0	L_1P_0	L_0P_{80}	L_1P_{80}
Shoots								
% Al	.04	.03	.01	.01	.01	.02	.05	.02
% P	.09	.09	.27	.20	.06	.10	.13	.15
P:Al	2.25	3.00	27.0	20.0	6.00	5.00	2.60	7.50
Roots								
% Al	.07	.07	.13	.05	> .50*	.12	.48	.16
% P	.11	.11	.19	.11	.09	.11	.17	.15
P:Al	1.57	1.57	1.46	2.20	< .18	0.92	0.35	0.94

* Actual values were greater than 1.0 but some soil contamination was possible

These high values for root aluminium and low ratios of P:Al suggest that aluminium could be interfering in plant physiological processes, or that it is rendering soil-P unavailable; they do not suggest mutual precipitation of Al-P compounds within the plant root because root P levels are not abnormally high.

Further research is planned to investigate the apparent low availability of phosphorus to plants in Darleith soil to which superphosphate has been applied.

The final objective in these experiments was to compare chemical and biological assessments of phosphorus availability in the treated soils, but not all analytical results are yet available. Results to date suggest that chemical measurements of P availability will only apply when there are no other constraints to plant growth. In Darleith soil the effect of high levels of Al in the soil seems to be restricting root growth, thus reducing nutrient uptake, and the expected response to P.

Reference:

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SOIL ANALYSIS

04003, 04007, 04011/54002

1. Method development: continuous flow analysis of soil extracts

A.D. Ironside

Due to the large number of soil extracts requiring analysis, faster and more versatile coloration techniques have become necessary.

In the case of phosphorus, an existing continuous flow coloration technique (Allan, 1974) has been developed and modified. Various P-concentration ranges in different extracts can be measured by changing pump-tube sizes, reagent concentrations and sample-wash composition. Table 1 gives the extracts that can now be analysed together with their respective concentration ranges, relative precisions and lower detection limits.

Table 1.

Extract		Standard Range (mg P/litre)	Relative Precision (%)	Lower Detection Limit (mg P/litre)
Name	Reagents			
Morgan's	NH_4OAc	0 ⟶ 1	± 1.5	0.02
Water Soluble	H_2O	0 ⟶ 1	± 1.0	0.02
Truogs	0.002N H_2SO_4	0 ⟶ 1	± 1.0	0.02
Acetic Acid	CH_3COOH	0 ⟶ 1	± 1.0	0.02
Anion-Exchange	0.5 M HCl	0 ⟶ 2	± 1.0	0.02
Morgan's	NH_4OAc	0 ⟶ 5	± 1.0	0.1
Water Soluble	H_2O	0 ⟶ 6	± 1.0	0.05
Bache's	0.02 M KCl	0 ⟶ 10	± 1.0	0.1
Total	H_2SO_4, Se, H_2O_2, Li_2SO_4	0 ⟶ 25	± 1.0	0.3
Organic	1 N H_2SO_4	0 ⟶ 60	± 1.0	0.4
Bache's	0.02 M KCl	0 ⟶ 60	± 0.5	0.2

Interference is caused by the citrate ion in Citric Acid Soluble-P, Neutral Ammonium Citrate Soluble-P, and Alkaline Ammonium Citrate Soluble-P solutions. Further development is therefore taking place to eliminate this.

Since use of Stannous Chloride as a reducing agent causes noticeable base-line drift, the use of Ascorbic Acid and 2-amino-4-sulphonic acid as reducing agents is also being investigated.

Aluminium in ammonium acetate and KCl extracts is now being measured using a modification of an existing continuous flow analysis procedure (Lancaster and Balasubramanian, 1974).

Iron in Tamm's Oxalate Extractant (3% oxalic acid) is measured using a modification of the automated procedure developed by Quarmby and Grimshaw (1967), due to interference caused by oxalate ions, the extract requires dilution by a factor of 5 and dialysis before the colorimetric determination takes place. The standard range for this method is 0 ⟶ 50 mg Fe/litre, the Relative Precision is ± 1.5% and the Lower Detection Limit is 0.5 mg Fe/litre.

References:

ALLEN, S.E. (1974). ed. Chemical analysis of ecological materials. Oxford, Blackwell Scientific. 32.4 and 85.12.

LANCASTER, L.A. and BALASUBRAMANIAM, R. (1974). An automated procedure for the determination of aluminium in soil and plant digests. J. Sci. Fd. Agric. 25 (4), 381-386.

QUARMBY, C. and GRIMSHAW, H.M. (1967). Rapid method for the determination of iron in plant material with application of automatic analysis to the colorimetric procedure. Analyst, Lond. 92, 305-310.

GLASSHOUSES, GROWTH ROOMS, MICROCLIMATE

54001:

D. Suckling

The growth rooms and constant temperature room have been functioning reasonably well throughout the year with only a few breakdowns. Glass-house use has been at a fairly high level.

Output from the two automatic weather stations at Lephinmore and Glensaugh has been reasonable during the year until after the onset of winter when both loggers broke down.

Table 1 (see over) gives an example of the final output from the Lephinmore system. Column (i) gives the date whilst column (ii) gives a spot reading of the 0900 h temperature on any selected channel in this case of column (viii). The number of scans used to make up the daily totals and means is shown in column (iii). Daily rainfall totals are listed in column (iv) and column (v) shows the daily total windrun in kilometers. The wet bulb and dry bulb temperatures in columns (vi) and (vii) are both measured in a Stevenson Screen. Columns (viii) and (ix) are ground surface temperatures taken at different parts of the site and (x) and (xi) are temperatures at 5 cm depth at two different locations. Columns (xii) and (xiii) show the daily minimum and maximum temperatures from column (vii) - the Stevenson Screen dry bulb temperature. All temperatures shown in the table are meaned over 24 h from 0900 h.

The original program for translating logger output has been extensively modified by Don Bruce and soon facilities will exist that will make extraction of particular forms of data much easier.

Table 1. Example of output from Lephinmore Automatic Weather Station

(i) Day	Mth	Yr.	(ii) 0900 temp. on channel 'Temp. 1'	(iii) Number of Scans	(iv) Rain mm	(v) Windrun km	(vi) Wet bulb °C	(vii) Dry bulb °C	(viii) Temp 1 °C	(ix) Temp 2 °C	(x) Temp 3 °C	(xi) Temp 4 °C	(xii) Min. °C	(xiii) Max. °C
1	6	77	18.0	96	0	238.1	6.0	11.0	32.2	26.2	9.8	9.0	5.2	16.0
2	6	77	19.4	96	0	334.2	6.5	10.6	28.4	25.6	8.8	7.6	5.3	15.0
3	6	77	12.3	96	0.5	664.6	6.2	8.7	30.1	23.1	9.1	7.9	4.5	12.9
4	6	77	10.1	96	9.0	1040.3	4.5	7.1	21.0	19.3	7.5	5.9	5.7	9.9
5	6	77	10.1	96	9.0	895.2	1.0	5.1	19.5	16.1	6.5	6.1	2.3	8.5
6	6	77	2.5	96	26.5	969.4	-1.1	2.4	10.7	11.3	3.1	0.9	0.3	5.3
7	6	77	8.5	96	0	823.7	1.2	4.8	23.0	19.6	4.4	3.4	2.0	8.6
8	6	77	8.4	96	6.5	776.8	2.4	5.8	13.2	14.0	3.8	2.4	4.2	7.8
9	6	77	10.2	96	9.5	867.6	2.1	6.1	19.0	17.2	5.4	4.8	2.6	10.2
10	6	77	10.0	96	0	1327.5	0.6	6.1	19.0	16.6	5.6	6.0	2.3	10.2

ANALYTICAL SERVICES

54002

1. Inorganic Chemistry

C.C. Evans and J. MacKenzie

During the year 17800 analyses were made from 11600 samples of plant tissues, soil extracts, biological fluids including blood, ruminant digesta and milk.

The PW1212 automatic X-ray spectrometer is now in routine use and has increased analytical throughput significantly. However, due to problems associated with the power supply to the excitation tubes, 'down-time' has been at an undesirable level.

Method development

In order to streamline the blood plasma Cu determination procedure was introduced involving the dilution of the sample with an aqueous solution of 7.4% n-butanol. This procedure supercedes one involving a protein precipitation stage prior to Cu estimation.

The suitability of the wet digestion procedure of Parkinson and Allen has been evaluated in association with Dr. Pimplaskar and A.D. Ironside for the determination of phosphorus in plant materials. This procedure involve the molybdenum blue colorimetric estimation of the digest solution. Results from samples analysed by this method and by the standard X-ray spectrometric procedure were in excellent agreement in the range 0.15-0.45% P indicating the suitability of the wet digestion method for herbage phosphorus analysis.

Reference:

PARKINSON, J.A. and ALLEN, S.E. (1975). A wet oxidation procedure suitable for the determination of nitrogen and mineral nutrients in biological material. *Commun. Soil Sci. Pl. Anal.* *6*, 1-11.

2. Tracer Chemistry

A.R.M. Chambers

The use of radioactive tracers in HFRO has greatly increased over the last year, notably by the animal nutrition department. During the year 16400 samples have been counted. The isotopes that have been used are ^{3}H, ^{14}C, ^{57}Co, ^{103}Ru and ^{51}Cr. All the samples have been counted using the Nuclear Enterprises Automatic Beta Gamma Spectrometer NE 8312. ^{3}H and ^{14}C have been counted using liquid scintillation techniques and ^{57}Co, ^{103}Ru and ^{51}Cr have been counted using the gamma head which contains a NaI (H) crystal.

3. Electronics

A.R.M. Chambers

In addition to the work carried out on the projects listed below, various electronic instruments have been repaired and maintained, and advice on electronics has been given to members of staff.

a) <u>Measurement of the grazing behaviour of sheep and cattle using automated equipment</u> (for Project 03003)

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

Measurement of the mechanics of the grazing process are important to an understanding of the effects of sward characteristics on diet selection and herbage intake. Particular importance is attached to observations on jaw movements during the prehension, severing and swallowing of mouthfuls of herbage, and of the time spent in grazing. Without the aid of automated equipment these measurements are very labour-intensive, and some are very difficult to make.

Equipment has been designed and built to measure the number of jaw movements during grazing and rumination, the number of grazing bites taken, and grazing time, and has been tested in the field. The equipment consists of:-

1. A micro-switch attached to a head harness which is activated by a tension strap under the lower jaw, and thus senses all jaw movements.

2. An accelerometer mounted on the head harness which responds to movement of the head in the longitudinal plane, and thus senses the characteristic head-jerk associated with teasing off a mouthful of herbage.

3. A switch mounted on a shoulder harness and actuated by a cord attached to the head harness when the head is in the grazing position.

4. A small recording, display and battery pack mounted on the shoulder harness, incorporating an LCD display, mercury batteries with an effective life of five days, and a timing device.

There are four counters in the recording unit, allowing the monitoring of:-

a) The total number of jaw movements (sensor 1).

b) The number of jaw movements during grazing (sensor 1 modified by 3).

c) The number of grazing bites (sensor 2 modified by 3).

d) The time spent grazing, counted in units of 5 seconds, whenever counter c) is activated.

A prototype was tested successfully on sheep in the field by transferring outputs from the sensors to a chart recorder, using a VHF transmitter and receiver, and comparing the chart record with visual records. It is intended to use a number of units in sheep grazing studies during 1978, and also to investigate their use on cattle.

b) <u>Leaf area measuring device</u> (for Project 04006)

A.R.M. Chambers and W.I.C. Lamb

A leaf area measuring device has been designed and is in the process of being built.

The detector head of the device consists of 15 photo diodes and 15 photo transistors. To each photo diode is fitted 15 plastic light pipes which are positioned such that each can be 'read' with one photo transistor; this forms an array of 225 light sources which are read individually by pulsing the photo diodes separately and by reading the photo transistors at the appropriate times. The device is designed so that the leaf is passed at a constant speed between the light pipes and photo transistors. The electronic circuit will count each time any light beam is interrupted by the leaf as it passes through the detector head. The total count, after the leaf has passed through, will give an integrated value of the widths of the leaf over its length, thereby giving an estimate of its area. The light pipes are $\frac{1}{2}$ mm diameter, and the leaf will be scanned at a rate such that the width will be measured every $\frac{1}{2}$ mm along its length; this will give an overall resolution of 0.25 mm^2. The leaf is passed through the detector head sandwiched between two pieces of glass, which are held on a moving table driven by an electric motor at a speed of 1 cm/sec. The detector head has a 'reading' width of 11.25 cm and the length of sample which can be measured is 30 cm.

It is hoped that this leaf area measuring device will be at least as sensitive as the commercially available devices, and that it will be produced at a fraction of the cost.

c) Environmental control in photosynthesis chambers (Project 04006)

A.R.M. Chambers and W.I.C. Lamb

Temperature Control

Two proportional heater control circuits have been designed and built for regulating the temperature in cuvettes. These held the required air temperature to ± 0.25°C over the range 15°C to 25°C.

Dew Point Measurement and Humidity Control

A device for measuring the dew point temperature and for controlling the humidity automatically in a cuvette has been designed and is in the process of being made. The dew point temperature is measured by cooling a strip of metal, using a Peltier cooling module, until dew forms. The formation of dew is recognised by measuring the amount of light reflected by the strip from a photo diode to a photo transistor. The amount of light reaching the photo transistor drops on dew forming, and at this point the temperature of the strip is measured and recorded. The actual dew point temperature is then compared with the required dew point temperature, and the difference in the two is measured, and used to give information to the humidity control circuit to bring the humidity automatically to the correct level.

The device has been designed so that it will be small enough to be incorporated into a leaf cuvette system, and at the present there is no commercially available device which can be used for this.

d) The development of a method for the measurement of urinary output in grazing female sheep

A.R.M. Chambers and I.R. White

The urine measuring and sampling equipment (UMASE) has been designed and built for use with either penned or grazing female sheep to measure the volume of urine excreted over a 24-hour period and to collect a sample of urine which is compositionally representative of that excreted throughout the period of measurement. The apparatus measures the urine output in units of 40 ml. Urine flows from the sheep into a measuring vessel in which the level is monitored using optical switches. When the vessel is full, a sample is taken (4%) and the remainder of urine in the vessel is drained to the outside. When the vessel has emptied, urine from the sheep is again directed into the vessel and the cycle repeats. The flow of urine in and out of the measuring vessel is controlled by a three-position stopcock driven by an electric motor. The equipment is fitted with a counter which shows the total number of cycles operated, and thus the total volume or urine measured by the apparatus. The motor is controlled by an electronic circuit designed using 'CMOS' integrated circuits.

Following the use of the apparatus at Lephinmore during 1977, several improvements have been made to the equipment:-

a) The electronic circuit has been altered so that bubbles which get trapped in the urine in the measuring vessel when the animal moves violently, do not effect the control logic.

b) The voltage regulation has been improved so that it is now possible to run the equipment from alkaline manganese batteries which greatly reduces the overall weight of the equipment and simplifies the running of the equipment.

c) The filter for removing solid material in the urine has been improved by increasing the filtering surface area, thereby reducing the need to change it during a 5 day running period.

e) <u>The determination of foetal number during late pregnancy</u> (Project 02002)

A.R.M. Chambers, I.R. White and A.J.F. Russel

The determination, some six to eight weeks before lambing, of the number of foetuses carried by individual ewes would constitute a significant advance in the management of the ewe flock at around lambing time. Such a technique would afford considerable financial advantages. It would allow the flock to be divided into groups of ewes with similar nutrient requirements, and thus make more efficient use of the supplementary feeding given before lambing. It could also be expected to lead to a reduction in lamb mortality, by allowing attention to be focussed at lambing time on the ewes carrying twins, and by ensuring, through proper nutrition, that the birth weights of twin lambs were not reduced to any significant extent.

To have wide practical application, the technique of determining foetal numbers must be capable of dealing with a large number of animals quickly, and it must provice an immediate diagnosis. Radiographic techniques can meet these requirements, but are likely to be too expensive to be used in commercial practice.

We have recently investigated the use of an instrument - the Sonicaid Foetometer - which is commercially available. It is designed to detect small movements within a body, and functions on the Doppler principle at a frequency of 2MHz. Low intensity ultrasound is transmitted into the body from a small transducer, and is reflected from the interfaces within that body. If these interfaces or boundaries are in motion the frequency of the reflected signal is altered and the change detected by the instrument.

Although it is possible with this instrument to determine fairly readily whether or not a ewe is pregnant, it is, in our opinion, not suitable in its present form for the rapid determination of foetal numbers. The instrument is designed to be used with a transducer applied to the external surface of the abdomen, and for a positive identification of a multiple pregnancy it is necessary to locate at two separate points foetal hearts which are beating at different rates. In practice, this is very time consuming.

The instrument has been modified by incorporating a "twin-D" crystal transducer in a small rectal probe to scan the area where the foetus or foetuses are lying. A number of crystals of different specifications have been used to give varying combinations of area covered and degree of penetration. The transmitting power of the crystals has also been increased, and a further amplifier and filter stage built into the receiver circuit. The signal received can be displayed on an oscilloscope to allow its components to be examined visually as well as aurally. To date the results of the trials with this modification of the instrument have been disappointing. X-ray examination of the position of the foetus in relation to the rectal probe indicates that pockets of gas in the intestines may be absorbing the ultrasound and weakening the signal.

We have also attempted to tackle the problem by converting the instrument into a single crystal scanner by pulsing the transmitter circuit. The high reflectancy of bone to ultrasound enables the foetus or foetuses to be located relatively easily by this approach but is not possible to determine with any certainty the number of foetuses represented by the bone mass.

Another approach which has been examined involved the building of a sonic device for detecting low frequency waves. This was made using a quartz crystal as a receiver, and two frequency amplifiers with high gain characteristics in the frequency range 0 to 30 cpsec. The output signal of the amplifiers was fed into a waveform generator circuit in such a way that the output audio frequency of the circuit was modulated. The output of the generator was then fed into an audio amplifier. With this device it was possible to detect very small low frequency waves by examination of the audio modulation. As with the other instruments examined, this worked well in laboratory trials but when used on the sheep it was not possible to differentiate the foetal heart from the other sources of noise within the sheep. It is concluded that this approach is likely to require a complex process to analyse the signal received from the probe.

A Sonicaid real time scanner incorporating 64 crystal receiver/transmitter arrays was recently loaned to us by the manufacturers. The crystals in this instrument are contained in a head which is applied to the external surface of the abdomen, and shows on a display screen an ultrasonic 'picture' of the area examined. Although it is relatively straightforward to use and, in skilled hands, would appear to give good results, it is considered that the time taken per ewe for a confident diagnosis of foetal numbers would be excessive, and that considerable experience would be required to interpret the display.

Although we have not yet been able to design an instrument which will allow us to determine foetal number quickly or accurately, a number of possibilities remain to be explored. Of these, we believe that the most fruitful is likely to make use of the Doppler principle and having improved transmitting and receiving circuits.

f) <u>A method for automating the scanning and recording of peak heights from a mass spectrometer (for Project 04003)</u>

A.R.M. Chambers

With the increase in the use of N15 and the subsequent increase in the number of analyses required, it was decided to automate the scanning and recording of peak heights from the mass spectrometer control unit. A circuit was therefore designed and built which had the following functions:-

(a) Amplify the output from the mass spectrometer control unit so that it could be displayed on a three-digit voltmeter such that there would always be three significant digits displayed on it. This involved building three X10 amplifiers in series, and circuitry which would switch the output of the appropriate amplifier, depending on the magnitude of the output of each amplifier, to the recording circuit.

(b) Detect the position of the required peak to be measured from the 'mass' output on the control unit.

(c) Measure the height of the required peak.

(d) Hold the information about the peak height and transfer it to the digital voltmeter circuit.

(e) Take the parallel information from the digital voltmeter and change it to a serial form suitable for transfer to a teletype.

(f) Take the information concerning the power of 10 by which the signal from the control unit was amplified, and the voltmeter reading and put the information on to the teletype.

The circuit has been built and is undergoing test.

g) <u>Thermo-gradient bar (for Project 04002)</u>

A.R.M. Chambers, J.A. Rogers and D. Bruce

The thermo-gradient bar consists of a piece of aluminium, 14 x 42 x 2 cm, which is heated at one end and cooled at the other. The hot end temperature is held constant by a low voltage heater in which the current is controlled by a comparator which compares the temperature of the hot end of the bar, as measured with a thermistor, with the required temperature. The cold end temperature is held constant using a Peltier effect cooling module in which the cooling is proportional to the current passed through it. Similar to the heating control circuit, the current through the cooling unit is controlled by a comparator which compares the temperature of the cold end of the bar with the required temperature. The hot side of the cooling unit is cooled with heat sinks through which water at room temperature is continually passed. To prevent silting up of the heat sinks, a closed system has been designed which runs on distilled water. The aluminium bar is covered with expanded polystyrene to insulate the bar from external fluctuations. The temperature of the bar is continually monitored at six positions along its length, using platinum resistance thermometers and the temperatures are recorded on a pen recorder.

During the year the bar has been used for several germination trials over the range 2°C to 9°C. During the hot weather, in the summer, the cooling power was insufficient to hold the cold end at a constant temperature due to excessive room temperatures. To overcome this problem, an air conditioning unit is being fitted in the room. A new heat sink is being made to overcome the problem of the water-flow rate being reduced during a germination trial, due to bubbles of gas being caught in the pipe. The standard deviation in temperatures along the bar, over the period of a germination trial, was found to be around 0.15°C.