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HILL FARMING RESEARCH ORGANISATION

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HILL FARMING RESEARCH ORGANISATION

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CONTENTS

HILL FARMING RESEARCH ORGANISATION

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A. ANIMAL PRODUCTION AND NUTRITION

REPRODUCTION

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

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

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

The reproductive responses of ewes are known to be positively related to body condition at mating but can be influenced by the current level of nutrition at certain intermediate levels of condition. Experimental evidence for these effects has largely been derived from studies in which required live weight and condition have been achieved by manipulation of nutrition to groups of ewes. Recent evidence, however, suggests that, in a grazing situation where ewes may eat to their own individual appetite, variation in voluntary intake may be linked to the variation in reproductive performance expressed by individual ewes within the flock. Studies in 1978/79 (see 1979 Annual Report) on North Country Cheviot ewes grazing good quality ryegrass/clover pasture for the last 4 weeks prior to mating have demonstrated an inverse relationship between DM intake at the time of mating, based on faecal nitrogen estimates, and body condition at 4 weeks before mating. Those ewes which had been in lean condition (grades 2-/2) at 4 weeks before were still eating at mating up to 35% more total DM (1473 vs. 1090 g/day) or 55% more per kg of mating live weight (22.0 vs. 14.2 g/day) than those which had been in fat condition (grades 3+/3½), while the intake at mating of ewes in intermediate condition at 4 weeks before was also intermediate. These estimates of intake were derived from sample ewes from within the flock. The reproductive responses of all ewes in the flock were also studied by the level of body condition at 4 weeks before mating and showed that ewes in intermediate condition, although still lighter and leaner at mating than the ewes initially in fat condition, had a similar ovulation rate (intermediate = 2.21, fat = 2.23) but a higher lambing rate (intermediate = 1.53, fat = 1.29). The ewes in lean condition at 4 weeks before mating, although gaining substantially in weight and condition, associated with their greater intake, were still lighter and leaner at mating than the rest of the flock and had a lower ovulation rate (1.87) but a similar lambing rate (1.33) to that of the initially fat ewes. The response of the ewes in lean and intermediate condition may be interpreted as being associated with their higher voluntary intake. This may be an explanation for the greater reproductive response to a high current level of nutrition, the flushing or dynamic effect, particularly in ewes in initially intermediate condition which at mating are still lighter and leaner than ewes in fat condition whose appetite is depressed. Work in this area continues.

2. The optimisation of pasture-use by North Country Cheviot ewes in different body conditions in the pre-mating period

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

Previous studies with the North Country Cheviot flock on East Finella at Glensaugh in 1977, '78 and '79 have shown that the reproductive response of ewes in poorer condition at 4 weeks before mating was at least as good if not better than that of ewes initially in good condition after all had been run on good pasture for the 4 weeks prior to mating. Since the poorer condition ewes were still lighter and in relatively poorer condition than the fatter ewes at mating, a dynamic response is implied. The question can therefore be asked as to whether it is necessary to provide such good nutrition for the better condition ewes during this time? It may be sufficient to provide only a maintenance level of nutrition for fat ewes and therefore have more good pasture for stimulating a dynamic response in leaner ewes. This might be done by providing two types of pasture resource and an experiment was run in 1980 to test this.

The flock was managed after weaning to widen the range of body condition by mid-October. It was then split into two groups by age and body condition. Pasture was made available in a series of paddocks of approximately 3 ha each. One paddock was previously managed to provide about 1200-1400 kg DM/ha by mid-October (M) and four other paddocks were managed to provide about 1900-2100 kg DM/ha (H). One group of ewes was put into paddock M and the other into one of the H paddocks on 17 October.

Calculations based on stocking rate (about 36/ha), standing crop and an estimate of daily consumption (1.75 kg DM/head/day) were carried out to determine the likely time (12-15 days) to graze paddock H, down to 1200-1400 kg DM/ha (pasture growth and therefore accumulation was considered to have ceased). Measurement of pasture was also carried out as a check on the above calculations.

When paddock H_1 was down to 1200-1400 kg DM/ha, group H was moved to paddock H_2 and group M was moved to paddock H_1. This system of group M following group H was repeated until after a synchronised mating. In this way group H was provided with the best of the available pasture and group M cleaned up what was left.

Standing crop of pasture in the H paddocks ranged between 1850 and 2500 kg DM/ha (mean approx. 2150) and was eaten off by group H to between 1100 and 1500 kg DM/ha (mean approx. 1250) in 10 to 17 days per paddock. Some difficulty was experienced in measuring residual standing crop after the period of grazing by group M, as a result of the little amount left, the high stocking rate for 3-4 weeks and the wet weather that predominated in November. Defoliation by group H (+ senescence) was in the region of about 1.85 kg DM/head/day.

Mean live weights (kg) and condition scores of the ewes initially $\geqslant$ condition 3- (F) and $\geqslant$ 2½ (T) on the high (H) and maintenance (M) pastures were:-

	No. of ewes*	17 Oct.	3 Nov.	13 Nov.	28 Nov.
FH	32	68.8	72.5	72.9	75.6
		2.87	3.02	3.06	3.19
FM	32	68.2	66.5	67.0	66.5
		2.85	2.77	2.69	2.89
TH	32	61.2	66.1	66.8	69.6
		2.27	2.60	2.77	3.00
TM	29	61.4	59.9	60.5	60.0
		2.28	2.36	2.38	2.55

* 3, 4 and 5-year-old ewes only.

Mating took place between 20 and 23 November.

The reproductive responses of these ewes were:-

	First mating			All matings		
	Lambing rate* ++	Litter size+	% of ewes lambed	Lambing rate*	Litter size+	% of ewes lambed
FH	1.53	1.81	84	1.72	1.77	97
FM	1.28	1.52	84	1.44	1.53	94
TH	1.47	1.62	91	1.59	1.59	100
TM	1.17	1.55	76	1.28	1.48	86

* Per ewe mated + Per ewe lambing
++ Ewes lambing to later matings are included as barren

The most striking result of this experiment was the enhanced response of the fatter ewes to the high level of pasture (FH), particularly in litter size which was significantly greater than that of the other three groups. This has to be related to the continued increase in live-weight and body condition achieved by these ewes and is probably due to their mean level of condition initially, which was less than that of the fatter ewes in previous years (see 1979 Report) which failed to respond and could therefore still be within the sensitive limits where dynamic response may be expected.

The thinner ewes on a high level of pasture (TH) responded well but not significantly more so than the thinner ewes on maintenance (TM) whose only real problem seems to have been an increase in barrenness. The fatter ewes on maintenance (FM), although having a similar mean litter size to the two groups of thinner ewes (TH and TM), had a lower lambing rate than the TH ewes but not significantly so with the numbers involved. Nevertheless, in relation to their live weight and condition at mating and to the amount of pasture which they were offered, the response of the FM ewes was sufficiently encouraging to justify further examination of the relative responses of fat and thin ewes to different pasture resources. The pasture resources were different not only in amount but also in quality, because of the system of group M following group H on the same area. Group H ewes had a choice of leaf while group M were left mostly sheath and stem. Such a differential would not necessarily be present with separate pasture resources previously prepared.

3. The optimisation of pasture-use by upland ewes in the recovery period

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

Earlier work on the Greyface systems studies at Glensaugh has demonstrated the importance of direction of live-weight change in the individual ewe around the time of mating in relation to lamb production. This has emphasised the need to avoid ewes losing live weight if lamb production is not to be adversely affected. Work continues in this area, mainly to determine the optimum live weight, body condition and pattern of change for most efficient reproductive responses and to examine management methods of achieving these on pasture. This also requires the determination of the optimum standing crop and pasture allowance or stocking rate for recovery to mating.

The present study was designed to compare set-stocking of pasture during the recovery period from late August, through mating, starting in late October, until early December, with the saving of pasture by exclosure from late August until opening up in mid-October at 2 weeks before the start of mating. Only one stocking rate was imposed, namely 12 ewes/ha set-stocked. Tentative calculations on likely pasture accumulation and consumption suggested that the saving of more than 50% of the area might impose too great a grazing pressure on the remainder during the 6 weeks of exclosure. The area exclosed was therefore fixed at 50% of the treatment paddocks.

The study was run at Glensaugh and there were two replicates, one in the Bows field which had been intensively grazed by sheep in the upland systems studies for at least 6 years and the other in the Near Woodside field which was a second year reseed and had been cut for silage. In both replicates, the herbage mass in all paddocks, namely the control and each half of the treatment (grazed and saved), was measured. There were differences in mass between the replicates initially and at the time of opening up the exclosed areas but these rapidly disappeared thereafter.

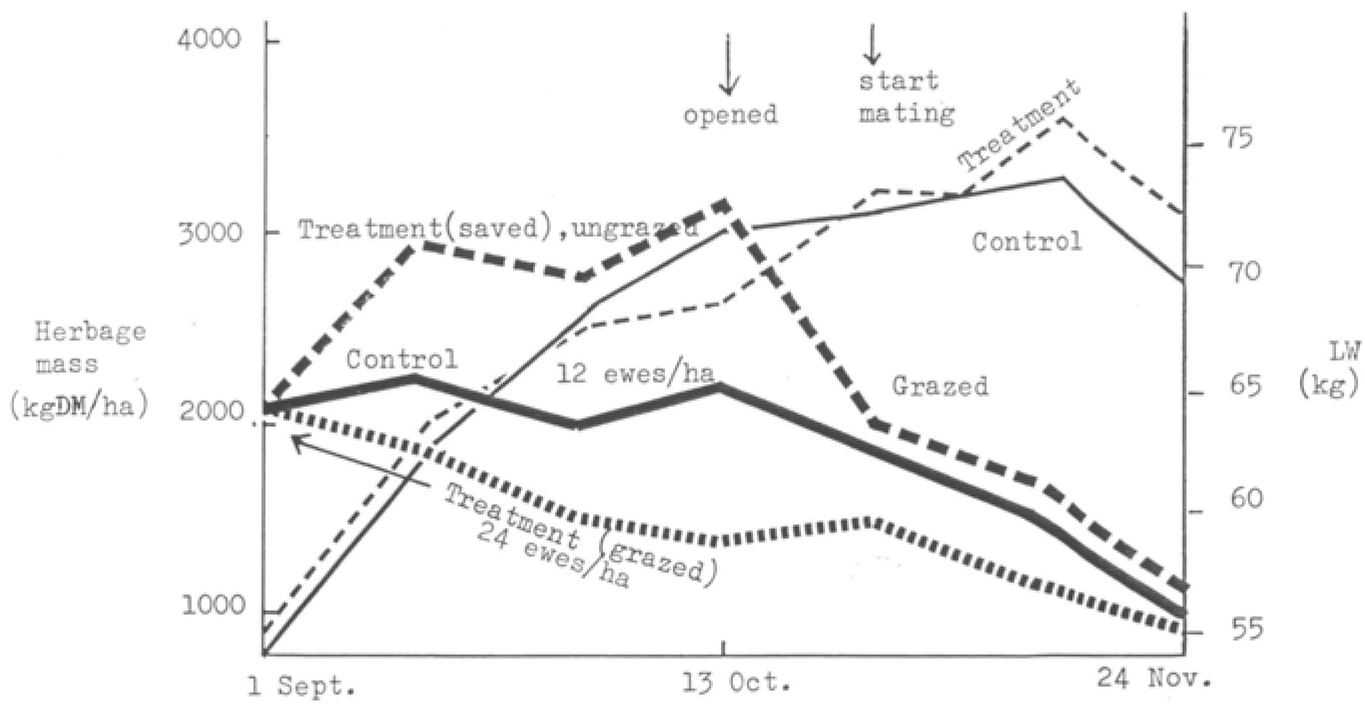
Table 1. Approximate levels of herbage mass (kg DM/ha)

Date		Stocking rate (/ha)	Bows	Near Woodside	Mean
25 Aug.			1700	2100	1900
13 Oct.	Control	12	2200	2200	2200
	Treatment	24	1200	1600	1400
		0	3000	3300	3150
24 Nov.	Control	12	1100	900	1000
	Treatment	(24)	(900)	(950)	(925)
		(0)	(1050)	(1250)	(1150)
		12	975	1100	1037

In both exclosed areas, there was a net pasture accumulation of about 25 kg DM/ha/day between 25 August and 13 October. Although not measured after opening up these areas to grazing on 13 October, growth and therefore accumulation had virtually ceased by that date. A mean estimate of consumption, based on measurement of mass before and after grazing plus accumulation, was approximately 1.75 kg DM/ewe/day between 1 September and 13 October and was lower on the Bows field (1.5) than on the Near Woodside (2.0). Between 13 October and 24 November, defoliation through grazing and senescence was at the rate of about 2.4 kg DM/ewe/day and was again lower on the Bows field (2.2) than on the Near Woodside (2.6).

Pasture allowance on the control paddocks started at 161 kg DM/ewe, rose to 184 kg by 13 October and fell to 83 kg by 24 November. On the grazed treatment paddocks, allowance was 78 kg initially and fell to 58 kg by 13 October. When the saved pasture was opened up on 13 October, total allowance on this (131 kg) plus the grazed area was 189 kg and fell to 86 kg by 24 November.

The GF ewes in this experiment were in relatively low live weight and body condition (55 kg and grade 2.19) at the start. Their LW responses and the changes in herbage mass over the period are shown in Figure 1. Liveweight recovery was rapid in both treatment and control groups and although the rate of recovery of the treatment ewes declined relatively towards the end of the period when stocked at 24/ha, they were still gaining when the saved pasture was opened up. Generally there was no decline in LW until the herbage mass fell to below 1500 kg DM/ha in mid-November.



Overall, there was no difference between the treatment and control groups in litter size to first mating (2.03 and 2.00, respectively) or to all matings (1.98 and 1.96, respectively). There was no effect of the level of condition 8 weeks before mating on litter size in the control group but there was a suggestion that litter size was greater in the initially leaner ewes in the treatment group (Table 2).

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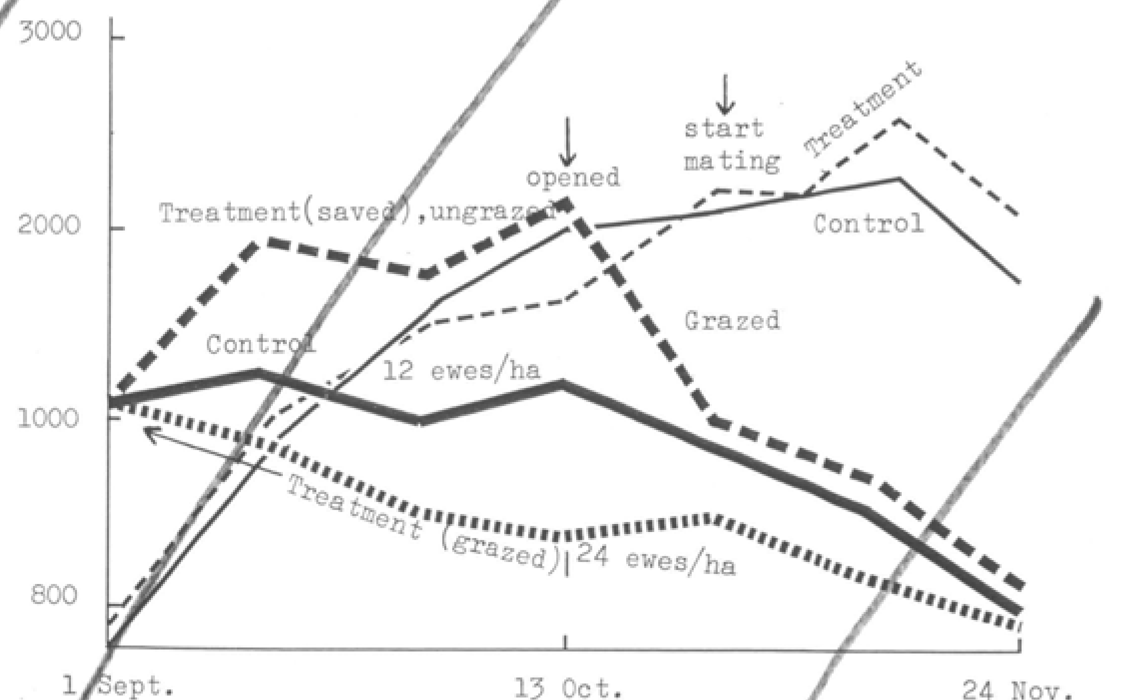

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Table 2. Condition score at 8 weeks before mating

	1½/2-	2/2+	2½/3-	3/3+
Control	1.93(14)	2.00(17)	1.91(11)	2.00(3)
Treatment	2.25(12)	1.92(13)	1.77(13)	2.00(4)

(Nos. of ewes in brackets)

The levels of pasture were clearly adequate for reproductive requirements at the stocking rate applied and there was no apparent advantage in saving pasture relative to set-stocking it, unless the above suggestion justifies differential management for fat and thin ewes.

It is of interest that the overall performance was better on the Near Woodside field than on the Bows (litter size 2.14 and 1.85, respectively, $P < 0.1$; lambed to first mating 89% and 75%, respectively). Although there were differences in herbage mass between these replicates, there were also considerable differences in morphology, the saved pasture in the Bows remaining mostly short and vegetative as well as being much denser than that in the Near Woodside which grew higher and became more reproductive. It is also possible that there was a lower worm burden associated with the young grass on the Near Woodside field which may have been responsible for the difference in animal response.

4. Fertility in East Friesland x North Country Cheviot ewes. Comparison of reproductive performance at the gimmer stage with pure-bred North Country Cheviot ewes on two different pasture resources

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

In the study on optimisation of pasture-use by North Country Cheviot (NCC) ewes in different body conditions in the pre-mating period (see elsewhere in this Report), the gimmer age was partly pure-bred NCC and partly East Friesland x NCC (EFX). Comparison of live weight and body condition in the two breeds during the experimental grazing period on high (H) and maintenance (M) levels of pasture standing crop was as follows:-

			17 Oct.	3 Nov.	13 Nov.	28 Nov.
NCC	H	19	57.2	60.7	61.3	62.8
			2.97	3.09	3.14	3.30
	M	16	56.2	55.1	55.5	54.3
			2.78	2.84	2.73	2.77
EFX	H	14	57.3	62.3	62.2	64.3
			2.54	2.80	2.88	3.00
	M	18	57.2	55.7	56.1	54.7
			2.53	2.58	2.50	2.56

Mating was synchronised and took place between 20 and 23 November. All were mated to the NCC.

Reproductive performance was as follows:-

		First mating			All matings		
		Lambing rate* ++	Litter size+	% ewes lambed	Lambing rate*	Litter size+	% ewes lambed
NCC	H	0.79	1.67	47	1.37	1.63	84
	M	0.94	1.36	69	1.06	1.31	81
		0.86	1.50	57	1.23	1.48	83
EFX	H	1.57	1.83	86	1.71	1.85	93
	M	1.44	1.86	78	1.72	1.72	100
		1.50	1.85	81	1.72	1.77	97

* Per ewe mated   + Per ewe lambing

++ Ewes lambing to later matings are included as barren

Live weight responses were very similar in the two breeds on each of the pasture resources. Between-breed differences in body condition score are not necessarily meaningful since the EFX is known to lay down a greater proportion of its fat reserves internally than does the NCC.

The EFX had significantly higher lambing rate ($P < 0.01$) and litter size ($P < 0.05$) to both first and all matings than did the NCC. The percentage of ewes lambing to first mating was also greater ($P < 0.1$). There was very little difference in performance of the EFX on the two pasture resources. Within the NCC breed it was not possible to compare the response of fat and thin gimmers, 31/35 being in the former category. Within the EFX breed, 11 fatter gimmers produced a mean 2.00 lambs, all to first mating, and significantly more ($P < 0.01$) than the mean 1.24 produced to first mating by the 21 thinner animals. This was, to a large extent, due to 29% barrenness to first mating, which was, however, still considerably less than that exhibited by the NCC. Barrenness virtually disappeared after later matings.

The EFX NCC is therefore a highly fertile and fecund cross-breed which appears capable of a high level of performance irrespective of pre-mating live weight, condition score or level of nutrition at maintenance or above.

5. Effects of age of ewe on ovulation rate and early embryo mortality

R.G. Gunn, J.M. Doney, W.F. Smith, T.K. Whyte, A.D.M. Smith and D.A. Sim

From 1975 to 1977, an experiment was carried out to examine the effects of age on ovulation rate and early embryo mortality in Blackface ewes, without the confounding effect of differences in body size which can arise when comparing ewes of different ages (see 1977 Report). A group of ewes born in 1975 was managed for 2 years to achieve a similar live weight and size at 2½ years as 1971-born draft-age ewes off the hill at

6½ years and their reproductive performance was determined at a standard body condition and pre-mating nutritional level.

The contemporaries of the 1975-born ewes remained on the Schil at Sourhope for their normal hill life-time and, when drafted at 6½ years in 1981, their adult body size (body length x chest depth x hip width) and reproductive performance were determined in the same standard states for comparison with those of the same age group in 1977 at 2½ years. An attempt to get all ewes into the 3 ± 0.25 condition score range at mating by feeding in the Sourhope shed from late September proved to be difficult because of initially low condition and too short a time to overcome it. Only 59 ewes out of 100 were therefore in the required condition range at mating. All ewes were fed at maintenance over the last 2½ weeks before a synchronised mating and until slaughter at 20 ± 2 days after mating.

Mean body volume, live weight (LW) and condition score (CS) of these ewes are compared in the following Table with their 2½-year-old contemporaries born 1975 and with the 1971-born 6½-year-olds.

Year Born	Age (years)	No. of ewes	Body volume (cu dm)	LW (kg) and CS at mating - 10 wks	mating
1975	2½	44	45.6	63.1 2.81	66.9 3.00
	6½	59	45.8	56.1 2.64	61.4 2.88
1971	6½	40	45.2	50.9 2.16	60.6 2.90

There was clearly little difference in body size between the 2½- and 6½-year-old ewes born 1975. The younger ewes were obviously heavier at the start in September and were able to respond to treatment and be heavier at mating. There was no difference in mating weight and condition between the 1975 and 1971 age groups at 6½ years.

Reproductive performance was as follows:-

Year Born	Age (years)	Ovulation rate	On day 20 ± 2 Ova loss (%)	Potential lambing rate	litter size
1975	2½	1.91	25	1.43	1.66
	6½	1.88	18	1.54	1.69
1971	6½	2.05	15	1.75	2.00

There was no difference in any parameter between the 1975-born ewes grown rapidly to 2½ years and their contemporaries run on the hill until 6½ years, when short-term nutritional limitations were removed prior to and at mating. Since the younger ewes were heavier at mating, it could be argued that their performance might have been greater and there may therefore be a real effect of age independent of difference due to size. There was, however, a significant difference in ovulation rate ($P < 0.05$) and litter size ($P < 0.001$) between the 1971 and 1975 age groups at 6½ years. Since there was no difference in live weight or condition at mating it can be suggested that there is therefore a true difference in genetic potential between these age groups and that the advantage of the old over the young, as reported in the 1977 Report, was not necessarily an effect of age. Apparent age effects may therefore be less than the effects of size in any comparison between age classes.

6. Effects of pre-mating nutrition on pre- and post-mating endocrine status, ovulation rate and embryo survival

S.M. Rhind, R.G. Gunn, J.M. Doney, W.F. Smith, I.D. Leslie and D.A. Sim

The ovulation rate and lamb production of Cheviot ewes is influenced by the pattern of nutrition prior to mating as well as by body condition at mating. The aim of this work was to investigate the endocrine mechanisms through which this effect may be mediated.

From mid-September, 104 cast North x South Country Cheviot ewes from Sourhope were individually penned at HQ. They had an initial mean weight of 56.1 kg and a mean body condition score of 2.37. They were allocated to four treatment groups on the basis of live weight and condition so that all groups were initially similar. Animals in two of the groups were fed to achieve and then maintain a mean condition score of approximately 2.5 while the remainder were fed so that they declined in condition to a mean score of approximately 2.0 after about 6 weeks. During the 4-week period immediately prior to mating, ewes in the low-condition groups were fed ad libitum while the others were kept on a maintenance ration. After synchronised mating on 26th November one group of ewes on a rising plane and one on a maintenance ration were fed ad libitum while the remainder were fed so that they gradually lost condition up to the time of slaughter which was about 20 days after mating.

Ewes were synchronised in oestrus using intravaginal pessaries inserted for a 14 day period. At the second cycle following pessary removal, ewes were tested for oestrus activity every 3 hours from 15 days after the onset of their previous oestrus, using vasectomised rams. All ewes were individually mated by at least two different entire rams at 12 to 24 hours after oestrus onset.

On 19th November (approximately day 11 of the cycle following pessary withdrawal), blood samples were collected from 40 selected animals (10 from each treatment group) every 20 minutes for 10 hours. This was repeated for 5-hour periods on 23rd, 24th and 25th November (days 15, 16 and 17 of the cycle). A frequent sampling regime was used because the release of LH, FSH and prolactin is not constant but pulsatile and can only be accurately quantified if samples are collected frequently. Following oestrus onset at about day 17, the ewes were sampled at 3-hour intervals so that the timing and size of the preovulatory LH peak can be determined. From days 2 to 8 after mating, samples were collected twice daily and thereafter daily until slaughter for progesterone determinations to provide a measure of luteal activity.

The reproductive tracts were recovered at slaughter and the ovulation rate and number of embryos present were recorded. The ovulation rates given in Table 1 are for the oestrus at which the ewes were mated, irrespective of whether or not they subsequently returned to oestrus.

The mean ovulation rate of 2.0 for ewes rising in body condition at mating compared with 1.4 for those on maintenance ration but in a similar condition at mating clearly illustrates the effect of current nutrition.

The recorded rates of embryo wastage are difficult to interpret. This may be complicated by the differences in ovulation rate between treatment groups.

Results of hormone determinations are awaited.

Table 1

Nutritional treatment: 4 weeks pre-mating/post-mating		*ad libitum*/ *ad libitum*	*ad libitum*/ submaintenance	maintenance/ *ad libitum*	maintenance/ submaintenance
No. of animals		10 (26)	10 (24)	10 (27)	10 (27)
Condition score at mating		2.38 (2.42)	2.30 (2.45)	2.50 (2.41)	2.43 (2.40)
No. of ewes with 1 to 3 CL from 2nd oestrus after pessary removal	1	0 (3)	3 (4)	7 (16)	5 (16)
	2	8 (21)	7 (16)	3 (11)	5 (11)
	3	2 (2)	0 (4)	0 (0)	0 (0)
Mean ovulation rate		2.20 (1.96)	1.70 (2.00)	1.30 (1.41)	1.50 (1.41)
No. of ewes with 0 to 3 embryos at slaughter	0	0 (5)	1 (3)	2 (4)	2 (6)
	1	2 (9)	2 (5)	5 (14)	7 (15)
	2	7 (11)	7 (14)	3 (9)	1 (6)
	3	1 (1)	0 (2)	0 (0)	0 (0)
% of CL not represented by embryos at slaughter		13.6 (33.2)	5.9 (18.5)	15.4 (15.6)	40.0 (29.1)

Figures in brackets refer to all the animals in the groups. Other figures refer to the 40 animals selected for intensive investigation.

7. Effects of body condition of ewes at mating on their endocrine status, follicle development and ovulation rate

S.M. Rhind, A.S. McNeilly and I.D. Leslie

The aim of this work is to investigate the effects of body condition at mating on ovulation rate and associated hormone status in Blackface ewes. In addition, follicle development and the development of their steriodogenic capacity is also being examined in some detail.

From the end of September, two initially similar groups of 11 cast ewes from House o' Muir were fed so that ewes of one group increased their body condition score to a mean of 2.75+ while the other declined to a mean score of approximately 1.75. Thereafter all animals were fed a maintenance ration.

In mid-December, they were synchronised in oestrus using intravaginal progestagen pessaries inserted for a 14 day period. Ten days after the induced oestrus, they were injected with prostaglandin $F_{2\alpha}$ to induce luteal regression and oestrus and the times of oestrus onset were observed using vasectomised rams. Eleven days after this oestrus all ewes were blood sampled every 15 minutes for 10 hours. The following day, they were injected with prostaglandin again and from 18 hours after injection the ewes were tested for oestrus every 3 hours. From 20 to 28 hours after injection they were bled every 15 minutes. (The choice of sampling time was based on the expected time of oestrus onset as determined following the previous prostaglandin treatment i.e. 24 to 48 hrs after injection). The sampling regime was repeated 24 hours later for ewes which had not shown oestrus by that time. After oestrus onset they were sampled every 3 hours for 30 hours to establish the time of the LH surge. The samples collected at 15 minute intervals will be analysed for LH, FSH and prolactin and the patterns of hormone production compared for animals with one or more than one ovulation.

The ewes were slaughtered between 11 and 14 days after this oestrus and the ovaries recovered. Half of the ewes in each treatment group were treated with prostaglandin 24 hours before slaughter so that they were in the early part of the follicular phase of their cycle when the ovaries were collected.

Corpora lutea were counted and follicles were counted, measured and then cultured in the presence of gonadotrophins to determine their ability to produce steroids. Ovulation rates are given in Table 1.

Table 1.

Target condition score		High (2.75+)	Low (1.75)
No. of ewes with	0		2
0-3 ovulations	1	3	8
	2	7	1
	3	1	

8. <u>The effects of body condition and stress on the endocrine status of ewes and on their associated ovulation and embryo survival rates</u>

S.M. Rhind, J.M. Doney, R.G. Gunn, W.F. Smith, A.D.M. Smith, I.D. Leslie and D.A. Sim

A detailed description of the design of this experiment was given in last years' report, so only a brief outline is necessary here.

Two groups of cast Scottish Blackface ewes were fed to achieve mean condition scores of approximately 1.8 and 2.8 by four weeks before mating and thereafter fed a maintenance ration. Half of the ewes in each group were subjected to stressful procedures over a 7 day period around the time of mating. The effect of these treatments on reproductive performance was recorded. Blood samples were collected at intervals of 3 or 6 hours around the time of oestrus and analysed for LH, FSH and prolactin. The ewes were also sampled daily during early pregnancy and the samples analysed for progesterone.

LH determinations are not yet completed.

Prolactin levels (Fig. 1) were significantly affected by nutritional treatments at almost all times between 48 hours before oestrus onset and 48 hours after, levels being approximately twice as high in animals with a high condition score as in animals with a low score. Mean values for all groups showed a peak at about the time of oestrus but at this time there was some evidence that secretion was greater in the stressed animals.

Treatment effects on FSH levels were less marked (see Fig. 2) but levels were slightly lower in the stressed/low condition group than in any of the others. The expected rise in FSH levels around the time of oestrus and also the secondary rise about 24 hours later were detectable in many animals but these changes are partially masked in the presentation of the mean values.

There was no evidence of any effect of treatment on the circulating progesterone levels between days 4 and 14 of pregnancy other than that which was attributable to the differences in ovulation rate and induced by the nutritional treatments.

These results provide some insight into the mechanisms by which nutritional, and, to a lesser extent, stressful treatments may affect follicle development and ovulation and consequently reproductive performance.

LACTATION

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

1. <u>Lamb growth; milk and herbage intake</u>

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

During 1981 an improved field system for controlling milk intake by artificially reared lambs at pasture was developed. One of the objectives was

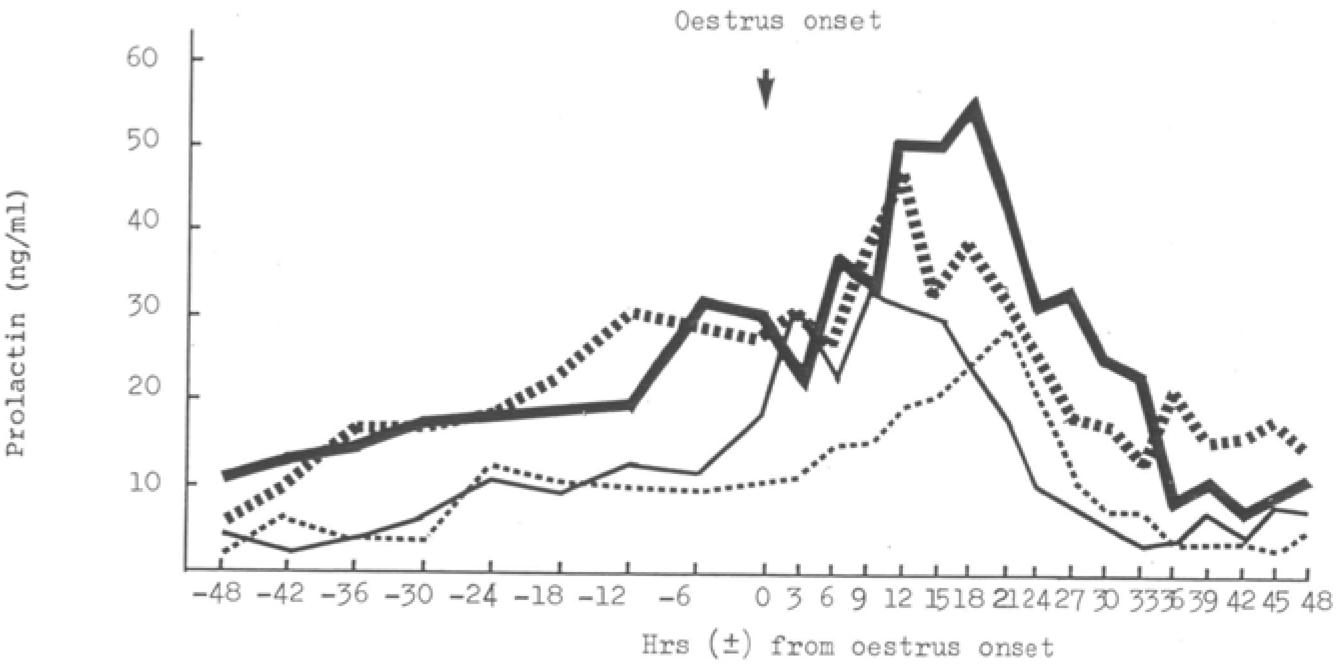

Fig.1. Mean plasma prolactin levels (ng/ml) for ewes in each treatment group

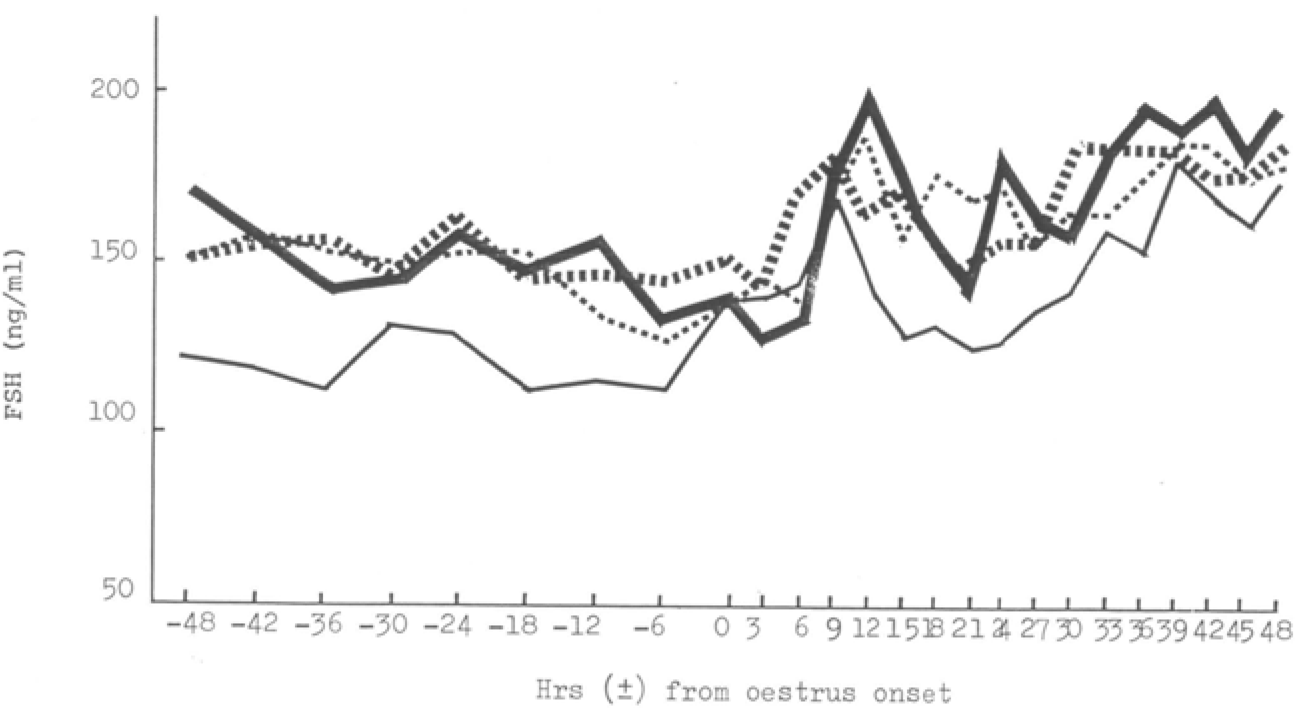

Fig. 2. Mean plasma FSH level (ng/ml) for ewes in each treatment group

High plane - stressed
High plane - unstressed
Low plane - stressed
Low plane - unstressed

to permit adequate and frequent access to an individual milk source without either reducing the grazing opportunity unduly and without incurring excessive use of out-of-hours labour on a continuous basis throughout lactation. A set of pens were constructed giving the lambs 96 sq. ft. area which permitted both access to milk and grazing. Observations on the effect of night-penning were carried out. The back of pens was moved at suitable intervals to provide clean night access to grass and during the day the lambs were given free access to the whole paddock, being brought in for 3 separate feeds of milk. One of the problems encountered in the previous year was milk scour. This system, by discouraging large infrequent feeds of milk seemed to reduce the incidence of scour. Faeces collections suggested that herbage intake was not restricted. It was found, however, that a proportion of lambs seemed to lose their demand for milk, perhaps associated with the reduction of operator-contact. It was decided, however, that it would form a suitable model for a full-scale study planned for the following year.

2. Lactation in East Friesland x Cheviot ewes

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

Previous studies have shown that the crossbred ewes produced by crossing Scottish Blackface ewes with East Friesland rams have a higher and sustained lactation potential in a good nutritional environment than the purebred BF ewes. The objective of this small trial was to ascertain whether the East Friesland x Cheviot cross has a similar potential. The trial was carried out at Glensaugh using crossbred or pure Cheviot gimmers grazed on ryegrass dominant sward, maintained by stock density at a relatively low herbage mass. The measurements of herbage intake were made. Under these conditions the potential difference in performance was not shown. Milk yields of crossbred ewes with singles or twin lambs or twins reached a peak of 2.65 and 3.65 kg/day respectively as compared with 2.40 and 3.45 kg/day for Cheviot ewes. The results suggested that under conditions of potentially restricted grazing intake differences associated with breed type disappeared by 9 weeks. Further studies with older ewes and better pasture provision will be carried out.

GENOTYPES

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

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

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

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

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

The performance results for 1981 are given in Tables 1 and 2 which show the pre-mating weights of each age and breed group of ewes (November 1980), the number of lambs and the weaning weights of lambs by genotype. All cross-bred ewes were mated to Dorset Down rams.

A summary of the lambing performance of the Finella flocks is given in figure 1 from 1976 to 1981.

Mid and West Finella

Table 1. Mean Ewe Bodyweights (kg)

Breed	Premating November 1980			Weaning August 1981		
	Mid Finella	West Finella	Mean	Mid Finella	West Finella	Mean
BLACKFACE						
Born 1975	64.5	-	64.5	56.5	-	56.5
1976	69.0	62.3	66.0	60.5	53.9	57.4
1977	67.2	63.1	65.3	59.1	53.0	56.2
1978	60.6	55.7	58.4	55.8	51.5	54.0
1979	56.7	48.3	52.5	52.4	47.0	49.6
All ages	62.3	55.9	59.3	56.1	50.5	53.5
TEXEL x BLACKFACE						
Born 1976	76.2	66.5	70.0	63.0	58.7	60.0
1977	61.5	61.2	61.4	55.9	52.9	54.8
1978	59.3	57.8	58.7	55.4	51.7	53.7
1979	56.8	53.3	55.0	54.3	48.6	51.3
All ages	61.2	58.9	60.1	55.9	52.4	54.2
BORDER LEICESTER x BLACKFACE						
Born 1976	70.4	68.9	69.5	61.2	58.9	59.8
1977	68.4	65.1	66.9	64.5	55.2	60.6
1978	62.7	55.1	59.5	60.3	54.6	57.9
1979	59.9	54.7	57.1	59.0	48.9	53.6
All ages	65.2	61.3	63.3	61.5	54.4	58.1

Table 2. Mean Lamb Bodyweights (kg) with lambing and weaning percentage

GENOTYPE

Dam	Sire	Ewes to tup	Lambs born	Lambing %	Combined lambing %	Heft	Weaning weight	Combined weaning weight	Lambs weaned	Weaning %	Combined weaning %
BF	BF	47 36	68 36	144.7 100.0	125.3	MF WF	29.3 26.1	28.2	60 36	127.7 100.0	115.7
BF	Texel	16 20	17 19	106.2 95.0	100.0	MF WF	29.7 28.5	29.0	13 18	81.2 90.0	86.1
BF	BL	21 19	24 22	114.3 115.8	115.0	MF WF	30.1 31.0	30.5	24 18	114.3 94.7	105.0
Texel x BF	Dorset Down	35 33	47 44	134.3 133.3	133.8	MF WF	33.5 30.5	32.2	42 32	120.0 97.0	108.8
B. Leic. x BF	Dorset Down	35 33	54 51	154.3 154.5	154.4	MF WF	32.0 30.3	31.2	43 42	122.8 127.3	125.0
Tex. x BF BL x BF	BF BF	2 1	1 2	50.0 200.0	100.0	WF WF	30.0 21.5	24.3	1 2	50.0 200.0	100.0

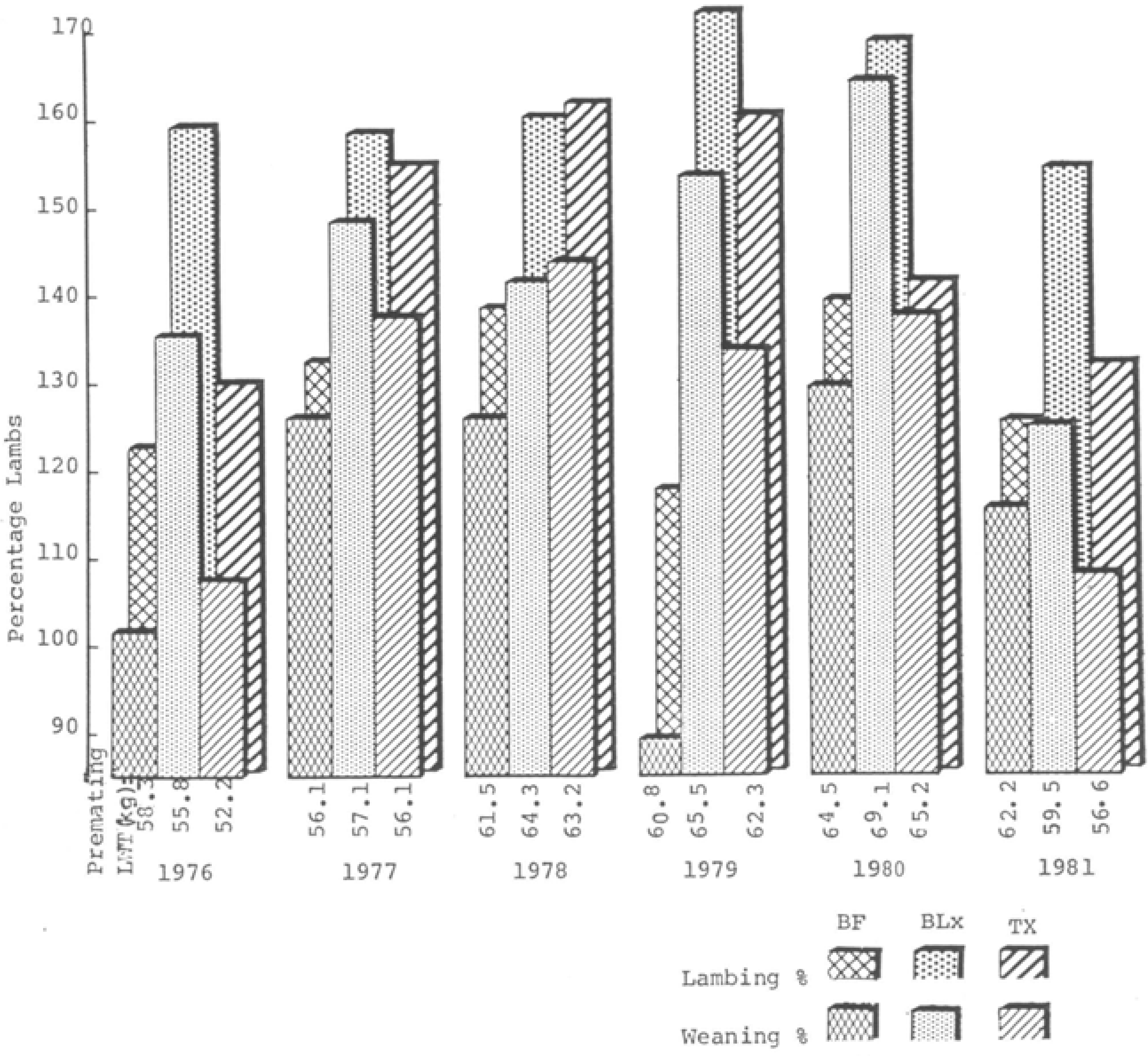

Fig. 1. Summary of lambing performance (Mid and West Finella) 1976-81.

VOLUNTARY INTAKE

02001: Factors affecting voluntary intake of roughages by sheep

1. Effects of Zeranol (Ralgro) on the growth performance and blood chemistry of pasture finishing lambs

D. Zygoyiannis, J.M. Doney, S.M. Rhind, W.F. Smith, A.D.M. Smith I.D. Leslie and D. Sim

The aim of this work was to investigate the effects of the growth promoter Zeranol (Ralgro) on herbage intake, growth and the blood chemistry of lambs finished at pasture. Details of the experimental design were given in last year's report and so only the outline of the experiment is given below:

Diet	No. of lambs	Treatment
	10 male	5 implanted 5 controls
Grass	10 female	5 implanted 5 controls
	10 male	5 implanted 5 controls
Grass + supplement	10 female	5 implanted 5 controls

Details of liveweight change, circulating insulin and non-esterified fatty acid levels were given in last year's report and the first analysis of estimated herbage and concentrate intake will be presented later.

Determinations have been completed for prolactin, thyroxine tri-iodothyronine, glucose, urea, albumin, globulin and total protein and the results are summarised in Figs. 1 to 8.

Despite clear effects of treatment on lamb performance, effects on blood hormone and metabolic levels were generally small, particularly when considered in relation to the variation in levels in animals on the same treatment. Nevertheless, trends are apparent which are probably indicative of differences in metabolism attributable to Ralgro treatment.

Prolactin levels throughout the period of treatment were generally higher in lambs treated with Ralgro but were not obviously affected by supplement feeding. The significance of the trend is not clear as the role of prolactin in the control of nutrient utilisation and growth is not understood.

Thyroxine levels were increased by supplement feeding but little affected by Ralgro while the more potent thyroid hormone, tri-iodothyronine was not consistently affected by either parameter. Levels of both thyroid hormones declined as the lambs grew, probably indicating a decline in metabolic rate.

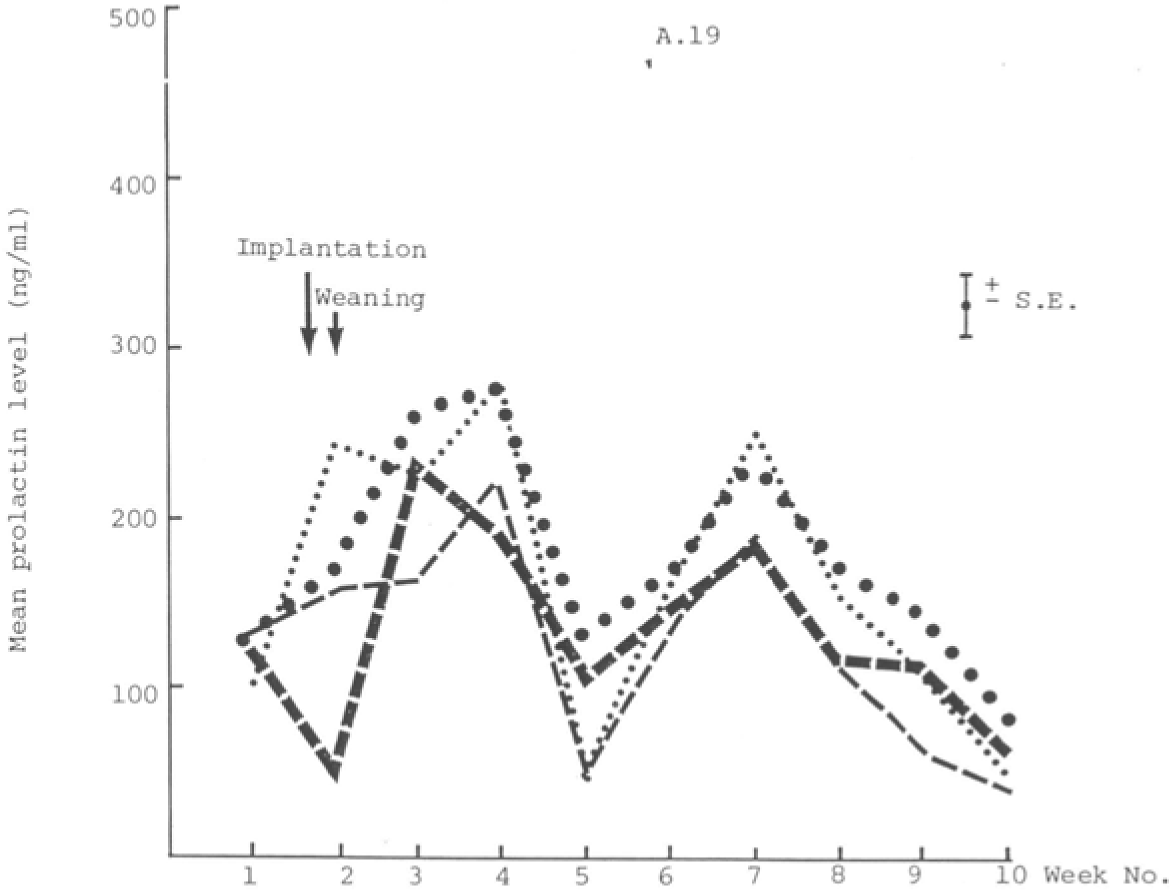

Fig. 1. Mean plasma prolactin levels for animals of each treatment group

Key for Figs. 1-8

●●●● R + S ······ R + No S ▬▬▬ No R + S — — — No R + No S

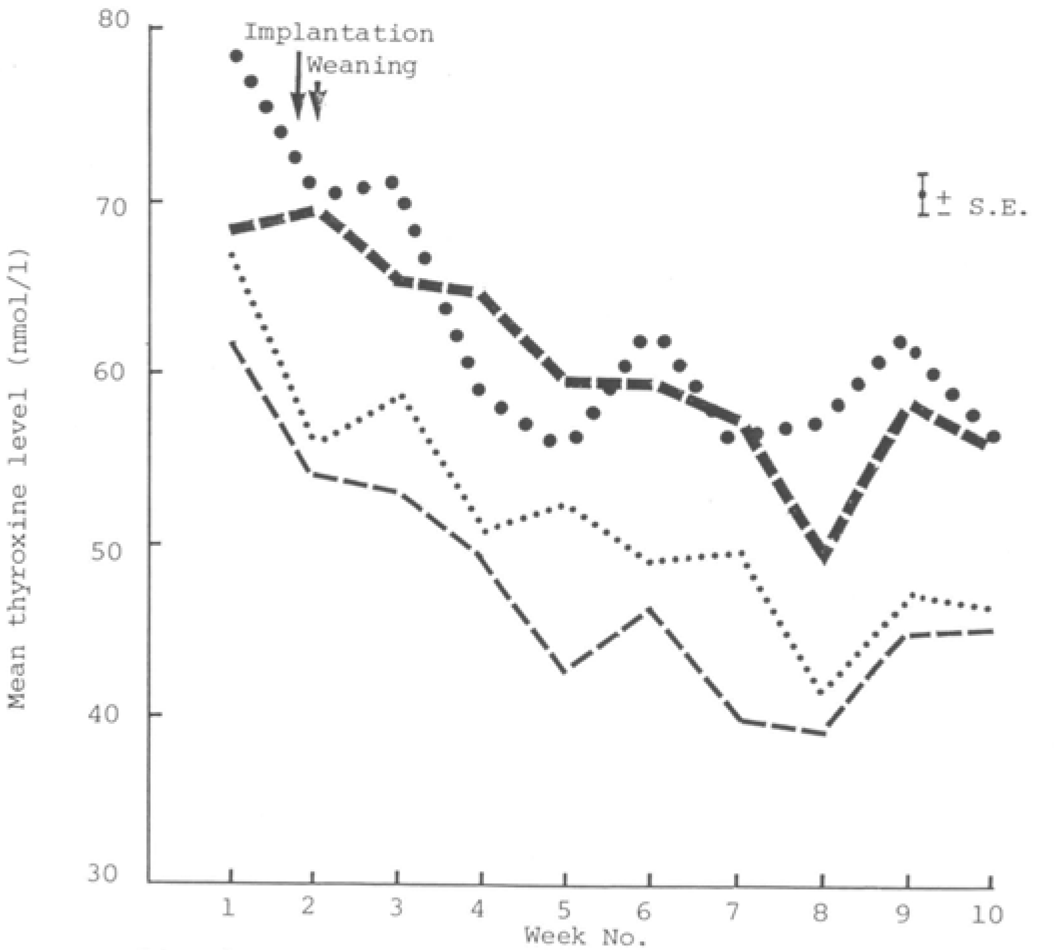

Fig. 2. Mean plasma thyroxine (T_4) levels for animals of each treatment group.

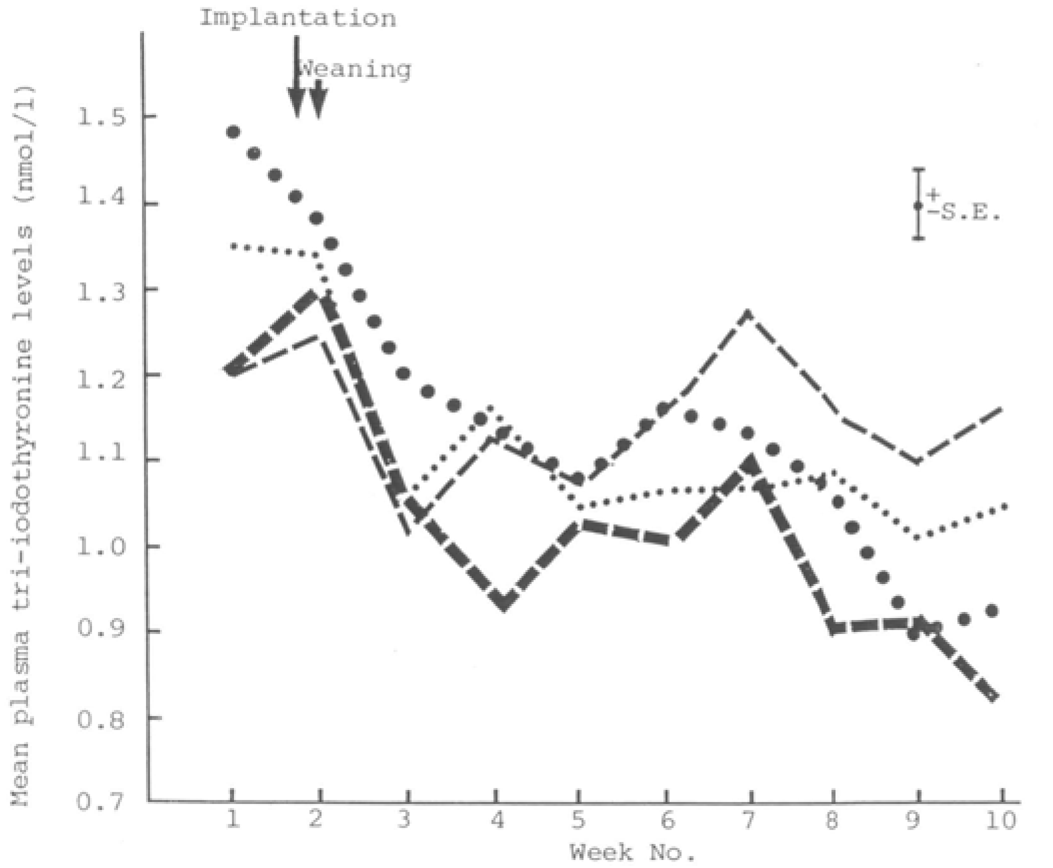

Fig. 3. Mean plasma tri-idothyronine levels for animals in each treatment group

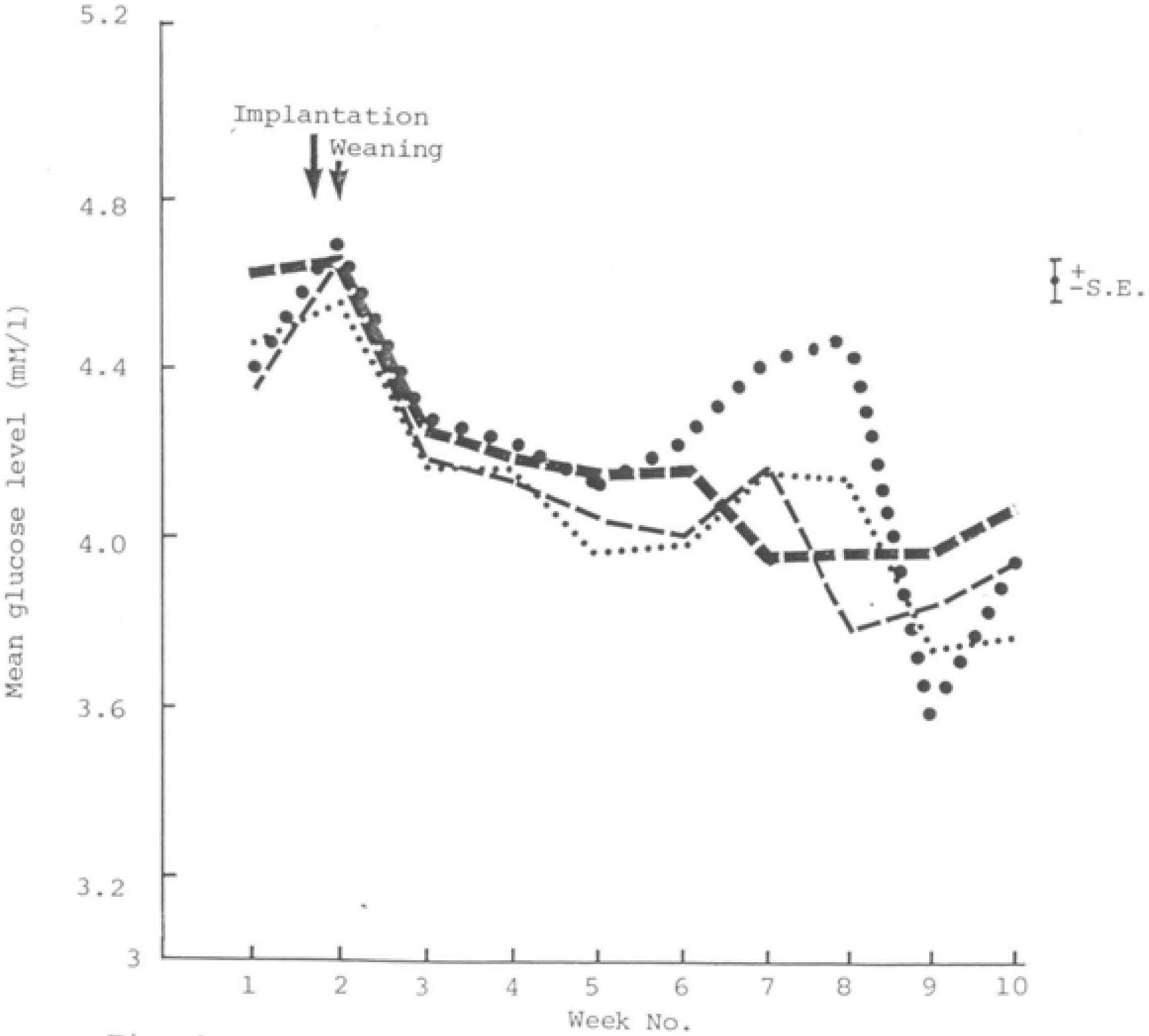

Fig. 4. Mean plasma glucose levels for animals in each group

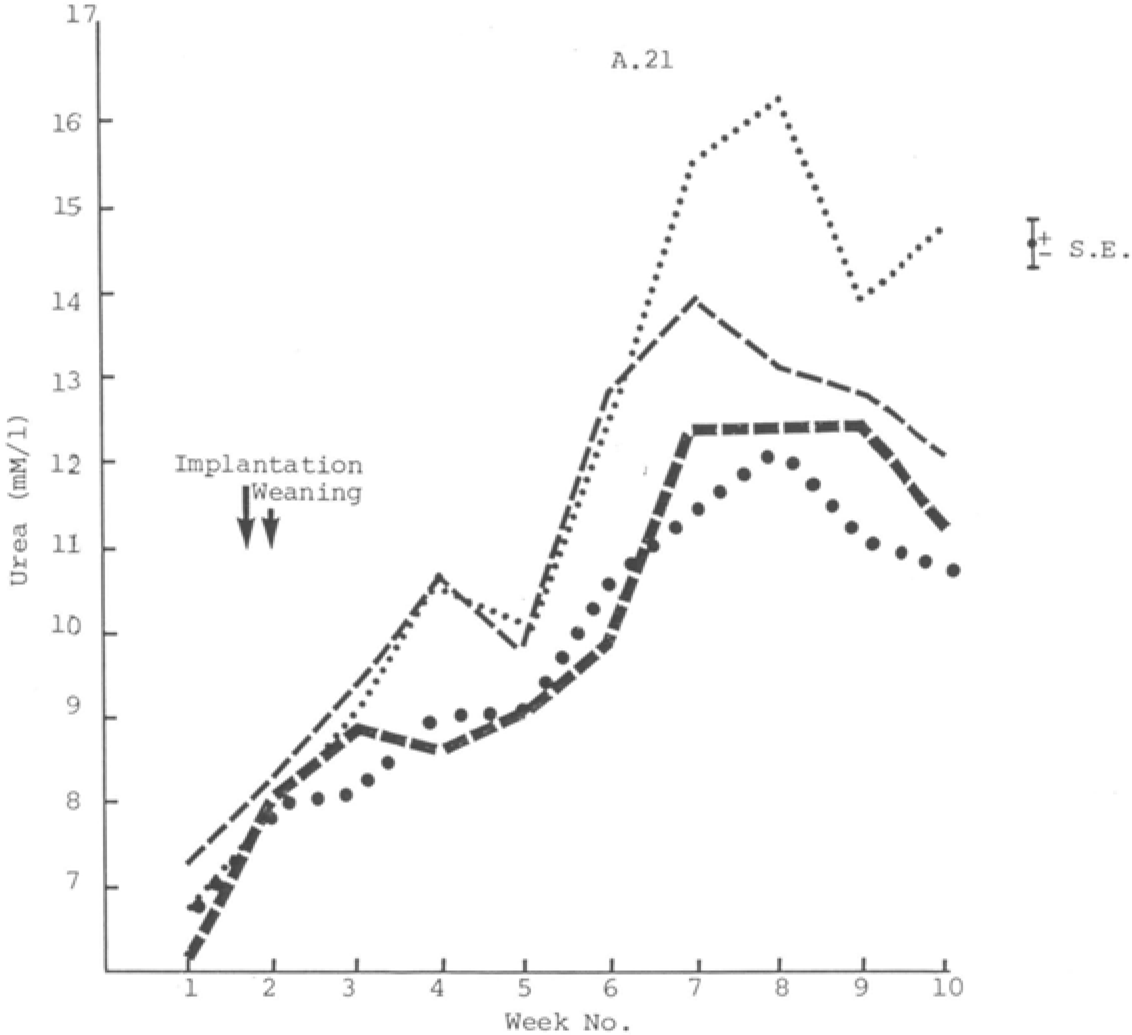

Fig. 5. Mean plasma urea levels (mM/l) for animals of each treatment group

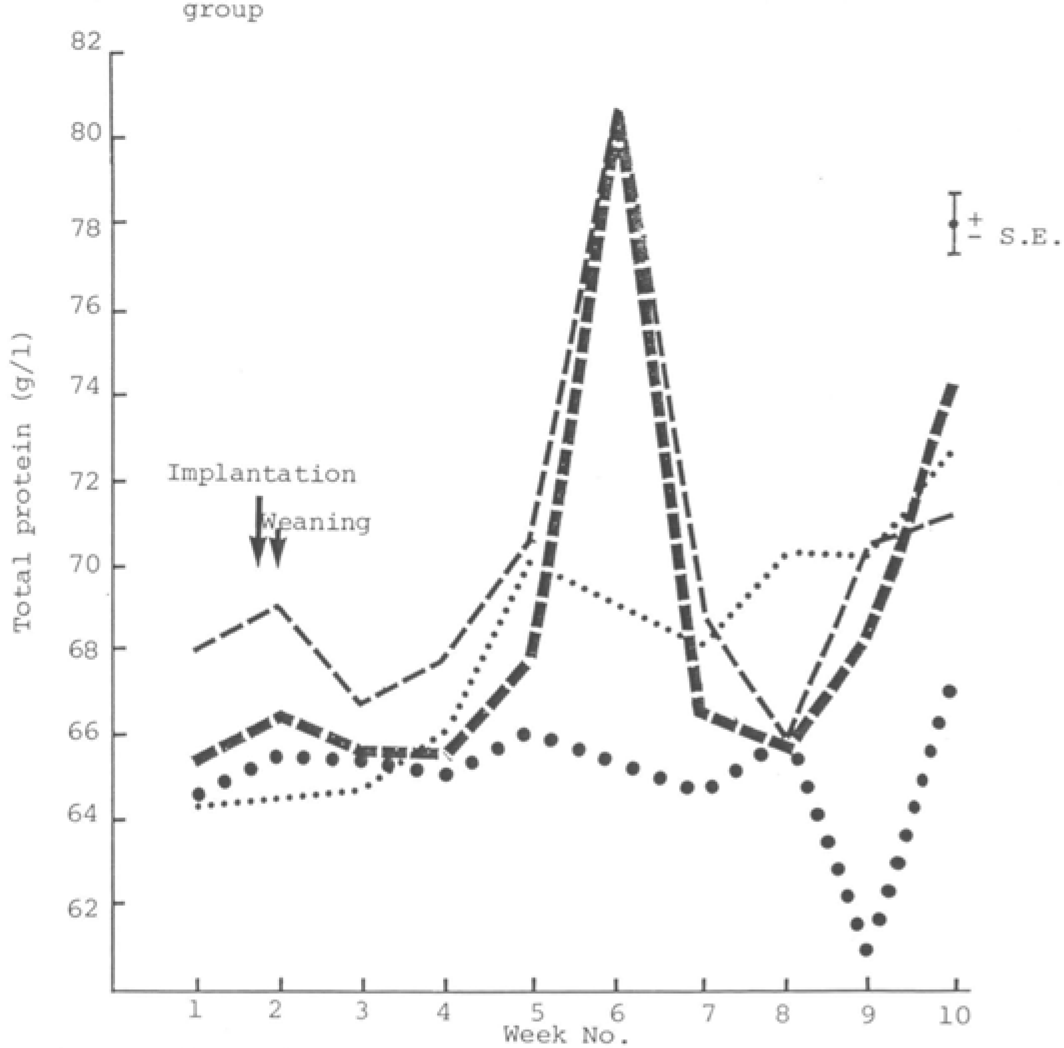

Fig. 6. Mean plasma total protein levels (g/l) for animals of each treatment group.

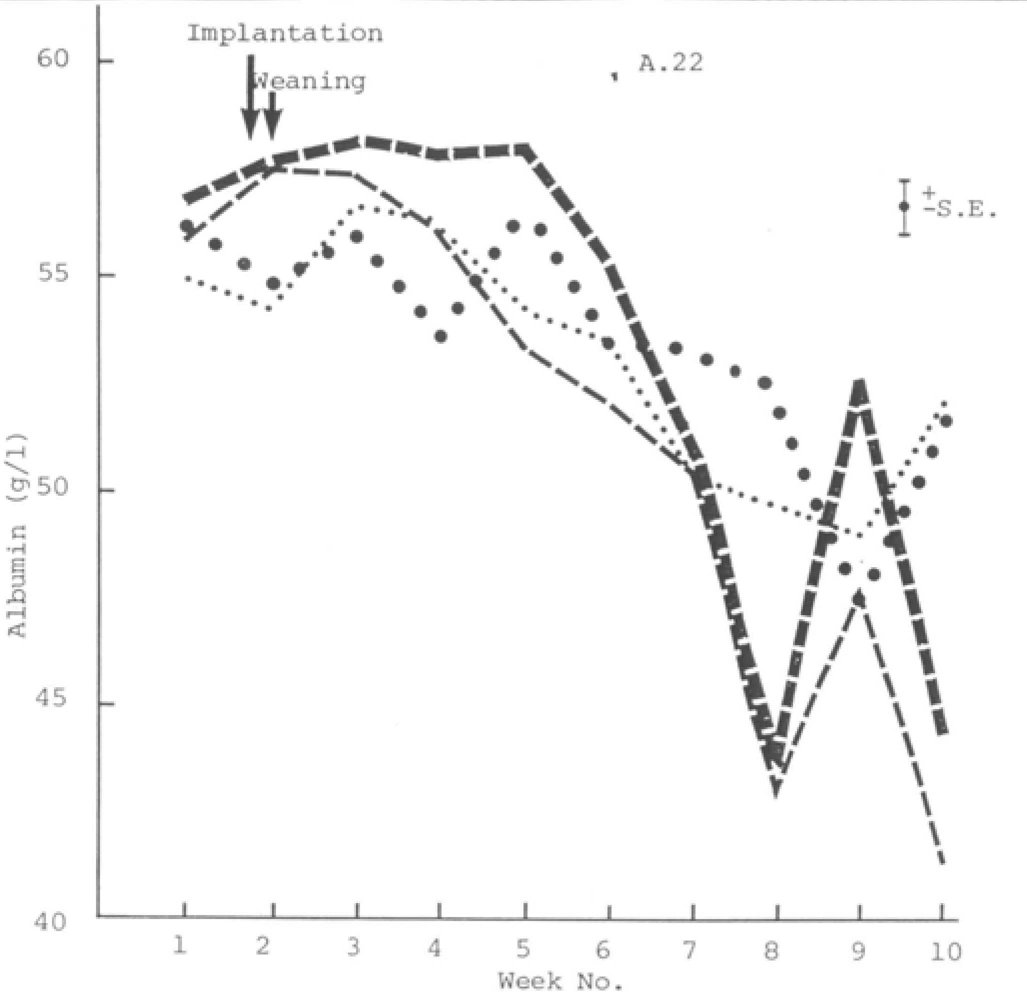

Fig. 7. Mean plasma albumin levels (g/l) for animals of each treatment group

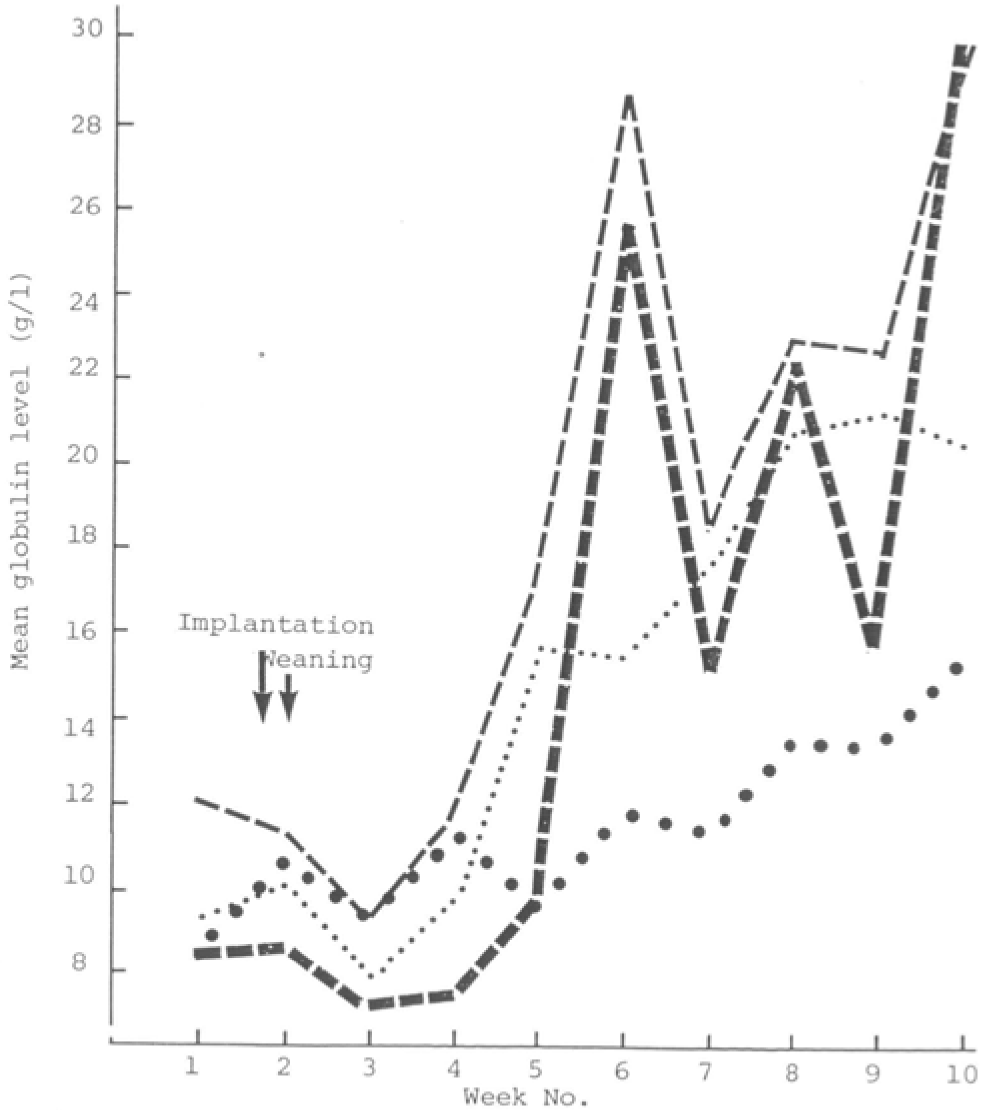

Fig. 8. Mean plasma globulin levels (g/l) for animals of each treatment group.

Glucose levels, like N.E.F.A. levels appear to be under very precise homeostatic control and consequently provide little indication of the effects of Ralgro, if any, on energy metabolism. The decline in glucose levels following weaning may reflect changes in the nutrients absorbed from the gut or a decline in tissue requirements for glucose associated with a decreasing metabolic rate.

Interpretation of the results of blood urea determinations is difficult as urea may originate both from products of digestion in the rumen and from protein turnover in the body. Thus the increase in blood urea with age, and the lower levels in animals fed supplement may be a function of changes in rumen metabolism rather than of changes in protein turnover.

A better indication of nitrogen status is perhaps provided by plasma protein levels. Total protein levels were lowest in animals treated with Ralgro and fed supplement, levels in all other groups being fairly similar. This trend was mainly attributable to differences in globulin levels rather than albumin. The result is indicative of a greater conversion efficiency of nitrogen to tissue in the Ralgro/supplement group.

2. <u>Finishing lambs on forage crops</u>

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

In 1980 three types of forage crops were made available at Hartwood for a preliminary trial of factors affecting the finishing of lambs. Nine hundred lambs from the farms of Lephinmore, Glensaugh, Sourhope and Hartwood, comprising pure BF, Cheviots and Dorset Down crossbreds were randomly allocated, within breed, to one of three treatments intended to create the opportunity for early, intermediate or late finishing. At the start of the trial lamb weights ranged from 15 to 37 kg and body condition scores from 1 to 2¼. The early group were transferred at the beginning of September to a crop of Tyfon, and remained there until the crop had been fully utilised, at which time the remaining unfinished lambs were transferred to a crop of rape. The intermediate group were held on available pasture from the start of the trial in September until transferred to a rape crop in late October. The late finishing group were held on rough, unimproved pasture prior to transfer to a turnip crop in late October. Three stocking rates were set for each crop to give 9 groups, each of approx. 100 lambs.

The criteria of finish were set as a minimum live weight of 35 kg (40 kg for crossbred lambs) and a body condition score not less than 2¼. These criteria were determined in relation to expected optimisation of killing-out percentage, carcase weight and carcase grade. All carcases were individually weighed and graded at the abattoir by arrangement with the meat inspectors. Up to 30 carcases from each breed were retained for analysis in terms of commercial jointing.

Lambs were weighed and graded at 2-week intervals although deviations to give shorter or longer intervals according to progress of the different groups was accepted. For the early group, the Tyfon crop lasted for 26, 37 and 79 days, depending on stocking rate, by which time 3, 7 and 55 lambs had finished. The allocated rape crop lasted a further 77, 65 and 45 days when 24, 16 and 22 lambs, respectively, remained unfinished. In the intermediate group some lambs, by virtue of their initial weight, were finished before allocation to the rape crop which lasted 48, 58 and 58 days according to stocking rate. At the end of the rape crop 69, 41 and 46 lambs remained unfinished. Even on the poor grazing made available to the late group a few lambs finished in the early stages. The turnip crop lasted 62 days for all stocking-rates and 72, 70 and 64 lambs remained unfinished.

Various analyses are in progress, relating to crop utilisation, time of finishing, live weight and condition gain etc. One of the objectives of the investigation was to establish the relevant criteria for the allocation of lambs to different 'finishing' systems and for this purpose the results have been analysed by breed and by initial weight. Table 1 shows the probability of a lamb being finished by end-of-crop according to initial live weight, breed and system of finishing.

Table 1. Percentage lambs finished by breed, system and initial weight class at the time the forage crop was finished (all stocking rate treatments combined)

Crop	Early			Intermediate			Late		
Breed Initial weight (kg)	BF	CH	X	BF	CH	X	BF	CH	X
15 - 25	39	77	83	11	29	71	4	0	57
25 - 27.5	68	78	92	22	56	58	15	8	65
27.5 - 30	81	95	100	28	72	100	5	26	93
30 - 32.5	83	100	100	67	87	84	20	33	80
32.5 - 35	100	100	100	46	100	92	0*	-	100
35+	86*	100	87*	50	100	100	-	-	83*
Total %	68	91	96	28	58	86	7	14	79

* indicates a small group size

It can be seen that only the system designated early was reasonably successful in allowing a high proportion of lambs to be finished on the forage crop provided (the rape crop for the early group ran out between mid-December and mid-January, that for the intermediate group in early December and the turnips were finished in early January). Overall best results in terms of finishing but not necessarily in terms of profitability were obtained from cross-bred lambs with Cheviot lambs second and Blackface a poor third. None of the systems was very effective where lambs, especially BF, were less than 27.5 kg at weaning. Table 2 shows the proportion of lambs finished in each month to end of crop and finally the proportion still unfinished at termination of the trial on 1 April.

(Table 2 see over)

When the provided forage crop was eaten out, any remaining lambs were transferred to a grass field and were supplementary fed on a ration of concentrate (600 g rising to 900 g/head) and barley (300 g/head). At this stage all lambs were run together irrespective of original grouping. Lambs

Table 2. Numbers of lambs sold in each month for September-March

Group	Breed	Init. wt. range (kg)	Sept. Av.price(p) 172	Oct. 170	Nov. kg/DCW: 170	Dec. 178	Jan. 184	Feb. 189	Mar. 190	Residual No. of lambs	Total
E	BF	17 - 34	1	36	4	30	8	14	16	11	120
	C	19 - 36	3	52	6	23	2	7	6	1	100
	X	22 - 39	6	63	2	3	2	4	0	0	80
I	BF	16 - 35	0	8	9	17	0	7	32	47	120
	C	18 - 36	5	8	11	31	0	8	32	5	100
	X	21 - 44	3	3	9	11	0	10	5	0	80
L	BF	15 - 37	0	0	0	0	8	9	63	40	120
	C	17 - 35	2	2	0	0	9	23	54	10	100
	X	22 - 42	0	18	0	39	0	17	6	0	80

continued to be removed for slaughter when assessed as ready, until the end of March when the trial was terminated and standards were slightly lowered. At this stage some 114 lambs still remained (early group, 12; intermediate group, 52; and late group, 50). The majority of these lambs were of the Blackface breed (97) and had initial live weights of around 20 kg or less.

Further analyses on crop yields, the utilisation of crops, the influence of stocking rate and other factors on weight/condition change during the crop phase and in the post-crop period will be carried out.

3. Studies on the indoor finishing of lambs

Robin H. Armstrong and A.J.F. Russel

Most diets used for the indoor finishing of lambs are based on cereals fortified with a source of protein. With such diets metabolic disorders, such as acidosis, can constitute a serious problem frequently leading to high levels of mortality. The use of "change-over" diets prior to the feeding of the finishing diet does not wholly obviate the risk of acidosis. It was accordingly decided to evaluate the suitability for the indoor finishing of lambs of diets containing relatively high proportions of fibre and fed in association with a long roughage with the objectives of maintaining proper digestive function and mininising the incidence of metabolic disorders.

A production investigation was conducted at Sourhope with some 400 Scottish Blackface lambs on three diets and in which performance, in terms of live-weight gain and blood conversion efficiency, was measured; in which management factors, including the use of slatted floors and straw bedding and the feasibility of using self-feed hoppers, were examined; and which included an economic assessment of indoor finishing on the diets used. An account of this work will be presented in the next Farm Report.

4. Evaluation of diets

A.J.F. Russel, I.R. White and Robin H. Armstrong

Ancillary studies were conducted at Headquarters to determine the *in vivo* digestibility of the diets used at Sourhope and to study the effect of the quantity and quality of ingested roughage on the *ad libitum* concentrate intake of finishing lambs.

The diets used were:

		% composition
Diet A	Dried grass	50
	Molassed sugar beet pulp	50
Diet B	Molassed sugar beet pulp	20
	Dried lucerne	35
	Barley	45
Diet C	Molassed sugar beet pulp	20
	Dried lucerne	35
	Barley	41
	White fish meal	4

All diets were pelleted and contained standard mineral and vitamin supplements.

Apparent organic matter digestibilities were determined using 12 Scottish Blackface wether lambs from the same population as used at Sourhope. Each of the above diets was fed at a flat rate of 750 g/day in association with either hay or straw at three levels, viz. 100, 200 and 300 g/day, for three periods, each of 21 days, with faecal collections being made over the final 10 days of each period. Lambs were allocated to diets, roughages and level of roughage intake by restricted randomisation. The digestibilities of the concentrate diets were estimated by the constants of the regressions of diet digestibility on roughage intake, and the digestibilities of the roughages were estimated from the regression coefficients. Apparent organic matter digestibilities and calculated energy contents of the diets are given in Table 1.

Table 1. Apparent organic matter digestibilities, acid detergent fibre contents and calculated energy concentrations of concentrate diets and roughages

	OMD	ADF	ME (MJ/kg DM)
Diet A	0.73	0.17	11.6
B	0.72	0.12	11.5
C	0.73	0.10	11.7
Straw	0.47	0.44	7.1
Hay	0.68	0.29	10.2

Relationships between *ad libitum* concentrate intake and restricted intakes of straw and hay were determined using 36 Scottish Blackface wether lambs from the same population as that used at Sourhope. Lambs were fed hay *ad libitum* for a preliminary period of 10 days and were thereafter allocated to treatment according to their voluntary intake. In each of three 18-day periods lambs were fed either hay or straw at one of six levels ranging from 50 to 300 g/head/day by 50 g increments and were offered one of the three concentrate diets *ad libitum*.

In the lambs offered restricted quantities of straw and *ad libitum* concentrates straw intake seldom exceeded 150 g/day and even at lower levels of offering roughage intakes were variable. With lambs offered hay and concentrates hay intakes covered the range offered but intakes were again variable. Concentrate intakes increased from the first to the second periods and declined again in the third period in a manner similar to that noted in other investigations in which *ad libitum* intakes have been measured.

The between-period differences in intake required a fuller analysis of the results than is presently available to elucidate a complete picture of the effects of roughage quality and quantity on concentrate intake. It is however clear at this stage that concentrate intake was not affected by the type of roughage offered and that the amount of roughage consumed did not depress concentrate intake. Indeed many of the relationships show that total energy intake (i.e. from concentrates and roughage) increased with increasing roughage intake at a rate greater than the energy content of the roughage component, i.e. that roughage stimulated concentrate intake.

The overall mean intake of the three concentrate diets over the measurement periods was 1.26 kg/head/day, which with the restricted quantities of roughage consumed gave energy intakes of some 15 MJ ME/head/day, equivalent to approximately 3 x maintenance. There were no cases of acidosis or other metabolic disorders.

The results indicate that the diets studied appear well suited for the indoor finishing of lambs and that they can be employed safely and ultimately fed *ad libitum* without the need for any preliminary use of a change-over diet. It will probably be desirable to feed concentrate diets in association with long roughage, either in the form of straw bedding or of hay, to maintain proper digestive function, but it would appear to be unnecessary to seek means of restricting roughage intake in an attempt to maximise total energy intake.

NUTRITION IN PREGNANCY

02002: Studies on the nutritional physiology of the pregnant ewe

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

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

The first phase of this experiment studied the effects of different nutritional states during mid-pregnancy on the subsequent performance of sheep within systems of management which provided different levels of summer nutrition.

The results indicate that improved "summer" nutrition (i.e. grazing improved pasture during lactation and again prior to and during mating) resulted in an increase in output of more than 3 kg (17%) weaned lamb per ewe mated, despite a distinct trend over the course of the experiment of increasing output from ewes maintained wholly on the hill grazing. During the first two of the four years of the experiment the difference in output between the two levels of "summer" nutrition was in the order of 30% in favour of ewes grazing improved pasture.

The high level of nutrition during mid-pregnancy (from early January to early March) showed advantages in lamb birth weight, lambing percentage (provisionally attributed to reduced embryonic and foetal mortality), weaning weight and weaning percentage, which resulted in an additional 2.5 kg weaned lamb/ewe mated.

Examination of patterns of ewe live-weight changes during the first phase of the experiment showed that even in the "high-high" group on reseeds prior to and during the early part of the mating period, followed by the high level of mid-pregnancy nutrition from early January, weight losses in the latter part of the year were considerable. These were generally in the range 6-9 kg, with greatest weight loss occurring in the period from mid-December to early January i.e. when the ewes were transferred from the reseeds to the hill. Consideration of the extent and the timing of these weight losses suggest that they could affect lambing percentage adversely, and consequently the second phase of the study includes provision to examine the effect on production of a nutritional strategy designed to limit the extent of weight loss in early pregnancy.

It is clearly impracticable to contemplate a system of hill sheep management which requires ewes to be fed throughout the entire pregnancy period, and thus the current investigation is designed to examine not only the effect of improved nutrition in earlier pregnancy, but also the interaction of that with nutrition at other periods, to determine the optimum timing of inputs of supplementary feeding.

The design adopted constitutes a logical extension of the previous phase of the experiment. The medium level of mid-pregnancy nutrition is dropped, and is replaced by one in which ewes on reseeded pastures before and during early mating are allowed free access between reseed and hill during the later part of the mating period and receive supplementary feeding at that time. In half of these ewes feeding is continued into mid-pregnancy and in the other half it is withdrawn.

Of approximately 360 Scottish Blackface ewes, two-thirds are stocked on reseeds before and during early mating, and one-third remain on the hill grazings. From early December half of the ewes on the reseeds are allowed free access between the reseeds and the hill, and receive supplementary feeding when the improved grazings are deemed to be finished, usually in mid-December.

At the beginning of mid-pregnancy in early January, each of the three early pregnancy treatment groups are divided into high and low levels of feeding designed to create differences in patterns of live-weight change. These groupings are maintained during late pregnancy when inputs of supplementary feeding are based on biochemical assessments of nutritional state.

Table 1. The effects on production of nutrition during "summer" and during the early and mid-pregnancy periods.

Summer Nutrition	Early Pregnancy		Mid-pregnancy High	Mid-pregnancy Low	Mid-pregnancy Mean
High	High	Lamb birth wt. (singles) (kg)	4.2	3.9	4.1
		Lambing %	103.6	110.7	107.2
		Weaning %	90.9	98.2	94.6
		Output (kg weaned lamb/ewe)	22.6	22.7	22.7
	Low	Lamb birth wt. (singles) (kg)	4.0	3.9	4.0
		Lambing %	110.7	103.5	107.1
		Weaning %	101.8	91.2	96.5
		Output (kg weaned lamb/ewe)	24.0	21.0	22.5
Low		Lamb birth wt. (singles) (kg)	4.0	3.6	3.8
		Lambing %	107.0	98.2	102.6
		Weaning %	93.0	78.2	85.6
		Output (kg weaned lamb/ewe)	25.6	19.9	22.8
Mean		Lamb birth wt. (singles) (kg)	4.1	3.8	
		Lambing %	107.1	104.1	
		Weaning %	95.2	89.2	
		Output (kg weaned lamb/ewe)	24.1	21.2	

After lambing and throughout lactation the ewes are grouped according to the levels of nutrition applied at the pre-mating period i.e. two-thirds on reseeds and one-third on the hill.

The production results from the first year (1980-81) of the second phase of the experiment are summarised in Table 1.

Lambing percentages were generally high, even in those ewes which had no access to improved pasture at any time, supporting the previously made contention regarding the improvement in quality of the hill grazings. Early pregnancy treatment appeared to have had little if any effect in this particular year, but those imposed at mid-pregnancy were generally similar to those observed in the first phase, i.e. the higher level of nutrition in January/February resulted in higher lamb birth weights, lambing and weaning percentages, and in output of weaned lamb.

The experiment has been continued for a further and final year.

2. Changes in endocrine status of ewes during late pregnancy in response to different levels of dietary protein

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

Results have now been obtained from thyroxine and tri-iodothyronine determinations. No effect was found of protein level in the diet on either of these parameters.

Results of growth hormone determinations are given in Fig. 1. Levels were higher in late pregnancy in animals given a low protein supplement.

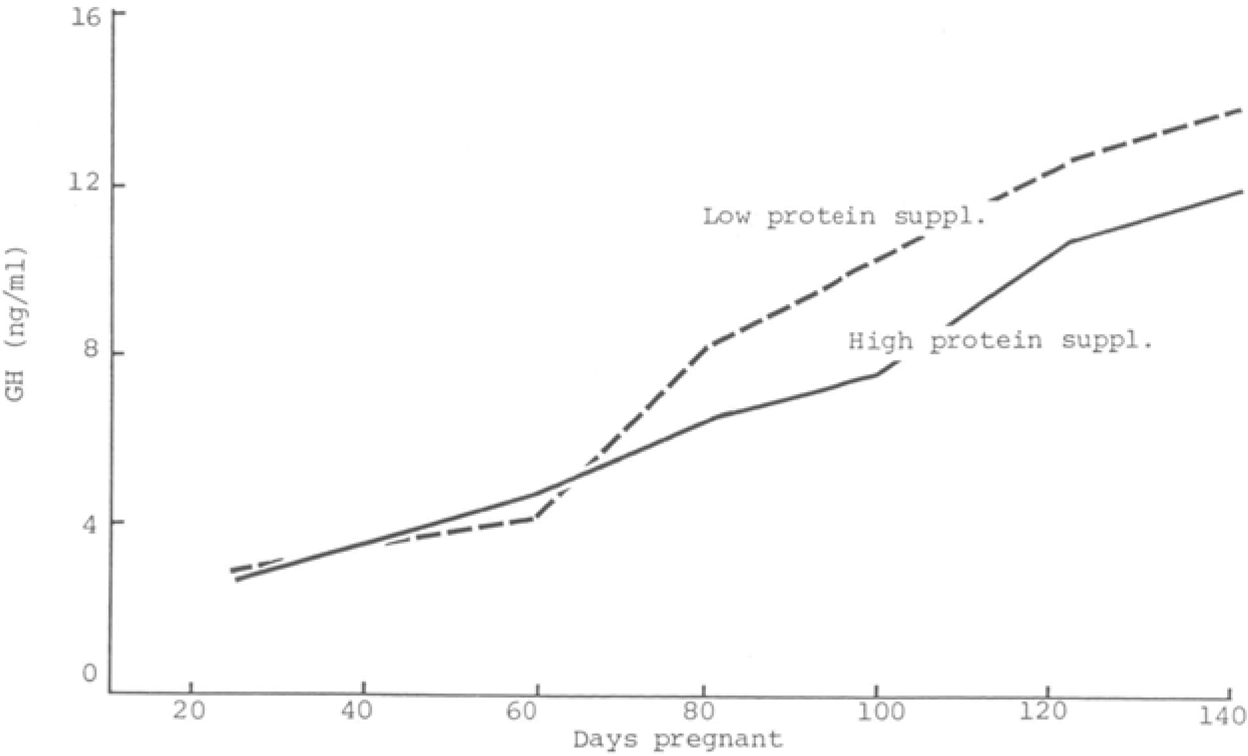

Fig. 1. Mean plasma growth hormone (GH) levels during pregnancy in ewes given high or low protein supplements.

Differences in hormone levels with treatment were generally fairly small or absent despite the fact that treatment differences in blood metabolites were recorded. However, levels of individual hormones are much less meaningful than the associated changes in the ratio of one hormone to another e.g. growth hormone/insulin ratio determines levels of energy providing substrates in the blood while growth hormone/cortisol and insulin/cortisol ratios are likely to influence protein metabolism. There are indications that the protein level of the supplement given influenced these ratios substantially and consequently altered protein and energy metabolism.

3. <u>The shearing of housed pregnant ewes</u>

Robin H. Armstrong, A.J.F. Russel, T.K. Whyte and I.R. White

In recent years there has been a considerable interest in the shearing of housed pregnant ewes. From a survey of investigations conducted in this country in the past 12 years, this practice would appear to increase the voluntary roughage intake of ewes by about 10% in late pregnancy, and to increase lamb birth weights, also by about 10%. Lamb mortality has generally been reduced, presumably as a consequence of the birth weight effect, but also, it is claimed, because the new-born lamb is able to suckle more easily and is less likely to be damaged by the ewe. Most reports also indicate that lambs from shorn ewes have superior growth rates, and indeed this would be expected from what we know of relationships between birth and weaning weights.

It is somewhat surprising that there do not appear to be any reports in the literature of investigations in which feed inputs have been restricted, and in which the effects of shearing on production have been measured in animals receiving equal food inputs in late pregnancy.

It has been suggested that the beneficial effects of shearing are due to the alleviation of heat stress, and while this may eventually be proved to be correct, present evidence is sparse.

Accordingly, the objectives of the first experiment on this topic which was carried out at Sourhope in the early months of 1981, were:

1. To study, under conditions of controlled and equal food intakes, the effects of shearing on production (measured in terms of numbers and weights of lambs at birth, marking and weaning) in a system of management where the ewes are housed and lambed indoors and turned out with their lambs within 24 hours of lambing.

2. To make such measurements as can readily and simply be obtained and which might be expected to give an insight into whether the removal of the fleece alleviates a heat stress.

The experiment was conducted on 112 Scottish Blackface ewes from the Gairs flock. The ewes were housed in late January in four pens in the Sourhope sheephouse, the groups being balanced for age and live weight. Ewes in two of the pens were shorn four days after housing. All shorn ewes ate from a common food trough, as did all unshorn ewes; the quantities of food supplied to the two groups were identical at all times and followed the normal practice and pattern employed with the Gairs flock in recent years.

Live weights and condition scores of all ewes were recorded at fortnightly intervals, blood samples were collected from 28 shorn and 28 unshorn ewes (1 pen of each) on seven occasions (twice at fortnightly intervals and thereafter weekly) and measurements of respiration rate and rectal temperature made on 12 shorn and 12 unshorn ewes at weekly intervals.

As is normal, there was a substantial loss of live weight in all ewes following housing, but within a week of shearing shorn ewes were some 2.3 kg lighter than those remaining in full fleece, after making allowance for the weight of wool removed at shearing. Thereafter the live-weight difference, which was highly significant ($P < 0.001$), remained relatively constant until lambing.

From mid-February to mid-March the mean plasma 3-hydroxybutyrate concentrations of the shorn ewes were significantly higher ($P < 0.005$ to 0.001) than that of the unshorn ewes (approximately 0.45 and 0.35 mmol/l respectively). Concentrations thereafter were very similar and not significantly different, increasing gradually to about 0.75 mmol/l in both groups shortly before lambing. These concentrations indicate that the level of feeding was such as to prevent other than a very moderate and acceptable degree of undernourishment, and there was no indication in late pregnancy that the shorn ewes were under any more severe nutritional stress than those in full fleece.

Mean rectal temperatures of the unshorn ewes were on every occasion higher than those of the shorn ewes, although the differences were very small (averaging 0.25°C) and only occasionally significant ($P < 0.05$). From the beginning of February until late March the mean respiration rates of the unshorn ewes were consistently and significantly higher ($P < 0.001$) than those of the shorn ewes (24.7 v 15.2/min) and on the last two occasions, when ambient temperatures had increased to 13^{o}C, the difference increased markedly (87.8 v 22.1/min).

Production data in terms of lamb birth, marking and weaning weights and ewe live weights post-lambing and at weaning are given in Table 1.

Table 1. Live weights (kg) of lambs from shorn and unshorn housed pregnant ewes and of ewes post-lambing and at weaning

	Shorn		Unshorn	
	Singles	Twins	Singles	Twins
Lambs				
Birth	4.6	3.9	4.6	3.7
Marking	13.2	8.2	12.3	9.5
Clipping	26.5	20.2	25.9	21.2
Weaning	33.5	27.8	33.6	28.6
Ewes				
Post-lambing	50.7		54.8	
Weaning	56.7		57.7	

Single lambs were born 1.7 days earlier (NS) and twin lambs 3.4 days later ($P < 0.01$) from shorn than from unshorn ewes, but without accurate information on mating dates it is impossible to interpret this apparent interaction affecting assumed gestation length. There were no significant effects of treatment on lamb birth weight, even after correction for the above effect, nor were there any significant effects on lamb weights at marking, clipping or weaning. The differences in ewe live weights post-lambing (4.1 kg) and at weaning (1.0 kg), after correction for wool weights, indicate that the January-shorn ewes were some 2.5 kg lighter in real terms after lambing and that this difference was maintained throughout lactation.

A further experiment, with a greater number of ewes and with different levels of nutrition in the weeks immediately following the January shearing, is currently in progress.

NUTRITION : SUPPLEMENTATION

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

1. Relationships between host-animal demand for energy and amino acid metabolism in pregnancy: an attempt to define the composition of the supplement that should be fed to ewes in late pregnancy.

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

The amounts of supplement to be given to hill ewes in late pregnancy to achieve adequate lamb birthweights and early lactation performance have been assessed in general terms according to the energy deficit of the ewe. Since the foetus has an obligatory need for glucose and amino acids it is possible that the supply of either of these nutrients could limit performance. As many amino acids are glucose precursors it is important to know which is first limiting: glucogenic energy or amino acid supply for protein synthesis. Since the supply of the major glucogenic precursor, propionate, can be influenced by the type of ruminal fermentation and the amounts of available amino acids are largely dictated by the protein flow at the duodenum, it is clear that not only feeding level but also the composition of the supplement could have a profound effect upon performance.

An experiment was conducted to ascertain if it is amino acid supply or glucogenic energy which is first-limiting with respect to performance in terms of N balance in late pregnancy, lamb birthweight and early lactation performance. Two diets of equal ME and potential glucogenic energy content were compared. One diet, consisting of formaldehyde-treated soya bean meal and hay ('protein' diet), was designed to supply much of its glucogenic energy as absorbed amino acid. The other diet contained sodium propionate ('propionate' diet) as the major glucogenic energy source and also contained sugar beet-pulp and hay. The experiment reported here was half of a two-year experiment in which both diets would be offered at three levels. Because of restrictions in the available facilities three of the six treatments were used in 1981: high levels of the 'protein' and 'propionate' diets (90% of ARC (1980) ME requirement) and the low level of the 'protein' diet (70% of ARC (1980) ME requirement). The experiment comprised of three parts:

a) Production trial - 24 pregnant ewes per treatment for production measurements.

b) Metabolism trial - 8 pregnant ewes (half were rumen fistulates) per treatment for studying glucose, propionate, threonine and glycerol metabolism, and for N balance and digestibility estimates in two measurement periods.

c) Digestion trial - 12 wethers with rumen and intestinal cannulas for estimating VFA production rates and flow rates of N and OM at the duodenum and ileum.

Results are summarised in Table 1. Lamb birthweights were significantly higher for the two 'protein' treatments than for the 'high propionate' treatment. There were also significant increases in N retention from the 'high propionate' treatment to the 'low protein'

Table 1. Summary of results of 1981 Pregnancy Experiment

	Treatment			
	Low Protein	High Protein	High Propionate	Significance (P<)
Lamb birth weight (kg)	4.384[a]	4.572[a]	3.907[b]	0.001
Ewe Lwt. Change (kg) (-8 weeks to post lambing)	-0.764[a]	3.662[b]	0.262[a]	0.01
Daily milk production (kg) (day 3-5 post lambing)	2.231	2.267	2.054	NS
N Retention (g/d)*	5.88[a]	11.00[b]	0.87[c]	0.001
OM Intake (g/d)*	687	916	811	-
OM Digestibility (%)*	71.6	72.7	70.0	NS
Metabolite Production Rates (gC/d)*				
Glucose	64.6	70.0	62.3	-
CO_2	340.6	367.2	335.3	-
Glycerol	16.4	18.6	21.7	-
Propionate‡	34.3	44.3	74.2	-
% Threonine C to:*				
Glucose	3.2	3.3	2.6	-
CO_2	5.4	7.6	8.2	-
% Glycerol C to:*				
Glucose	46.1	58.1	46.7	-
CO_2	26.2	18.1	25.8	-
NAN absorbed in small intestine (g/d)‡	11.7	16.4	8.7	-

* Figures from 2nd Period of metabolism trial

‡ Obtained from wethers, adjusted to ewe OMI

Statistical analysis not completed where no significance values given treatment and a further increase to the 'high protein' treatment. Daily milk production measured within the first 5d following lambing did not significantly differ between treatments. There was little change in ewe live weight from 8 weeks prior to lambing to immediately after lambing.

Production rates of glucose, CO_2 and glycerol were not affected by treatment, but sheep bearing twins had higher values than those bearing single lambs. Although estimates of propionate production rates in the ewes were not usable because of poor ' plateaux' specific activity values, estimates from the wethers gave higher production rates from the 'high propionate' diet. Threonine production rates have not yet been evaluated. There was evidence that the proportion of glycerol-C converted to glucose was higher in sheep receiving the 'high protein' treatment. The results from the wethers, though not yet complete, indicate that the diets were digested in a similar manner to that which was predicted; the 'high propionate' diet supplied more propionate whereas the 'protein' treatments supplied more absorbed amino acid. The amounts of OM digested in all parts of the digestive tract were similar for both diets at the same feeding level, suggesting that they did, as intended, supply similar quantities of ME.

These results indicate that the differences in lamb birthweights and N balance, between the two diets at the high feeding level, were due to the additional absorbed amino acid supplied by the 'protein' diet and not due to glucogenic energy supply. Thus, it is clear that, in terms of ME intake, at or just below maintenance pregnant ewes are able to respond in performance to additional protein passing the duodenum. The lack of any response in glucose production rate to treatment suggests that sufficient glucogenic energy was supplied by both diets. This does not necessarily imply that glucogenic energy is never limiting in practical feeding systems. It is the intention that this aspect will be investigated the following year.

REFERENCE

A.R.C. 1980. The Nutrient Requirements of Ruminant Livestock. London: Commonwealth Agricultural Bureaux.

2. ARC collaborative trial on methodology of measuring digesta flow and N metabolism in cannulated animals

R.W. Mayes, C.S. Lamb and P.M. Colgrove

The recent system, proposed by the ARC Working Party on Nutrient Requirements of Ruminants (ARC, 1980), for estimating protein requirements for ruminants and the protein value of feeding-stuffs is dependent, in part, on the need to estimate digesta organic matter and N flows at the duodenum, together with a measure of the microbial contribution to that N. In recognising this need in respect of the various techniques of measurement and the large variability between laboratories, it was suggested that a collaborative trial be carried out in a number of ARC and University centres. In light of the fact that HFRO was involved in the development of some of the techniques (the use of unlabelled chromium and ruthenium in animals fitted with simple cannulas) and has equipment and facilities superior to most of the other laboratories likely to participate it was decided that this Institute should take part in the trial.

The objectives of the collaborative trial were to ascertain whether the large variability in digesta OM and N flows and microbial N flows reported in the literature is due to technique or to diet, and also to establish the precision of these estimates as a basis for further studies and for use in commercial diet formulation. These should be fulfilled by the use of two diets, supplied to all participants and chosen to cause different OM, total N and microbial N flows at the duodenum, and the use of a fixed number of replications (six replications per diet). It was considered that each participant represents a total package of methods and conditions within a laboratory.

The diet designed to cause a small flow of OM and N at the duodenum was based on barley, whereas the other diet, intended to result in much larger duodenal OM and N flows contained grass meal and fish meal as the major ingredients. Each diet was continuously fed at a maintenance level of feeding to six wethers fitted with ruminal, duodenal and ileal cannulas. The animals received continuous intraruminal infusions of non-radioactive Cr-EDTA and Ru-phenenthroline markers for 10d followed immediately by infusions of ^{51}Cr-EDTA and ^{103}Ru-phenenthroline for 16d. During the period when animals received non-radioactive markers ruminal methane and VFA production rate measurements were made from the administration of (^{14}C)-labelled methane, acetate, propionate and butyrate. Two 24-hour duodenal collections were also made, following intraruminal (^{35}S)-sulphate infusion, for the determination of duodenal OM, N and microbial N flows. The duodenal sampling was repeated during the period of administration of radioactive digesta markers. A 24-hour ileal collection, preceded by 8-day faeces and urine collections, were also made during this period.

As the collaborative trial is being conducted over the period of a year, comparative results between laboratories are not yet available.

REFERENCE

A.R.C. 1980 . The Nutrient Requirements of Ruminant Livestock. London: Commonwealth Agricultural Bureaux.

3. The effects of supplementary feeding in early lactation and herbage mass on the performance of ewes and lambs

J.A. Milne, T.J. Maxwell, R.D.M. Agnew and A.R. Sibbald

In a previous experiment (Milne, Maxwell and Souter, 1981) the growth rate of twin lambs suckling Greyface ewes was found to increase as herbage mass, maintained at the same level for the first six weeks of lactation, increased from 450 to 1500 kg DM/ha. The feeding of a conventional cereal and vegetable protein supplement at two levels of intake to ewes grazing swards of 450 or 750 kg DM/ha did not improve lamb growth rates but reduced live-weight losses of ewes. In most management systems herbage masses will increase during the period of early lactation rather than remain constant and the longer-term effects of early lactation nutrition on ewe and lamb performance to weaning have not been adequately quantified. Both these aspects were examined in the present experiment. The observations of Robinson *et al* (1979) have suggested that the feeding of a supplement, which would provide an increased supply of absorbed protein to the small intestine, improves growth rates of lambs in early lactation and the provision of additional ruminal acetate rather than propionate may remove a limitation on ewe milk fat synthesis. Consequently the composition of the supplement fed to ewes in early lactation at pasture was also examined.

The present experiment was undertaken at Hartwood to examine the effects on ewe and lamb live-weight change of (a) two patterns of increase in herbage mass, particularly in early lactation, (b) variations in the amount and type of supplement given in early lactation and (c) the long-term performance of the ewes and lambs to weaning.

Three supplements (450 g/d sugar beet pulp (supplement L), 900 g/d of a supplement containing 86% barley and 14% soyabean meal (H1) and 900 g/d of a supplement containing 86% sugar beet pulp and 14% herring meal (H2) were given to 219 Greyface (Border Leicester ♂ x Scottish Blackface ♀) ewes in groups in 3 replicates. Initially it was intended to have a zero supplément treatment but because of low growth rates of herbage and poor weather conditions in early lactation supplement L, which contained 80g crude protein and 10.3 MJ ME per kg DM was offered. The H1 and H2 supplements contained 126 and 149 g crude protein and 10.6 and 10.1 MJ ME per kg DM respectively. The composition of the H1 supplement was similar to that which has been commonly advocated. The H2 supplement was designed to provide additional protein to be absorbed from the small intestine and additional production of acetate in the rumen.

In each replicate the ewes grazed swards of mixed species composition which were allowed to increase in herbage mass from 450 kg DM/ha to either 800 or 1200 kg DM/ha by the end of the first 8 weeks of lactation. The herbage masses were then allowed to increase from 800 and 1200 kg DM/ha to 1400 and 1600 kg DM/ha respectively by weaning at 15 weeks of lactation.

The ewes weregiven a ration of hay and cereal supplement in the last 6 weeks of pregnancy such that only moderate levels of undernourishment were sustained. They were in moderate body condition (mean condition score, 2.0) at parturition. The ewes were allocated to treatments 2-3 days after lambing (mean lambing date, 31 March) according to age of ewe (half of the animals were gimmers), number of lambs (1.75 lambs/ewe), live weight of ewe and date of lambing. Supplements were offered immediately and there were no refusals after the first week. The ewes and lambs were grazed on parasite-free swards at 10 ewes/ha in the first 8 weeks of lactation. Additional ewes and lambs from the same flock were used to adjust herbage masses to the required amounts in later lactation. Measurements of ewe and lamb live weight were made at birth and at 2-week intervals thereafter.

The effect of the supplements on the performance of the ewes and lambs is given in Table 1.

Table 1. Ewe and lamb performance from birth to weaning of supplements given in the first 8 weeks of lactation

	Supplement			SE of mean
	L	H1	H2	
0-8 weeks of lactation				
Live-weight gain of lambs (g/d)				
Single	368	387	403	10.6
Twins	278	296	337	4.5
Live-weight change of ewe (g/d)	19	38	91	13.8
8-15 weeks of lactation				
Live-weight gain of lambs (g/d)				
Single	233	259	198	15.8
Twins	233	222	204	6.1
Live-weight change of ewe (g/d)	16	- 1	-74	14.5

The live-weight gains of lambs in the first 8 weeks of lactation were significantly ($P < 0.01$) greater for the H2 than for the L or H1 supplements. There was a smaller but significant ($P < 0.05$) benefit of the H1 over the L supplement. The live weights of the lambs from the three treatments at the withdrawal of supplementary feeding were significantly ($P < 0.01$) different from one another and were 21.8, 23.0 and 24.6 kg for the L, H1 and H2 treatments respectively. The advantage of the H2 supplement can probably be attributed to the combination of an increase in the amounts of absorbed protein in the small intestine and a slightly different rumen fermentation. The smaller responses to the H1 supplement are in agreement with the findings of Milne et al (1981).

From the withdrawal of supplement at 8 weeks to weaning at week 15 of lactation the live-weight gains of lambs were significantly ($P < 0.01$) higher for lambs from ewes that had previously received the L or H1 supplements. Consequently at weaning there was no significant difference between the combined data for the live weights of single and twin lambs given the different supplements in early lactation although the live weights of twin lambs were still significantly ($P < 0.05$) higher for those lambs whose ewes had received the H2 supplement rather than the L supplement. The mean live weights of twin lambs at weaning were 31.6, 32.1 and 32.9 kg for the L, H1 and H2 treatments respectively.

Ewe live-weight changes were small throughout lactation. There was a significantly ($P < 0.05$) greater live-weight gain of ewes receiving the H2 supplement in early lactation than the L or H1 supplements but this was compensated for by greater gains of ewes in later lactation which had received the L or H1 treatment so that there were no significant differences over the whole lactation period between supplement treatments.

During the first 8 weeks of lactation differences between the herbage mass treatment only occurred consistently between all treatment plots in weeks 6-8; an analysis of the data provided no evidence of a treatment effect on herbage mass for this period. However, when mean herbage mass and herbage mass^2 data from each experimental plot were used as co-variates they explained highly significant amounts of the total variation in lamb live-weight gain for each of the four, two-week periods up to week 8 of lactation. Positive curvilinear relationships were observed for each of these two-week periods. The data from this experiment suggests that in early lactation when the potential intake of the lactating ewe is some 50% greater than the dry ewe, small changes in herbage mass at low levels (i.e. less than 700 kg DM/ha) bring about changes in herbage intake and therefore in milk production. These changes in turn influenced lamb growth rates even though the amount and type of supplement also had a significant effect on lamb performance.

Between weeks 8 and 15 of lactation the herbage masses followed the planned design. Live-weight gains of single and twin lambs were significantly ($P < 0.05$) greater for the high than the low herbage mass and ewe live-weight changes were also significantly ($P < 0.05$) different between herbage masses (see Table 2).

Table 2. Ewe and lamb performance as affected by herbage mass in weeks 8 to 15 of lactation

	Herbage Mass		SE of mean
	High	Low	
Live-weight gain of lambs (g/d)			
Single	266	198	12.5
Twin	247	194	5.3
Live-weight change of ewes (g/d)	+27	-68	11.9

The following conclusions were drawn from the experiment:

(a) that herbage mass presented to the ewes had an important influence on lamb live-weight gains both in early lactation at low levels and in later lactation;

(b) that a supplement based on sugar beet pulp and herring meal produced higher live-weight gains of ewes and lambs than one based on barley and soyabean meal or from a lower level of sugar beet pulp in early lactation;

(c) that the advantages of supplementary feeding were lost in later lactation except for twin lambs given the sugar beet pulp and herring meal supplement.

REFERENCES

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Robinson, J.J., McHattie, I., Calderon Cortes, F.J. and Thompson, J.L. 1979. Further studies on the response of lactating ewes to dietary protein. Anim. Prod., 29: 257-269.

4. The effect of method of feeding and the nature of the supplement on the nutrition in winter of ewes grazing a predominantly heather hill

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

In the last HFRO Annual Report (1980, p A.38) we described an experiment conducted in 1979/80 on Birnie Hill, Glensaugh to examine the effect of supplementary feeding in mid-pregnancy on the performance of ewes, the birthweight of lambs and some nutritional variables. With ewes grazing an area of 20% *Agrostis/Festuca*:80% heather at 1 ewe/ha the feeding of 170g of a barley:urea supplement as a feed block or pellet reduced ewe live-weight losses and increased lamb birthweights. No difference was found between the performance of ewes grazing areas containing 20 or 40% *Agrostis/Festuca* at the same stocking rate.

In 1980/81 the same plot areas were used to compare the following four treatments:-

a) 40% *Agrostis/Festuca* area - no supplement in days 30-100 of pregnancy, stocking rate 0.5 ewes/ha.

b) 20% *Agrostis/Festuca* area - no supplement in days 30-100 of pregnancy, stocking rate 1 ewe/ha.

c) 20% *Agrostis/Festuca* area - 200 g/d supplement as barley and urea in feed block in days 30-100 of pregnancy, stocking rate 1 ewe/ha. The feed block placed on *Agrostis/Festuca* followed by heather.

d) 20% *Agrostis/Festuca* area - 200 g/d supplement as barley and urea in feed block in days 30-100 of pregnancy, stocking rate 1 ewe/ha. The feed block placed on heather followed by *Agrostis/Festuca* area.

Treatment plots 2, 3 and 4 were grazed by 50 ewes and plot 1 by 25 ewes. During late pregnancy the sheep on each treatment were fed similarly on an ascending scale of feeding using feed blocks.

The results of the performance of ewes and lambs are summarised in Table 1. The mean lambing percentage was 111% and there was no difference between treatments in this variable.

Table 1. Effect of mid-pregnancy treatments on ewe and lamb performance

	Treatment				SE of mean
	1	2	3	4	
Ewe live weight at start of mid-pregnancy (kg)	54.8	54.7	54.9	55.0	0.68
Ewe live weight at end of mid-pregnancy (kg)	55.7	53.9	56.6	55.5	0.73
Lamb birthweight (kg)	3.81	3.47	3.72	3.61	0.101

There was no effect of pattern of feed block placement on performance but when the feeding of supplements in mid-pregnancy (treatments 1 and 2) is compared with the no supplement treatment (treatment 3) losses in ewe live weight in mid-pregnancy were significantly ($P < 0.05$) greater and birthweights were significantly ($P < 0.05$) lower in the unsupplemented ewes. The initial herbage allowances of *Agrostis/Festuca* on Treatments 1 and 2 were 600 and 180 kg DM/ewe respectively and these were associated with significantly ($P < 0.05$) lower ewe live-weight losses in mid-pregnancy and higher lamb birthweights on treatment 1 than on treatment 2. Although there were only small differences in the digestibility of the diet selected from the *Agrostis/Festuca* vegetation ruminal NH_3 concentrations were significantly ($P < 0.05$) lower on treatment 2 than treatment 1.

Feed block placement influenced grazing behaviour with ewes spending more time grazing on the vegetation type on which the feed block was placed. This was reflected in the significantly ($P < 0.05$) lower ruminal NH_3 concentrations of ewes when the feed block was placed on heather (1.9 mM) than when it was placed on *Agrostis/Festuca* vegetation (3.2 mM).

The intakes of feed block were regulated by providing feed blocks weekly in mid-pregnancy. Daily intakes of feed block increased over the first 1-3 weeks by which time all the block offered was consumed. Thereafter between-day variation in intake was observed with higher intakes at the beginning of the period that sheep had access to new feed blocks (see Table 2).

Table 2. Daily intakes of feed block (g/ewe/d) when positioned on *Agrostis/Festuca* and heather areas in mid-pregnancy

	Plot 2		Plot 4	
	Mean intake over period	Mean of 1st 3 days of period	Mean intake over period	Mean of 1st 3 days of period
	Feed block on *Agrostis/Festuca*		Feed block on heather	
Week 1	160	170	0	0
2	200	170	165	156
3	200	200	190	180
4	210	300	190	300
	Feed block on heather		Feed block on *Agrostis/Festuca*	
Week 5	200	150	200	200
6	200	330	200	290
7	200	350	200	300
8	-*	310	-*	300

* Snow cover at end of week

Concomitant observations showed that there was also considerable between-animal variation in block intake with coefficients of variation ranging from 30 to 60% within groups of 10 ewes. In this experiment and in the experiment of 1979/80 there were significant ($P < 0.01$) rank correlations of intakes of blocks by ewes over successive measurement periods suggesting that it should be possible to reduce the coefficients of variation in block intake if the factors influencing individual intakes by sheep were elucidated.

CATTLE

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

1. Spring calving 1981. The response in milk yield and calf growth rate to changes in nutrition at different stages in lactation

J. Hodgson, R.A. Hetherington and E.A. Hunter (ARCUS)

This experiment was essentially an extension of the simple, preliminary trial carried out at Hartwood in 1980 (Annual Report 1980, p A.53).

Forty cows (28 Hereford x Friesian and 12 Blue Grey) which calved to a Charolais bull in March were allocated at turnout on 22 May to swards maintained at either 3-4 cm (L) or 6-8 cm (H) under continuous stocking management. Cows were either maintained on treatment, or switched between treatments, for three successive periods of six weeks; animals were allocated at random to each of the eight possible sequences of treatment within blocks balanced as far as possible for genotype and calving date. A Charolais bull ran with each group of cows until the end of June.

The swards were predominantly perennial ryegrass, and received approximately 240 kg N per ha over the grazing season. The specified sward heights were maintained by introducing non-experimental animals and, as the season progressed, removing some experimental animals.

Cows and calves were weighed fortnightly, and estimates of milk yield were made using the oxytocin technique, once in Period 1 and twice in the other two periods. The results shown in Table 1 refer to four blocks of cows which completed the experiment.

Table 1. Effect of treatment in each period of the grazing season season upon cow and calf performance in the same period

Period	1		2		3	
Treatment	L	H	L	H	L	H
Cow LWG (kg/day)	0.28	0.82	-0.78	0.42	0.17	-0.15
SED	0.100***		0.126***		0.187^{ns}	
Milk yield (kg/day)	10.1	11.1	9.4	11.0	9.2	9.9
SED	0.78^{ns}		0.69*		0.50^{ns}	
Calf LWG (kg/day)	0.97	1.28	0.88	1.29	1.19	1.18
SED	0.067***		0.091***		0.095^{ns}	

Cow weight change was significantly affected by current treatment in Periods 1 and 2, but not in Period 3. There were no residual effects of treatment in one period upon subsequent weight changes, and interactions between the effects of treatment in different periods were not significant. Treatment in Period 3 had the greatest effect on overall weight change, suggesting that the effect was largely gut fill.

Milk yield was higher on treatment H than on treatment L in all three periods, but the difference was only significant in Period 2. There were no interactions between treatments in successive periods, but Period 1 treatment had a residual effect on yield in Period 2 ($P < 0.05$). The change in milk yield between Periods 1 and 2 reflected principally Period 2 treatment; the change between Periods 2 and 3 was influenced by treatment in both periods.

Calf LWG was substantially higher on treatment H than treatment L in Periods 1 and 2, but was unaffected by treatment in Period 3. There were no residual effects of treatment in earlier periods, but there was a significant interaction between the effects of treatment in Periods 1, 2 and 3 on calf LWG in Period 3 ($P < 0.05$). Changes in calf LWG between Periods 1 and 2 and between Periods 2 and 3 were both affected by treatment in Periods 1 and 2. Final calf LW was affected by treatment within period in the order Period 1 > Period 3 > Period 2.

These results illustrate the response in milk yield and in calf growth rate to changes in nutrition up to at least the sixth month of lactation. Observations on milk composition, herbage intake and blood metabolites are not yet available, but should help to explain the observed effects. A similar experiment will be carried out in 1982; it will be confined to two eight-week grazing periods, but will involve autumn and spring calving cows and periods of contrasting feeding during pregnancy (for the spring calves) and lactation before the start of the grazing season.

2. The energy requirements of pregnancy in suckler cows

A.J.F. Russel, I.A. Wright and E.A. Hunter (ARCUS)

Results of earlier research on the nutrition of pregnant suckler cows indicate that there are considerable opportunities for using the cow's body reserves to effect economies in the use of expensive winter feeding stuffs. For example, with cows in good body condition (condition score 3 or greater) 3 months before calving, body reserves can contribute between 30 and 40% of total nutrient requirements without prejudicing subsequent cow or calf performance. The extent to which body reserves can be used for maternal maintenance and foetal growth is, however, dependent on body composition and there is a need to quantify the effects of the extent of body reserves on the food inputs required to ensure that any production penalties in terms of calf birth weight and subsequent performance are kept within acceptable limits. An experiment with this objective is planned to begin in autumn 1982.

As a preliminary to this investigation an experiment was conducted during the 1981/82 winter at Hartwood to provide information on the energy requirements of pregnancy in suckler cows. This was necessary because the very limited information in the literature on the energy requirements of the conceptus and how these change in late pregnancy make it difficult to define optimum patterns of nutrient input, as opposed to 'flat rate' systems of feeding. It was also considered necessary to estimate rates of tissue depletion in undernourished pregnant cows varying in initial body composition.

The approach to the estimation of energy costs of pregnancy involved the use of both pregnant and non-pregnant cows. The non-pregnant cows were used to provide an estimate of maintenance requirements under the conditions of the experiment. This was done by feeding 8 Blue-Grey and 8 Hereford x Friesian cows four levels of energy intake ranging from approximately 30 to 110% of anticipated maintenance requirements (16-57 MJ ME/day) in a systematically determined sequence which ensured that no individual was subjected to the lowest level of intake for an excessive period, and which gave the same total intake (per unit body weight) to each animal over the course of the experiment. Cows were weighed twice weekly for 12 weeks to permit accurate estimates of daily live-weight change to be made from regressions of live weight on time. The relationships between daily live-weight change and energy intake provide estimates of maintenance energy requirements. The cows were also blood sampled twice weekly to permit the establishment of relationships between concentrations of circulating metabolites (principally free fatty acids and 3-hydroxybutyrate) and energy status. Maintenance requirements, as determined above, are then used to convert energy intakes to assessments of energy surpluses and deficits to permit the estimation of energy status in pregnant cows from a knowledge of concentrations of circulating metabolites.

Twenty-four pregnant Blue Grey and 24 pregnant Hereford x Friesian cows, selected primarily from the Nutrition herd supplemented with some of the earlier calving cows from the Grazing herd, were also fed a range of levels of intake. The four nutritional treatments varied from approximately 55 to 95% of likely maintenance requirements (29-49 MJ ME/day) and were fed in an ordered fashion to ensure equal intakes (per unit body weight) over the experimental period of 12 weeks, thus minimising possible effects on calf birth weight. These cows were also weighed and blood sampled twice weekly to provide data for the development of relationships between concentrations of circulating metabolites and time. These will provide information on the pattern of increasing energy demands, and differences in concentrations between levels of energy intake will facilitate the quantification of these demands.

Deuterium oxide infusions, Scanogram measurements of fat depth at the 12th/13th rib site, and linear measurements of height, width and length were made periodically throughout the experiment to permit estimates of *in vivo* body composition to be made. All cows were condition scored routinely at each weighing.

The experiment has been recently completed.

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

I.A. Wright and A.J.F. Russel

Full results of this study are available in the thesis entitled "Studies on the body composition of beef cows" by Iain A. Wright, a copy of which has been lodged in the HFRO library.

The following is an abstract which appears in the thesis:-

"Suckler cow management systems generally require cows to be dependent on their body reserves of energy and protein at some stage of the production cycle. In nutritional studies with suckler cows it is therefore important that the rate of use or replenishment of body reserves be considered with contemporary nutrition. This requires the quantification of body reserves and hence a means of measuring body composition in the live animal.

The methods available for the estimation of *in vivo* body composition in animals are reviewed and a number of techniques (live weight, skeletal size, total body water as estimated by deuterium oxide dilution, blood and red cell volumes as estimated by Evans Blue dilution, ultrasonic measurement of subcutaneous fat depth and eye-muscle area, and body condition scoring) were examined using 73 non-pregnant, non-lactating cows of five genotypes (Hereford x Friesian, Blue-Grey, Galloway, Luing and British Friesian) ranging in body condition score from 0.75-4.5. Direct measurement of body composition in terms of water, fat, protein and ash were made following slaughter.

Live weight, deuterium oxide dilution, ultrasonic measurement of subcutaneous fat depth and eye-muscle area, and body condition scoring were all considered to be potentially useful predictors of body composition, but a combination of techniques offered a better prediction than did any single index. Using a combination of techniques it was possible to predict body fat and protein with residual standard deviations of 13.1 kg and 3.15 kg respectively.

Body composition changes were also examined, and it was calculated that the composition of empty body-weight change was dependent upon empty body weight, containing more fat and less water, protein and ash at higher empty body weights.

Important breed differences were found in the partition of fat among the main adipose tissue depots, with the Friesian cows having a greater proportion of fat in the internal depots and a lower proportion in the subcutaneous depot. The implication of breed differences in fat partition are discussed in relation to *in vivo* body composition measurement.

An ancillary study was carried out into the effects of body condition on maintenance requirements and on the use of blood metabolites to measure energy status in suckler cows. This indicated that body condition affected maintenance requirements to the extent that at 500 kg live weight, maintenance requirements were 8 MJ ME/day less for each unit increase in condition score. Plasma free fatty acids were shown to be particularly useful in assessing energy status in cows, but 3-hydroxybutyrate concentrations were of little value in non-pregnant, non-lactating animals.

Finally, the conclusions of the two studies are discussed in relation to areas of study likely to prove useful in the development of efficient systems of suckled calf production."

4. <u>Nutrition and performance of weaned suckled calves</u>

A.J.F. Russel, I.A. Wright, T.J. Maxwell and E.A. Hunter (ARCUS)

There is a need to define with some objectivity the place of weaned suckled calves on hill and upland farms. In many enterprises weaned calves have to be sold irrespective of prevailing prices because of limitations of conserved fodder for winter use. Consideration of hill and upland beef production systems indicates possible economic advantages of incorporating weaned suckled calves as integral components of such systems, even when this might entail a reduction in cow numbers to make conserved fodder available for the calves. Evidence that performance of beef cattle at pasture is inversely related to performance during the previous winter suggests that there is scope for wintering such calves inexpensively with the expectation of high levels of performance from inexpensive grazed herbage the following summer.

The generalisation that rate of live-weight gain at pasture is inversely related to rate of gain during the preceding winter must be subject to limitations at either end of the live-weight gain range and be constrained within upper and lower threshold live weights. Factors such as sex, genotype, pre-weaning nutrition and age at weaning and/or housing are also likely to be important.

It was against this background that work was initiated at Glensaugh in late 1981 to establish in quantitative terms the effects of at least some of the factors noted above. The objectives of the particular experiment currently in progress are:-

(i) To produce, by different nutritional treatments, three distinctly different rates of live-weight gain over the winter period.

(ii) To relate rates of live-weight gain and changes in certain indices of body composition to nutrient provision, and to quantify the effects of sex, genotype, age and previous nutritional history on performance over the winter housing period.

(iii) To quantify, in the grazing situation, the effects of live-weight change and some indices of body composition, of factors including: herbage mass, rate of live-weight gain during the previous winter, indices of body composition at turnout, sex, age, genotype and previous nutritional history.

The work is being conducted on 60 calves of two genotypes (Charolais crosses from Blue Grey and Hereford x Friesian cows) using both females and castrated males drawn in equal numbers from the autumn-calving Nutrition herd and the spring-calving Grazing herd at Hartwood, and balanced as far as possible for the nutritional treatments applied to their dams. All calves receive a basal diet of 16 kg silage per day, plus a barley mineral supplement in quantities designed to produce three distinctly different rates of live-weight gain (250, 500 and 750 g/day) over the winter period.

The calves are weighed fortnightly and condition scores and measurements of fat depth (using the Scanogram) are recorded regularly. To date actual rates of live-weight gain have approached the prescribed rates very closely and significant effects due to sex, genotype and age have been noted.

Following turnout, the calves will graze sown pasture at two herbage masses (1000 and 2500 kg DM/ha). Rates of live-weight gain and changes in condition score and fat depth will be recorded periodically. Herbage intakes of the calves grazing the higher herbage mass will also be measured in an attempt to determine what part of any differences in performance is due to differences in voluntary intake.

NUTRITION : MINERAL

02009 : Mineral nutrition and animal performance

1. Copper studies, Sourhope 1981: further investigations in the prophylaxis of induced hypocuprosis in hill lambs by the administration of cupric oxide needles

A. Whitelaw, R.H. Armstrong, E. Skedd, C.C. Evans and A.R. Fawcett

In 1980 the use of cupric oxide needles administered to ewes prepartum at a dosage rate of 4g, and to lambs at marking (approximately five weeks of age), at a dosage rate of 2g confirmed that this method of prophylaxis was extremely efficacious. Twin lambs were used from dosed or undosed ewes and one twin was dosed whilst its sibling was untreated. Additional studies (1980 Report p A.42) had indicated that a dose rate to lambs of 1g cupric oxide needles would suffice in producing similar live-weight gains, adequate plasma copper concentrations but lower, yet adequate liver copper concentration.

In previous years it was also found that the administration of cupric oxide needles in the prepartum period, whilst giving a short period of protection to the lamb, did not maintain the ewe in normocupraemia for as long a period as when the ewe had been given copper at the time of parturition.

In 1981 the studies examined the differences obtained in the same year between the two times of dosing the ewes, the responses obtained in lambs given 1g of cupric oxide needles, and the differences in treated and untreated lambs which were not twins. In addition a study involving a trial copper injectable preparation (Product R) was incorporated in the studies. Four groups of twin lambs were formed as follows:-

Group 1. Twin lambs from ewes given 4g cupric oxide needles in the prepartum period (10-24 days prelambing) and themselves given 1g cupric oxide needles at marking (3-5 weeks of age).

Group 2. Twin lambs from ewes given 4g cupric oxide needles at the time of parturition and themselves given 1g of cupric oxide needles at marking.

Group 3. Twin lambs from ewes given 4g cupric oxide needles prepartum and themselves given 10 mg injection of product R at marking.

Group 4. Twin lambs from untreated ewes and themselves not treated.

All four groups of ewes and lambs grazed the improved Sourhope reseeds from birth to weaning on the 20th August.

Table 1 summarises the results.

Table 1. Mean plasma copper concentrations µg/100 ml

	10/4	14/6	12/6	2/7	20/8
1. Ewes dosed prepartum	75.3	53.7	33.7	25.4	22.4
2. Ewes dosed at parturition	75.3	94.6	85.7	85.8	51.6
3. Control ewes	75.3	24.5	15.2	12.9	14.0
Lambs given 1g at marking (Gp1) Dams dosed prepartum		76.7	109.9	109.4	106.9
Lambs given 1g at marking (Gp2) Dams dosed at parturition		95.9	112.3	120.3	100.6
Lambs given product R (Gp 3)		76.7	108.0	65.3	30.2
Control lambs (Gp 4)		35.9	12.7	12.5	15.3

Mean live-weight gains, birth to weaning

Group 1	23.08 kg
2	23.60 kg
3	21.71 kg
4	21.55 kg

Mean liver copper values, lambs representative of each group

Group 1 (3)	202 mg/kg DM	sufficient
2 (3)	78 mg/kg DM	sufficient
3 (6)	8.8 mg/kg DM	deficient
4 (6)	9.0 mg/kg DM	deficient

Discussion: The results show that all lambs from dosed ewes were normocupraemic at marking (14/5). The lambs from undosed ewes were hypocupraemic. All lambs given 1g cupric oxide needles at marking remained normocupraemic at weaning. Lambs given product R became hypocupraemic one month after dosing and control lambs were severely hypocupraemic. Live-weight gains showed significant differences between lambs treated with 1g cupric oxide needles and the other two groups; their liver copper concentrations were within the normal range whilst the other two groups were deficient.

2. Copper studies, House o' Muir 1981: cupric oxide needles in the prophylaxis of swayback

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

The occurrence of cases of delayed swayback in lambs derived from ewes confined to an improved reseeded pasture during pregnancy in 1980 provided an opportunity in 1981 to evaluate the prophylactic use of cupric oxide needles administered to ewes against swayback. Fifty ewes were confined to an improved reseed during pregnancy. Twenty-five were dosed orally with 4g cupric oxide needles in mid-pregnancy, the remainder were untreated.

Table 1 shows the results.

		Congenital Swayback	Delayed Swayback
Group 1.	Treated	Nil	Nil
Group 2.	Control	6	8

These results confirm that cupric oxide needles administered to ewes in mid-pregnancy will prevent swayback in their offspring.

3. Copper studies, Hartwood 1981: studies in copper status and the administration of cupric oxide needles to lambs grazing brassicae

A. Whitelaw, A.R. Fawcett, C.D. Kerr and A.J. Macdonald

Lambs grazing brassicas can be subjected to growth limiting factors. One is a Heinz body anaemia due to the presence of S-methyl cysteine sulphoxide (SMCO) in the plant which is converted to dimethyl di-sulphide by rumen micro-organisms and which is a haemolysin. Another is the presence of declining plasma copper concentrations to produce a copper deficiency resulting from elevations in the molybdenum and sulphur content of brassicas.

Fifty Scottish Blackface lambs were split at random into two groups of twenty-five. Group 1 were given 2g cupric oxide needles in a gelatin capsule orally. Group 2 were untreated. All lambs were dosed with an anthelmintic on the 6th November 1980 and folded on to 1.4 ha of a brassica crop. The lambs were blood sampled and weighed weekly until the termination of the trial on the 12th January 1981, when livers were taken from lambs from each group for copper estimations. Blood samples were analysed for the following - plasma copper concentrations, superoxide dismutase concentrations, haemoglobin, packed cell volume and for Heinz bodies as a percentage of erythrocytes.

Results: Copper treated lambs were normocupraemic throughout the trial. Untreated lambs became hypocupraemic by week four, showing a steady decline in copper status till week 9 when they were severely hypocupraemic. Liver copper concentrations of lambs representative of each group showed that treated lambs were well within the normal range whilst untreated lambs were markedly deficient.

The first surge of Heinz body anaemia from weeks 1-3 did not show any differences between the two groups in the percentage of affected erythrocytes, haemoglobin values or packed cell volume values. However, the second surge from weeks 4-7 showed that the treated group showed a significantly lower degree of Heinz body anaemia, corresponding with the onset and continuation of hypocupraemia in the control lambs. Whilst values for superoxide dismutase differed at the onset of the trial, values at week four were considerably higher in the treated group. This trial demonstrates that lambs folded on to brassica crops can develop a severe hypocupraemia which could affect the performance of lambs which had not reached a 'finished' condition by 70 days. It also indicates that copper administration may influence the second 'surge' of Heinz body anaemia and further studies are being carried out.

NUTRITION : METABOLISM

02010 : Studies of the metabolism of the grazing ewe

1. Aspects of glucose metabolism in non-pregnant, pregnant and lactating ewes

S. Wilson

The importance of glucose production in the ruminant, particularly during pregnancy for the nutrition of the foetus and during lactation for lactose production, is well established. Although a number of experiments have shown that propionate supplies approximately 30-50% of the glucose-carbon produced in non-pregnant, non-lactating animals very little information is available on whether the contribution changes during pregnancy and lactation.

A series of experiments was therefore conducted (following a period of technique development and evaluation as described in the 1980 Annual Report, p. A.35-37) to determine the contribution that propionate made to glucose in non-pregnant, non-lactating (NP) ewes and ewes in mid-pregnancy (MP), late pregnancy (LP) and "peak" lactation (PL).

A 3-pool modelling approach, involving the calculations of propionate, glucose and CO_2 production rates (determined from the relationship between the "plateau" specific activity (SA) and the infusion rate) and the respective transfer quotients (TQ), (i.e. the proportion of product derived from precursor, determined from the relationship between the SA of product and precursor) was adopted. This type of methodology has the advantage of not only providing estimates of the proportion of glucose derived from a specific precursor, but also provides information on the proportions of glucose and the precursor which are oxidised to CO_2 and diverted to other metabolites.

Seven pregnant Scottish Blackface ewes (2 with a single foetus and 5 with twin foetuses) were fed continuously a diet of 1200g dried grass per day. At approximately days 85 and 125 of gestation they, together with 3 similar but non-pregnant ewes fed the same diet, were subjected to continuous infusions (18 hr) of the following tracers on separate days: (2-^{14}C)-propionate into the rumen, (U-^{14}C)-glucose into the jugular vein and (^{14}C)-bicarbonate into the jugular vein. At the same time as the (^{14}C) tracers were being infused, (6-^{3}H)-glucose was also infused to check for any day-to-day variation in glucose production rate (GPR) (Wilson et al, 1981). Following lambing, the intake of the 7 lactating ewes (4 suckling single lambs, 3 suckling twin lambs) was increased to 2500g per day and at approximately day 28 of lactation, they were subjected to the same infusion procedures as before.

Although propionate production in the rumen of the non-pregnant and pregnant ewes fed 1200g dried grass per day was constant (34$\pm$ 2.0g C/day), the GPR rose significantly in late pregnancy, particularly in the ewes with twin foetuses ($P < 0.01$, see Table 1). No increase in the proportion of glucose-C supplied by propionate meant that the additional glucose-C (i.e. 20g) was derived from other metabolites. The proportion of the GPR which was oxidised to CO_2 was reduced significantly in the pregnant ewes (NP, .84; MP, .76; LP, single foetus, .66; twin foetuses, .59). Consequently the proportion of the GPR which was diverted to metabolites other than CO_2 in the pregnant ewes was increased. There was a trend towards a reduction in the proportion of propionate oxidised directly to CO_2 in the later stages of pregnancy but the differences were not significant. Approximately 30% of the propionate produced was diverted to other metabolites in non-pregnant and pregnant ewes.

Table 1. The production of glucose (gC/day) and the transfer of carbon (g/day) to and from glucose and propionate in non-pregnant and pregnant ewes fed 1200g dried grass per day and lactating ewes fed 2500g dried grass per day.

	Mid pregnancy experiment			Late pregnancy experiment			Lactation experiment	
	non-pregnant[1]	1 foetus[2,4]	2 foetuses[3]	non-pregnant[2,4]	1 foetus[2,4]	2 foetuses[3]	ewes suckling single lamb[3]	ewes suckling twin lambs[1]
glucose production rate	40.30 ±1.30	47.00 (±4.30)	47.85 ±2.57	41.00 (±0.30)	52.60 (±5.10)	60.25 ±1.44	94.83 ±6.04	104.37 ±8.50
propionate to glucose	9.90 ±0.17	11.34 (±2.42)	13.09 ±1.79	14.70 (±0.28)	18.02 (±1.78)	16.75 ±1.73	31.14 ±2.00	36.82 ±4.86
CO_2 to glucose	8.25 ±0.53	8.29 (±3.31)	7.36 ±0.72	4.27 (±0.35)	6.21 (±0.00)	5.35 ±0.09	12.03 ±1.17	14.19 ± 1.47
other metabolites to glucose	22.96 ±1.89	28.51 (±1.02)	28.24 ±0.91	22.69 (±0.29)	29.17 (±3.40)	38.87 ±1.39	53.21 ±4.02	54.70 ±3.56
glucose to CO_2	33.13 ±3.48	36.51 (±4.25)	35.77 ±3.91	34.78 (±0.40)	34.71 (±4.13)	35.46 ±2.95	45.88 ±4.74	30.63 ±0.53
glucose to other metabolites	8.13 ±2.40	11.70 (±0.52)	13.05 ±1.32	6.83 (±0.00)	18.59 (±1.01)	25.50 ±2.20	50.25 ±7.59	74.74 ±8.91
propionate to CO_2	15.43 ±1.30	10.53 (±7.11)	13.62 ±3.48	9.68 (±1.17)	6.65 (±0.80)	5.31 ±1.03	14.26 ±1.15	16.61 ±2.06
propionate to other metabolites	9.69 ±0.75	12.97 (±4.20)	12.65 ±1.78	7.96 (±0.58)	7.94 (±2.64)	10.56 ±1.54	11.41 ±1.44	11.02 ±5.79

1 mean of 3 values
2 mean of 2 values
3 mean of 4 values
4 values in parentheses are the distributions around the means

GPR in the lactating ewes fed 2500g dried grass per day was approximately twice that of the non-pregnant and pregnant ewes fed 1200g per day, although the production of propionate was only 75% higher. The proportions of GPR derived from propionate and other metabolites were similar to the non-pregnant and pregnant ewes. The only parameters to show any variation between ewes with single and twin lambs were those concerning the metabolism of glucose. Significantly less glucose was oxidised to CO_2 ($P < 0.05$) in the ewes suckling twin lambs. There was also a trend (NS, $P > 0.05$) in these ewes towards a greater diversion of glucose-C to other metabolites which probably reflected an additional contribution of glucose to lactose. The use of (^{14}C)-propionate to assess the contribution of propionate to glucose has been criticised on the grounds that it will underestimate the contribution due to the "crossover" of label in the TCA cycle and theoretical methods have been proposed to calculate the extent of the problem (Thompson, 1971). These methods were shown to be inapplicable to the data derived from this experiment. If there had been any under-estimation of the contribution of propionate to glucose due to "crossover" of label in the present experiments, it may have been counteracted by a possible over-estimation of propionate-C contribution caused by the use of (2-^{14}C)-propionate for determination of the TQ. Theoretically, only $\frac{5}{6}$ of the glucose-C can possibly come from propionate; the other carbon comes from CO_2. The use of a tracer, such as (12-^{14}C) propionate, which transfers 100% of the label to glucose, potentially over-estimates the contribution of propionate-C by 17%. Further over-estimation may also occur due to recycling of (^{14}C) via CO_2 during the synthesis of succinate from propionate and also because less carbon from position 1 of propionate is transferred to glucose, than from positions 2 and 3. For these reasons the experimentally determined TQs may not have been too far removed from the "true" values.

Increases in GPR in late pregnancy have usually been associated with an increase in the level of feeding. The present experiments have demonstrated the ability of the pregnant ewe to increase glucose production significantly (by up to 50%) in response to foetal demands, when propionate production remained constant, and with no increase in the proportion of glucose derived from propionate. The magnitude of the increase in late pregnancy (i.e. 8 and 20g C/day is in agreement with estimates of umbilical uptake of glucose in late pregnancy (i.e. 1.7g C/kg foetus/day; Paxson et al, 1978).

Although the production rate of glycerol, another glucose precursor, was not determined directly in the present experiments, indirect estimates derived from plasma glycerol concentrations (Bergman, 1968) suggested that glycerol could have contributed a maximum of only 8-12g C/day to the GPR. This would have accounted for only 19, 17 and 11% of the GPR in the non-pregnant, pregnant and lactating ewes, respectively. It is therefore probable that the remaining 36-48% of the GPR was derived from amino acids (i.e. 15, 19, 30 and 43g C/day in non-pregnant ewes, ewes carrying single and twin foetuses and lactating ewes, respectively). Assuming that in ruminants 28g glucose (i.e. 11.2g C) can be produced from 100g protein (Lindsay, 1979), then 134-384g protein/day would require to have been catabolised to achieve the measured amounts of glucose production. It is likely that the bulk of the contribution would have come from the non-essential amino acids. The reduction in the proportion of glucose-C oxidised to CO_2 as foetal demands increased indicates that the synthesis of other metabolites, such as non-essential amino acids, was becoming increasingly important. Synthesis of non-essential amino acids could also also account for some of the propionate-C produced in the rumen which was not used for glucose synthesis and not oxidised directly to CO_2.

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2. The use of 3-hydroxybutyrate concentrations in plasma to describe the level of undernourishment in late-pregnancy

J.A. Milne

From the results of indoor experiments relationships have been developed between the concentration of 3-hydroxybutyrate (3-OHB) in plasma and the degree of undernourishment of ewes in late pregnancy. These relationships have since been used in the field in our development study flocks to describe the degree of undernourishment of flocks of ewes. Adjustments were made to the amount of supplement given based on the ewe's current 3-OHB concentration and using a degree of personal judgement. This system appeared to work satisfactorily over several years.

More recently a computer programme has been developed to estimate the amount of supplement that should be fed to maintain a given 3-OHB concentration, i.e. a degree of undernourishment, given information on current e-OHB concentration, stage of pregnancy, estimated lambing % and current and pre-mating live weight. This more quantitative approach could allow the use of 3-OHB concentrations as a means of predicting undernourishment to be extended to situations beyond those at HFRO. The computer programme has been applied rigorously in three experiments to ration ewes in late pregnancy. In one of the experiments the programme did not predict sufficient supplement and the 3-OHB concentrations were higher than those desired. In the other two experiments 3-OHB concentrations never rose. In one experiment Greyface ewes were grazing PRG pasture and ingesting a diet of 60% OMD and in the other experiment (Birnie Hill, Year 1) ingesting a diet of 55-60% OMD. In the second experiment the birth weights of the lambs was depressed suggesting that nutrition in late pregnancy was inadequate (in the first experiment more supplement was eventually given than predicted from the programme to satisfy the aims of the experiment). Thus there is some cause for concern about the adequacy of the relationship between 3-OHB concentration and degree of undernourishment in late pregnancy in some circumstances.

In the original indoor experiments ewes were fed once daily and in the development studies the sheep were mainly fed once daily against a background nutrition of poor-quality roughage. Blood samples were taken just prior to feeding and thus undernourishment would be at its daily maximum at the time of blood sampling. In the experiments where 3-OHB concentrations did not rise, even although there was a suggestion of moderate undernourishment, particularly in the Birnie Hill experiment, the degree of undernourishment at the time of sampling may not have been great because of the higher background nutrition provided by the higher quality roughage. Thus the ewes may have been equally under-nourished in both sets of circumstances when integrated over the whole 24 h period but not have exhibited the same pattern nor the same value of 3-OHB concentration at the time of sampling.

Lindsay (1978) reviewed the effect of feeding pattern on various blood parameters but reported no values for ketone bodies or 3-OHB concentrations. However, FFA concentrations showed a rise pre-feeding in a once daily feeding regime and it is possible that the same phenomenon may occur with 3-OHB concentrations.

An experiment was conducted to test the hypothesis that the pattern of feeding of a supplement and the quality of the basal roughage may affect diurnal variation in 3-OHB concentration when the same level of undernourishment (i.e. of daily ME intake) was imposed in late pregnancy. If the hypothesis was proved correct then it would provide an explanation for some previous results and also provide insight into situations where feed blocks were being fed and where better quality roughage was being ingested.

Twelve ewes, half carrying twin lambs and half carrying single lambs, were used in the last 8 weeks of pregnancy to compare three treatments in a 3 x 3 Latin Square design with 4 squares and with each period being of 2½ weeks duration. The three treatments were:-

A. Barley straw + a cereal supplement given once daily.

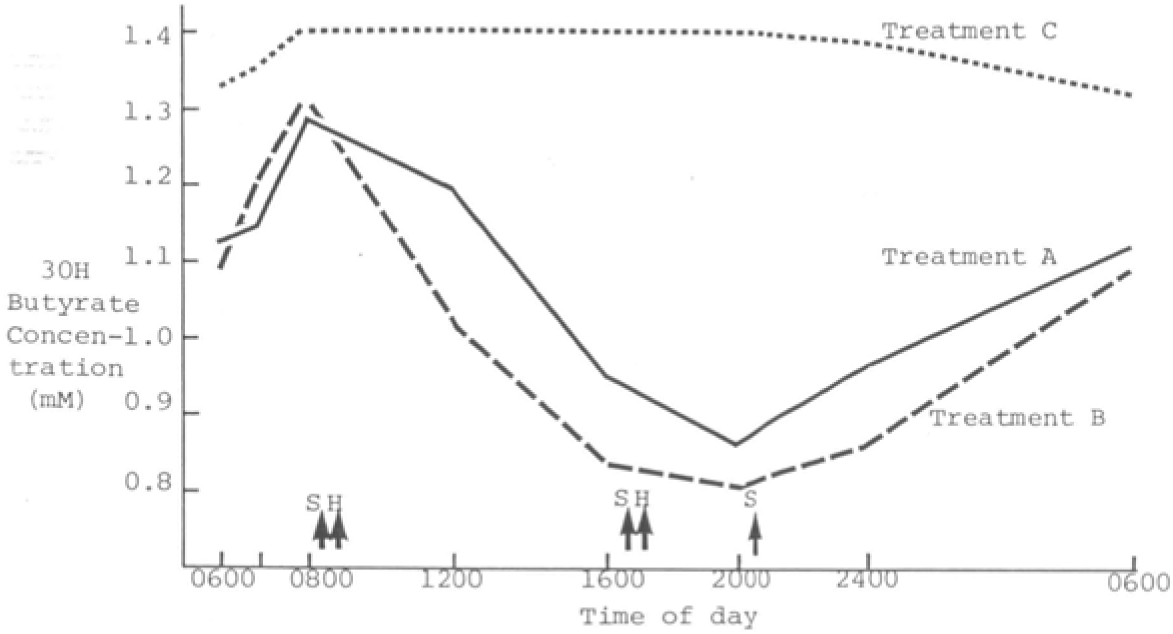
B. A good quality hay + a cereal supplement given once daily.

C. Barley straw + a cereal supplement given in three weeks.

The roughage was given in 2 meals/day and the diets were estimated to provide the same ME intake, which met 75% of the ewe's maintenance requirements of energy.

Figure 1 shows the diurnal variation in 3-OH Butyrate concentration. With treatments A and B there was a diurnal pattern with a peak before feeding at 0830 h followed by a decline to 2000 h and then an increase up to the pre-feeding peak. With treatment C, 3-OH Butyrate concentration remained relatively constant throughout the day. The values for treatment C also tended to be higher than those for treatment B. The results of the experiment show that pattern of supplementation feeding can influence 3-OH Butyrate concentrations which could have implications for the use of the method when the supplement is given as a feed block in late pregnancy. The quality of the basal roughage did not appear to influence the level of 3-OH Butyrate concentration.

Figure 1. Diurnal variation in 3OH Butyrate concentration when hay (H) and supplements (S) were given at different meal frequencies



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UTILISATION : NUTRITION

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

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

J. Hodgson, S.A. Grant, Richard Armstrong, D.E. Suckling, M.M. Beattie, L. Torvell, T.G. Common, G.R. Bolton, T.D.A. Forbes, R. Thompson (ARCUS)

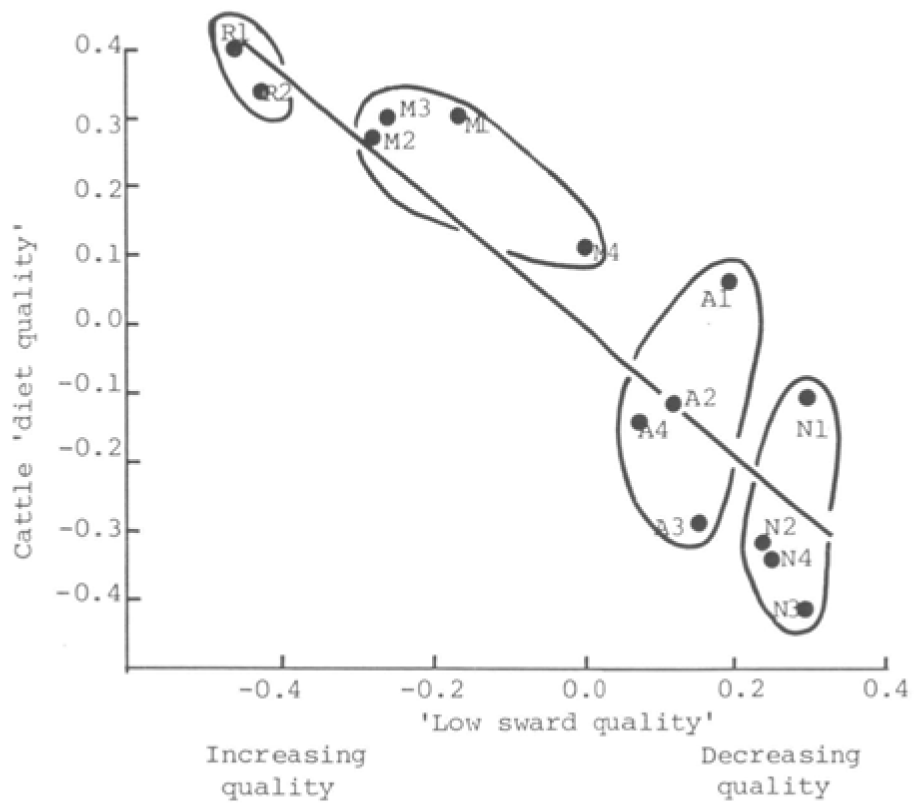
Preliminary results of studies on the diet selection, ingestive behaviour and herbage intake of cattle and sheep grazing a series of indigenous hill plant communities were given in the annual reports of 1978, 1979 and 1980. An analysis of the associations between these variables and their response to varying sward characteristics within the range of grass and grass heath communities (ryegrass, *Agrostis-Festuca*, *Nardus* and *Molinia)* has now been completed and written up in a PhD thesis (Forbes, 1982). The following conclusions were drawn:

The cattle and sheep selected diets of similar organic matter digestibility (OMD), except in the spring and autumn on short swards containing a high proportion of dead herbage, where the sheep obtained diets between 5 and 12 units of digestibility higher than those of the cattle. Intake per bite was found to be the major determinant of daily herbage intake in both species, and was influenced primarily by sward height. Where intake per bite declined, due to declining sward height, rate of biting increased. Increases in grazing time occurred where intake per bite was particularly low, but this was not a consistent response. The cattle responded to increases in the density of the sward by increasing rate of biting; the sheep increased grazing time. Very low intakes per bite in the early spring on short swards where the digestibility of the diet selected was low led to digestible organic matter intakes by the cattle that were only barely adequate for maintenance.

Cattle consistently ate higher proportions of grass flower stems and *Juncus* whilst the sheep consistently ate higher proportions of dicotyledons. To obtain these diets the cattle grazed the surface horizons whilst the sheep grazed nearer the base of the sward. On short swards in the spring the cattle were unable to avoid eating a higher proportion of dead herbage than the sheep.

Principal component analysis was used to reduce the multivariate sward and diet composition data to compound variates which were then used to examine the relationships between sward composition, diet composition and ingestive behaviour. These analyses indicated a general relationship across communities between the sward principal component dominated by the proportions of dead material and fine-leaved grass leaf (negative vectors) and broad-leaved grass leaf (positive vector) and designated "low sward quality", and the diet principal component dominated by the same components with signs reversed (designated "diet quality") for both sheep and cattle (Figs. 1 and 2), implying that differences between swards for these particular variates were differences of degree rather than of kind. However, the responses of ingestive behaviour variables to sward principal components were not consistent across swards.

Figure 1. The relationship between cattle 'diet quality' derived from the proportions of herbage components in the cattle diet, and 'low sward quality' derived from the proportions of herbage components in the sward.



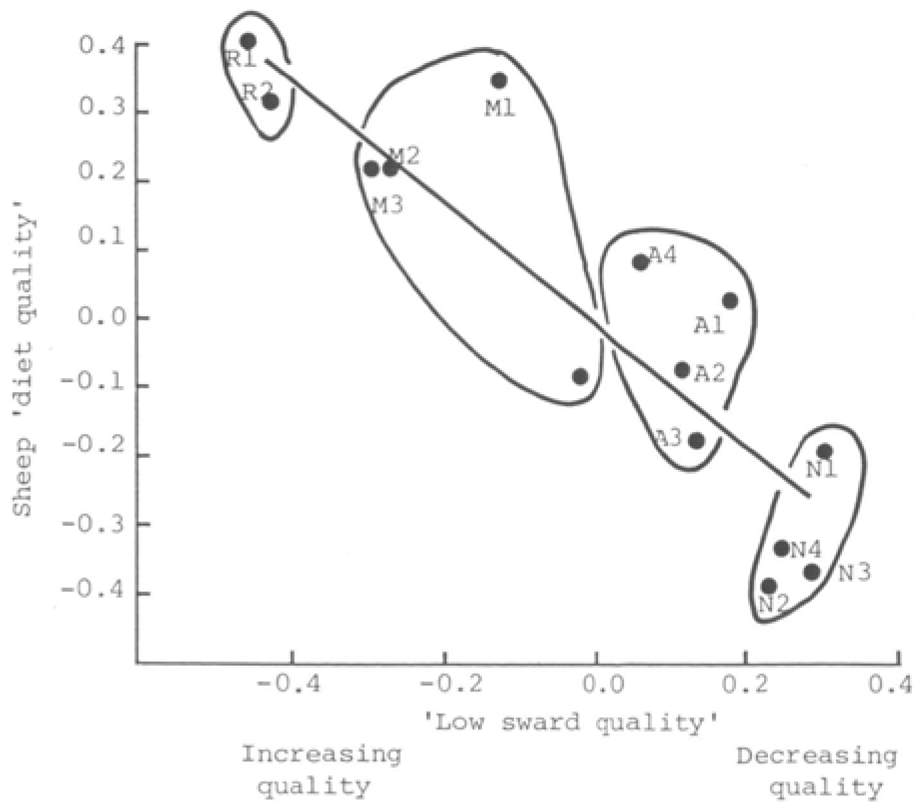


Figure 2. The relationship between sheep 'diet quality' derived from the proportions of herbage components in the sheep diet, and 'low sward quality' derived from the proportions of herbage components in the sward

The following conclusion was drawn from the results. The selective ability of the sheep, particularly when herbage quality was poor, allowed them to maintain the nutrient concentration of their diets. The cattle on the other hand maintained their rate of herbage intake, particularly in the summer months when swards were taller and denser than earlier or later in the grazing season. The fact that cattle and sheep tended to graze different horizons in the sward meant that they were not competitive grazers, in the summer months at least.

Phase II of this project will be concerned with the use of grazing management to manipulate the botanical composition and nutritive value of *Nardus* dominated grass heath, *Molinia* dominated heath, and a mixed *Calluna/Molinia* community. Preliminary preparation of the *Nardus* and *Molinia* communities will start in 1982.

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

Richard Armstrong, J. Hodgson, T.G. Common, D.R. Campbell, M.M. Beattie, H.K. Smith (ARCUS)

Statistical examination of the principal relationships are now complete and the experiment is being written up for publication. Ancillary data on the contents and *in vivo* ('true') digestibility of neutral detergent fibre, acid detergent fibre and lignin are tabulated here together with apparent digestibility of herbage organic matter (OMD).

Table 1 (see over)

The relationships between herbage concentrations of fibre components, their digestibility and apparent digestibility of organic matter will be examined when the faecal analyses are complete. Preliminary examination shows that the relationships in herbage derived from indigenous hill grasses or sedges are broadly similar to those from sown species. The possible use of faecal fibre fractions as independent variables in association with faecal nitrogen content for the prediction of diet digestibility in grazing animals will also be investigated.

Drawn *Eriophorum* trial

Since animals grazing *Eriophorum vaginatum* consume leaf and stem bases 'drawn' from below the sward surface (Grant *et al*, 1976) an experiment was conducted to measure the *in vivo* digestibility of this material to relate to *in vitro* digestion of the same herbage and to earlier estimates of digestibility from the *in vitro* process (Grant and Campbell, 1978).

Table 1. The content of fibre fractions in herbages and digestibility of neutral and acid detergent fibre and of organic matter

	Fibre content			True digestibility		OMD
	NDF	ADF	L	NDF	ADF	
AF1	46.68	26.47	2.64	.778	.716	.768
AF2	48.69	27.98	5.32	.556	.496	.613
AF3	62.44	33.40	5.33	.488	.443	.525
N1	59.73	32.19	3.60	.606	.605	.634
N2	62.01	35.63	5.31	.491	.504	.525
N3	67.01	38.14	6.31	.482	.469	.500
M1	62.79	32.69	5.23	.664	.606	.671
M2	66.47	41.41	9.45	.532	.484	.543
M3	69.94	43.52	9.48	.471	.412	.475
T1	56.26	30.87	4.88	.554	.424	.623
T2	58.02	35.74	8.77	.515	.384	.572
T3	60.66	46.51	14.10	.404	.344	.464
E1	58.58	33.74	8.68	.525	.461	.606
E2	59.46	36.00	10.31	.445	.344	.524
E3	69.54	42.18	15.39	.376	.269	.371
RG1	39.44	22.70	1.61	.760	.748	.796
RG2	53.20	31.58	4.08	.598	.569	.675
RG3+	57.83	34.66	4.85	.519	.485	.600
Cl 1	31.03	NA	2.88	.712	NA	.788
Cl 2	36.80	NA	6.85	.520	NA	.684
Hay+	73.78	NA	6.22	.640	NA	.606

Legend for Table 1

AF = *Agrostis*
N = *Nardus*
M = *Molinia*
T = *Trichophorum*
E = *Eriophorum*
R = ryegrass
Cl = clover

1 = first cut
2 = second cut
3 = third cut

Fibre components (% ash-free in dry matter)

NDF = neutral detergent fibre
ADF = acid detergent fibre
L = lignin
\+ = means for 2 years
NA = not yet available

Eriophorum vaginatum was drawn from a community by hand in early March. It was separated by cutting into leaf and leaf base, then chopped and each component fed to two mature Blackface wethers at 520 g OM/head/day. A third feed consisting of mixed leaf and leaf base was fed concurrently to two other sheep. Faecal collections were made as for the main experiment, and *in vivo* digestibility (OMD) was calculated with correction for refusals using the *in vitro* digestibility (IVOMD) values of these refusals. The results from this experiment agree with the relationships of OMD to IVOMD and to percentage dead established in the main study which used leaf alone. Extrapolating from this data suggests that the OMD value for pure leaf base (i.e. containing no dead material) would be 0.57, which compares with mean predicted DM digestibility values of 0.63 and 0.61 for leaf bases collected in February and May respectively by Grant and Campbell (1978).

Results

	Herbage % dead	IVOMD	OMD	Predicted* OMD
Leaf base	38	0.416	0.477	0.488
Leaf	65	0.309	0.412	0.410
Whole plant	-	0.324	0.419	0.420

* Predicted using standards from the main experiment

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3. Herbage production and utilisation in swards grazed by cattle and sheep

J.C. Arosteguy, J. Hodgson, W.G. Souter, J. King and R. Thompson (ARCUS)

The results of the previous study in this series (Annual report 1980, p. A.50) indicated that rates of herbage growth and net production were higher on sheep-grazed than on cattle-grazed swards at any given level of maintained herbage mass, in association with higher tiller densities. This study was carried out to examine the hypothesis that tiller densities and herbage production should be similar on swards grazed by mixed populations of sheep and cattle and in swards grazed by sheep alone. Twelve paddocks involving two replicates of treatments grazed by cattle alone, sheep alone, or a mixture of the two (approximately 1:1 on the basis of predicted herbage intakes) each at two levels of herbage mass (Table 1) were established in July and maintained under continuous stocking by Greyface wethers or yearling Friesian cattle until October. The paddocks were established on a perennial ryegrass/*Poa annua*/white clover sward in its first harvest year with numbers of tillers or stolon growing points in the proportions 0.80, 0.12 and 0.05 respectively. Measurements of tiller and stolon growing point densities were made in September and October, and of tissue flow in September. Carbon exchange observations were made throughout the period. Measurements were made separately on grazed and ungrazed areas, the proportion of which were estimated.

Tiller densities were higher in swards grazed by sheep alone, or by sheep and cattle, than in swards grazed by cattle alone (Table 2), and were higher at the lower herbage mass. Rates of herbage growth and net production were also higher on sheep-grazed and mixed-grazed swards than on cattle grazed swards at the higher herbage mass, but were unaffected by the species of grazing animal at the lower mass (Table 2), so there were significant ($P < 0.05$) animal x herbage mass interactions for both parameters. The sward observations are all weighted for the relative proportions of grazed and ungrazed areas on individual paddocks.

Herbage intake per animal was greater at the higher than at the lower herbage mass, but intake per unit area was lower (Table 3). The proportion of leaf lamina in the diet, and diet digestibility, were greater at the higher herbage mass. Cattle selected diets with a lower proportion of leaf lamina and lower digestibility than sheep, and the discrepancy was particularly marked in the case of cattle grazing with sheep on the lower herbage mass treatment.

Results of the carbon exchange measurements have not yet been analysed.

Table 1. Experimental treatments: Herbage height and stocking rates of cattle and sheep for the period July - October 1981

Animal species/ Herbage Mass		Sheep	Sheep + Cattle	Cattle
Low	Height cm	3.1	3.6	3.1
	Stocking rate An ha^{-1}	48.2	18.5 + 6.2	13.3
High	Height cm	4.4	4.4	4.3
	Stocking rate An ha^{-1}	24.8	9.9 + 3.3	5.7

Table 2. Herbage growth, senescence, net production and active site density for the first two weeks of September 1981.

Animal species/ Herbage Mass Level		Sheep	Sheep + Cattle	Cattle	$SE\bar{x}$
Low	Growth kg DM ha^{-1} day^{-1}	78.4	77.2	70.1	13.13
	Senescence "	22.5	23.4	16.5	6.07
	Net production "	55.9	53.8	53.6	11.91
	Active site individuals m^{-2} x (1000)	33.7	31.0	25.4	1.38
High	Growth kg DM ha^{-1} day^{-1}	134.5	135.9	78.7	13.13
	Senescence "	47.2	53.6	30.0	6.07
	Net production "	87.3	82.3	48.7	11.91
	Active site† individuals m^{-2} x (1000)	25.0	23.7	21.0	1.38

† Observation made on the first week of October 1981.

Table 3. Herbage intake per individual and per hectare, diet composition and digestibility of the diet.

Animal species/ Herbage Mass		S*	S + C	C*	C + S	$SE\bar{x}$
Low	Herbage intake per animal (g OM day^{-1})	770	800	3580	3670	C = 292.4 S = 70.7
	Herbage intake per area (kg OM ha^{-1} day^{-1})	37.6	37.4	47.6	37.4	3.08
	Laminae of leaf (propn)	0.862	0.832	0.815	0.646	C = 0.0337 S = 0.0177
	OM digestibility	0.735	0.741	0.721	0.690	C = 0.0066 C = 0.0041
High	Herbage intake per animal (g OM day^{-1})	950	1120	4430	4540	C = 292.4 S = 70.4
	Herbage intake per area (kg OM ha^{-1} day^{-1})	23.4	25.4	25.3	25.4	3.08
	Laminae of leaf (propn)	0.897	0.921	0.824	0.863	C = 0.0337 S = 0.0177
	OM digestibility	0.748	0.758	0.724	0.736	C = 0.0006 S = 0.0041

* S = Sheep
* C = Cattle

4. Factors influencing the intake of fodder crops by grazing animals

Richard Armstrong, J. Hodgson, W.G. Souter, M.M. Beattie, T.G. Common and H.K. Smith (ARCUS)

This experiment was carried out as a preliminary test of alternative techniques for estimating the consumption of fodder crops in the field. The use of the conventional indirect method of predicting animal intake from estimates of diet digestibility and faecal output may be inappropriate in this programme for several main reasons. Firstly, repeated movement of sheep on plots for twice-daily dosing, plus fistulate handling, may lead to a degree of crop damage and soiling which would confound interpretation. Secondly, digestibility is likely to be very high (i.e. indigestibility low) and errors proportionately high in relation to it and to resulting predicted intake. Thirdly, the likely future use of supplements may affect crop digestibility and hence estimates of intake.

Consequently, a preliminary comparison was carried out between the animal technique and direct (plant) methods of estimating herbage intake against a background of differing crop condition.

The crop was Giant Rape ("Lair"), half of this had been pre-grazed for two weeks by the experimental animals so that virtually all leaf was removed - "stem"; the ungrazed half was designated "leaf". Animal measurements were made on both "crops" using Blackface lambs or adult wethers separately. Plot sizes were related directly to lamb or wether live weight within crops so that herbage allowance (g/kg LW) was equated between adult and lamb treatments but not between leaf and stem. Live-weights were 32.8 kg and 63.0 kg respectively; plot areas for groups of six lambs and six wethers were 0.0571 and 0.0962 ha respectively.

Estimates of diet digestibility were made on herbage samples obtained by hand plucking or clipping and by extrusa samples taken from adult fistulates which were rotated round treatments. Estimates of faecal output were made from twice daily chromic oxide dosing and faeces sampling.

The 12-day measurement period was divided into two 6-day sub-periods to allow an estimate of changes with time.

Direct estimates of herbage consumption were made in two ways from herbage mass estimates at the beginning and end of the 12 days. Firstly by cutting six 60 x 40 cm quadrats to ground level and weighing cut herbage and litter after washing and drying; secondly by counting plants in similar quadrats and cutting and weighing one-fifth of these after drying. These plants were dissected into stem, petiole and lamina and *in vitro* digestibility (IVOMD) estimates were made on the separate components at the beginning and end of the experiment. Estimates of net herbage change (due to new growth, or losses due to senescence or consumption by pests) were made concurrently on ungrazed crops using exclosures. Alternative estimates of weight loss due to crop damage and associated senescence and leaching were made by pre- and post-experimental weighing of damaged and soiled plant components which were placed in the surface of an excluded area.

Intake and digestibility were measured concurrently with sheep in pens to provide standards of known *in vivo* digestibility for prediction of the *in vitro* digestibility of diet samples from the grazing experiment. Two groups of sheep (2 adults and 2 lambs each) were fed fresh chopped 'stem' or 'leaf' in two feeds per day. The stem and leaf crops were cut from the relevant treatments ≃ 10 cm and ≃ 40 cm above ground surface respectively. The sheep were fed to 20% excess in two feeds/day and consumption was measured for two weeks; then to voluntary intake while faecal collections were made for three consecutive 4-day periods. Samples were taken of feed offered, of any refusal and of extrusa samples of feeds (obtained from penned fistulates) for *in vitro* digestion and dry matter and ash estimation.

Some analyses are not yet complete; the available data is given below.

Pen-feeding trial

Voluntary intake (Table 1) was very much lower than would be indicated by extrapolation from known digestibility:intake relations for grasses, but the relation between *in vitro* organic matter disappearance (IVOMD) and apparent *in vivo* digestibility of organic matter (OMD) agrees with that for high quality grass. The high OMD values of both 'leaf' and 'stem' are partly due to petiole (Table 2); this in turn appears to result from the high values for pith and the low content of fibre.

Grazing trial

Estimates of herbage mass made by cutting quadrats to ground level (Table 3) show that coefficients of variation were high, especially when crops were partly grazed down due probably to erratic grazing patterns, and to higher proportions of litter. The variability of estimates of intake by difference would be even greater.

The mean rate of loss of litter DM was only about 1.5% per day but, unfortunately, there is no information on net herbage change on excluded areas of 'leaf' because of mishap.

Fistulates were reluctant to eat stem in or out of doors, so few extrusa samples were collected. Consequently, estimates of stem OMD and the resulting intakes (Table 6) are based on 'crop' mean values for plucked or clipped samples. The comparison between extrusa and 'hand' samples is consequently inadequate, however the high predicted OMD values for the latter relative to *in vivo* values from penned animals and especially to extrusa (Table 2) suggest that stem in particular is prone to rapid chemical change which may invalidate the use of fistulates. It is planned to investigate feed:extrusa differences further with this material.

Predicted OMD is especially high for young 'stem' and 'leaf' (Tables 4, 5) though there is a marked decline of stem OMD with closeness to ground level. This presumably reflects an increasing proportion of fibre. The lower values for 'stem' OMD in period 2 can be partly explained by this effect, and it is possible that intake was limited not by OMD *per se* but by the increasing amount of fibre, in a physical rather than digestive sense. It is of interest that animals appeared to have difficulty biting stem as grazed height declined and 'toughness' increased.

Because the missing information on net herbage change (OM) is incomplete, we can not critically compare the alternative methods of predicting intake. Estimates based on quadrat cuts assuming OM contents of standing crop and litter agree roughly with 'animal' estimates for the stem treatments but are much lower than animal estimates on leaf. This suggests that some growth was still occurring on the leaf treatments; it also indicates the importance of the assessment of current growth.

Because of gut-fill effects in addition to reservations about intake predictions, relations between performance and digested intake (Table 7) may be of little value. However, loss of weight of animals occurred on stem crops and there was a sharp decline of intake on the latter in Period 2. It is usually observed that animal performance on rape is sensitive to low herbage allowance with its implied dependence on older stem.

Table 1 Intake (g OM/head) and *in vivo* digestibility (OMD) of stem and leaf fractions of rape crop fed to lambs and adult wethers indoors, and *in vitro* digestibility (IVOMD) of fractions offered.

	'Stem' crop	'Leaf' crop
Voluntary intake (g OM/head/day)		
Lambs	548 (±15.8)	615 (± 58.4)
Adults	661 (±112.0)	898 (± 5.3)
In vivo digestibility (OM)		
Lambs	0.78 (±0.015)	0.83 (±0.004)
Adults	0.79 (±0.015)	0.85 (±0.004)
Mean	0.79 (±0.009)	0.84 (±0.005)
Extrusa*	0.68 (1 only)	0.81 (±0.006)
IVOMD (feed offered)		
Mean	0.77	0.85

* Predicted mean values

Table 2. Indoor trial: proportions of plant fractions in the feed offered to animals, and predicted digestibility (OMD) of each fraction and of pith and fibre components of leaf and stem

	'Stem' crop	'Leaf' crop
Diet composition (% DM)		
Stem	84.6	27.3
Petiole	11.1	20.6
Lamina	4.3	52.1
Digestibility (predicted OMD)		
Lamina	0.79	0.81
Petiole	0.87	0.88
Stem	0.84	0.83
Digestibility of separated stem and petiole	Feed	Refusal
Pith	0.90	0.79
Fibre	0.69	0.71

Table 3. Herbage mass (kg OM/ha) from quadrat estimates at start and end of grazing period

Treatment		Start			End		
		Mass	C.V.	H	Mass	C.V.	H
Stem:Adult	S.C.	4140	17.3	47.6	2172	17.5	38.0
	L	460	56.4		756	49.6	
	T	4600	17.1		2928	16.4	
Stem:Lamb	S.C.	3869	27.0	44.7	2172	25.1	34.3
	L	456	28.2		402	33.4	
	T	4325	25.0		2574	23.0	
Leaf:Adult	S.C.	5600	16.9	45.0	4588	35.3	42.5
	L	158	28.0		378	46.8	
	T	5758	16.1		4966	29.7	
Leaf:Lamb	S.C.	5463	22.2	44.5	4284	26.8	44.4
	L	124	25.9		332	28.3	
	T	5586	21.7		4616	23.2	

S.C. - Standing Crop
L - Litter
T - Total
CV - Coefficient of variation (%)
H - Height of grazed plants (cm)

Table 4. Grazing experiment: predicted digestibility (OMD) of sections of stem and of leaves of different age

	Stem portion (above ground level) 0-20	20-40	40-60
Stem	0.67	0.72	0.78

Leaf No.*	8	9	10	11	12	13	14
Leaf (lamina and petiole)	0.87	0.88	0.86	0.87	0.86	0.87	0.77

* older leaves (1-7) shed

Table 5. Grazing experiment: predicted OMD of 'hand' samples

Treatment	Period 1	2
Stem:adult	0.89 (±0.008)	0.84 (±0.034)
Stem:lamb	0.89 (±0.006)	0.73 (±0.039)
Mean	0.89 (±0.005)	0.79 (±0.036)
Leaf:adult	0.86 (±0.013)	0.83 (±0.018)
Leaf:lamb	0.85 (±0.006)	0.86 (±0.005)
Mean	0.86 (±0.006)	0.85 (±0.010)

Table 6. Grazing experiment: herbage intake (g OM/day)

Treatment	Period 1	Period 2	Mean
Stem:adult	1073 (±108.1)	749 (±107.7)	911 (±87.6)
Stem:lamb	659 (±49.6)	482 (±53.6)	570 (±44.4)
Leaf:adult	1170 (±71.0)	1113 (±52.0)	1142 (±42.8)
Leaf:lamb	705 (±47.8)	682 (±72.8)	693 (±41.6)

Table 7. Grazing experiment: digested organic matter intake (DOMI g/day) and live-weight change (LWC g/day)

Treatment	Period 1	Period 2	Mean	LWC 29/10-24/11/81
Stem:adult	955	588	763	-65
Stem:lamb	587	378	478	-115
Leaf:adult	1000	944	973	+62
Leaf:lamb	603	578	588	+62

5. The ingestive behaviour of sheep and cattle grazing a crop of barley *(Hordeum vulgare)*.

Richard Armstrong, M.M. Beattie, W.G. Souter, T.G. Common, M.D. Hunte (CTVM MSc Student), J. Hodgson, R. Thompson and H.K. Smith (ARCUS).

This project was carried out as a pilot trial for a projected study of ingestive behaviour and herbage intake in cattle and sheep grazing a range of forage *graminae*. It should also have included measurements on swards of *Lolium perenne* and *Festuca rubra*, but these swards were too heavily infested with weeds for sensible observations.

The barley, a spring variety, was sown at seeding rates of 94, 188 and 377 kg/ha on 14 May and was grazed for a preliminary period from 17 to 27 July, and an experimental period from 24 to 31 July, by which time ear emergence was well advanced. Each seeding rate was grazed by a group of five mature cows (four non-fistulates and one oesophageal fistulate) and replicate groups of five wether sheep (four non-fistulates, with a set of three fistulates alternating between the two replicates of three groups). Fistulates were cycled round treatments in successive two-day or three-day periods.

Observations of ingestive behaviour, diet composition and herbage intake were made using conventional techniques. Some difficulty was experienced in sampling from the fistulates, particularly towards the end of the study.

An indoor trial was carried out concurrently to the grazing work to measure 'potential' intake, *in vivo* digestibility (OMD) and *in vitro* digestibility (IVOMD). This was conducted as the previous experiment with indigenous herbages (pages A25-27, 1978 Report), though freshly-cut herbage was fed. The values for OMD and IVOMD were 0.736 ± 0.009 and 0.759 respectively.

Estimates of herbage intake are not yet available.

Both cattle and sheep selected for leaf and against stem initially, but the proportion of leaf in the diet declined with time and that of live stem increased. By the end of the trial the diets of both sheep and cattle contained substantial proportions of the main broad-leaved weed, Hemp nettle (*Galeopsis* spp).

Intake per bite fell from 0.4 to 0.3 g DM in sheep and from 1.9 to 0.6 g DM in cattle, whereas grazing time increased from 6-7 h to 8-12 h in sheep and was in excess of 10 h for cattle throughout with a maximum in excess of 14 h. Bite rates ranged from 25 to 60 bites/min in both species with a mean of 34 bites/min. Sward surface height declined from 70 cm to 20 cm over the course of the study, whereas bulk density increased from 30 kg OM/ha/cm height to about 100 kg OM/ha/cm height. Grazing time and biting rate increased with declining sward height and increasing bulk density in sheep and cattle; intake per bite declined in cattle but tended to increase in sheep with declining sward height.

6. Preliminary studies on the use of goats in hill sheep grazing systems

A.J.F. Russel, T.J. Maxwell, G.R. Bolton, D.C. Currie and I.R. White.

Experience has shown that when mosaic reseeds are stocked with sheep the animals graze the indigenous vegetation only when minimal amounts of herbage remain on the reseeded areas. Any species such as sedges (*Carex* spp) and rushes (*Juncus* spp) invading the reseeded areas remain virtually ungrazed by sheep. These invading species progressively dominate the reseeded areas thereby reducing their potential for improving sheep productivity.

Results of work in New Zealand indicate that goats discriminate against legumes in their grazing habits. They are also known to exhibit preferences for material with a high fibre content. These factors suggest that the introduction of goats to mosaic reseeds could provide a means of grazing the indigenous vegetation with less discrimination than occurs with sheep, without increasing the grazing pressure on the sown ryegrass-clover areas. It would then be reasonable to contemplate a system of hill sheep production in such areas where a complement of goats are used as a means of grazing control to the benefit of sheep production. Saleable products from the goats would be regarded as a bonus.

With this in mind a small-scale investigation was conducted in the summer of 1981 at Lephinmore to compare the grazing preferences and habits of sheep and goats stocked separately on areas containing both sown and indigenous species. Two adjacent and vegetationally similar areas each of approximately 0.6 ha were used. These comprised about 45% sown ryegrass-clover pasture (*Lolium perenne* and *Trifolium repens*) which had degenerated and contained clumps of indigenous grasses, sedges and rushes. The remainder of each plot consisted of indigenous vegetation - a heterogeneous association of heather (*Calluna vulgaris*), draw moss (*Eriophorum vaginatum* and *E. angustifolium*) and deer grass (*Tricophorum caespitosum*) with some wavy-hair grass (*Deschampsia flexuosa*), flying bent (*Molinia caerulea*), sedges (*Carex* spp) and rushes (*Juncus effusus*).

In late June one plot was stocked with 14 yearling female and castrate male Anglo-Nubian goats and the other with seven mature castrate male Scottish Blackface sheep, the total weight of livestock on the two plots being the same (c 500 kg).

Assessments of the proportions of grass grazed and of clover in the reseeded areas were made subjectively using permanently marked quadrats on ten sites in each plot on four occasions: at the beginning of the study on 26 June, on 9 and 29 July and at the conclusion on 20 August. At the same times estimates of the plant species and of the degree of utilisation of these species were made on the indigenous vegetation using a vertical point quadrat, again on ten sites in each plot, and recording 20 points at each site. The results are presented in Tables 1 and 2.

Table 1. Improved areas : percentages of ryegrass grazed and of clover cover remaining in plots grazed by sheep and goats.

	% Grass Grazed				% Clover Cover			
Date	25.6.81	9.7.81	29.7.81	20.8.81	25.6.81	9.7.81	29.7.81	20.8.81
Sheep	24.0	64.5	67.5	76.5	27.0	15.5	16.0	10.0
Goats	22.6	11.0	41.5	57.5	40.5	44.5	37.5	35.0
S.E. of Difference	9.07	7.53	11.19	14.91	6.94	7.07	7.00	6.99

On each reseeded area the initial figure of some 23% of the ryegrass in both plots recorded as having been grazed was due to an earlier stocking with ewes and lambs before the experimental area was fenced. The difference in the clover cover between plots at that time was attributed to ewes and lambs having broken into the sheep plot before the start of the study. After two weeks some 65% of the sown grass in the sheep plot had been grazed. The corresponding figure of 11% in the goat plot indicated no grazing by the goats, the decrease from the initial value being the balance between plant growth and senescence. This accords with visual observations that the goats initially concentrated their grazing activities on the indigenous area. Subsequently the figure for sown grass grazed in the sheep plot increased to over 75%, and although in time the goats started to graze sown grass, this was always to a lesser extent (maximum value, 58%) than the sheep. The clover cover was always much greater in the goat plot (Table 1). The figures in Table 1 refer only to whether or not the grass had been grazed and to the proportion of ground covered by clover. From visual observation it was clear that the sheep grazed the ryegrass and clover virtually to ground level, whereas there was, by hill standards, a relatively luxuriant sward of grass and clover in the goat plot.

It was not possible to make objective measurements of the effects of grazing on the indigenous vegetation persisting in or invading the reseeded areas. From visual assessment, however, it was apparent that the sheep did not graze the indigenous species or rushes in the reseeded areas, but concentrated on the sown ryegrass and clover, whereas the goats showed a marked preference for the invading indigenous species and grazed the top 25-30% of the *Juncus effusus* including all the seed heads.

Table 2. Indigenous areas : percentages of plant species recorded as having been grazed by sheep and goats, and estimated degree of utilisation

	% Grazed		% Utilisation	
Plant species	Sheep	Goats	Sheep	Goats
Calluna vulgaris	7.9	5.2	5.0	3.9
Eriophorum vaginatum	7.4	12.7	4.4	8.1
Eriophorum angustifolium	3.8	10.7	2.6	8.6
Tricophorum caespitosum *Deschampsia flexuosa* *Molinia caerulea* *Carex spp.* Others	20.8	36.0	11.6	19.4

In retrospect the recording on areas of indigenous vegetation of only 20 points at ten sites per plot per occasion was insufficient to provide an adequate picture of any changes in grazing preferences with time. Accordingly the data for the four dates have been pooled in presenting the figures in Table 2. These indicate that on the indigenous areas the sheep tended to graze more heather shoots than did the goats, but that when the goats did graze heather they ate further into the woody material. Assessments of grazing of other plant species and of the degree of utilisation (which combines in a single figure the number of leaves grazed and the proportion of material removed from grazed leaves) show clearly that the goats grazed more of the non-heather indigenous vegetation than did the sheep.

As with the reseeded areas, a visual assessment of the indigenous areas in the two plots indicated more striking differences than the objective measurements can suggest. This was due to some extent to the nature of the grazing of the Eriophorum vaginatum in which the entire leaf is frequently drawn from the leaf sheath leaving nothing to indicate whether or not a particular tiller has been grazed. It appeared that the goats grazed off virtually all the plant material above the heather horizon, leaving a uniform canopy without the rough appearance and tussocks evident in the sheep plot.

The results suggest that goats may have a use in some sheep production systems as an aid to management of the varied plant communities of hill land, and particularly in the maintenance and further improvement of reseeded pastures. This limited study also indicates the need to investigate the complementary grazing of sheep and goats on certain types of hill pastures.

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 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 were sprayed with Asulox at a cost of £33.11 per hectare. In 1977 the more accessible 15 ha of the 18.2 ha in paddock I were treated with ground magnesium limestone at the rate of 7.5 tonnes per hectare. One hectare was enclosed and reseeded using a paraquat-rotavation technique on a trial basis.

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

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

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

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

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

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

In the spring of 1980 a 316 m extension to the high tension fence enclosing paddock 2 was erected thus dividing the paddock in two. The 3.4 ha in the northernmost part which had been resprayed for bracken control in late 1979 was reseeded in early May using the paraquat-rotavation technique.

The 1.6 ha of hill ground within paddock 1 which was reseeded in 1979 was sprayed with MCPB/MCPA in June to control boar thistles. Auchope hayfield and surrounds (3.6 ha) received a total of 11 tonnes of Ground Magnesium Limestone, and 1.75 tonnes Phossac (20% P_2O_5).

Cattle

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

Sheep Stocks and Livestock Reconciliation

Ewes & Gimmers Nov. 1980	Cast	Deaths	Gimmers Bought Into Flock	Hoggs Born 1981	Ewes & Gimmers Nov. 1981
649	110	19	154	151	674

Total Stock Numbers

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
NCC	175	210	260	269	300	295	292							
SCC	223	241	254	259	273	305	309							
TOTAL	398	451	514	528	573	600	601	620	621	623	622	631	649	674

Sheep Year 1980/81

a) Winter Feeding : N.E.H.L. (4 crop, 3 crop, 2 crop ewes)

16.1.81	Commence feeding Colborn blocks
16.2.81	S.B.P. pencils introduced at 227 g/hd/day Hay fed as required during February and March during periods of snow cover, and in lambing area during lambing
26.3.81	Commence feeding Ewbol cobs at 500 g/hd/day S.B.P. Pencils stopped Concentrate feeding continued through lambing, and to ewes nursing twins after lambing

	January (kg)	February (kg)	March (kg)	April (1st-16th inc) (kg)	April (17th-30th inc) /May (kg)
Colborn Blocks	420	800	560	360	240
S.B.P.	-	975	3773	-	-
Hay	-	300	1775	600	250
Ewbol cobs	-	-	1125	2400	1615
Ewbol pencils	-	-	-	245	835

Auchope (1 crop ewes, gimmers)

16.1.81	Commence feeding colborn blocks
16.2.81	S.B.P. pencils introduced at 227 g/hd/day Hay fed as required during February and March during periods of snow cover, and in lambing area during lambing
27.3.81	Commence feeding ewbol cobs, S.B.P. pencils stopped Concentrate feeding continued through lambing and to ewes nursing twins after lambing.

	January (kg)	February (kg)	March (kg)	April (1st-16th inc) (kg)	April (17th-30th inc) /May (kg)
Colborn blocks	420	720	560	240	360
S.B.P.	-	975	3150	-	-
Hay	-	300	1650	75	300
Ewbol cobs	-	-	225	1600	1290
Ewbol pencils	-	-	-	-	365

Hoggs : (N.E.H.L. and Auchope) **(157)**

2.12.80 Ewe and lamb feed introduced at 227 g/hd/day, gradually changed over to Green Keil within a week. Hay fed as required during periods of snow cover. Ewbol cobs introduced during the last week of feeding.

	December (kg)	January (kg)	February (kg)	March (kg)
Ewe & Lamb mix	50	-	-	
Green Keil	1000	1000	1000	375
Hay	50	625	700	750
Ewbol cobs	-	-	-	175

Total Feed Consumption (kg) and costs per head

	Ewes and Gimmers	Hoggs
Hay	8.1	13.5
Colborn Blocks	7.2	-
S.B.P.	13.7	-
Ewbol cobs	12.7	1.1
Ewbol pencils	2.2	-
Ewe and lamb mix	-	0.3
Green keil	-	21.5
TOTAL COST/HEAD	£5.35	£3.57

b) Lambing Performance

Ewes to Tup	649	
Tup Eild	34	
Kebs	7	
Ewe losses to lambing	5	
Total lambs born (alive and dead)	808	(124.5%)
Total lambs marked	691	(106.5%)
Total lambs weaned	675	(104.0%)

c) Lamb Weights (kg)

Birth weights,	singles	4.3
	twins	3.7
Marking weights,	singles	10.9
	twins	8.5
Weaning weights,	singles	26.7
	twins	26.2

d) Wool Production (kg)

Age 5 crop
" 4 crop
" 3 crop
" 2 crop
" 1 crop
Gimmers
All ages

Fleeces not weighed in age groups
Total weight of wool 1301.7 kg (637 ewes)

= 2.0 kg average fleece weight

e) Ewe Body Weights (kg) 1980/81

	Nos.	Pre-Mating Nov. 1980	Pre-Feeding	Pre-Lambing	Marking	Weaning	Pre-Mating Nov. 1981	Nos
4 Crop	86	67.6	66.2	65.8	63.1	63.2	67.1	102
3 Crop	117	66.9	65.7	65.2	64.6	64.6	66.1	115
2 Crop	125	62.7	61.2	63.1	61.0	62.7	61.1	138
1 Crop	148	57.1	56.3	57.4	56.0	57.5	56.9	165
Gimmers	173	51.6	49.2	49.9	49.8	52.3	52.1	154
All Ages	649	59.9	58.3	59.0	57.7	59.1	59.9	674

Summary of Production and Performance 1968/81

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

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
NCC	54.8	56.1	58.9	59.5	60.3	54.7	56.7	-	-	-	-	-	-	-
SCC	47.8	50.2	53.2	55.8	58.2	52.8	54.8	-	-	-	-	-	-	-
NCCxSCC	-	-	-	-	-	-	-	58.0	53.6	57.7	59.1	58.1	59.9	59.9

g) Production Data

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Stock Nos.	398	451	518	528	573	600	601	620	621	623	622	631	649
Wean %	84.7	86.7	102.5	104.7	99.5	91.5	102.7	108.5	106.9	105.1	113.3	118.2	104.0
Total Wt. Lamb Weaned	7786	9188	14177	14046	14193	14329	16042	17902	17596	16470	17837	19471	17905
Total Wt. Wool (inc. Hoggs)	850	1017	1253	1369	1561	1454	1535	1543	1503	1523	1601	1887	1610

YRGS II: On blanket bog - Lephinmore/Midhill

T.J. Maxwell, J. Eadie, D.C. Currie and D.N. McFarlane

Land Resources

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

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

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

The 26 hectares of enclosed improved pasture includes 14.3 ha which has been reseeded. During the summer of 1978 fields '8 East' and '8 Mid' received a dressing of 205 kg/ha of basic slag (14% P_20_5). Field '8 Mid' was topped in late July 1979 and subsequently sprayed with Perselect (24 DB/MCPA), to eradicate rushes.

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

Lephinmore : Midhill 1980/81

Sheep Stocks and Livestock Reconciliation

Ewes and Gimmers Nov. 1980	Cast	Deaths	Gimmers brought into flock	Hoggs born 1981	Ewes and Gimmers Nov. 1981
468	107	25	113	119	449

Sheep Year 1980/81

a) Winter Feed

There was no storm feeding.

Lean Ewes (50)

Thirty lean ewes were drawn off on 19th February 1981 and housed on 2nd March 1981. A further 20 ewes were brought in 9th March 1981. They received 0.11 kg cobs and 0.22 kg hay, until 9th March 1981, then 0.22 kg hay until they lambed and were put out.

Ewes and Gimmers (400)

A total of 130 blocks standard Rumevite were put out starting 20 January 1981. Late pregnancy feeding was started on 9 March 1981 at 0.22 kg cobs. This was raised to 0.34 kg on 24th March 1981 and to 0.45 kg on 7th April 1981 until lambing. They also received a total of 3.15 t hay.

Hoggs (120)

Hoggs were housed on 5th December 1980 and fed a ration of 0.11 kg ewbol pencils and 0.68 kg hay until being put on on 8th April 1981.

The total feed consumption for ewes, gimmers and hoggs for the winter were as follows:-

	Lean Ewes	Ewes & Gimmers	Hoggs
Hay (£61.5/tonne)	1.94 t	3.15 t	10.12 t
Cobs (£140/tonne)	0.67 t	4.49 t	-
Rumevite (£4/block)	-	130 blocks	-
Ewbol pencils (£140/tonne)	-	-	1.64
	£4.26 /lean ewe	£3.35 /ewe	£7.10 /hogg

b) Lambing Performance

Ewes to Tup	453	
Tup Eild	45	
Kebs	8	
Ewe losses to lambing	8	
Total lambs born (alive & dead)	472	(104.2%)
Total lambs marked	407	(89.8%)
Total lambs weaned	395	(87.2%)

c) Lamb Weights (kg)

Birth Weights,	singles	3.8
	twins	2.8
Marking Weights,	singles	10.7
	twins	9.0
Weaning Weights,	singles	23.5
	twins	21.5
	All lambs	23.2

d) Wool Production (kg)

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

e) Ewe Body Weights (kg) (1980/81)

	Nos.	Pre-mating Nov. 1980	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov. 1981	Nos.
4 Crop	49	52.4	43.8	46.3	45.0	49.0	50.3	55
3 Crop	77	50.6	40.8	43.5	43.3	47.2	50.2	84
2 Crop	98	49.1	40.6	43.9	43.9	47.7	50.5	90
1 Crop	112	48.0	39.5	42.3	43.2	47.2	46.4	107
Gimmers	132	43.5	34.9	37.6	39.2	43.6	41.8	113
All ages	468	48.0	39.2	42.0	42.5	46.6	47.3	449

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

1968	1969	1970	1971	1972	1973	1974	1975	1976	1978	1979	1980	1981
44.9	49.3	49.4	51.2	49.9	48.3	47.9	47.1	49.2	49.8	49.9	47.8	47.3

g) Production Data

	Stock Nos.	Wean %	Total Weight Lamb Weaned	Total Weight Wool
1969	339	85.0	7207	652
1970	361	92.5	8500	772
1971	373	103.5	10268	772
1972	384	103.6	9924	814
1973	422	103.3	10218	815
1974	433	98.2	10870	856
1975	434	91.0	9638	934
1976	458	91.3	9701	915
1977	452	92.9	10419	882
1978	454	92.1	10583	898
1979	444	91.7	9428	924
1980	455	80.1	9129	965
1981	468	87.2	9164	909

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

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

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

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

Land Resources

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

ALDERHOPE

Sheep Stocks and Livestock Reconciliation

Ewes & Gimmers Nov. 1980	Cast	Deaths	Gimmers brought into flock	Hoggs born 1981	Ewes & Gimmers Nov. 1981
266	58	6	73	74	275

Sheep Year 1980/81

a) Winter Feeding

16.1.81 Commence feeding Uvoblocks
16.2.81 S.B.P. pencils introduced at 227 g/head/day
Hay fed as necessary during February and March during periods of snow cover, and in lambing area during lambing.
3.3.81 S.B.P. Pencils increased to 450 g/head/day
30.3.81 Commence feeding Ewbol cobs at 376 g/head/day
S.B.P. pencils stopped. Cobs fed to grit ewes in lambing areas throughout lambing.
21.4.81 Ewbol pencils introduced to ewes nursing twins and gradually increased to 500 g/head/day.
30.5.81 All feeding to ewes finished.

	January (kg)	February (kg)	March (kg)	April (1st-16th inc) (kg)	April (17th-30th inc) (kg)	May (kg)
Uvoblocks	160	180	220	160	240	-
S.B.P.	-	687	2863	-	-	-
Hay	-	350	1600	50	825	75
Ewbol cobs	-	-	375	1425	825	713
Ewbol pencils	-	-	-	-	94	1031

1.12.80 Hoggs started on ewe and lamb mix, and on to green keil. Hay fed during snow cover.
16.4.81 Feeding stopped, hoggs to hill.

Total Feed (74 hoggs)

Hay	1032.8 kg
Ewe and lamb mix	22.7 kg
Green Keil	1645.7 kg
Intensive sheep pencils	272.4 kg

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

	Ewes & Gimmers (kg)	Hoggs (kg)
Hay	10.9	13.9
Uvoblocks	3.6	-
S.B.P.	13.3	-
Ewbol cobs	12.5	-
Ewbol pencils	4.2	-
Ewe and lamb mix	-	0.3
Green Keil	-	22.2
Intensive sheep pencils	-	3.7
Total Cost per Head	£4.87	£3.99

b) Lambing Performance

Ewes to tup	266
Tup Eild	8
Kebs	5
Ewe losses to lambing	1
Total lambs born (alive & dead)	372 (139.8%)
Total lambs marked	347 (130.5%)
Total lambs weaned	338 (127.1%)

c) Lamb Weights (kg)

Birth weights,	singles	4.6
	twins	3.8
Marking weights,	singles	13.6
	twins	8.2
Weaning weights,	singles	33.1
	twins	26.4

d) Wool Production (kg)

Total (ewes & gimmers) 461.3 kg (260 ewes & gimmers)

Average weight 1.8 kg

e) Ewe body weights (kg) 1980/81

	Nos.	Pre-Mating Nov. 1980	Pre-Feeding	Pre-Lambing	Marking	Weaning	Pre-Mating Nov. 1981	Nos.
4 crop	46	62.2	58.4	63.0	54.4	56.2	61.6	45
3 crop	50	62.5	59.0	64.6	56.1	55.9	62.6	48
2 crop	53	62.0	59.5	64.8	55.7	57.4	61.6	52
1 crop	55	58.2	55.8	63.0	55.6	57.2	58.6	57
Gimmers	62	55.2	49.8	54.9	50.4	53.7	56.6	73
All Ages	266	59.8	56.2	61.8	54.3	56.0	59.8	275

Summary of Production and Performance (1972-81)

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

1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
54.4	51.8	55.7	54.5	55.3	56.8	58.3	56.9	59.8	59.8

g) Production Data

	1973	1974	1975	1976	1977	1978	1979	1980	1981
Stock Nos.	217	222	242	255	272	259	266	269	266
Wean %	112.9	109.0	116.6	106.3	112.9	97.3	115.0	128.6	127.1
Total Wt.	6615		7981		8934		8325		9878
Lamb Weaned		6534		7751		7056		9394	
Total Wt.	493		560		536		469		610
Wool (inc. Hoggs)		490		542		501		586	

YRGS IV: On heather moor - Glensaugh, Cairn

T.J. Maxwell, J. Eadie, J.A. Milne, and R.D.M. Agnew

From 1973 until 1978 the unit was managed in the context of the year round grazing system outlined in the Introduction as a prelude to the testing on a practical scale of ideas emerging from the heather research programme.

Land Resources

The Cairn lies on the north-eastern part of Glensaugh on land rising from 150 m to 470 m, extending to 205 hectares, including 23 ha of permanent grassland and an enclosed area of the hill used for lambing.

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

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

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

In 1980 a similar dressing of compound fertiliser was applied to all the mosaic reseeds during May.

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

Sheep Year

a) Winter Feeding

Concentrates - Ewes & Gimmers

Dates	g/head/day
9 Jan - 13 Mar.	256
14 Mar - 27 Mar.	385
28 Mar - 18 Apr.	512
19 Apr. - 7 May	385
8 May - 12 May	256
13 May - 22 May	128

Hay - Ewes & Gimmers

Month	g/head/day
Nov-Dec. (7 days)	540
Jan. 1 - 31	322
Feb. 1 - 29	359
Mar. 1 - 31	119
Apr. 1 - 13	100

Total feeds and cost per head

Ewes and gimmers	Concentrates	43.17 kg	£6.13
	Hay	29.00 kg	£1.74
			£7.87

Hoggs

The Cairn hoggs were fed hay outside from 27th November. They were housed on 8th December, and fed concentrate in addition to hay. Feeding ceased at turnout on 9th April.

Concentrates	8 Dec. - 9 Apr.	254 g/head/day
Hay	27 Nov. - 9 Apr.	586 g/head/day

Total feeds and cost per head

Concentrates	34.0 kg	£4.85
Hay	78.0 kg	£4.68
		£9.53

Sheep Stocks and Livestock Reconciliation

Ewes & Gimmers November 1980	Cast	Deaths	Gimmers brought into flock	Hoggs born 1981	Ewes & Gimmers November 1981
200	25	15	74	73	263

Sheep Year 1980/81

b) Lambing Performance

Ewes to Tup	200	
Tup Eild	20	
Kebs	-	
Ewe losses to lambing	8	
Total lambs born (alive & dead)	256	(128.0%)
Total lambs marked	222	(112.0%)
Total lambs weaned	201	(100.0%)

c) Lamb Weights (kg)

Birth weights,	singles	4.1
	twins	3.3
Marking weight,	singles	12.7
	twins	13.2
Weaning weights,	singles	27.1
	twins	25.7
	All lambs	26.5

d) Wool Production (kg)

Age 4 crop	2.4
3 crop	2.6
2 crop	2.5
1 crop	2.6
Gimmers	2.6
All ages	2.5

e) Ewe Body Weights (kg) 1980/81

	Nos.	Pre-mating Nov. 1980	Pre-Feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov. 1981	Nos
5 crop	—	—	—	—	—	—	57.1	8
4 crop	6	63.5	63.2	66.8	61.8	57.6	55.9	29
3 crop	26	61.4	60.2	66.2	58.9	53.8	55.9	35
2 crop	48	60.5	59.9	63.9	58.7	52.4	55.0	54
1 crop	54	57.7	54.9	59.6	58.7	52.5	53.0	63
Gimmers	66	52.9	48.4	51.4	53.7	50.1	43.7	74
All ages	200	57.5	54.9	58.9	57.2	51.9	51.6	263

Summary of Production and Performance (1972-81)

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

1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
52.8	51.8	55.8	50.0	47.5	51.3	54.0	56.7	57.5	51.6

g) Production Data

	Stock Nos.	Weaning %	Total Weight Lamb Weaned	Total Weight Wool
1973	234	97.9	5061	
1974	187	96.3	5078	
1975	190	111.6	5307	410
1976	204	99.0	4909	433
1977	196	67.3	3452	381
1978	176	86.4	4173	442
1979	187	101.6	5468	486
1980	178	105.6	4842	512
1981	200	100.0	5327	547

YRGS V: Barnacarry/Feorline

T.J. Maxwell, J. Eadie, D.C. Currie and D.N. McFarlane

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

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

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

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

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

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

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

Sheep Year 1980-81

No storm feeding was given during the winter.

Ewes - a total of 134 standard Rumevite blocks were fed from 3rd February.

134 @ £4 = £536 - £1.95 per ewe

Seventy-six hoggs were put into the shed for two weeks from 14/10/80. They received 0.11 kg ewebol pencils and 0.68 kg hay. On 3/11/80 they were put up to the forest, where they received 0.11 kg pencils only. On 29/1/81 29 hoggs which had not been coming to the trough were housed and given 0.68 kg hay. All hoggs were stepped up to 0.17 kg pencils and the hoggs remaining outside received 0.18 kg hay.

g) Production Data

	Stock Nos.	Weaning %	Total Wt. lamb weaned (kg)	Total Wt. Wool (kg)
1975	227	78.4	4530	468
1976	243	76.5	4652	482
1977	251	74.9	4668	502
1978	256	82.8	5377	525
1979	259	71.0	4543	533
1980	280	78.2	6063	693
1981	282	80.7	5636	548

OFF-WINTERING/INWINTERING SYSTEMS

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

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

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

Land Resources

The Rigg and Gairs are two similar units, each of 101 ha, each traditionally stocked with 130-140 ewes and gimmers. Both sheep stocks are inwintered for the same length of time in the same wintering house. On the Gairs Unit a substantial area of improved pasture has been made available. An area of 15 ha of *Agrostis-Festuca* pasture was enclosed and limed and slagged early in the winter of 1969/70. During the summer of 1971 this was oversown with clover. Further in th spring of 1971, 10 ha of *Molinia-Nardus* grass heath at 450 m received 6.35 tonnes lime and 1.65 tonnes slag per ha. It was later sprayed with Paraquat, rotavated and direct reseeded in mid-July with 380 kg per ha of high phosphate compound. This area was grazed for the first time in the autumn of 1971. In 1975, ground magnesium limestone at 6.3 tonnes/ha and super-slag (16% P_2O_5) at 0.88 tonnes/ha was applied to the Gairs reseed. In early June 1979 reseed E_2 on Gairs received 250 kg/ha of a compound fertiliser (22:11:11).

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

Stocking Policy

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

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

Sheep Stocks and Livestock Reconciliation

Both the Rigg and Gairs have carried South Country Cheviots. Stocking rate increases were made equally on 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

Total feed given:-

1.54 t Ewebol pencils @ £140/t = £216
2.64 t Hay @ £61.5/t = £162

Total cost = £378

Sheep Stocks and Livestock Reconciliation

Ewes and Gimmers Nov. 1980	Cast	Deaths	Gimmers brought into flock	Hoggs born 1981	Ewes and Gimmers Nov. 1981
282	69	23	52	59	242

Sheep Year 1980/81

b) Lambing Performance

Ewes to Tup	274
Tup Eild	30
Kebs	17
Ewe losses to lambing	5
Total lambs born (alive & dead)	260 (94.9%)
Total lambs marked	237 (86.5%)
Total lambs weaned	221 (80.7%)

c) Lamb Weights (kg)

Birth weights,	singles	4.0
	twins	3.0
Marking weights,	singles	10.6
	twins	11.0
Weaning weights,	singles	26.1
	twins	23.5
	All lambs	25.5

d) Wool Production (kg)

Age 4 crop	1.7
3 crop	1.6
2 crop	2.0
1 crop	2.0
Gimmers	2.0
All ages	1.9

e) Ewe Body Weights (kg) 1980/81

	Nos.	Pre-mating Nov. 1980	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.1981	Nos.
4 crop	41	47.7	48.1	47.8	46.5	48.9	47.7	26
3 crop	41	46.7	44.6	44.8	45.7	47.6	49.7	52
2 crop	63	47.1	46.3	46.2	46.0	47.8	49.0	60
1 crop	76	46.7	42.2	43.0	45.2	48.0	45.6	52
Gimmers	61	40.7	36.4	37.1	39.8	43.7	41.8	52
All ages	282	45.7	43.3	43.6	44.5	47.1	46.6	242

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

1974	1975	1976	1977	1978	1979	1980	1981
47.2	44.1	46.6	45.5	46.1	48.9	45.7	46.6

on both units. Cheviot ewe stocks were replaced progressively by Scottish Blackfaces. For this reason the flock data is presented separately for the two breeds.

	Ewes and Gimmers Nov. 1980	Cast	Deaths	Gimmers brought into flock	Hoggs born 1981	Ewes and Gimmers Nov. 1981
Rigg	266	69	9	72	65	260
Gairs	272	51	9	69	73	281
Total	538	120	18	141	138	541

Total Stock Numbers

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	198
RIGG													
S.C.C.	205	205	238	278	279	298	234	152	93	40	-	-	-
B.F.	-	-	-	-	-	-	65	128	191	231	264	266	260
GAIRS													
S.C.C.	209	207	233	260	279	297	240	165	111	45	-	-	-
B.F.	-	-	-	-	-	-	65	132	199	230	271	272	281

Sheep Year 1980-81

a) Winter Feeding

Rigg Ewes and Gimmers Housed 13.1.81

Commence ration of 120 g conc.
570 g hay
230 g S.B.P.

Gairs Ewes and Gimmers Housed 23.1.81

Commence ration of 120 g conc.
570 g hay
230 g S.B.P.

All lean ewes shed off and conc. ration increased to 180 g.

7.2.81 Hay ration to all ewes and gimmers raised to 680 g.

23.2.81 S.B.P. ration to all ewes and gimmers raised to 280 g.

6.3.81 Lean ewes (34) conc. ration increased to 230 g.

17.3.81 All ewes and gimmers (except lean ewes) conc. ration increased to 170 g.

27.3.81 Lean ewes conc. ration increased to 280 g. All other ewes and gimmers conc. ration increased to 230 g.

2.4.81 Lean ewes conc. ration increased to 450 g. All other ewes and gimmers conc. Ration increased to 340 g.

10.4.81 Ewes conc. ration increased to 400 g. Gimmers and lean ewes remain on ration of 2.4.81.

All Rigg and Gairs late lambers put out of sheds on 8.4.81 - early lambers lambed in sheds.

Total Feed (kg) : (538 ewes and gimmers)

	Pre-lambing	Post-lambing	Total	Per Head
Hay	33,950	3,575	37,525	69.7
S.B.P.	12,325	725	13,050	24.3
Ewbol Pencils	8,450	3,338	11,788	21.9
Ewbol cobs	131	2,201	2,332	4.3
Colborn Block	-	20	20	-
Green Keil	-	425	425	0.8
				£ 10.24

Hoggs Rigg and Gairs hoggs (144)

Housed 12.1.81

Commence ration of 340 g Hay
230 g Green Keil

23.2.81

Ration increased to 450 g Hay
280 g Green Keil

16.3.81

Ration increased to 450 g Hay
340 g Green Keil

2.4.81

Hoggs out of shed.

Hoggs Total Feed (kg)

		Per Head
Ewe and lamb mix	50	0.3
Green Keil	3,912.5	27.2
Hay	5,262.5	36.5
	Cost per head	£ 5.40

b) Lambing Performance

	Ewes Mated	Eild	Kebs	Ewe losses to lambing	Total lambs born	Total lambs born	Total lambs born
Rigg	266	12	2	4	342(128.6%)	318(119.5%)	315(118.4%)
Gairs	272	7	6	3	371(136.4%)	336(123.5%)	331(121.7%)

c) Lamb Weights (kg)

	Rigg	Gairs
Birth weights, singles	4.9	4.6
twins	3.7	3.6
Marking weights, singles	11.8	11.9
twins	9.1	8.9
Weaning weights, singles	29.6	32.7
twins	29.4	27.9

d) Wool Production (kg)

Fleeces not weighed in age groups:-

Rigg (255 e+g) 366.5
= 1.4 Av. fleece wt.

Gairs (209 e+g) 319.3 (summer shorn)
= 1.5 Av. fleece wt.

(56 e) 88.2 (January shorn)
= 1.6 Av. fleece wt.

e) Ewe Body Weights (kg)

RIGG:

Ages	Nos.	Pre-Mating Nov. 1980	Pre-Feeding	Pre-Lambing	Mark.	Wean.	Pre-Mating Nov. 1981	Nos.
4 crop	58	54.8	53.5	60.8	50.6	52.3	59.0	39
3 crop	44	57.2	55.3	62.2	51.6	54.3	61.2	41
2 crop	48	56.9	55.7	62.3	55.3	57.5	59.9	50
1 crop	55	55.8	54.6	62.1	54.0	57.0	56.7	59
Gimmers	61	51.2	50.5	56.8	49.9	53.5	50.7	72
All ages	266	54.9	53.7	60.6	52.2	54.8	56.7	261

GAIRS:

Ages	Nos.	Pre-Mating Nov. 1980	Pre-Feeding	Pre-Lambing	Mark.	Wean.	Pre-Mating Nov. 1981	Nos.
4 crop	45	57.8	53.7	59.5	51.8	54.9	61.6	49
3 crop	55	60.7	56.4	61.6	55.0	59.3	59.1	49
2 crop	51	58.7	54.8	60.2	53.4	57.0	57.9	54
1 crop	57	55.6	51.2	56.8	51.2	56.7	57.0	60
Gimmers	64	54.2	52.1	58.9	51.1	57.1	51.5	69
All ages	272	57.2	53.6	59.4	52.5	57.1	57.0	281

Summary of Production and Performance 1969-1981

f) Pre-mating Ewe Body Weights (kg)

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
RIGG													
S.C.C.	48.3	49.7	51.5	51.2	50.6	50.0	51.8	53.8	55.6	55.6	-	-	-
B.F.	-	-	-	-	-	-	-	48.5	52.1	55.0	56.9	54.9	56.7
								52.4	54.0	55.1			
GAIRS													
S.C.C.	49.9	50.5	51.9	53.5	52.9	54.1	53.8	56.6	56.7	59.0	-	-	-
B.F.	-	-	-	-	-	-	-	48.5	51.5	55.1	58.0	57.2	57.0
								54.7	54.4	55.7			

g) Production Data

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
RIGG												
Stocking Nos.	205	205	238	278	279	311	299	290	284	271	264	266
Weaning %	83.0	87.0	100.8	87.8	91.0	89.6	90.6	105.2	105.6	121.0	121.6	118.4
Total Wt.	3706		5712		6155		6640		7920		9020	
Lamb Weaned		4432		5324		6257		8218		8519		9299
Total Wt.	402		641		680		674		525		530	
Wool		534		732		670		567		521		503
GAIRS												
Stocking Nos.	209	207	233	260	279	305	305	297	310	275	271	272
Weaning %	83.0	96.0	91.4	93.1	87.0	87.2	99.0	109.4	111.9	127.2	129.9	121.7
Total Wt.	3581		5176		6394		7943		9542		10102	
Lamb Weaned		5246		5675		6381		9248		9956		9962
Total Wt.	461		634		766		738		624		552	
Wool		524		752		732		643		512		531

SIMULATION

03009: Systems modelling

1. Modelling grazing systems

A.R. Sibbald, J. Hodgson, T.J. Maxwell, S.A. Grant, J. King, J.C. Arosteguy and L. Torvell

A knowledge of crop geometry is essential to an understanding of the processes involved in the utilisation of a sward by grazing animals and to an understanding of the regrowth of the grazed sward itself. For grasses, the tiller is the only identifiable, measurable unit of structure within the sward, so an understanding of the mechanisms which control the structure of the individual tiller becomes essential to an understanding of whole crop geometry as does the need to understand those factors which influence the number of tillers in a sward throughout the annual cycle.

Crop geometry can be considered as providing information on the positions of individual leaves within the canopy, leaves being the sites for photosynthesis and also being the units of consumption of nutrients, energy etc. by the grazing animal. Tiller population dynamics will determine the spatial distribution of sites for leaf development in two dimensions horizontally. Vertical distribution will be determined from leaf positions and dimensions on individual tillers. These leaf positions themselves will be determined by rates of leaf appearance and leaf extension.

A model of the dynamics of leaf turnover

Leaf appearance means that the tip of a growing leaf becomes visible at the top of the sheath of an existing leaf. The new leaf has, however, been growing before this time and its appearance is a relatively arbitrary occurrence related to its extension rate and the length of the sheath through which it has grown. Initiation of leaf extension may therefore be a more important event in determining the structure of a tiller than leaf appearance, although the latter may act as a trigger for initiation of leaf extension.

If it is assumed that a vegetative tiller of ryegrass has a fixed number of live leaves, that only two of these leaves are extending simultaneously and that the final length of a lamina is proportional to the length of the sheath through which it has emerged, then a hypothetical leaf "management" model can be put together for a single vegetative tiller as follows:-

a) the primordium of a potential leaf will not be triggered until the leaf created from the primordium at two positions older has ceased dividing

b) a primordium, once triggered, will generate lamina cells until leaf appearance at which stage it will generate sheath cells (and form the ligule at this point?)

c) sheath cell division will continue until the lamina stops extending (i.e. all divided cells are fully expanded) at which point the primordium at two positions younger will be triggered to generate lamina cells

d) sheath cell extension will continue until all sheath cells are fully expanded

A flow chart of the proposed "management" model is shown at figure 1.

The tiller "management" model shown in figure 1 controls the structure of a vegetative tiller through trigger or control mechanisms, i.e. it senses events and uses them to trigger the start or end of processes. The rates at which these trigger events occur will however be dependent on those "black boxes" which define potential for lamina extension (figure 1 box 7) and potential for sheath extension (figure 1 box 13). These boxes relate the potential for extension to temperature, light, water, nutrients and carbohydrate reserve levels.

An attempt has been made to interpret the "management" model as a "state" model from which it should be possible to derive estimates of lamina and sheath "sizes" for each leaf on a vegetative tiller so that quantities of nutrients may be derived for each part of the tiller (figure 2).

In order to generate assimilate from a tiller of known structure, leaf area could be derived from the "size" parameter in the model. Leaf area could then be used in an existing Carbon exchange model, for example, the GRI model of Sheehy, Cobby and Ryle (1979), to generate assimilate. Assimilate would then be partitioned into separate tiller parts. The partitioning component is the least well understood part of the model.

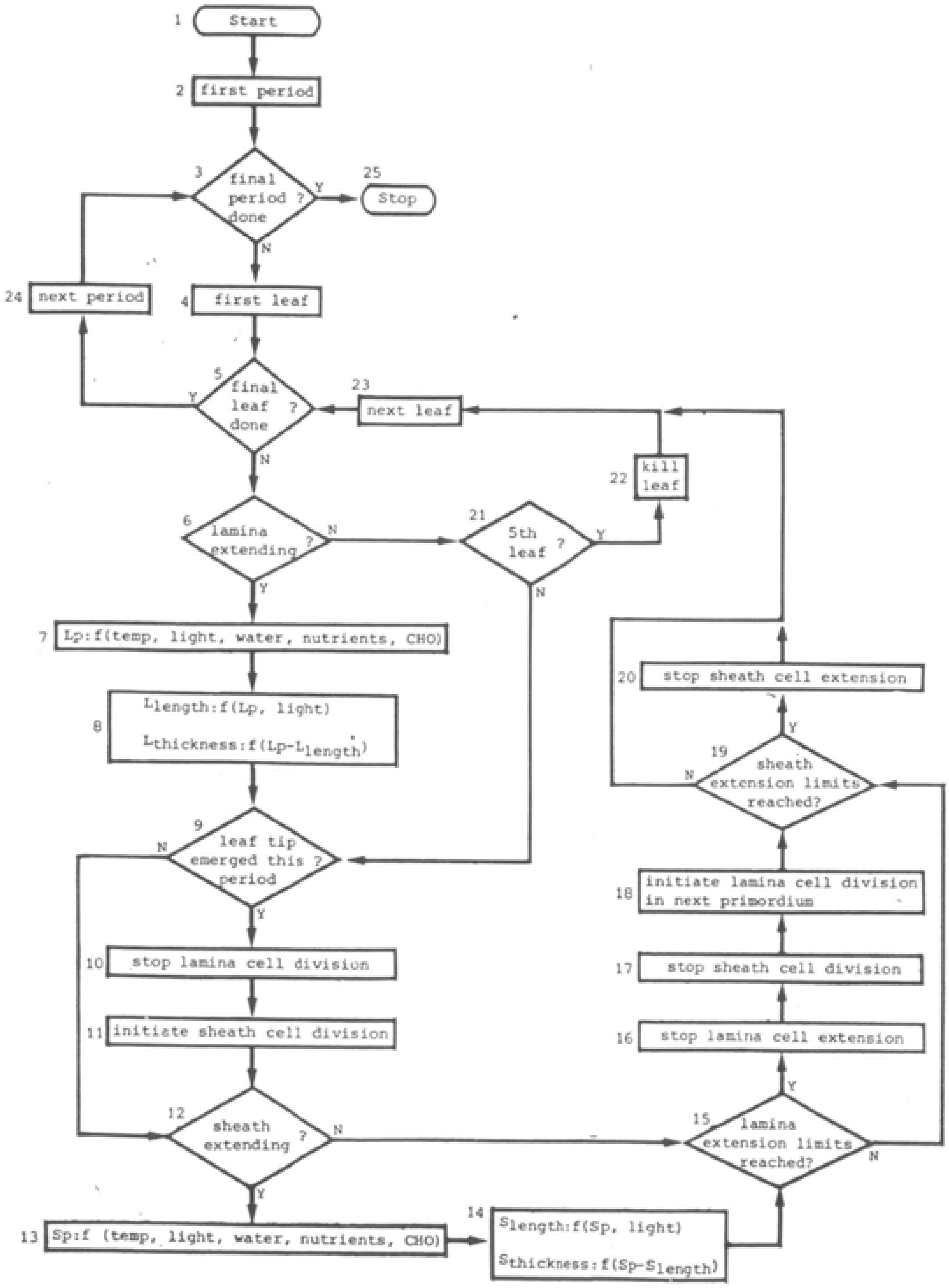

Fig. 1. A conceptual approach to the relationship between leaf structure of an individual, vegetative tiller of ryegrass and lamina and sheath extension.

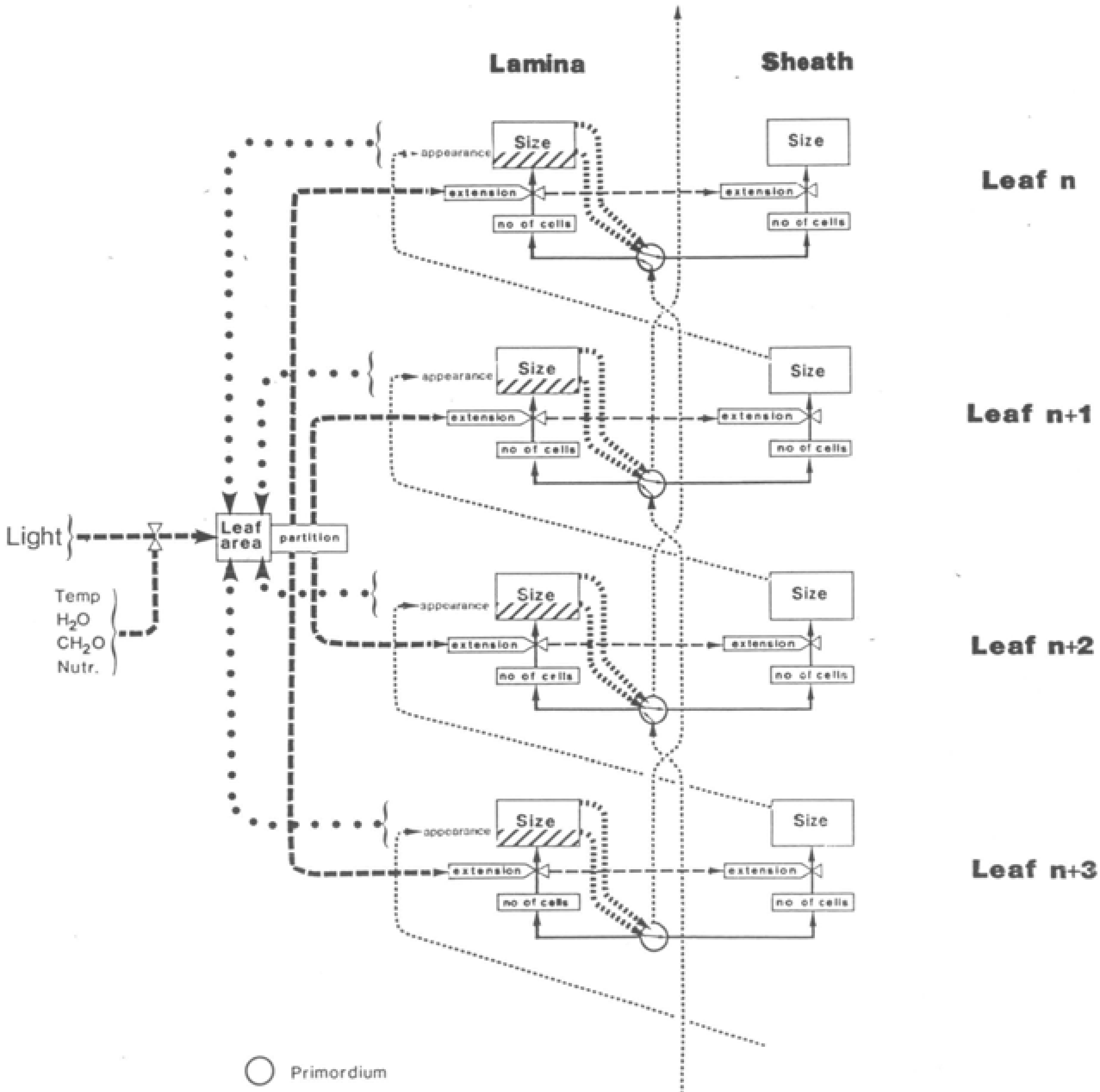

Fig. 2. A state model of a vegetative tiller of perennial ryegrass.

Key:

(1) "Trigger" effects from management model (Fig. 1):
- ········ within leaf effects
- ········ between leaf effects

(2) • • • • indicate that current 'size' of all leaves on the tiller will contribute to leaf area

(3) Flow of assimilate:
- ━━━━━ indicate partition control between leaves
- ---- indicate some form of priority for expansion of both lamina and sheath simultaneously

The construction of a separate, conceptual tiller dynamics model has now also begun.

These models have been constructed following discussions at meetings of the Grazing Group attended by members of the Animal Production, Grazing Ecology and Plants and Soils departments.

REFERENCE:

Sheehy, J.E., Cobby, J.M. and Ryle, G.J.A. 1979. The growth of perennial ryegrass : a model. Ann. Bot. 43: 335-354.

DATA HANDLING

01004, 02002, 03004, 03005, 03008, 48001

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

Data from each of the eight Systems Development projects at Sourhope, Lephinmore, Glensaugh and Hartwood continued to be processed at Headquarters and summarised by the ICL 2980 computer at the Edinburgh Regional Computing Centre at Bush using their Edinburgh Multi Access System (EMAS). In addition data from the mid-pregnancy nutrition project at Lephinmore were similarly processed and summarised using the System Development data handling program package, as was the data from the Hill Sheep Development Project, using a simpler version of the package.

In all approximately 21,000 individual records were processed during the year, made up of roughly 8,000 records from the Systems Development projects, 1,000 records from the mid-pregnancy nutrition project and 12,000 records from Hill Sheep Development Project.

1. PDP 11/03 Micro-computer system (51002, 51003, 51004)

A.R. Sibbald, P.E. Moberly and E. Skedd

The laboratory data capture and processing system has again been used successfully throughout the year. An additional 16 lines were installed between the computer room and various laboratories. A new electricity mains supply was also installed in the computer room as a means of resolving power fluctuation problems encountered earlier in the year.

During the year locally written software was produced to process paper tapes produced by the X-ray spectrometer, this software, which will analyse data for both major and minor elements, is still undergoing tests.

The microcomputer is also used regularly for transfer of data from the scintillation counter to EMAS, the Edinburgh University main-frame computer system.

2. General micro-computer services (All projects)

J.A. Rogers

Programs (software) have been written for the Superbrain micro-computer for data preparation and for graph plotting and regression analysis of data.

Multplot

Two programs (MULTPLOTA and MULTPLOTB) have been written to calculate regressions with up to two independent variables. Graphs can then be plotted on the printer showing the scatter of data points and the fitted linear regression. Additional facilities include calculation of derived variates, data summaries, correlation coefficient matrix, data listing and tables of fitted values and residuals.

MULTPLOTA will accept data sets of up to 15 variates in up to 50 sets, while MULTPLOTB, which operates more slowly, will accept data sets of up to 30×100.

Data preparation

Programs have been written to format keyed-in data and also to verify them.

FORMIN2, FORMIN5 and FORMIN6

Data are keyed in, formatted according to the pattern supplied by the user and then stored in floppy disc files. Up to 10 formatting codes may be input and stored for future use. Data may also be appended to existing files.

FORMIN3

This version enables extra columns of data to be inserted in existing data files.

VERIFY

Versions of this program have been written to check files prepared by the FORMIN programs. They work in an analogous manner to the FORMIN programs.

Data logging

Software has been developed to a preliminary stage to handle data from a Datamyte hand-held solid-state field data logger.

VETERINARY MONITORING

02008, 03004, 03005, 99007, 05001

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

Laboratory	1979	1980	1981
Faecal worm egg counts	2467	2460	3560
Pasture larvae counts	43	40	79
Baerman lungworm larvae	-	50	40
Haematology	1067	1764	1823
*Plasma copper estimations	2467	3639	1889
*Liver copper estimations	90	77	72
*Brain copper estimations	-	-	11
‡Glutathione peroxidase	87	-	26
‡Serum vitamin B_{12} estimations			207
Liver Cobalt			20
‡+ Serological examinations			811
Snail samples		12	14
Miscellaneous	91	660	124

* Carried out by the biochemistry dept. ‡ Carried out by the V.I. service
\+ Carried out at ADRA Moredun

Disease records from the experimental stations were collated with V.I. centre reports.

LEPHINMORE

Sheep 03004, 03005

The overall death rate for ewes and gimmers was 6.26% (Black loss 4.05%). The highest proportion was in ewes found dead and unsuitable for post mortem.

Liver Fluke. Monitoring of the whole flock of Lowend and Midhill by faeces egg counts showed the incidence to be still well below 1%. Additional post mortem examination of livers (252) available from sheep from other experimentation revealed no evidence of fascioliasis between 1976 to 1980.

Listeriosis

In the autumn a small outbreak of listeriosis in lambs folded on to rape was interesting. L. monocytogenes was isolated from mesenteric lymph nodes. This organism lives in the soil and the findings suggested ingestion to be the route of infection. The association with silage is well established and it is of interest that cattle being fed silage in the previous year grazed this field.

Parasitic Gastro Enteritis

Monitoring of pasture larvae showed the counts obtained in 1981 to be the highest ever in June and July, and warnings were sent to the farm.

Cattle 02008

One cow was presumed to have died from hypomagnesaemia. In collaboration with ADRA Moredun a comparison of subcutaneous and intramuscular injection of the enteric vaccine under trial monitored site reaction and serological responses.

HARTWOOD

Sheep 99007

In the Greyface flock the overall ewe death rate was 12.5%. The largest proportion of these was due to Jaagsiekte and acute and chronic pneumonia.

Enzootic Abortion (EAE)

At the commencement of lambing, abortions due to this agent were confirmed by microbiological and serological findings. A decision was taken when the first cases were confirmed, to inject all ewes with long acting oxytetracycline. No controls were kept. There were no further cases, and subsequent enquiries ascertained that this approach is being investigated in other flocks. E.A.E. vaccine which has been extremely efficacious for many years has recently been associated with breakdowns in immunity and currently work at the A.D.R.A. Moredun has been investigating the possibility that new chlamydial strains are involved which in turn should lead to their incorporation in a new vaccine.

It is therefore a current policy to segregate the bought-in flock of Blackfaces from the Greyface flock to prevent or minimise the spread of EAE as well as Jaagsiekte.

Parasitic Gastro-enteritis

The extensive monitoring of lambs and ewes by worm egg counts has shown that the presence and continuance of a clean grazing system is feasible. The live-weight gains of lambs reared under such a system reflected the influence of clean pasture.

Cattle 02008

There were no serious outbreaks of disease in the cattle. The occurrence of scour in calves in the spring was not found to be associated with any specific agent, bacterial, viral or protozoal. A few cases of pneumonia in calves were encountered in June and required repeated treatments. Dictyocaulus larvae were not recovered from routine samples. Two calves showing central nervous system disorders were acquired by Glasgow University Practice teaching unit for further investigation. Examination of C.N.S. material sent to Moredun suggested a viral encephalitis. (Possibly B.V.D. or IBR?). In the autumn five cows died, and the findings and comments upon these are appended below.

1.	Cow J14	10/4/81	Found dead in burn. Not notified.
2.	Cow 80	18/9/81	Ex. H.O.M. put on aftermath developed Fog Fever. Treated. Died 25/9/81
3.	Cow 192	5/10/81	Ex. H.O.M. Fog Fever at post mortem
4.	Cow J59	6/10/81	Fog Fever. Fascioliasis at post-mortem
5.	Cow K8	6/10/81	Hypomagnesaemia at post-mortem
6.	Cow H51	13/10/81	Hypomagnesaemia treated recovered
7.	Heifer A41	26/10/81	Positive Johne's to G.V. School

Comments

It is probable that Cow J14 died of hypomagnesaemia as did Cow K8. Whilst these animals had magnesium acetate available in the drinking water the heavy rainfall meant that they were not taking sufficient treated water. The weather at the time was of the type associated with hypomagnesaemia. It is recommended that in future magnesium cobs be fed at dangerous times. The Fog Fever outbreak occurred in cows ex H.O.M. placed on aftermath. This is essentially an anaphylactic pneumonitis, the antigen is considered to be tryptophan. The syndrome is per-acute, not readily responsive to treatment and where an outbreak has occurred the animals require to be handled with caution e.g. removal off aftermath may in fact precipitate more cases. Outbreaks are sporadic but nevertheless it is recommended that in future cows should not be put straight on to aftermath in the autumn without a run-in period.

The findings of viable liver flukes in cow J59 indicates that Hartwood may have the conditions predisposing to this disease.

The possibilities were

(a) That J59 had acquired the infection at Glensaugh prior to going to Hartwood.

(b) That infection had been acquired at Hartwood.

The group containing J59 had been examined in July 1981 and all were negative for fluke eggs. They had all been dosed with radoxanide at Glensaugh and again in July 1981. Fascioliasis in the bovine is self-limiting so the evidence suggests that the infection had been acquired at Hartwood. Previous enquiries had suggested that Hartwood had not a liver-fluke problem. Either this was the case or the Greyface flock which arrived undosed at Hartwood may have introduced an infection. Checking cow movements suggests that the Parkhead field is a potential site. A search for snails was negative on this site but the time of year was not ideal for snail recovery.

Further examinations for potential sites will be carried out in spring 1982. All cows in the house are being systematically examined for fluke eggs. Results so far are negative. Tracer lambs have shown no evidence of fascioliasis. However monitoring for liver fluke will be intensive in both cattle and sheep at Hartwood. One further point is that current flukicidal drugs are less effective in cattle than in sheep, but on the other hand cattle do have an immune response which limits the duration of infection.

A positive case of Johne's disease in a Hartwood bred heifer indicates that all cases of intermittent scour should be promptly faeces sampled and examined for acid fast bacilli.

In 1981 all cows were vaccinated with the ADRA Moredun Rotavirus/E. coli K99 vaccine.

Hartwood cattle may disclose veterinary problems not encountered previously. The previous commercial herd, the cows ex Glensaugh and House o' Muir and purchased stock for experimental purposes imply different populations being exposed to new disease entities. It is therefore important that records, monitoring, and prompt notification be maintained.

GLENSAUGH

Sheep 03004

Tick-borne fever. A severe outbreak of tick-borne fever, complicated by pasteurellosis and louping-ill was encountered at the end of May in the Cairn reseeded pastures. There was also an associated prevalence of tick pyaemia. It was evident, not only from our own experience but from veterinary investigation centre reports that in 1981 a heavy tick-rise occurred. The herbage matt in the vicinity of the reseeded area was very suitable for ticks and a susceptible population of young lambs was present. Whilst evidence of heavy infestation of ticks has not been present in the Cairn area for many years, the influence of grouse and hares in spreading ticks back into this area is ever present and the climatic conditions in the spring were ideal for tick populations. This pattern at Cairn is likely to by cyclical, and the point must be made that dipping affords no protection against infection by tick bites, and is of dubious value in controlling tick populations. Work with T.B.F. at headquarters investigated the potential of trying to immunise lambs with leucocyte lypsates prepared from donors infected with a homologous strain against subsequent challenge, and also by infecting ewes premating and prepartum. The results were not promising. It is intended in 1982 to immunise lambs with the 'Cairn' strain soon after birth and using control lambs to evaluate this approach. The problem in this is that if the tick-rise in 1982 is minimal, and this is quite likely, we may not get the information we require. Louping ill vaccination of the Cairn and Birnie hoggs is carried out as a routine procedure.

It is a costly vaccine, and because of the very cyclical nature of the disease it has not been the policy to revaccinate adult stock annually. Evidence at Sourhope has shown that as more land is improved tick populations diminish markedly, indeed it is extremely difficult to obtain positive T.B.F. sheep at Sourhope, and tick infestations on lambs are rare. The reason for this is related to the reseeded areas being incapable of supporting tick populations because of the disappearance of an adequate basal herbage matt necessary as an environment for ticks.

Cattle 02008

It is a pleasure to record that the suckler herd at Glensaugh had no problems whatsoever with enteric disease in the calves after so many years when it seemed as if there was a predilection for attracting new enteric disease agents. A significant factor could be that over recent years a large percentage of the cows had been used in the ADRA vaccine trials and this was supported by the demonstration of high antibody titres in cows vaccinated three years previously.

SOURHOPE

Sheep 03004, 03005

The overall death rate of 3% was the same as in 1980 and is very satisfactory. A breakdown of losses shows that scrapie is still a problem in the Cheviot flocks of Fasset and Park Law and was the biggest single cause of loss in adult sheep. Trials with a new ADRA pneumonia vaccine in combination with clostridial vaccine are in progress in the Rigg and Gairs hoggs and serological monitoring will continue throughout their breeding years. Losses due to other causes were incidental and there were no serious disease outbreaks.

Cattle 02008

Part of the Sourhope herd was used in successful enteric vaccine trials in collaboration with Moredun.

SURGERY 1981

	Cattle	Sheep
Oesophageal fistulation	2	16
Rumen cannulation	-	11
Rumen, duodenal and ileal cannulation	-	24
Rumen and abomasal cannulation	-	15

03004: A comparison between lambs derived from a clean grazing system and lambs derived from contaminated pasture but routinely dosed when both groups were placed on contaminated pasture

A. Whitelaw and A.R. Fawcett

The results showed that the group of lambs derived from a clean grazing system showed a poor liveweight gain, and had a significantly higher worm burden ($P = < 0.01$) than the group derived from contaminated pasture but routinely dosed with anthelmintic. This is directly associated with the difference in immune status against nematode parasitism in the two groups in that the lambs derived from a clean grazing system would have no competent immune system compared with those derived from contaminated pasture. The findings highlight the consequences arising when adherence to the principles of a clean grazing system cannot be maintained.

Table 1 summarises the results

	Group 1 (n = 20)	Group 2 (n = 20)
Mean starting weight kg	29.5	29.9
Mean finishing weight kg	37.2	40.1
Mean liveweight gain per day g	107	139 ($P = < 0.05$)
Mean total worm count	36,025	10,790 ($P = < 0.01$)

C. PLANTS AND SOILS

PLANT NUTRITION

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

1. Growth of white clover in pots of brown earth soil from Sourhope

A. Rangeley, P. Newbould and J. Leask

In the previous annual report (HFRO 228) it was reported that the growth of white clover grown in pots containing either deep peat or brown earth soils was not as good as in earlier years and that, contrary to experience in the field, growth was particularly poor in the brown earth soil. Some preliminary experiments to investigate the reasons for the poor performance of white clover in pot experiments in the glasshouse were described. This work has continued with the brown earth soil alone and although vigorous and heathly shoot growth of white clover was achieved by mixing additional surface litter into the soil the precise reasons for the success of this treatment have not yet been elucidated (Table 1). It could be due to the better physical environment for root growth, to an increase in the total supply of available nutrients, or to better positioning of the latter throughout the soil in the pot. There is a strong possibility, based on the concentrations of phosphorus found in the shoot tissue (Table 1) and the known critical level (0.20%) below which P supply limits growth, that the small amount (5%) of additional litter incorporated into the soil has enhanced phosphorus supply to the plants. However, this cannot be confirmed since it has so far proved difficult to design experiments with strictly comparable control treatments; efforts to resolve this problem will be continued.

Table 1. The effect on shoot production (g DM/pot) and on nutrient content (% of DM) of white clover, of soil storage and alterations in packing brought about by adding sand or litter on the growth of plants in pots in the brown earth soil from Sourhope in the glasshouse

Shoot		Stored soil alone	Stored soil + sand	Fresh soil alone	Fresh soil + sand	Fresh soil + litter
Production (g DM/pot)		0.4	0.6	0.6	0.7	1.8
Nutrient content (% DM)	P	0.17	0.13	0.18	0.17	0.25
	K	3.0	3.3	3.3	3.4	2.7
	N	3.2	2.9	3.2	2.9	2.8

2. Growth of white clover in recently sown pastures on Cairn hill, Glensaugh

A. Rangeley, P. Newbould, T.J. Maxwell, J.A. Milne and J. Leask

The reseeds sown on Cairn hill, Glensaugh, in both 1978 and 1979 as part of the mosaic patterns of improvement of heather moor for the hill sheep systems development programme (see YRGS IV, HFRO 228) have shown poor and patchy growth. In 1981 production of herbage from all areas was low, the leaves of perennial ryegrass in mid to late season were yellow and there were few tillers, the white clover was small leaved, had a leaf-spot disease (*Leptosphaerulea trifolii)* and the roots possessed only a few small brown nodules. Both ages of reseed were weedy with rushes dominating that sown in 1978 and bare ground and *Rumex* spp. that prepared in 1979.

An intensive programme of herbage and soil analysis was carried out to ascertain the reasons for the poor performance of the reseeds. The bare patches on the 1979 reseed appeared to be linked with low soil pH, with the implication that lime had not been applied uniformally; the pH over the area varied from 4 to 6. Soil and herbage analysis indicated that the supply of P, K and Mg appeared to be adequate for both white clover and ryegrass. However, the level of calcium was low in white clover but adequate for ryegrass, and the concentration of nitrogen was high in white clover but very low in ryegrass. It was concluded that the main problem was poor nodulation and low levels of nitrogen fixation in white clover with little transfer of fixed nitrogen to the grass, resulting in depressed growth. Determination of the precise reasons for the poor performance of white clover in this environment and where inoculation with effective strains of *Rhizobium* had taken place at sowing is necessary as is the elaboration of procedures to enhance production from the improved areas rapidly. While lack of lime may be the prime cause it is possible there was insufficient potassium early in the season, that inoculation was unsuccessful, or that certain trace elements are missing. The following small-plot experiment with herbage sampled by cutting has been planned to investigate this problem further. It will be carried out on both the 1978 and 1979 reseeds and will link with large-scale treatments (lime and pattern of N-fertiliser application) to be carried out in grazed areas of the mosaic improved patches.

Treatments

Complete (Lime 5 t ha^{-1}, N 40 kg ha^{-1} spring and autumn
Trace elements, *Rhizobium*, potassium (60 kg ha^{-1})

Complete plus extra N (2 x 40 kg ha^{-1})

Complete minus N

Complete minus *Rhizobium*

Complete minus *Rhizobium* and N

Complete minus Trace elements

Complete minus potassium

Untreated

Herbage growth will be assessed on four occasions and there will be four replicates of each treatment. Nitrogen will be applied in the spring when the accumulated degree days above 5°C at 10 cm depth in the soil reach 42°C.

3. The response of white clover and perennial ryegrass growing in soil of the Rowanhill series from Hartwood to added phosphorus

A. Rangeley, P. Newbould and J. Leask

Analysis of soil from Hartwood by the West of Scotland Agricultural College indicated a low level of P, a moderate level of K and a lime requirement of 5 t magnesium limestone per ha. To assess the likely requirements of improved pasture to be grown at Hartwood for phosphorus fertiliser, a pot experiment with white clover and ryegrass grown separately was carried out in the glasshouse. The clover was inoculated with *Rhizobium* and not fertilised with nitrogen, and either 0 or 60 kg N ha^{-1} were added to the ryegrass. Four levels of phosphorus equivalent to 0, 40, 80 and 160 kg P ha^{-1} were added and the experiment was carried out with 0 or 5 t lime to investigate if interactions between lime and phosphorus would occur in this soil type. A moderate level of potassium (50 kg K ha^{-1}) was added to all the pots.

There were four replicates - ryegrass alone was sampled after six weeks and ryegrass and white clover after eight weeks. Results for the latter sampling and for ryegrass with added nitrogen alone are shown in Fig. 1.

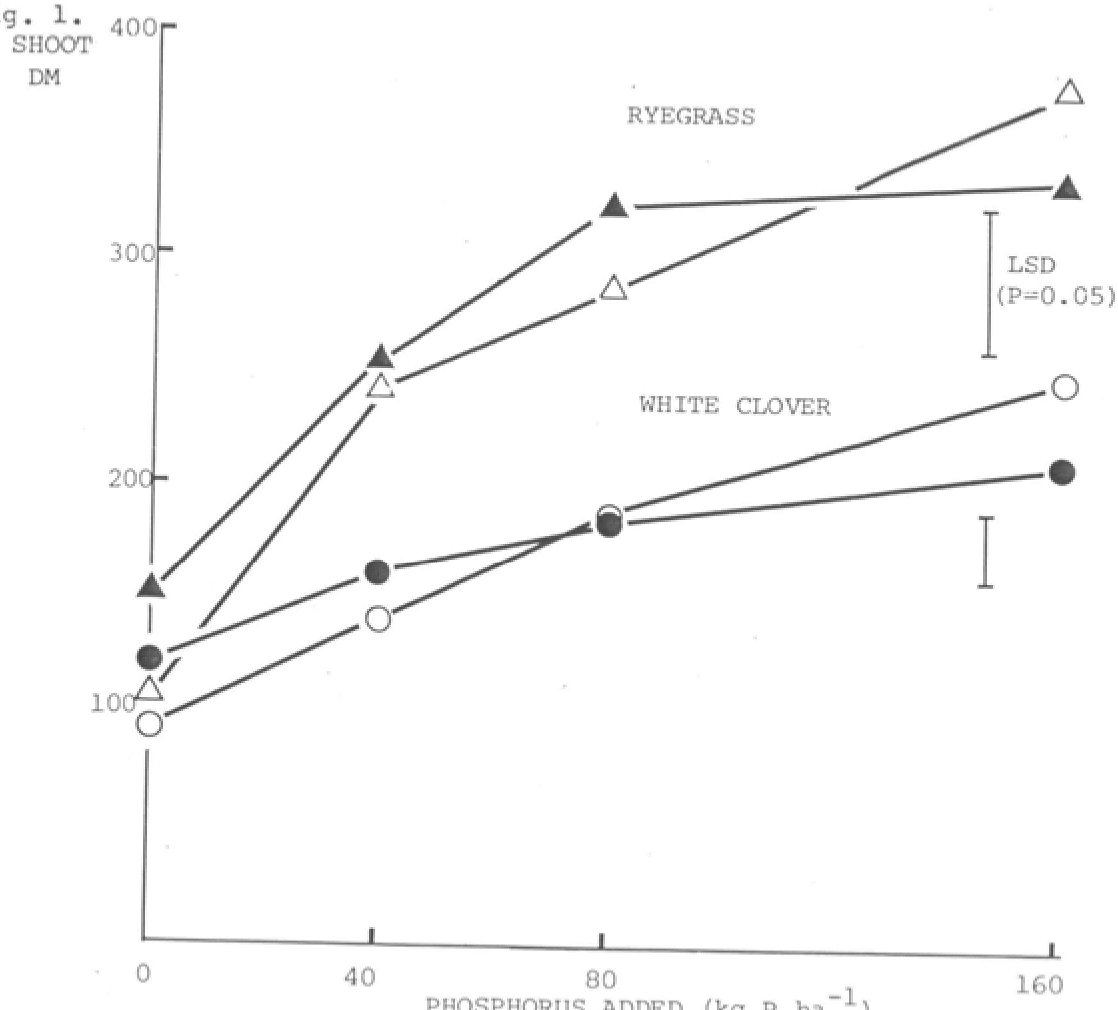

Figure 1. The effect of lime (solid symbols) on the response in production of short (mg DM/pot) of ryegrass (△) and white clover (O) to added phosphorus in soil from Hartwood

The production of shoots of both plants increased significantly ($P = 0.001$) with each quantity of added phosphorus. In both plants there was a trend for lime to increase shoot dry weight at the low levels, and to decrease it at the highest level of added P, but this interaction was only statistically significant ($P = 0.01$) for white clover. The analysis of shoot production at a further sampling occasion, chemical analysis of the herbage and further statistical analysis is in progress. The opportunity was also taken to examine the response of white clover to inoculation with ***Rhizobium*** and mycorrhiza in this soil type (see p.C.31).

4. Methods to assess the nutrient status of shoot material grown in hill and upland soils

A. Rangeley, P. Newbould and J. Leask

It has been shown previously (HFRO 226) that analysis of the total quantity of the major nutrients in shoot tissue can be used to indicate the need for maintenance dressings of fertiliser. The method of analysis used in this procedure is time consuming and can result in delays in applying required fertilisers in the field. Attempts to save time in this process have commenced using the analysis of nutrients in plant sap expressed from growing leaves. A number of published methods (Ulrich, 1948; Barakiva, 1970; Scaife, 1979, Bouma and Dowling, 1980; Besford, 1980), including colorimetric methods for total elements, enzyme assays for nitrate reductase and acid phosphatase in sap, and the use of leaf content indicator papers, have been tried. White clover and ryegrass leaves of different physiological age taken from the contrasted treatments in the experiment described earlier in section 3 have been examined. Leaf samples taken from a number of field experiments at different sites are also under examination.

Considerable difficulty has been found in applying methods developed initially for horticultural crops to white clover and ryegrass and further work is required before the applicability of the tissue analysis method to practical situations can be assessed.

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5. The effectiveness of different forms of P fertilisers

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

This experiment was conducted by Dr Pimplaskar in 1977, and previous accounts have appeared in the Annual Reports for 1977 (HFRO 220) and for 1980 (HFRO 228). In 1977 it was only possible to interpret treatment effects in terms of herbage DM yield, but because soil P analyses have been completed, the three forms of P fertiliser can be assessed now in terms of P removal by ryegrass.

In 1980, data for P in soil before and after the growth of ryegrass were only presented for water soluble-P. Acetic soluble-P has now also been determined on the same samples and the data are given in Table 1. These show that in the absence of added P the acetic-soluble-P content of Linhope soil (0.6 mg/100 g) was slightly higher than that of the Darleith soil, but after plants had grown in these soils, both were very similar at about 0.4 mg/100 g P. The largest amounts of P were found in the Linhope soil with Ground Mineral Phosphate (GMP) or a 1:1 (with respect to P content) mixture of GMP with superphosphate. In the Linhope soil both 6-month storage, and growth of ryegrass in the soils (with consequent uptake of P) reduced the levels of acetic soluble-P - but most markedly at the P.80 level of treatment. In the Darleith soil, P treatment and storage time had much less effect on the level of acetic soluble P in the soil - probably because it was rapidly fixed in association with the high iron and aluminium content of this soil. Levels of acetic-soluble-P were remarkably similar before and after the growth of ryegrass suggesting that the rate of uptake by plants may have been commensurate with the rate of replenishment of P in soil from other sources.

Table 1 (see opposite)

BRACKEN CONTROL

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

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

G.E. Davies (retired 1/10/81), P. Newbould and G.J. Baillie

The design of this trial and the main findings have been described previously (HFRO 226, 228). Monitoring in 1981 was confined to observations of the number and height of bracken fronds slowly reappearing on the sprayed plots. Results given in Table 1 show the control of bracken achieved one year after spraying (1974) and that present seven and eight years later (1980, 1981).

Table 1. Acetic-soluble-P in P-treated soils after different storage periods, before and after the growth of ryegrass (mg/100g)

(See also Table 5, p C.12 Annual Report, 1977 (HFRO 220) and Table 1, p C.2, Annual Report, 1980 (HFRO 228)

Treatment	Acetic-soluble-P			
	0 months storage		6 months storage	
	pre-treatment	post-treatment	pre-treatment	post-treatment
LINHOPE SOIL				
NO-P L0 P0	.68	.40	-	-
L1 P0	.64	.40	-	-
Super-phosphate L0 P20	1.32	1.04	1.16	.98
L1 P20	1.76	1.10	1.44	1.40
L0 P80	7.00	3.12	4.36	3.24
L1 P80	9.00	4.86	7.00	3.72
GMP L0 P20	1.48	.86	1.04	.96
L1 P20	2.32	1.84	1.84	1.40
L0 P80	8.76	9.49	7.30	4.98
L1 P80	14.60	13.14	15.33	6.50
Mix L0 P20	1.28	1.06	1.22	.92
L1 P20	3.68	1.42	1.44	1.14
L0 P80	11.00	4.16	8.00	4.02
L1 P80	15.00	12.21	9.00	7.00
DARLEITH SOIL				
NO-P L0 P0	.44	.40	-	-
L1 P0	.44	.48	-	-
Super-phosphate L0 P20	.76	.70	.88	.72
L1 P20	.76	,66	.68	.60
L0 P80	1.48	1.32	1.32	1.30
L1 P80	1.34	1.26	1.24	1.18
GMP L0 P20	.76	.66	.72	.78
L1 P20	1.04	.74	.76	.60
L0 P80	1.52	1.40	1.56	1.36
L1 P80	3.04	3.37	3.04	1.56
Mix L0 P20	1.52	.88	.84	.74
L1 P20	.84	.78	1.40	.86
L0 P80	1.44	1.28	1.04	1.30
L1 P80	2.00	1.60	1.40	3.42

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

	Year	Control No.	Control Height	Sprayed No.	Sprayed Height	% Reduction No.	% Reduction Height
Site 1	1974	39	67	1	35	97.9	47.8
	1980	27	57	5	39	81.8	32.7
	1981	33	64	7	39	80.4	38.9
Site 2	1974	34	57	<1	28	98.6	50.6
	1980	27	51	5	36	82.7	28.9
	1981	23	51	5	36	78.8	29.2

The effect of phosphate on height of bracken fronds found in the three years immediately following additives of P, and especially at Site 2 (HFRO 226) was not observed. Thus the loss of effectiveness of the phosphate fertiliser noted last year (HFRO 228) is confirmed.

2. The effects of lime and phosphate on pasture production following control of bracken - House o' Muir

G.E. Davies (retired 1/10/81), P. Newbould and G.J. Baillie

The design of the trial and early results have been described previously (HFRO 226, 228). Asulam was applied in August 1977 at the commercial rate of 11.2 l/ha and lime (5 t/ha) and phosphate 628 kg P/ha) in November 1978 and March 1979, respectively.

Results given in Table 1 show the control of bracken achieved one year (1978) and four years (1981) after spraying. Lime and phosphate had no effect so means for the main treatments are alone given in the table.

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

Year	Control No.	Control Height	Sprayed No.	Sprayed Height	% Reduction No.	% Reduction Height
1978	33	86	1	35	97.8	59.0
1981	41	86	3	46	91.9	47.0

Control of bracken following spraying is still good but, as at Sourhope, the number of fronds, although only of moderate height, show signs of beginning to increase.

Assessments of botanical composition (Table 2) indicate a continuing increase since the first year after spraying in the proportion of broad-leaved grasses (At. Ac. Pp) and it appears that the application of lime and phosphate has enhanced this.

Table 2. The effect of (a) spraying asulam on botanical composition and amount of bare ground (% cover), and (b) of lime and phosphate on cover (%) of broad-leaved grasses

(a) SPRAYING

Year	Treatment	At.Ac.Pp	Df.Fo	Herbs	Bare ground
1978	Control	19.7	43.3	21.2	6.9
	Spray	8.1	50.8	18.1	11.0
1981	Control	17.7	46.9	10.6	1.0
	Spray	28.0	37.6	15.7	0

(b) LIME AND PHOSPHATE (At.Ac.Pp only)

		L0		L1	
		P_0	P_1	P_0	P_1
1981	Control	16.5	19.9	21.4	13.4
	Spray	6.9	23.8	30.9	51.4

Production of pasture was enhanced by spraying (P 0.01) and by the application of lime and phosphate (P 0.05), and from Table 2 it appears that the latter effect is due largely to the increased proportion of broad-leaved grasses.

Table 3. The effect of spraying bracken and of lime and phosphate on accumulated production (April-November) of pasture (kg DM/ha)

	L0		L1	
	P_0	P_1	P_0	P_1
Control	1556	1591	1244	1400 (1580)?
Spray	2365	2826	2989	4255

Soil analysis is in progress and when complete it is hoped to prepare all the results for publication after which work in this project ceases.

REGROWTH

04006: Regrowth of hill and upland pastures

1. Regrowth and nitrogen fixation by pure stands of white clover subjected to various defoliation regimes

J. King, S.A. Grant, E. Sim, L. Torvell and V.A. Doughty

In 1980 an experiment was carried out using box grown ryegrass swards in the glasshouse, cut to maintain a range of LAI values from 1 to 6. Growth and senescence rates were measured and related to the maintained LAI values. Net growth rate was found to be optimised at intermediate LAI levels between 3 and 4. In 1981 a second experiment was carried out with pure stands of S184 white clover. In this experiment a standard set of cutting regimes were applied and measurements made as the swards equilibrated to the regimes over a 6 week period. Measurements were made of LAI, total and net growth rate, harvested yield and N-fixation rate.

Nine cutting regimes were used, being a factorial combination of cutting height and frequency as follows:-

F1	Cut weekly		L	Cut at 2 cm	
2	Cut 2 weekly	x	M	Cut at 4 cm	x 6 replicates
3	Cut 3 weekly		H	Cut at 6 cm	

Analysis of the data is not yet complete but some interim results are given below.

Leaf Area Index (LAI)

The accumulated values for growth periods have been analysed. LAI increased with time as the experiment proceeded. It also increased as cutting interval increased (i.e. $F_1 < F_2 < F_3$) and as cutting height increased from Low to Medium but not between Medium and High (i.e. $L < M = H$). The mean values for accumulated LAI were as follows:-

L	21.4 a	F1	15.3 a
M	25.6 b	2	23.6 b
H	27.4 b	3	33.5 c
LSD (P = 0.05)	3.2		3.2

Residual LAI

The LAI left in the stubble after cutting did not change with time as the experiment progressed. The values were all very low but were greatest on the swards cut weekly at high level (i.e. $F_1 > F_2 = F_3$ and $L = M < H$). This contrasts with the results for accumulated LAI. The mean values for residual LAI for three harvest dates comparing two weekly cuts with weekly cuts and for two harvest dates comparing three weekly cuts with weekly cuts were as follows:-

Two weekly cuts				Three weekly cuts			
L	0.19 a	Fl	0.38 a	L	0.13 a	Fl	0.40 a
M	0.19 a	2	0.12 b	M	0.25 a	3	0.13 b
H	0.37 b			H	0.40 b		
LSD (P = 0.05)	0.06		0.27		0.13		0.11

Harvested Yield

Yield increased with time and there was a time interaction with both cutting frequency and height. Early in the experiment medium and high cutting at 2 or 3 week intervals gave the greatest yield (i.e. L < M = H and Fl < F2 = F3). Later on when the swards were more adapted to the regime the highest yields came from cutting at medium height while the differences due to frequency disappeared (i.e. L < M > H and Fl = F2 = F3).

The range of variation between L M and H treatments was not large however, the differences between M and L or H being about 8-10% of the mean. For example:-

Harvested yield (gm m^{-2} DM)

	Last 2 weeks				Last 3 weeks		
L	87.1	Fl	89.7	L	122.0	Fl	122.6
M	94.8	2	87.5	M	132.2	3	127.1
H	83.9			H	120.3		
LSD (P = 0.05)	6.0		4.9		8.3		6.8

Nitrogen fixation

This was measured twice weekly in terms of the rate of reduction of acetylene to ethylene. From this was obtained an index of potential N-fixation each week.

N-fixation increased with cutting height and with the increase in cutting interval from two to three weeks. The difference between one and two weeks (Fl and 2) was not significant (i.e. L < M < H and Fl = F2 < F3). There were no interactions with time.

The mean values were as follows:-

N-fixation (moles C_2H_4/pot)		Mean over 6 weeks	
L	343.0 a	Fl	390.4 a
M	382.9 b	2	406.5 a
H	532.8 c	3	461.7 b
LSD (P = 0.05)	29.1		29.1

N-fixation was linearly related to the accumulated LAI for each growth period. Using N-fixation rates and LAI for weekly periods the relationship is shown in Fig. 1 for the low, medium and high cut swards. In this diagram low LAI values represent swards measured only a short time after cutting or swards with a short cutting interval (weekly). It is evident that the relationship is similar for the Low and Medium cutting heights but that more N was fixed per unit LAI on the High cut swards. The reason for this effect is not immediately obvious but it may reflect a smaller impact of defoliation on the assimilate supply to the roots and nodules when cutting was at a high rather than a low level.

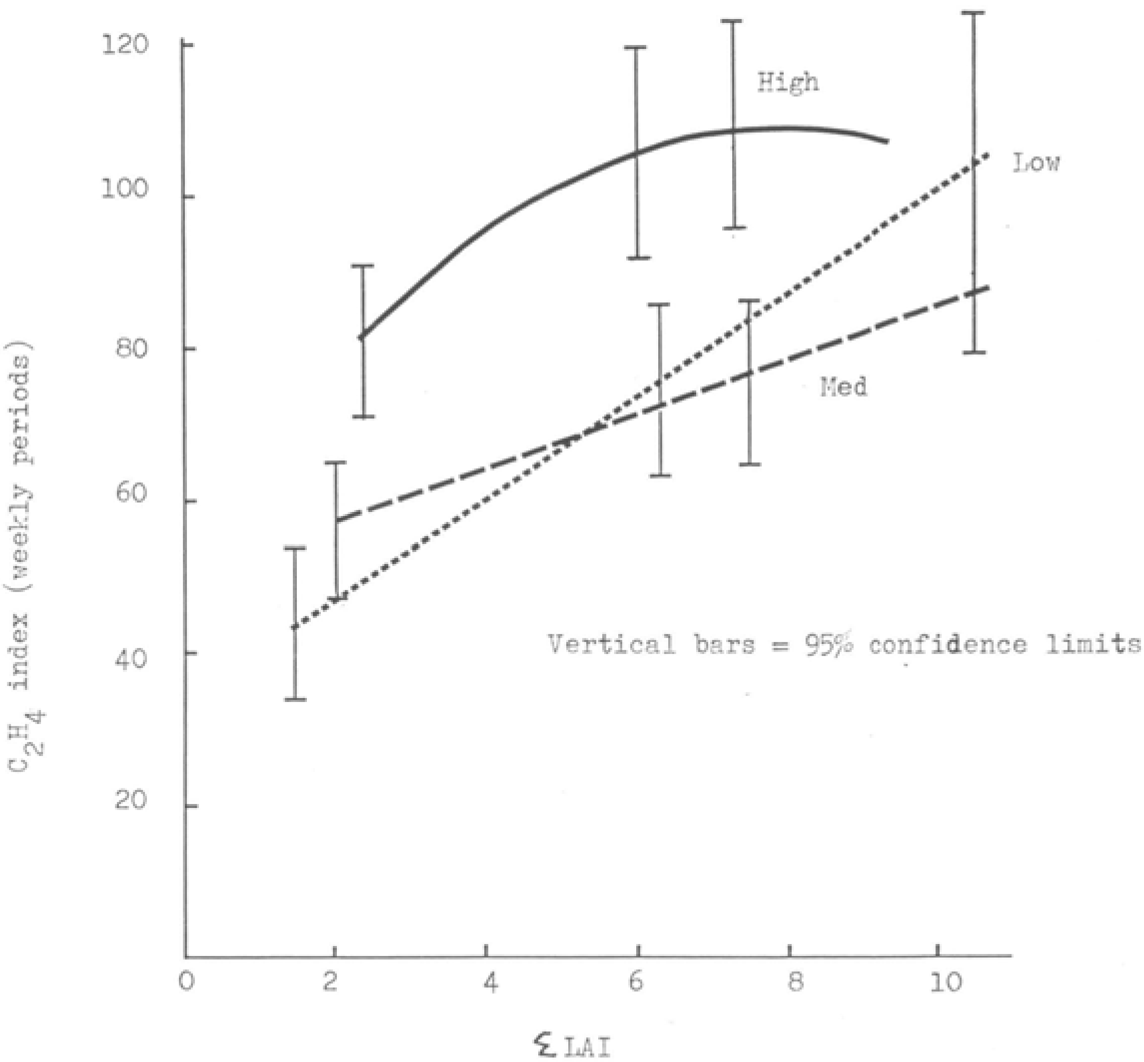

Fig. 1. Index of total acetylene reduction (C_2H_4) in relation to cumulative LAI for weekly periods for swards of white clover cut High (6 cm) Medium (3 cm) Low (2 cm) at 1, 2 and 3 week intervals

<u>Conclusion</u>

Accumulated LAI increased as cutting height and interval increased. N-fixation was related to LAI so that maximum rates were obtained in swards cut high at 3 week intervals. In contrast harvested yield was maximised at the Medium cutting height probably as a result of lower growth rates on Low cut swards and greater senescence losses on High cut swards. On adapted swards harvested yield was not sensitive to variation in cutting frequency, possibly due to compensatory density changes.

2. Growth rate of intermittently grazed swards

J. King, S.A. Grant, E. Sim, L. Torvell and V.A. Doughty

The work on continuously grazed swards has shown that while total growth rate increases with leaf area index (LAI) up to a maximum about LAI 6, net growth rate, after allowing for loss by senescence, reaches a maximum at comparatively low LAI values, about LAI 3, declining again on longer swards above LAI 4. This represents a maximum harvestable yield which cannot easily be increased except by increasing inputs of nitrogen. It may be possible to obtain greater harvested yields by resort to intermittent or rotational grazing. However, published data suggests that this will be possible only if the most efficient intermittent systems are used and the question arises: what constitutes such a system.

In 1981 an experiment was started with the object of identifying the growth rate characteristics of intermittent systems and how these are influenced by management.

For this purpose re-growth rate during the rest period must be measured separately from that taking place while grazing is in progress. There is reason to expect that the grazing process itself reduces growth rate and the experiment was designed to examine this possibility.

Measurements of growth rate and of net canopy photosynthesis were made on:-

(1) Ryegrass swards regrowing after a period of continuous grazing

(2) Similar swards while being grazed down from high to low mass over a period of either one week or three weeks.

The experimental swards were in 0.1 ha paddocks and the treatments were replicated twice.

The following measurements were made:-

(a) Net canopy photosynthesis and respiration on sample turfs taken from the field.

(b) Leaf tissue turnover by measurement of marked tillers and tiller density in the field.

(c) Change in herbage mass each week and the composition of this mass in terms of leaf lamina, sheath, litter etc.

(d) Litter disappearance rate using a litter bag technique.

The results are not yet completely analysed but some are available and are summarised here:

Sward photosynthetic potential

Figure 1 shows the change in net photosynthetic rate at 400 Wm^{-2} of the swards while they were being grazed down from 2800 to 1000 kg ha^{-1} DM and while regrowing after a period of continuous grazing.

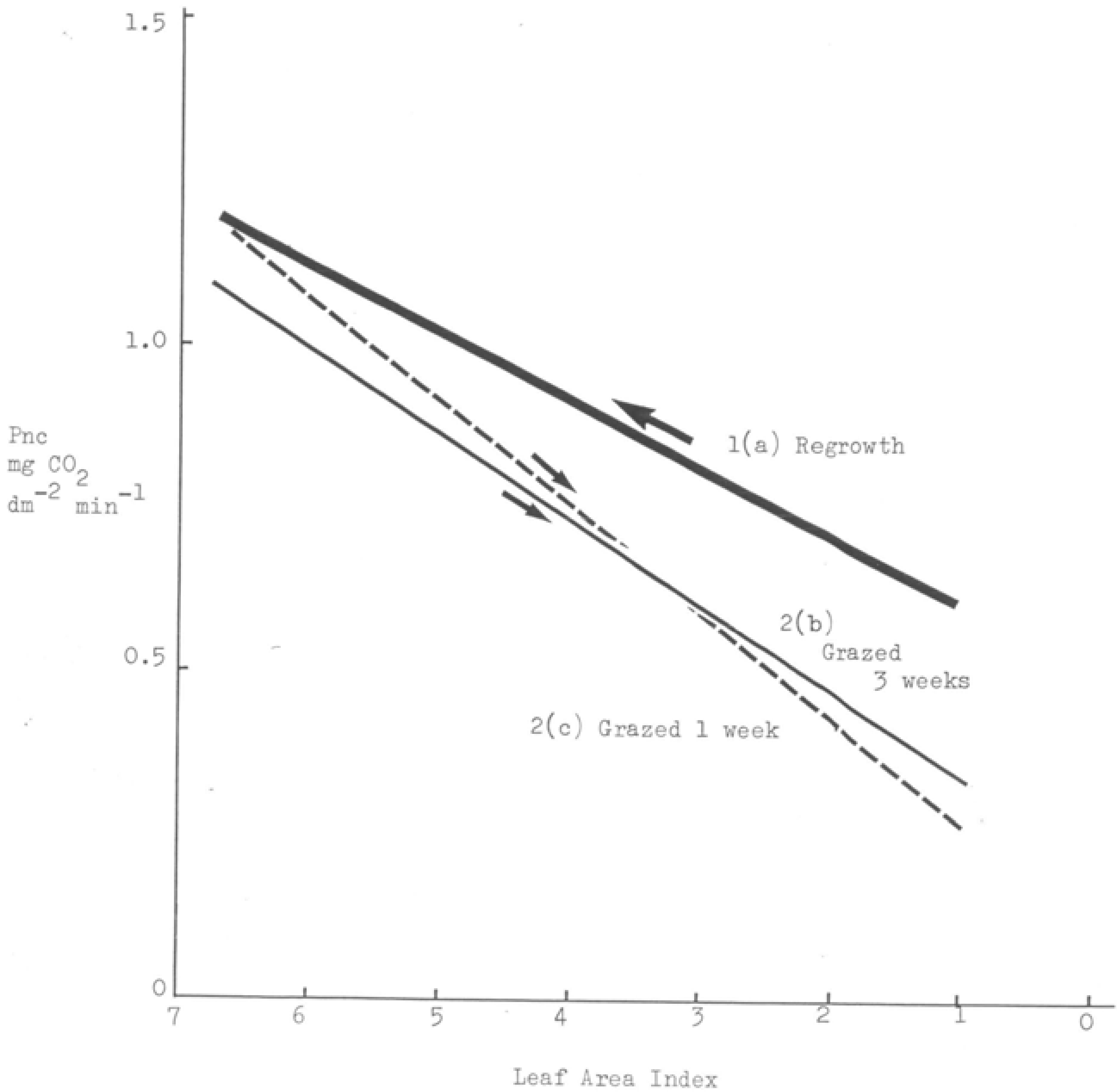

Fig. 1. Rate of net canopy photosynthesis of ryegrass swards at 400 Wm^{-2} irradiance : 1(a) Regrowing over a 3 week period
2 While being grazed down from high to low mass in
(b) 3 weeks (c) 1 week

It is evident from the figure that the photosynthetic potential of the regrowing sward was greater than that of either of the grazed swards. This almost certainly reflects the greater efficiency of the undisturbed canopy. The grazed canopies were both disturbed which would reduce their light interception abilities. In addition they were losing their younger and photosynthetically more efficient leaves as a result of grazing.

The linear regressions coefficients were all significantly different and were as follows:-

	b		Variance explained
Regrowth	0.076)		48.0%
	) **		
Grazed 3 weeks	0.129)	**	87.7%
	) **		
1 week	0.161)		83.4%

The data for the grazed swards were remarkably linear (83.4 - 87.7% of the variance explained) suggesting that selective removal of the younger leaves was not taking place at the start of the grazing period. Photosynthetic potential in these swards declined in direct proportion to the fall in leaf area index as grazing proceeded. The less steep fall observed on the sward grazed down over 3 weeks may reflect the production of new leaf tissue replacing that grazed. Such regrowth would be much less in the 1 week grazing period.

Tissue turnover

The processing of the samples to determine tiller population density to convert the growth and senescence data from tiller measurements to kg DM/ha has only recently been completed and the data are not yet in their final form. Meanwhile the relationships between growth and senescence and change in herbage mass during the grazing down and the regrowth periods were examined by plotting mm tiller per day growth or senescence against herbage mass. During the grazing down period the relationships were very similar to those found under continuous stocking across a range of swards managed to maintain their herbage masses at steady state. Growth (or gross production) showed a non-significant gentle sloped linear positive regression and senescence a significant linear positive regression. During the regrowth period, however, while growth showed a similar relationship with increase in herbage mass i.e. a linear positive regression the senescence rate remained low and showed no relationship with increase in mass. The contrasting senescence regressions are shown graphically in Figure 2.

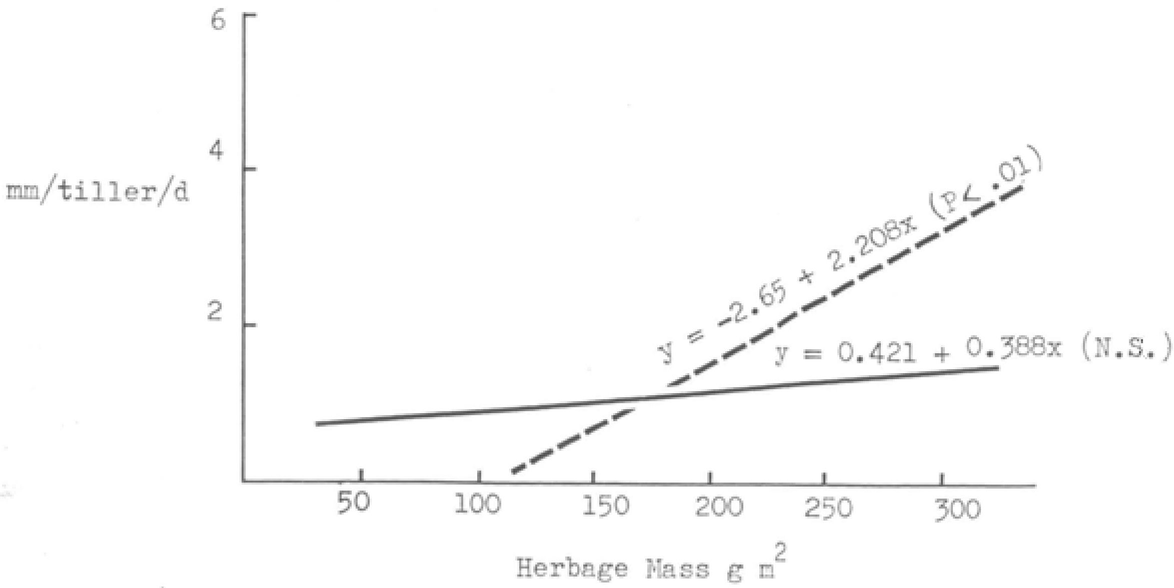

Fig. 2. Relationship between senescence rates and change in herbage mass during a three week grazing down (- - - -) and regrowth period (———)

The delay to senescence during regrowth was thought to be related to the need for leaves to achieve a degree of maturity before mutual shading in the leaf canopy causes senescence to begin. It is suggested that this effect could last for three leaf appearance intervals, i.e. until a normal age structure for the leaf population is re-established.

Litter decomposition

An unsuccessful attempt was made to measure the litter disappearance rate in the experimental swards. It was hoped to use this data, together with data on change in size of the quantity of litter, to estimate senescence rate.

Four litter sample sizes were used from 0.5 to 3.0 gm nominally, each sample in a hairnet litter bag (mesh 1 cm^2) placed on 1 cm^2 of close cut turf. The samples were left in place for 4 weeks. When they were lifted some difficulty was experienced due both to regrowth through the bags and to partial burial of the bags by worm casts. Many of the smallest (0.5 g) samples were irrecoverable. The results from the three larger sample sizes were as follows:-

Sample size:	Nominal	1.0	2.0	3.0
Sample size:	Actual at t_0	0.865	0.733	2.595
Sample size:	t_1	0.766	1.357	1.784
Disappearance rate (r) gm $gm^{-1} day^{-1}$		0.0043	0.0087	0.0133

It is evident that the value of r was increasingly overestimated as sample size increased. It seems likely, that in the large mesh size that was used sample losses took place other than by decay and that these losses were greater in the larger samples.

NUTRIENT CYCLING

04007/03002: Cycling of nutrients in grazed hill pastures and its influence on requirements for lime and fertilisers

1. Nutrient cycling in "Input-Output" experiments at Sourhope

M.J.S. Floate, T.G. Common, A.D. Ironside and J. Hodgson

Following the publication of 2 papers (British Grassland Society Symposium) in 1980, which summarised results and observations at that time plans have now been made to conclude the long-term "Input-Output" experiments over a period of 3 years.

The three sites (F_2 *Agrostis-Fescue*, G_3 *Molinia-Nardus*, and F_4 *Nardus-Agrostis*) were originally established in 1969, 1970 and 1971 respectively and details of treatments and results have been given in previous Annual Reports. Maintenance lime and P treatments were applied in 1976 and 1977, and on a 6-year cycle would normally have been due again starting on F_2 in 1981. For a number of reasons this was not done, and it has now been decided to conclude these field experiments with a comprehensive series of measurements (including soil properties, vegetation components, herbage yield, digestibility and intake, animal live-weight changes and grazing days, and total annual recycled nutrients) starting on the F_2 site in 1982.

During 1981 the standing crop yields at the start of each grazing period for 5 treatments at each of the 3 sites, and the total grazing days for 1981 were recorded; these data are presented in Tables 1 and 2.

Table 1. Input/Output data 1981 - Herbage available at the beginning of each grazing period (kg/ha dry matter)

		0	1	2	3	4
F_2	1st grazing period 7-25/5/81	1133	1156	1060	1046	1509
	2nd grazing period 23/7-17/9/81	2596	3120	3000	3541	4030
	3rd grazing period 22/10-12/11/81	1505	1011	1261	1123	1255
G_2	1st grazing period 7-28/5/81	516	646	679	809	1235
	2nd grazing period 23/7-11/9/81	2918	3102	3623	3412	3877
	3rd grazing period 23/10-13/11/81	1655	1876	1957	1487	1210
F_4	1st grazing period 7-25/5/81	529	632	907	980	1435
	2nd grazing period 23/7-6/9/81	2220	2672	2534	3634	4500
	3rd grazing period 20/10-10/11/81	2134	1964	2172	1549	1306

Table 2. Input/Output data 1981 - Grazing days/ha

F_2	1st grazing period	712	712	712	890	1067
	2nd grazing period	2214	2768	2768	3321	3875
	3rd grazing period	830	415	623	415	623
	Total	3756	3895	4103	4626	5565
G_3	1st grazing period	242	346	346	519	830
	2nd grazing period	2224	2224	2718	2471	2965
	3rd grazing period	830	1038	1038	726	519
	Total	3296	3608	4102	3716	4314
F_4	1st grazing period	178	267	445	623	890
	2nd grazing period	1715	1423	1423	2412	3746
	3rd grazing period	1245	1038	1245	726	623
	Total	3138	2728	3113	3761	5259

These data follow trends similar to those reported in earlier years.

2. Maintenance requirements for P and K fertilisers on deep peat

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

Previous field experiments, coupled with results from pot experiments, (see previous Annual Reports) have indicated that the annual requirement for P on improved pastures on peat is probably in the range 10-30 kg/ha^{-1}P, and recent experiments (see Annual Report, 1980) have indicated that application of multiple quantities on 3 or 4-year cycles may be feasible. Corresponding K requirements appear to be higher, but are more difficult to define precisely, and almost certainly need more frequent application. An experiment was laid down in 1980 with basal P K fertilisers, with the intention of monitoring the need for P maintenance by soil and plant analysis, and investigating the needs for more frequent K treatments.

Samples of soil were taken at each of 2 depths (0-5, 5-10 cm) in April 1981. That was approximately one year after establishment of the ryegrass-clover reseed on the peat in 1980, and before any differential treatments were applied in 1981. The analytical data for these soils is given in Table 1. Statistical analysis has shown that there were no significant differences between plots for any of the properties measured, at either depth, but that there were highly significant differences between depths for all properties.

Table 1. Analysis of soils before start of P.K maintenance experiment on deep peat. Reseeded 1980, soil samples taken April 1981.

Plot No.	Treatment (kg.ha^{-1})	pH		Extractable-P (mg/100g)		Extractable-K (mg/100g)	
		0-5 cm	5-10 cm	0-5 cm	5-10 cm	0-5 cm	5-10 cm
1	K.50	5.2	4.0	26.1	11.1	84.3	45.0
2	K. 0	5.6	3.9	24.4	9.1	86.4	45.5
3	K.25	5.7	4.2	25.4	9.1	99.4	46.2
4	K. 0	5.7	4.1	30.1	8.6	152.8	53.5
5	K. 0	5.7	4.2	21.3	10.9	94.6	47.5
6	K.25	5.9	4.2	20.5	5.8	75.3	48.1
7	K. 0	5.9	4.3	22.8	8.3	66.7	38.0
8	K. 0	5.5	4.1	23.9	7.7	74.4	44.5
9	K. 0	5.7	3.9	25.7	6.6	73.7	41.0
11	K.50	5.7	4.2	25.6	8.1	93.5	44.9
12	K. 0	5.6	4.0	23.6	8.7	80.0	44.7
13	K.50	5.5	4.0	21.5	8.4	85.0	41.2
14	K.25	5.5	4.1	16.8	8.6	67.2	45.7
15	K. 0	5.5	3.9	22.9	11.4	90.9	47.0
16	K. 0	5.5	3.9	24.7	9.5	82.1	44.4
17	K. 0	5.5	3.9	25.4	9.0	86.0	41.2
18	K.25	5.5	3.9	17.9	8.3	82.7	46.7
19	K.50	5.3	4.0	23.8	10.3	94.2	47.4
20	K. 0	5.6	4.1	15.3	8.6	64.2	40.0
21	K. 0	5.3	3.8	17.4	10.3	67.7	45.0
$\bar{x}$		5.6	4.0	22.8	8.9	85.0	44.9

Differential K treatments (0, 25, 50 kg/ha^{-1}K) on annual and biennial cycles were commenced in 1981 when a revised design of grazing management was also initiated. The principal of this revised system of grazing was to maintain a standing crop of herbage within the range where Net Accumulation rate (growth rate) was relatively unaffected by amount of standing crop. The intention was to maintain standing crop between 800-1500 kg/ha^{-1}DM but in practice, because of slow growth rates on some plots, the standing crop on occasions fell as low as 200 kg/ha^{-1}DM. In order to maintain the continuity of grazing by individual sheep on similar treatments, sheep were alternated between pairs of correspondingly treated plots on a 2-weekly cycle. For most the year, and on most plots, it was possible to maintain 2 sheep continuously grazing but alternating between 0.1 ha plots, without seriously departing from the standing crop guide-lines. This suggests, if intake was approximately 1400 g DM per sheep per day, that the average herbage growth rate was of the order 25-30 kg/ha^{-1} per day, or that total annual herbage production should exceed 3000 kg/ha^{-1} DM.

One of the objectives of the alternating grazing management system was to allow for a summation of herbage production assessments by quadrat cutting at the end of each 2-week growing period ("in-cuts") on alternating plots of the same treatment, and correspondingly to provide a continuous record of grazing days by summation of the data from the alternate member of each plot-pair.

In practice this did not work out too successfully because of slow growth rates on some plots, short intervals between successive cuts, and errors associated with non-uniform sward conditions: on the basis of differences between mean "in-cut" and "out-cut" this sometimes led to apparent negative growth rates but more representative data were obtained when means for each of K0, K25 and K50 treatments were calculated, and apparently negative values were ignored. These mean growth rates are given in Table 2 for each of the "odd" and "even" sets of plots in the plot-pair system, and show that there were no consistent differences due to K treatment. The overall mean growth rate of 16 kg/ha^{-1} per day appears to be low in relation to amounts of herbage consumed by grazing sheep.

Table 2. Mean growth rates (kg/ha^{-1}day^{-1}) calculated for 10 x 2-week periods in 1981, for reseeded pasture on deep peat under 3 K treatments grazed alternately on "odd" and "even" plots

Growth Period	"Odd" plots				"Even" plots			
	K0	K25	K50	$\bar{x}$	K0	K25	K50	$\bar{x}$
27:5 - 4:6	32	15	28	29				
9:6 - 18:6					14	7	32	14
22:6 - 2:7	24	28	22	24				
6:7 - 16:7					16	24	27	19
20:7 - 30:7	13	18	8	15				
3:8 - 13:8					11	14	17	12
17:8 - 27:8	4	8	4	5				
31:8 - 10:9					15	16	16	15
14:9 - 24:9	18	18	20	19				
28:9 - 8:10					8	7	1	7

Calculations for whole season production based on these mean growth rates (for 120 days May-Oct.) together with about 1000 kg/ha^{-1} accumulated before the first cut suggests annual production no more than about 3000 kg/ha^{-1} DM. It is suggested that this estimate may be low (compared with intake calculations) because of accumulated errors from losses in each growth period. Data from the companion plots allowing the simultaneous summation of sheep grazing days, are given in Table 3.

Attempts were made to correlate the sum of herbage production with herbage intake by sheep during grazing (calculated from grazing days x 1400 g DM per sheep per day) for individual plots. Using the sum of differences between pairs of "in-cut" and "out-cut" data gave a mean of 766 kg/ha^{-1} (for about 50 days) compared with a mean value of 1849 kg/ha^{-1} for calculated intake over a maximum of 76 days, and the correlation between these data sets was poor. It was found that in part this was due to smaller residual standing crops ("out-cuts") on many of those plots which had supported a smaller number of grazing days (i.e. they had been grazed more severely). When this bias was accounted for by deducting a multiple of mean "out-cut" values from the sum of all "in-cuts" for each plot, the correlation was improved, and the corresponding mean values were 1560 kg/ha^{-1} herbage production in 50 days, and 1849 kg/ha^{-1} calculated intake in periods ranging from 52 to 76 grazing days.

Table 3. Mean sheep grazing days for 3 K treatments on reseeded pasture on deep peat, on plot-pairs grazed alternatively

Grazing Period	"Odd" plots K0	K25	K50	$\bar{x}$	"Even" plots K0	K25	K50	$\bar{x}$	Maximum possible no. of days
1	7	7	7	7					7
1					12	12	12	12	12
2	12	11	12	12					14
2					13	15	15	14	15
3	12	11	11	11					13
3					11	13	13	12	13
4	13	10	9	11					14
4					11	14	14	13	14
5	13	9	11	11					14
5					10	11	14	12	14
6	11	11	12	11					12
6					8	8	8	8	8
Total	68	59	62	63	65	73	76	76	71

It was concluded that the average accumulation of some 1560 kg/ha^{-1} herbage in 50 days between measurements (equivalent to some 2215 kg/ha^{-1} herbage DM in 71 days between grazing periods) compares favourably with the calculated intake of 1849 kg/ha^{-1} DM (or about 80% utilisation) during the actual grazing periods.

Whether growth rate, accumulated herbage, or grazing days were used as the parameter for assessing the effects of K treatments, it was concluded in every case that there were no significant differences due to K treatment. This was, however, the first year of what had been planned as a long-term experiment, but this has now unfortunately been terminated.

A subsidiary part of this experiment included the continuous daily recording of K concentration in drainage water from one of the K50 treated plots, for a period of 10 days before fertiliser was applied in May, and for 97 days after application. Before application K concentration in run-off water ranged 1-2 mg/kg^{-1} and increased to 12-15 mg/kg^{-1} immediately after application. Highest concentrations (15-17 mg/kg^{-1}) were recorded when water flow was greatest following heavy rain. After about 30 days K concentration had fallen below 5 mg/kg^{-1} and continued to fall slowly to about 3 mg/kg^{-1} at the end of the period with the exception of 2 isolated occasions when 10-11 mg/kg^{-1} were recorded. It seems that the greatest surface loss of K fertiliser occurs in periods of heavy rain and rapid run-off, in the first month after application. As no flow measuring equipment was available it is unfortunately not possible to calculate estimates of losses in kg/ha^{-1} units. These data do, however, confirm similar reports of K run-off losses from peat in Ireland, and also confirm that frequent K fertiliser maintenance is likely to be necessary.

NITROGEN FIXATION

04008: Factors affecting the fixation and transfer of nitrogen by white clover in hill pastures.

The bulk of the work described in this section was carried out during the visit of Dr Haystead to the CSIRO Division of Land Resources Management, in Perth, Western Australia. Co-authors marked with an asterisk (*) are members of the Australian research group

1. Nitrogen Cycling in the pasture component of a *Trifolium subterraneum* - *Pinus radiata* agroforestry system

A. Haystead and J. Galbraith*

The integrated production of sheep and trees in Australia is a promising agricultural practice but one which as yet has not been extensively adopted by the farming community. Systems have been in operation at several sites in Western Australia for a number of years but little is known of the N-economy of these plant associations. The pasture component in Western Australia is essentially a monoculture of Sub-clover which grows and fixes nitrogen vigorously during the winter months of October through April. A series of experiments has been initiated to investigate the fate of biologically fixed nitrogen in these pastures using ^{15}N labelled legume residues incorporated into the soil prior to the break of the 1981 growing season. The experiments are designed to run for approximately three growing seasons during which the labelled microplots will be alternatively grazed and caged for a four week period. Herbage will be clipped from the microplots under the cages and separated into legume and non-legume (capeweed and Wimmera ryegrass) fractions which will be freeze-dried, weighed and analysed for total-N and isotopic enrichment. No data is available at the present time.

2. Mineralisation of legume residue nitrogen in a lateritic soil

A. Haystead and J. Galbraith*

Two experiments have been carried out to determine the rate and some factors affecting the mineralisation of Sub-clover roots and shoots. One was a laboratory experiment in which 100 g aliquots of soil were incubated with N-15 labelled legume residues at 25°C and 80% field capacity in the presence and absence of urea-N or NH_4NO_3. At regular intervals for 90 days after adding the labelled residues, the soil aliquots were extracted with 2M KCl to determine total exchangeable NO_3^- and NH_4^+ simultaneously biomass carbon and nitrogen were estimated using the fumigation procedure of Jenkinson and Powlson (1976). The isotopic labelling of the biomass nitrogen is currently being determined. The change in soil biomass over the 90 day period is shown in Fig. 1.

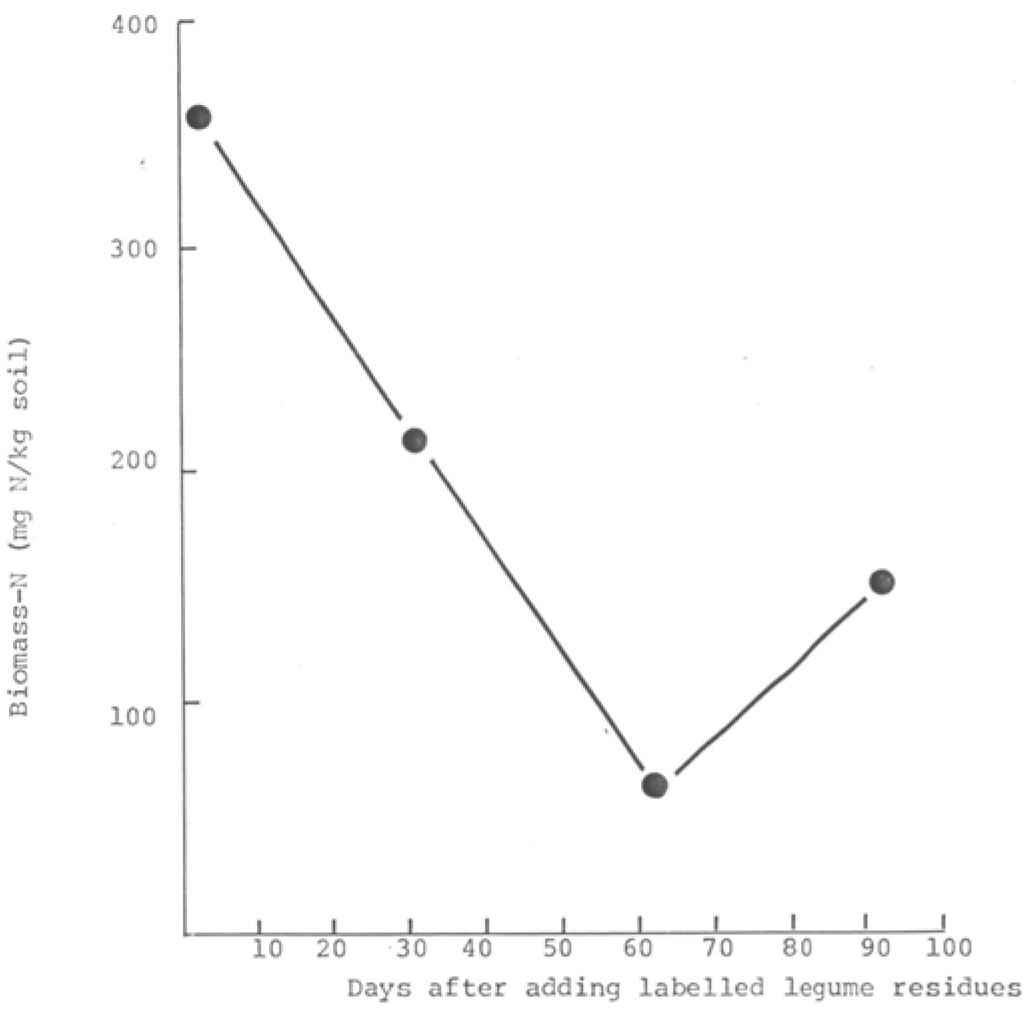

Fig. 1. Changes in biomass nitrogen after addition of labelled legume residues determined using the fumigation technique.

A second experiment involved taking 15 cm (diameter) x 1 m deep cores from the agroforestry site which were sealed into plastic tubes and buried in a yellow sand soil close to the laboratory in Perth (WA).

The top 0.1 m of the core was removed and labelled (30 Atom%-^{15}N) legume residue was added at a rate equivalent to 65 kg N per hectare. *Pinus radiata* seedlings were planted in the amended soil as it was replaced on top of the core. The cores were kept weed free and protected from grazing with exclosure cages. Cores were treated with monthly applications of nitrogen in the form of ammonium nitrate or urine at a rate equivalent to 10 kg N per hectare per addition during the 5 month pasture growing season when the soil was kept continuously moist by watering from the top to supplement rainfall. No growth differences were apparent between NH_4NO_3, urine or control (no nitrogen) seedlings and growth was rapid in all treatments. A preliminary analysis of leaf material removed from the *Pinus* seedlings has indicated a relatively low level of incorporation of legume residue nitrogen. Approximately 2% of the plant nitrogen is derived from the decomposing plant material in the zero nitrogen treatment. A detailed analysis is currently in progress.

REFERENCE:

Jenkinson, D.S. and Powlson, D.S. (1976). The effects of biocidal treatments on metabolism in soil. 1: Fumigation of Chloroform. Soil Biol. Biochem. 8: 167-177.

3. The role of vesicular arbuscular mycorrhizas in the associated growth of pasture legumes and grasses.

A. Haystead, T. Grove* and N. Malajczuk*

Experiments have been carried out to determine the possible effects of common mycorrhizal infection of the roots of associated pasture species on nitrogen transfer from a nitrogen fixing legume to a non-fixing species. Several associations of plant were examined including some in which the fungus formed an ectomycorrhiza. The experiment described here is one in which an association of *Trifolium subterraneum* with Wimmera ryegrass inoculated with a species of *Glomus* was examined. The plants were grown together in pots with the root systems of the individual plants growing together or separated by a variety of barriers. In each case treatments inoculated and uninoculated with *Glomus*, were prepared. Three clover plants and three grass plants were planted in each pot, shoots separated with a transparent plastic screen and the roots separated as shown in Table 1. Once the plants were well established ^{15}N in the form of 97 Atom% ^{15}N-urea in a 0.1% solution of Terrawet, a commercial wetting agent, was applied to the upper surfaces of the clover leaflets at a rate of 6 mg N per plant per application in a volume of 0.5 ml solution. Twelve such applications were made during the course of the experiment.

A number of possibilities exist for transfer of nutrients from the root system of one plant to another, assuming there is no mass flow of soil water between plants.

(a) Material may diffuse from one root system to another through the soil solution, in which case the rate of transfer will, according to Ficks law, be proportional to the concentration gradient, the diffusivity of the ion or molecular species (i.e. its diffusion coefficient) and inversely proportional to the spatial separation of the roots.

(b) The presence of mycorrhizal hyphae may reduce the distance over which nutrients must diffuse and will increase the area of 'root' surface across which the fluxes in and out may occur.

(c) Direct connection of the root systems via the mycorrhizal hyphae may occur.

Table 1. Experimental design and purpose of treatments in the Sub-clover/ Wimmera ryegrass experiment

Treatment		Possible transfer routes
impermeable plastic barrier	+ M - M	no below ground transfer possible
60 micron nylon mesh	+ M - M	A + B + C (no root contact) A
Semi permeable membrane (cellulose acetate)	+ M - M	A A
no barrier	+ M - M	A + B + C (root contact possible) A + B (root contact possible)

The semi-permeable membrane treatment did not produce any useful results due to the fact that the cellulose acetate material was degraded quite rapidly by soil organisms and in consequence was abandoned at an early stage. The results of the other treatments are summarised in Table 2.

Table 2. Effect of mycorrhizal infection of clover plants on transfer of labelled nitrogen to ryegrass plants

	Impermeable barrier		60μ nylon mesh	
	+ M	- M	+ M	- M
Percent N of Grass	1.92	2.02	1.93	1.99
Atom Percent 15-N of Grass	0.398[a]	0.387[a]	0.571[b]	0.411[b]

[a]Mean of 3 determinations carried out on material from three separate plants. The measured 15-N abundances are significantly ($P < 0.01$) greater than the natural abundance of grass grown in this medium.

[b]Mean of 9 determinations carried out on separate plants. Both values significantly above natural abundance ($P < 0.01$) and significantly different from each other ($P < 0.01$).

The interpretation of these data is at the present time problematic and it is too early to form definite conclusions regarding the quantitative significance of mycorrhizal nitrogen transport. The results indicate however, that under the rather artificial conditions of the experiment, uptake of nitrogen applied to the clover plants was greater in the treatments inoculated with *Glomus* spp. It is not however possible to determine whether the effect of mycorrhizal infection was due to a direct hyphal transport of nitrogen from a nitrogen sufficient to a nitrogen deficient plant or whether the effect was due to an increase in the flux of nitrogen into and out of the plant roots. The results are somewhat surprising in that the infection of the grass roots was rather low, around 10% of the root length being infected compared with about 80% infection of the clover roots. Further investigations are being carried out to resolve these problems.

4. Uptake and release of ammonia in clover-grass pasture canopies

A. Haystead, C. Marriott and J. Galbraith*

Recent work from a number of laboratories has demonstrated that ammonia can be released from plants most probably via the stomata. It has also been demonstrated using $^{15}NH_3$, at realistic partial pressures in air, that plants can assimilate ammonia and utilise it for growth when growing on a nitrogen poor medium. A concept has evolved of an ammonia compensation point which is analagous to the CO_2 compensation point in that it is a concentration of ammonia in the atmosphere above which plants will take up ammonia, and below which they may release ammonia. The actual value of the compensation point differs with plant species and is markedly affected by environmental factors such as temperature.

It is possible therefore that in the rather unique association between a nitrogen fixing legume (with presumably an abundant supply of nitrogen) and a non-fixing species growing under nitrogen limiting conditions that a net movement of nitrogen may occur from one plant to the other. We have tested this hypothesis in a model situation using plants of *Vicia faba* and *Zea mays* grown in separate pots but with their shoots enclosed in a common transparent polyethylene enclosure. ^{15}N labelled nitrate or ammonium was applied to the roots of the bean plant, and the leaf and root tissue of the corn plant examined for isotopic enrichment at several points during the growth of the plants. These results are to be presented fully elsewhere and are summarised in Table 1. Clearly, in this rather artificial situation in which the shoots are enclosed in a pool of still air uptake of gaseous ammonia by the corn plant is likely to be maximised. Under field conditions in which gaseous loss of nitrogen from the canopy will occur by turbulent transport outside the boundary layer then the potential for uptake by grass plants may be substantially reduced. A series of experiments in simulated swards has been carried out to investigate the likely significance of gaseous transfer of ammonia within a plant canopy. The results of these experiments are currently being analysed.

Table 1. ^{15}N abundance of bean* and corn shoots grown with enclosed canopies

	Harvest				
Plant	1		2		3
Bean	11.724	n.s.	13.163	*	9.124
Corn	0.368	*	0.392	**	0.471

*The bean plants were fed via the roots with $(^{15}NH_4)_2SO_4$ at approximately 17 Atom% ^{15}N throughout their growth and were nodulated to a very limited extent.

5. Natural variations in natural abundance of ^{15}N as an indicator of nitrogen fixing activity

A. Haystead, T. Grove* and N. Malajczuk*

Biological and geochemical transformations of nitrogen in the soil enrich or deplete the naturally occurring heavy isotope of nitrogen to varying degrees. Isotopic discrimination associated with nitrogen fixation is limited in extent whereas that associated with denitrification leads to an appreciable enrichment of ^{15}N. Exchangeable NO_3^- and NH_4^+ in most soils tend to have isotopic abundances in excess of atmospheric nitrogen and, in consequence, plants growing on soil nitrogen have isotopic abundances in excess of atmospheric nitrogen. A plant fixing all its nitrogen will have an abundance of nitrogen close to that of the atmosphere whereas one deriving nitrogen from both sources will have an intermediate abundance. It is possible that if these differences in natural abundance are consistent that one could rapidly screen the components of a complex ecosystem for nitrogen fixers, non-fixers and potential utilisers of fixed nitrogen. We have attempted such a survey in two ecosystems: a regenerating Karri (Eucalyptus diversicolor) forest ecosystem and a mature forest ecosystem dominated by Karri and Casuarina. Both ecosystems contained an abundance of potential nitrogen fixers. Fresh fully expanded leaf material was collected from the mature forest plants and a range of tissues from the regenerating Karri stand. The material has been dried and ground and is currently undergoing analysis for natural abundance of ^{15}N.

WHITE CLOVER SYMBIOSIS

04009: Microbial requirements of white clover growing in hill and upland soils

1. Isolation and characterisation of strains of *Rhizobium trifolii* indigenous to some upland Scottish soils

J.R. Jebb, P. Newbould, and B.E. Moseley (MD-ESA)

The background and early work in this project were described in HFRO 228 (p.C.20, 21). In 1981 work has been primarily concerned with the characterisation of indigenous strains of *Rhizobium trifolii* with respect to aspects of the effectiveness of the symbiosis, and their intraspecific competitiveness. Comparisons in all experiments were made with standard cultures of strains P_3 and FA6 (stocked at HFRO, originally supplied by Edinburgh University School of Agriculture) and two strains, RCR10 and RCR221 from the Rothamsted Collection of Rhizobia (Rothamsted Experimental Station, Harpenden, Herts). RCR10 is a known "Ineffective" strain originally isolated from the Kilpatrick Hills, Dumbartonshire, Scotland in 1942. RCR221 (commonly called TA1) was originally isolated in Bridport Tasmania and is a known "Effective" strain as are P_3 and FA6, which were isolated in Scotland. All other strains referred to were isolated in 1980 from 3 soil types in the Cleish Hills, Fife, Scotland.

Measurements were made of relative effectiveness and relative growth rate over a range of temperatures. These involved dry weight analysis and percentage nitrogen content of whole inoculated plants and acetylene reduction tests on excised whole root systems.

1a Relative effectiveness (nitrogen fixing ability) of strains of *Rhizobium trifolii*

Surface sterilised seeds of clover cultivars S184 and NZGH (New Zealand Grasslands Huia) were allowed to germinate on water agar before seedlings of uniform size were added to "Gibson Tube" arrangements (described in Vincent, 1970) incorporating full strength Dart and Pate seedling agar and ½ strength Dart and Pate seedling solution (Dart and Pate, 1959). These plants were then arranged in a randomised block design in a growth chamber (6 blocks x 2 clover cultivars x 16 strains) running concurrently to this was a similar experiment utilising the same materials and design but differing in the respect of not being inoculated and treated with 6 levels of NH_4NO_3 in the seedling solution.

All plants were harvested after 60 days growth and analysed for dry weight production, acetylene reduction and percentage nitrogen content.

Table 1. Response of 2 cultivars of white clover, grown in a Gibson Tube arrangement (explained in Vincent, 1970) for 60 days, to varying levels of added nitrogen (applied as NH_4NO_3 solution)

Total amount of N applied (μg/tube)	Mean dry weight (mg/plant)		Nitrogen Content %	
	S184	NZGH	S184	NZGH
0	8.3	7.2	1.38	1.12
175	19.5	15.4	1.18	1.29
437	39.0	29.9	1.12	1.41
700	61.4	56.2	1.07	1.52
1312	112.5	83.4	1.25	1.22
1925	152.2	161.0	1.07	1.15

Linear regression of dry weight against total nitrogen applied

(Y axis = Dry weight, x axis = total nitrogen applied)

NZGH

$Y = 0.00 + 0.08 X$

% variation explained by regression = 86.27% which is significant at the probability level of 1%.

S184

$Y = 0.01 + 0.08 X$

% variation explained by regression = 95.23% which is significant at the probability level of 0.1%.

Both cultivars appear to respond identically to an increase in nitrogen in the rooting media as is shown by the gradient (0.08) of the linear regression. Although S184 is generally regarded as a smaller variety and smaller seeding variety of white clover than NZGH the generally larger plants of S184 at the same treatment as NZGH (Table 1 and the intercept with the Y axis [S184 = 0.01, NZGH = 0.00]) can be explained by the fact that the seeds were sieved to a uniform size before germination. Selection was based on a 1 mm^2 mesh size which only trapped the largest few percent of S184 seeds whereas seeds of the same size are closer to the median of the normal distribution of NZGH. Thus the most vigorous genotypes of S184 were selected. This could also explain the greater inherent variability expressed by the NZGH results compared to S184.

Table 2. Relative "Effectiveness" of the symbiosis produced by 16 strains of *Rhizobium trifolii* with two cultivars of white clover (S184, NZGH) measured by dry matter production, acetylene reduction and percentage nitrogen content. Strains P_3, FA6 and RCR221 are known "Effective" strains, RCR10 is a known "Ineffective" strain.

	Mean Dry Weight (mg/plant)		Mean C_2H_2 Reduct. moles per hour (x 10^9)		N Content %	
	S184	NZGH	S184	NZGH	S184	NZGH
CL03	10.1	4.5	49	0.3	2.1	1.7
CL10	8.2	5.9	47	1.8	2.0	1.7
CL12	20.9	6.0	726	2.7	2.6	1.9
CL21	14.7	18.4	385	7.1	2.2	2.0
CL24	8.0	3.9	27	0.7	1.8	1.4
CL25	5.6	4.9	31	0.3	1.9	1.4
CL27	8.3	5.8	33	2.7	2.0	1.7
CL33	3.0	3.6	2	0.3	1.4	1.4
CL35	4.0	7.2	24	2.5	1.8	1.8
CL56	113.8	108.1	824	36.2	2.6	2.3
CL66	148.7	95.7	3803	49.2	3.1	2.2
CL96	3.6	4.8	0.2	1.6	1.3	2.0
P3	129.8	61.1	1154	32.9	2.6	2.3
FA6	320.1	400.7	3805	137.4	3.2	3.1
RCR10	3.7	4.2	10	1.2	1.5	1.6
RCR221	276.8	433.4	3417	89.4	2.7	2.5

Correlation Coefficients

NZGH

Mean Dry weight x C_2H_2 reduction		$r = 0.95$	$p = < 0.1\%$
Mean Dry weight	x % N content	$r = 0.81$	$p = < 0.1\%$
C_2H_2 reduction	x % N content	$r = 0.90$	$p = < 0.1\%$

S184

Mean Dry weight x C_2H_2 reduction		$r = 0.88$	$p = < 0.1\%$
Mean Dry weight	x % N content	$r = 0.79$	$p = < 0.1\%$
C_2H_2 reduction	x % N content	$r = 0.72$	$p = < 1.0\%$

These results clearly indicate the need for set criteria as to what is meant by "Effective" and "Ineffective" symbioses. Here the only criteria that can be used are measurements that are comparable with the known standard strains. However even the 'standard' effective strains represent a range of nitrogen fixing abilities in the broad sense. For example the mean dry matter production per plant for the known "Effective" strains ranges from 61.1 mg (P_3 on NZGH) to 433.35 mg (RCR221 on NZGH). Assuming that an effective strain is one that supports growth between these levels, the isolated strains CL56 and CL66 can be regarded as "Effective". However difficulties arise when determining when a symbiosis is "Ineffective" as the other 10 isolated strains represent a range of nitrogen fixing abilities which is also confounded by a "Host" effect i.e. the relative effectiveness is not only a trait peculiar to a particular strain, but is also determined by the compatability with the plant phenotype. This is particularly noticeable in the differences between plant cultivars with respect to the symbioses with CL03, CL12 and CL24 for example.

These results also show that data for relative effectiveness should not be compared quantitatively across cultivars. This is particularly the case with the standard effective rhizobia although it applies to all the strains. For example the rate of acetylene reduction (a measure of nitrogenase activity) is far greater in nodules formed by RCR221 on S184 although the dry weight data shows that the system in NZGH plants may be far more efficient and thus less costly to the plant. Comparison of the nitrogen content results in Tables 1 and 2 shows that in nearly every case nodulated plants contain a greater proportion of nitrogen in their tissues than fertilised plants. This difference may limit the value of dry matter production of plants as a comparison between those requiring fertiliser or fixed nitrogen. Nevertheless the problem of establishing a standard for determining whether or not a strain is ineffective may be overcome by comparing dry weight data between uninoculated, unfertilised controls (no nitrogen added) and inoculated trials. If this is done with the data from Tables 1 and 2 most of the strains isolated from Cleish can be regarded as "Ineffective" although they may be fixing small quantities of atmospheric nitrogen. This indicates that nitrogen fixation by these rhizobia is inefficient and energetically costly to the host. In fact as many of these relationships resulted in smaller plants than the uninoculated, no-nitrogen controls infection by ineffective or poorly effective rhizobia may almost be regarded as a parasitic interaction.

Further justification for using dry weight measurements as a convenient indicator of nitrogen fixing ability is shown by the highly significant correlation coefficients between the different sets of measurements. However all these comparisons are based on mean values for six plants and considerable variation between individual plants was observed despite attempts to select a uniform seed stock. The extent of this variation may genuinely reflect best phenotype x strain interactions and this possibility will be investigated in further detail using larger numbers of plants of the cultivar NZGH with single strain inoculation.

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1b Growth of *Rhizobium trifolii* at different temperatures

One of the major factors governing intraspecific competition between strains of rhizobia is probably their ability to multiply rapidly in the rhizosphere of their host legume. It was hypothesized, therefore, that one of the major environmental factors influencing competition would be temperature. This experiment involved growing all strains separately in 250 ml of Y.M. broth in a rotory incubator at 3 different temperatures 30°C, 20°C and 15°C. Changes in cell concentration were measured regularly using a "Nephelometer Head" and "Unigalvo" calibrated against replicated Haemacytometer counts of cell dilutions.

Table 3A. Time taken (hr) for 16 strains of *Rhizobium trifolii* to increase to a concentration of 1×10^8 cells/ml of Yeast-Mannitol Broth at 3 different temperatures

Strain	30°C	20°C	15°C
CL03	56	65	112.5
CL10	49	74	132
CL12	54	67.5	129
CL21	56.5	79	123.5
Cl24	56.0	78	128
CL25	52.5	61	116
CL27	51	79	127
CL33	50	58	112
CL35	52.5	76.5	118
CL56	49	71	104.5
CL66	53	52	116.5
CL96	54	85	115.5
P3	47.5	65	122
FA6	55	78	122
RCR10	*	42	89
RCR221	53.5	73	130.5

* Maximum concentration reached by RCR10 in stationary phase = 5.041×10^7 cells ml^{-1}.

Table 3B. Ranked positions of relative growth rates based on data provided in Table 3A.

Ranked Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
* 30°C	P3	CL10	CL56	CL33	CL27	CL25	CL35	CL66	RCR221	CL12	CL96	FA6	CL24	CL03	CL21	
20°C	RCR10	CL66	CL33	CL25	CL03	P3	CL12	CL56	RCR221	CL10	CL35	CL24	FA6	CL21	CL27	CL96
15°C	RCR10	CL56	CL33	CL03	CL25	CL66	CL35	P3	FA6	CL21	CL27	CL24	CL12	RCR221	CL10	CL96

Table 4. Maximum cell concentration ($x\ 10^{-8}$) recorded during growth period (stationary phase).
Number of cells per ml of Yeast-Mannitol Broth

Strain	30°C	20°C	15°C
CL03	1.38	3.60	4.31
CL10	1.86	4.25	3.72
CL12	1.60	4.35	3.60
CL21	1.50	4.40	4.60
CL24	1.29	7.20	4.10
CL25	1.88	4.05	3.90
CL27	1.64	3.79	3.85
CL33	2.02	5.59	5.04
CL35	1.41	4.25	4.35
CL56	1.63	3.52	4.50
CL66	1.48	4.57	4.10
CL96	1.70	4.50	3.62
P3	2.04	5.45	4.91
FA6	1.41	3.57	3.50
RCR10	0.50	1.85	2.38
RCR221	1.74	5.57	4.60

Correlation coefficients between growth rate (Table 3A) and maximum cell concentration (Table 4).

N.B. Results for RCR10 which has a noticeably different growth pattern to other strains have been omitted from this comparison.

30°C	$r = -0.76$	$P < 1.0\%$
20°C	$r = -0.68$	$P < 1.0\%$
15°C	$r = -0.35$	Not significant

The following trends can be observed from Tables 3A and 3B. Relatively speaking strains CL25 and CL33 and RCR10 are consistently fast growing although RCR10 reaches stationary phase at a much lower concentration than other strains (Table 4). Strain CL24 is consistently a slow grower as is CL96 with a relative growth rate that slows dramatically with a reduction in temperature. The "ranked" growth rates of CL03 and CL21 have a tendency to increase relative to others with a drop in temperature whereas the "ranked" positions of CL10 and P3 fall with a reduction in temperature. All the other strains showed no clear trend but these results indicate that temperature via changes in relative growth rates, could be an important factor in determining the outcome of competition between rhizobia in the initial phase of infection.

The correlations between growth rates and maximum concentration of cells are significant at the upper two temperatures showing that generally faster growing strains reach a higher cell concentration. This is of course omitting the case of RCR10 which is initially a very fast growing strain but reaches stationary phase earlier and at a lower concentration than any other strain.

The reduction of correlation from 30°C to 20°C and the lack of significance at 15°C is probably due to the fact that as the temperature falls the transition between log phase (exponential growth) and stationary phase becomes very long and instead of an easily defined partition between phases, stationary phases tend to become a curve where the rate of change of growth with respect to time tends to zero i.e. $\frac{dy}{dx} \rightarrow 0$ where y is Log_{10} cell concentration, x is time (linear scale)

It is therefore possible that at 15°C the figures recorded in Table 4 were not exactly the maximum concentration obtainable in the majority of cases. Also at 15°C the arbitrary concentration of 1 x 10^8 cells/ml is no longer in log phase as at 30oC but in the transition following log phase.

Nevertheless the results are encouraging and further growth response curves will later be obtained for lower temperatures more applicable to Scottish hill soils.

2. <u>The response of white clover (and perennial ryegrass) growing in the Hartwood soil to inoculation with mycorrhizal fungi</u>.

A. Rangeley, P. Newbould and J. Leask

Additional treatments were included in the P response experiment described earlier (p.C.4) to permit a preliminary appraisal of the responses to mycorrhizal inoculation in the Hartwood soil.

The low levels of available soil phosphate in this soil create a theoretical situation where responses to inoculation with mycorrhiza might be expected to occur. For this reason the benefit of inoculation to growth of perennial ryegrass was examined in addition to that of white clover. The soil for ryegrass plants given nitrogen (60 kg N ha^{-1}) and for white clover plants inoculated with *Rhizobium* was inoculated with sand containing equal numbers of spores from three species of VAM fungi (*Glomus mosseae, G. clarus, G. etunicatus*) at the same lime and phosphate levels used in the main experiment.

Levels of root infection with mycorrhiza have not yet been assessed but, in general, mycorrhizal inoculation was without effect on shoot production in both crops (Table 1). However, statistical analysis shows that white clover grown with 160 kg P ha^{-1}, both in the presence and absence of lime, may have responded to mycorrhiza. At first sight, the response in shoot production at the highest level of added P seems unlikely to be due to mycorrhiza; root infection measurements and soil and herbage chemical analysis are required before the observed response can be definitely attributed to mycorrhiza.

In the same experiment, attempts were made to assess the benefits to white clover growing in the Hartwood soil of inoculation with different strains of *Rhizobium* (Mr J.R. Jebb) but the plants failed to grow in the sterile pot assembly used. At a future date after modification of the apparatus this part of the experiment will be repeated.

Table 1 The response in shoot production (mg DM per pot) of ryegrass and white clover growing in the Hartwood soil to inoculation with mycorrhizal fungi.

Crop	Lime ($t\ ha^{-1}$)	Mycorrhiza	Level of added P ($kg\ ha^{-1}$) 0	40	80	160	LSD (P=0.05)
Ryegrass	0	0	109	241	292	383	
			115	226	300	348	
							64.8
	5	+	152	256	329	342	
			150	195	290	358	
White clover	0	0	93	137	175	230	
			91	143	197	276	
							40.7
	5	+	132	158	167	242	
			116	165	202	283	

EFFECTS OF UTILISATION

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

1. The effects of change in sward management on herbage production of continuously stocked swards

S.A. Grant, G.T. Barthram, L. Torvell, V.A. Doughty and H.K. Smith (ARCUS)

This experiment was planned to occupy the two years 1981 and 1982. Eight plots, each 33 m x 60 m, were provided. The plots were sown in 1980 and each plot was split longitudinally, one half being sown to *Lolium perenne* var 'Spirit' an erect genotype, and the other half to *Lolium perenne* var 'Mirvan' a prostrate genotype with the same heading date as 'Spirit'. During 1981 the plots were managed to provide two replicates of four steady state sward conditions, shown in Table 1.

Table 1. 1981 Sward management

	Height	Mass ($kg\ OM\ ha^{-1}$)
1	2 cm	750-1000
2	3 cm	1250-1500
3	4.5 cm	1750-2000
4	6.0 cm	2250-2500

The swards were continuously stocked from 21 May to 5 October and sheep numbers were adjusted weekly in relation to twice-weekly herbage height measurements and once-weekly herbage mass measurements. After 5 October both the slowness of growth and the ground conditions dictated the use of intermittent grazing, as and when necessary and possible, to maintain the plots at the desired herbage height and mass over winter.

Compound fertiliser (22:11:11) supplying 82.5 kg N ha^{-1} was applied in April, and thereafter N as Nitrochalk was applied at fortnightly intervals from 15 June to 26 August with a final dressing on 16 September. The rate of application was 25 kg N ha on 15 June and 15 kg N ha^{-1} on all other dates. Total N for the year was 197.5 kg ha^{-1}.

While the period April 1981-April 1982 was intended as no more than an establishment year for an experiment with treatments i.e. changed managements, and measurements of tissue flows planned for May-June 1982, it offered the opportunity to monitor tiller population response and changes in live/dead ratios in steady state swards over a complete annual cycle. In previous studies observations had been restricted to 2-3 months within the growing season.

At the start of the establishment phase in May 1981 tiller population densities were in the region of 17,000-20,000 m^{-2} with approximately 50% sown species and 50% *Poa annua*. Tiller numbers remained fairly static through May and fell slightly in early June on all except the highest herbage mass plots. Trends thereafter were consistent with previous experience i.e. with larger numbers of smaller tillers on the more heavily grazed compared with more lightly grazed plots. Table 2 shows the two-monthly averages for live tiller population density as affected by management.

Table 2. Tiller population densities (total live tillers, $N^o \times 10^3$ per m^{-2})

	SWARD MANAGEMENT			
	2 cm	3 cm	4.5 cm	6.0 cm
July/August	32.18	30.85	27.09	25.62
September/October	37.35	35.28	32.04	29.13
November/December	38.37	36.90	35.88	30.74
January/February	32.21	32.54	27.93	26.38

The order of response in relation to management was typical for a sown sward in the first year after sowing. The fall in tiller numbers between November-December and January-February reflects a large change in number of live tillers before and after the six weeks of arctic cold and snow lie in December-January, a change which was accompanied by an abrupt increase in the percentage of dead herbage. Trends in the proportion of dead herbage as affected by season and management are summarised in Table 3.

Table 3.

	SWARD MANAGEMENT			
	2 cm	3 cm	4.5 cm	6.0 cm
July/August	0.235	0.257	0.288	0.299
September/October	0.308	0.341	0.391	0.378
November/December	0.182	0.244	0.317	0.347
January/February	0.423	0.376	0.476	0.514

Further analysis of the tiller population data showed that the response of *Lolium perenne* across the range of steady state sward conditions as affected by season was markedly different to that of the accompanying weed grass *Poa annua*. In the case of *Lolium* there was a tendency for tiller numbers to show a seasonal cycle; the numbers built up to reach peak levels in late summer through autumn and reduced over the winter. Variation in average dry weight per tiller (live material only) was relatively modest, highest weights occurring in June and July when flowering tillers were most frequent and lowest weights in January-February when dead leaf was highest. In the case of *Poa annua*, tiller numbers also built up to reach high numbers in late summer but thereafter population numbers remained high. However average weight per tiller, which was similar to *Lolium* within treatments during late spring and summer, became progressively reduced through autumn and into winter so that within treatments the weights per tiller of *Poa* were no longer comparable with those of *Lolium perenne*.

The two varieties of *Lolium perenne* responded differently to management. The prostrate variety 'Mirvan' had in general a consistently higher weight per tiller than the erect variety 'Spirit' across all management regimes. Persistence of the two varieties in the sward, as evidenced by trends in *Lolium* as a proportion of *Lolium* plus *Poa* by weight, was similar when swards were maintained at 4.5 cm (1750-2000 kg/ha) or 6.0 cm (2250-2500 kg/ha). However, while 'Mirvan' showed a similar or even better order of persistence at 3 cm (1250-1500 kg/ha) as at the higher heights or masses, 'Spirit' performed less well. At the lowest height, 2 cm (750-1000 kg/ha), 'Spirit' performed poorly and was reduced to only 0.22 as at February 1982 compared with 'Mirvan' at 0.45.

Selected data illustrating the difference between *Lolium* and *Poa* and between the two varieties of *Lolium* are shown in Table 4.

Table 4. Seasonal trends in tiller number and tiller weight as affected by management+

	Lolium perenne		*Poa annua*		*Lolium* as a proportion	
variety	Tiller Number	Tiller Weight	Tiller Number	Tiller Weight	by No.	by Wt.
Treatment 6 cm 2250-2500 kg/ha						
'Spirit'						
June/July	9.93	8.73	11.48	8.26	0.464	0.477
Sept/Oct	12.81	5.71	14.93	5.17	0.462	0.488
Jan/Feb	10.02	4.68	15.64	2.72	0.390	0.524
'Mirvan'						
June/July	11.51	8.23	11.23	8.51	0.507	0.498
Sept/Oct	14.50	5.69	14.62	5.28	0.499	0.520
Jan/Feb	8.72	5.41	17.66	2.95	0.331	0.477
Treatment 3 cm 1250-1500 kg/ha						
'Spirit'						
June/July	9.72	4.39	11.28	5.60	0.480	0.421
Sept/Oct	15.23	2.83	20.86	2.87	0.412	0.409
Jan/Feb	11.67	2.51	21.57	2.01	0.352	0.403
'Mirvan'						
June/July	10.35	4.74	11.16	5.21	0.498	0.475
Sept/Oct	15.01	3.50	17.96	3.05	0.456	0.495
Jan/Feb	13.56	3.51	14.57	2.18	0.483	0.604

+ Tiller numbers are Nos x 10^3 per m^2
Tiller weights are mean dry weights in mg per tiller of live tissue of tillers and includes reproductive as well as vegetative tillers.

SOIL CHEMISTRY

04011: Soil Acidity

1. Analytical methods for measuring exchangeable acidity

K. Logan, M.J.S. Floate and A.D. Ironside

Exchangeable acidity ($H^+ + Al^{3+}$) of a soil has in the past been determined by manually titrating a KCl leachate to pH 8. NaF was then added to displace the hydroxyl ions from Al $(OH)_3$ and the solution back-titrated to pH 8 to give a value for exchangeable aluminium (Al). With the purchase of a memotitrator (automatic titration) it was intended to automate this procedure but difficulties arose over the stability of the endpoint. This instability had not been detected with manual titration because the increments of titrant added were much larger.

Investigation showed that titrating to an absolute endpoint of pH 8 did not give a true result as the pH of the endpoint is dependent on the amount of Al present. Using standard samples of known acidity and Al content, results for total exchangeable acidity closer to the theoretical results (corr. coeff. = 0.9997) were obtained by titrating to an equilibrium endpoint. Further study showed that the original procedure for exchangeable Al was also at fault as the efficiency of release of hydroxyl ions by NaF decreased markedly with increasing Al concentration. By first complexing the Al with NaF, the acidity due to H^+ alone can be measured by backtitrating to an equilibrium endpoint. Exchangeable Al can then be calculated by difference between total exchangeable acidity and exchangeable H^+ acidity. At present a comparison is being made between exchangeable Al found by difference and exchangeable Al measured directly by colorimetry as this technique may be less time-consuming.

2. CEC and soil pH response to lime

K. Logan and M.J.S. Floate

It was stated in the last annual report that the cation exchange capacity (CEC) of a range of 10 composite soils was determined using solutions buffered at pH 2.5, 3.5, 5.0 and 8.0. The CEC of these soils has now also been measured at pH 6.0 and 7.0, and using an unbuffered solution. The objective here was to measure CEC over a range of pH values and at the natural pH of the soil, but in practice, the pH of the extracting solutions changes slightly during the determination: thus the pH at the end of the analysis is more relevant than that of the buffer used. Because of this phenomenon, the unbuffered CEC gives the closest approximation to the CEC at the natural pH of the soil. Data for CEC determined using buffers with the above pH values and final pH values for the 10 soils are given in Table 1. There was a better correlation between CEC and final extract pH than between CEC and buffer pH.

Increments of lime were added to the soils in the laboratory and the resulting pH response curve was used to determine the amounts of lime required to attain the target pH of 5.0 or 5.5. Various functions of CEC were calculated from the above data to determine whether or not they correlate with the laboratory requirements (LR). These functions include the change in CEC from natural to target pH (Δ CEC) as well as the original 50% CEC at pH 7.0 and are given in Table 2.

Table 1. CEC values for 10 soils using buffered and unbuffered solutions

Sample	CEC @ pH 2.5 meq/100g	Final Extract pH	CEC @ pH 3.5 meq/100 g	Final Extract pH	CEC @ pH 5.0 meq/100g	Final Extract pH	CEC @ pH 6.0 meq/100g	Final Extract pH	CEC @ pH 7.0 meq/100g	Final Extract pH	CEC @ pH 8.0 meq/100g	Final Extract pH	Unbuffered CEC meq/100g	Final Extrac pH
FL-C-1/80	6.2	2.61	11.2	3.94	18.7	5.62	21.1	6.32	24.2	6.94	32.6	7.86	13.6	4.45
FL-C-2/80	9.3	2.74	14.9	4.19	20.7	5.65	30.6	6.51	36.4	7.09	38.1	7.94	20.9	4.94
FL-C-3/80	23.2	2.75	47.7	4.09	84.7	5.57	96.4	6.25	111.1	6.84	127.0	7.70	46.7	4.02
FL-C-4/80	16.6	2.74	35.0	4.05	59.6	5.67	78.0	6.43	88.7	6.95	101.5	7.82	39.4	4.36
L1-C-1/80	8.9	-	24.8	3.96	53.7	5.74	66.6	6.38	76.5	6.98	95.6	7.81	30.3	4.32
L1-C-2/80	7.4	2.69	16.5	3.99	20.3	5.63	25.8	6.44	25.8	7.02	24.4	7.80	19.3	4.76
L1-C-3/80	15.8	2.76	33.5	4.03	59.0	5.77	70.5	6.33	81.0	6.98	92.0	7.82	47.0	4.81
L1-C-4/80	7.4	2.72	18.4	4.08	23.5	5.58	29.4	6.39	34.2	6.99	32.9	7.81	20.5	5.00
L1-C-5/80	20.5	2.75	34.2	4.13	57.2	5.84	66.7	6.37	73.4	7.02	79.0	7.76	47.1	5.20
L1-C-6/80	8.1	2.71	15.6	4.01	22.2	5.62	26.8	6.39	29.9	7.07	32.9	7.92	19.8	5.86

Table 2. Lab. lime requirements, ΔCEC (to pH 5.0) ΔCEC (to pH 5.5) and 50% CEC at pH 7.0 for 10 soils

Sample	LR to pH 5.0 (meq/100 g)	LR to pH 5.5 (meq/100g)	50% CEC @ pH7 (meq/100g)	ΔCEC (to pH 5.0) (meq/100g)	ΔCEC (to pH 5.5) (meq/100g)
FL-C-1/80	10.5	13.9	12.3	2.4	4.6
FL-C-2/80	11.8	16.8	17.7	-2.8	-0.8
FL-C-3/80	69.4	156.0	57.0	23.6	36.2
FL-C-4/80	38.3	54.8	44.7	10.3	18.0
L1-C-1/80	33.4	59.2	38.5	11.6	19.5
L1-C-2/80	10.8	16.2	12.8	-0.5	0.8
L1-C-3/80	15.6	27.5	40.7	1.0	8.3
L1-C-4/80	9.2	14.7	17.1	1.9	2.6
L1-C-5/80	2.4	12.1	36.6	-1.7	5.1
L1-C-6/80	2.4	6.1	14.7	0.9	2.2

Since the unbuffered CEC varies with liming history, the ΔCEC functions are closely related to lime requirement with correlation coefficients (R) for LR to pH 5.0 v. either ΔCEC (to pH 5.0) or ΔCEC (to pH 5.5) of 0.96. R values for LR to pH 5.5 v. ΔCEC (to pH 5.0) and ΔCEC (to pH 5.5) are 0.95 and 0.96 respectively. CEC at pH 7 is independent of both natural soil pH and of past lime treatment and therefore is not as closely related to lime requirement (R = 0.76). This suggests that ΔCEC may be suitable as a parameter for the prediction of lime requirement of both unlimed and previously limed soils.

Some work has also been done in association with the Soil Science Department at ADAS Northern Region (Newcastle-upon-Tyne) and samples were obtained from peat at Redesdale EHF.

Calculations from their measured ΔCEC values indicated a lime requirement in the range 3.5-4.0 t ha^{-1} lime which accords with observations on the relative effectiveness of 2.5, 5.0 and 7.5 t ha^{-1} applied in 1969. ADAS are currently conducting a new field lime response experiment at Redesdale.

The study has involved only 10 soils, so work is continuing on other samples to see if the relationship holds for a wider variety of soil types. Laboratory pH response has been shown to differ from that in the field for Lephinmore and Linhope soils, and at present this is being investigated for other soils.

3. Lime response and lime maintenance on Linhope acid brown soil at Stanhope

M.J.S. Floate, K. Logan and A.D. Ironside

The original objectives of this experiment, started in 1975, included the measurement of reseeded pasture responses to lime rates up to 5 tonne ha^{-1} on acid brown soil, and the main effects were summarised in the Annual Report for 1979 (HFRO, 226). Because of declining yields in 1979, especially on L_0 treatments, a revised design was adopted in 1980: the plots were subdivided and maintenance treatments were applied to one half only of each plot. Maintenance treatments were a repeat of the original treatments, except on L_0 where 2.5 tonnes ha^{-1} was applied to one half in 1980.

The first observations on the effects of maintenance treatments were included in the Annual Report for 1980, and the continuing effects of these treatments, and of the original treatments, on yields in 1981 are illustrated by the data in Table 1.

In 1981 relative yields were very similar to those recorded in 1980 except that L_0 and $L_{\frac{1}{4}}$ treatments have declined further (to 55 and 77 respectively) while (L_0 + M) treatment has now recovered to almost 90% of the yield on L_2 treatment: with added maintenance $L_{\frac{1}{4}}$ + M, L_1 + M, and L_2 + M treatments were all in the range 100-110 and were not significantly different from L_2 (100). The remaining treatments with added maintenance

Table 1. Total herbage DM yields (kg/ha^{-1}) and relative yields (%) on original and maintained lime response treatments at Stanhope in 1981 (relative yields for 1980 in brackets).

Treatment (subscripts refer to ton/ac)	Total Lime Applied (tonne ha^{-1})	pH	Herbage DM Yield (kg/ha^{-1})	Relative Yield (1980 in brackets)
L_0	0	4.5	2190	55 (60)
$L_{\frac{1}{4}}$	0.6	4.7	3046	77 (85)
$L_{\frac{1}{2}}$	1.3	4.8	3369	85 (86)
$L_{\frac{3}{4}}$	1.9	4.9	3463	87 (92)
L_1	2.5	5.0	3436	86 (98)
L_2	5.0	5.3	3969	100 (100)
L_0 + M	2.5	5.2	3501	88 (76)
$L_{\frac{1}{4}}$ + M	1.3	4.8	3488	88 (88)
$L_{\frac{1}{2}}$ + M	2.5	5.0	3543	89 (97)
$L_{\frac{3}{4}}$ + M	3.8	5.4	3971	100 (101)
L_1 + M	5.0	5.7	4323	109 (99)
L_2 + M	10.0	6.3	4376	110 (115)

($L_{\frac{1}{2}}$ + M, $L_{\frac{1}{4}}$ + M, and L_0 + M) together with the original treatments $L_{\frac{1}{2}}$, $L_{\frac{3}{4}}$ and L_1 all gave yields in the range 80-90 and there were no significant differences among this group. These yields were, however, significantly higher than the yields on the original $L_{\frac{1}{4}}$ and L_0 treatments (Fig. 1).

It may be seen from Fig. 1 that it has taken 6 years for the yield on $L_{\frac{1}{4}}$ to fall below 80% of that on L_2 treatment, and that even L_0 did not fall below this level until the third year after the start of the experiment.

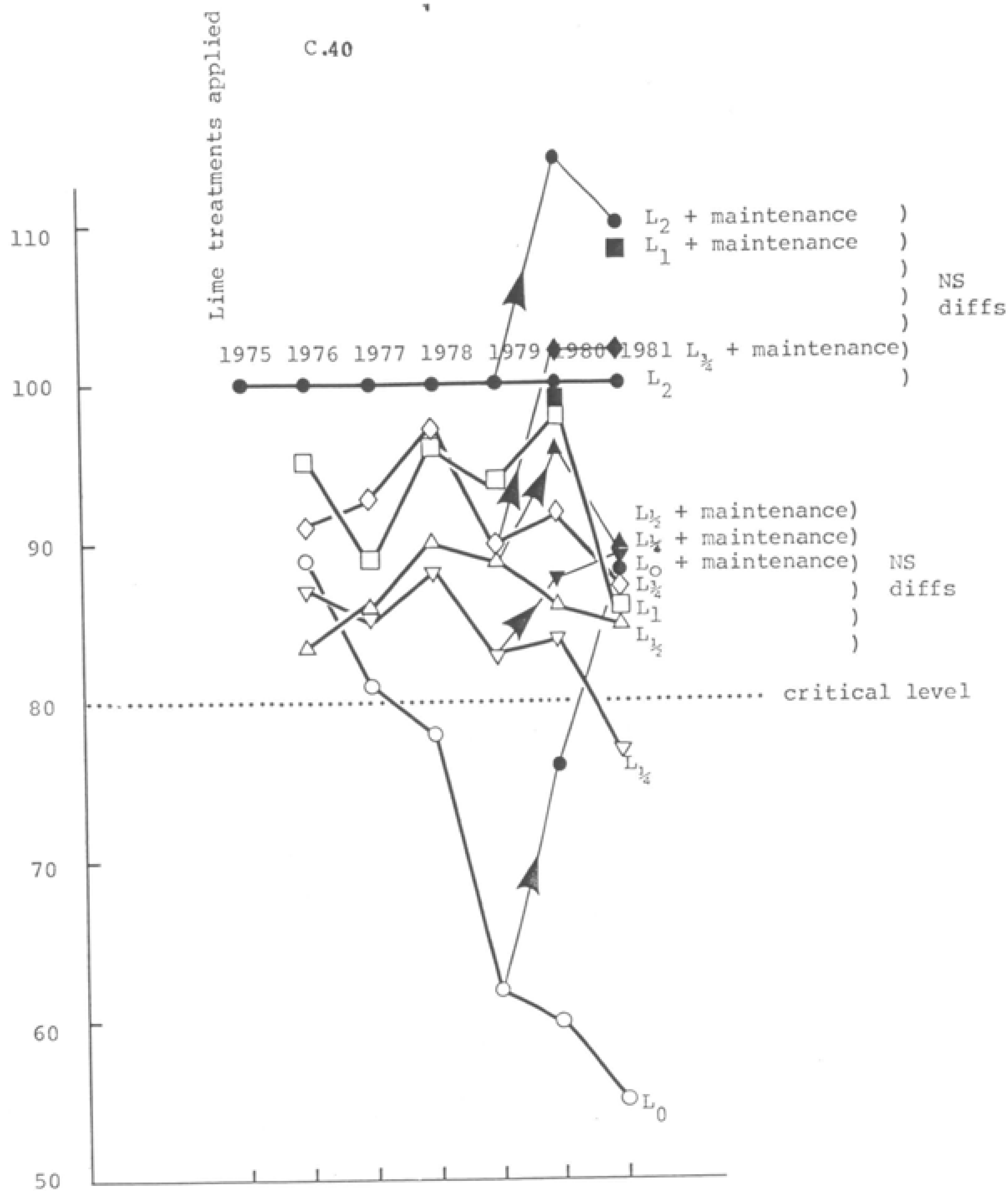

Fig. 1. Stanhope relative yield data 1975-1981

On this soil the lime requirement, calculated from 50% saturation of CEC (Floate, 1978) was 500 kg/ha^{-1}, or approximately the amount applied in 1975 on $L_{1/4}$ treatment. It now appears that this amount has sustained production at a reasonable level for 5 years. However, the surprisingly high yields on L_0 treatment for the first 2-3 years may have been due to the liming value of basic slag (at 1250 kg/ha^{-1}, this might have been equivalent to the calculated lime requirement of the soil). This suggests that the effects of lime alone may not have been so prolonged. We can therefore only conclude that the combined effects of basic slag and the original $L_{1/4}$ treatment have maintained production at 80% of yield on L_2 treatment, 80% relative yield may provide an indication of the critical stage to apply maintenance.

When maintenance lime (at 2.5 tonne ha^{-1}) was applied to the original L_0 treatments, which was when relative yield had declined to about 60, the recovery in the succeeding 2 years was rapid, to relative yield levels of 76 and 88 respectively.

Data on soil pH and the proportion of sown species in the sward (Table 2) indicate a close relationship between these properties. Soil pH increases from 4.5 to 5.3 through the sequence of original lime treatments, and from 4.8 to 6.3 on the treatments to which maintenance lime was applied in 1980. The amount of increase in soil pH was directly proportional to the amount of lime added, and ranged from 0.1 pH units with 0.6 tonne ha^{-1} lime to 1.0 pH units with 5 tonne ha^{-1}. The original L_1, L_2 treatment (where pH was maintained at 5.0 or above) retained about 30% of each ryegrass and white clover while at lower pH the proportion of clover decreased rapidly, and clover was rare on L_0 treatments in 1981. Where maintenance treatments were applied there were quite marked increases in clover on $L_{1/4}$ + M, $L_{1/2}$ + M, $L_{3/4}$ + M and L_1 + M treatments, but there was little effect on ryegrass. These data are in accord with conclusions from a previous (similar design) experiment at Lephinmore (L_e 3) which suggested critical pH values of 4.5 and 5.0 for ryegrass and clover respectively.

Table 2. Effects of lime on soil pH and ryegrass and clover persistence on acid brown soil at Stanhope

Treatment	pH	Clover	Ryegrass
L_0	4.5	0 - 10	0 - 10
$L_{1/4}$	4.7	0 - 10	10 - 20
$L_{1/2}$	4.8	10 - 20	10 - 20
$L_{3/4}$	4.9	10 - 20	20 - 30
L_1	5.0	20 - 30	20 - 30
L_2	5.3	30 - 40	30 - 40
L_0 + M	5.2	0 - 10	10 - 20
$L_{1/4}$ + M	4.8	10 - 20	10 - 20
$L_{1/2}$ + M	5.0	20 - 30	20 - 30
$L_{3/4}$ + M	5.4	30 - 40	20 - 30
L_1 + M	5.7	30 - 40	20 - 30
L_2 + M	6.3	30 - 40	30 - 40

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TRACE ELEMENTS

04014: The effect of hill pasture improvement on the trace element content of herbage consumed by grazing sheep

1. Reconnaisance survey of reseeded hill pastures

C.C. Evans, P. Newbould, G.J. Davies, J. Wood (ARCUS), J.C. Holmes (ESCA), R. Harkness (WSAC) and G.J. Copeman (NOSCA)

Copper deficiency problems associated with sheep which graze reseeded hill pastures have been identified at three HFRO research farms. Grazing sheep have responded to copper therapy and in young lambs treatment has resulted in increased growth rates. In addition the treatment of ewes during pregnancy has reduced or eliminated swayback in their lambs post partum. It has been ascertained that the primary cause of this problem is due to enhanced levels of sulphur and molybdenum in the herbage of the reseeded pastures. This has resulted in reductions in the availability of dietary copper to the grazing animal and symptoms of the deficiency have been regularly observed - an induced form of copper deficiency (Whitelaw *et al*, 1979; Whitelaw *et al*, 1980).

The improvement of hill pastures is an important prerequisite to increasing the efficiency and economic return from hill sheep production. It is now necessary that a wider assessment be made of the extent to which the problem of induced copper deficiency exists as a consequence of hill land improvement. In this context there is little systematic objective data available at the present time. It has been proposed and agreed that a relatively small reconnaisance survey be carried out across mainland Scotland of the herbages and soils from recently created hill pasture reseeds. A survey of 90-100 reseeds will be carried out in the autumn of 1982 with the collaboration of the DAFS Inspectorate, ARC Unit of Statistics and staff from the Scottish Colleges of Agriculture. The primary objective is to assess the dietary copper availability of herbage from reseeds located across wide ranges of soil type, geology and climate. This will involve the collection and analyses of herbage samples for copper, molybdenum and sulphur. An attempt will also be made to identify the more important factors which influence the relative herbage concentrations of Cu, Mo and S. This will involve a descriptive and laboratory examination of soil samples from each site.

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Whitelaw, A., Armstrong, Robin H., Evans, C.C., Fawcett, A.R., Russel, A.J.F. and Suttle, N.F. (1980). Effects of oral administration of copper oxide needles to hypocupraemic sheep. Vet. Rec. 107: 87-88.

2. Influence of lime and phosphate on soil/plant relationships of copper, molybdenum and sulphur in hill pastures

C.C. Evans, P. Newbould and G.J. Baillie

The results of a pot experiment carried out previously using a peaty podzol soil (see 1980 Annual Report p.C4) suggested that Mo and particularly S concentrations in perennial ryegrass (PRG) and white clover

(WC) were differentially influenced by lime and phosphorus (superslag) applications. Consequently a further pot experiment has been carried out to examine these effects in more detail using an acid brown earth as well as the peaty podzol. The lime was applied at 4 levels - L_0 (no lime); L_1 (2,511 kg/ha); L_2 (5,022 kg/ha) and L_4 (10,044 kg/ha) as ground limestone with ± P treatment at each level of lime. P was applied as calcium tetrahydrogen orthophosphate at 40 kg P/ha. A randomised block 4 replicate design was used and again included S184 white clover and S23 perennial ryegrass. Samples for chemical analysis were constituted by bulking the first six harvests of relatively juvenile growth taken over periods of 92 days (PRG) and 98 days (WC). Soil pH measurements were taken at the start and end of the experiment together with dry matter (DM) yield.

At the present time the chemical analysis has not been completed and therefore a statistical analysis has not yet been carried out. However, in the absence of data for the L_0P_0 and L_0P_{40} treatments, a summary of the available data is as follows:-

pH

The pH of both soils at the start and end of the experiment are shown in Table 1. There was no measurable effect of applying 40 kg P/ha as $CaH_4(PO_4)_2$.

Table 1. The effect of increasing amounts of lime on the pH of two soils at the start and end of the experiment.

Treatment	Brown Earth				Peaty Podsol			
	Start	ΔpH*	End	ΔpH*	Start	ΔpH*	End	ΔpH*
L_0	3.78	0.00	3.79	0.00	4.22	0.00	4.18	0.00
L_1	4.80	1.02	4.65	0.86	4.94	0.72	4.77	0.59
L_2	5.49	1.71	5.25	1.46	5.60	1.38	5.09	0.91
L_4	6.50	2.72	6.19	2.40	6.75	2.53	5.76	1.58

ΔpH = L - L_0

The increase in pH due to incremental lime application was greater in the brown earth than in the peaty podzol at both the start and particularly at the end of the experiment. This may be accounted for by the greater buffering capacity of the peaty podzol.

DM yield

DM yields are shown in Table 2 and are the mean of 4 replicates when aggregated over 6 harvests.

Table 2. Yield (g DM/pot) of perennial ryegrass and white clover when grown in two soils with varying lime and phosphorus applications

	Perennial ryegrass		White clover	
Treatment	Brown earth	Peaty podsol	Brown earth	Peaty podsol
L_0P_0	0.14	0.09	0.01	-
L_1P_0	2.25	1.09	2.03	0.72
L_2P_0	2.64	1.58	2.28	1.05
L_4P_0	3.07	2.27	2.37	1.52
L_0P_{40}	1.56	0.15	0.85	-
L_1P_{40}	2.40	0.87	3.76	2.75
L_2P_{40}	2.74	1.44	3.75	3.47
L_4P_{40}	3.16	2.06	3.52	4.08

Incremental lime additions increased DM in both soils and for both species with the exception of the P_{40} WC treatments in the Brown Earth.

Here the maximum DM was obtained at the L_1 level and higher lime applications actually depressed DM. With one exception the effect of P application was to increase DM's at each individual lime level and as expected, increases were greater for WC. However P application to PRG in the peaty podzol depressed yields except at the L_0 level. These two unexpected responses suggest that interactions between P, Ca and possibly Al occurred in the soil to effectively reduce the availability of P in these treatments.

Sulphur

Sulphur concentrations are shown in Table 3.

In PRG the response to both lime and P application was strongly dependent upon soil type. In the peaty podzol S concentrations increased with increasing levels of lime in both P treatments whereas P application brought about reductions. These results confirm those found previously (see 1980 Annual Report p.C5). However in the Brown earth there was a tendency for lime to reduce S concentration but only in the P_{40} treatments while at each level of lime they were increased by the addition of P. For WC in both soils P had a negligible effect. Lime also had little effect other than a tendency to increase S.

Table 3. Sulphur concentrations (%) in perennial ryegrass and white clover when grown in two soils with varying lime and phosphorus applications

	Perennial Ryegrass (%S)		White Clover (%S)	
Treatment	Brown earth	Peaty podsol	Brown earth	Peaty podsol
L_0P_0	N.A.	N.A.	N.A.	N.A.
L_1P_0	0.64	0.63	0.31	0.23
L_2P_0	0.62	0.70	0.33	0.23
L_4P_0	0.66	0.72	0.35	0.25
L_0P_{40}	N.A.	N.A.	N.A.	N.A.
L_1P_{40}	0.70	0.56	0.31	0.24
L_2P_{40}	0.68	0.66	0.33	0.23
L_4P_{40}	0.67	0.71	0.33	0.28

Molybdenum

Molybdenum concentrations are shown in Table 4.

Table 4. Molybdenum concentrations (μg/g) in perennial ryegrass and white clover when grown in two soils with varying lime and phosphorus applications

	Perennial Ryegrass (μg/g)		White Clover (μg/g)	
Treatment	Brown earth	Peaty podsol	Brown earth	Peaty podsol
L_0P_0	N.A.	N.A.	N.A.	N.A.
L_1P_0	4.2	3.6	1.9	1.3
L_2P_0	4.3	5.8	2.8	2.0
L_4P_0	5.0	6.7	3.2	3.9
L_0P_{40}	N.A.	N.A.	N.A.	N.A.
L_1P_{40}	3.5	4.0	1.9	1.4
L_2P_{40}	3.7	5.4	2.4	2.3
L_4P_{40}	4.5	7.1	3.5	2.5

As would be expected Mo concentrations increased with increasing levels of lime for both species and in both soils. PRG had consistently higher Mo levels than did WC and in PRG the response in Mo content to lime was greater in the peaty podzol than in the brown earth. The only consistent response to the addition of P was in the brown earth where a reduction in Mo occurred in PRG.

3. Initial assessment of a range of soils required for detailed studies on soil/plant relationships of trace elements in hill pastures

R.M. Paynter, P. Newbould, C.C. Evans and K.A. Smith (ESCA)

A range of soils from both improved and unimproved hill pastures has been collected. This is the first stage in a study of plant responses to physical and chemical soil parameters, in terms of the uptake of copper, molybdenum and sulphur. This will form the basis for future work towards a PhD thesis (RMP).

The criteria used to select the soils has been according to soil type classification as well as their probable mineral availabilities to growing plants. The preliminary preparations have been completed and analysis of some relevant constituents has commenced. It is intended that when this initial 'screening' is complete a restricted number of these soils will be chosen for more detailed study.

4. Monitoring of the copper, molybdenum and sulphur concentrations in reseeded and indigenous pastures

C.C. Evans

Samples of herbages and soils from the Alderhope (Sourhope) reseeds together with contiguous unimproved pastures were collected on two occasions during the year. These included a more comprehensive sampling from the reseed established during the year on Fasset hill. In spring samples were collected from both House o' Muir reseeded and indigenous pastures. All samples have been submitted for chemical analysis but the results are not yet available.

GLASSHOUSES, GROWTH ROOMS, MICRO-CLIMATE

54001: Maintain glasshouses and growth rooms at Bush and organise micro-meteorology required in field trials

1. Glasshouses, growth rooms and micro-climate

D.E. Suckling

During 1981, HFRO use of the glasshouses has been low, but the Institute of Terrestrial Ecology were able to make use of the spare capacity. Growth room facilities, however, have continued at virtually maximum use with comparatively little trouble.

Micrometeorological data have been collected at Lephinmore and Glensaugh but whereas the troubles experienced last year during translation have been overcome a new generation of translation difficulties has arisen. Work is going on both here and at SIAE to investigate and improve the system.

ANALYTICAL SERVICES

51002/51003/54002I/54002T: Forage, biochemical, tracer and inorganic analysis

1. Biochemistry, inorganic chemistry and forage analysis

E. Skedd, D.R. Campbell, P.E. Moberly and J. Mackenzie

A review of the arrangements for all analytical work took place during the year, the outcome of which was the union of the biochemistry, forage and inorganic laboratories to form the Analytical Services Group. Due to internal reorganisation within the Group no method development was undertaken during the year.

In support of the research programme 45,400 analyses were carried out on 24,850 samples of plant tissues, soil extracts, biological fluids, animal tissues and animal feeds.

Work continued on testing programs on the PDP 11/03 Micro-computer System (see Data Handling).

2. Tracer-electronics

D.R. Curtis

At the beginning of the year workshop and laboratory facilities were set up. The laboratory is now capable of coping with a reasonable range of applications for low frequency work. During the year various equipment has been maintained and repaired. Some of the projects carried out are listed:-

a) Sheep behavioural studies (with J. Eddison and J.A. Milne)

Development work on sensors for behavioural and environmental studies was carried out, as a continuation of a three year project involving data logging using an RCA 1802 microprocessor as the logger (previously developed by the Wolfson Microelectronics Institute).

The logger is strapped to the sheep's back and is fed by various sensors attached to the animal. It was originally hoped to monitor walking, grazing, ruminating, lying down, heart rate, temperature and wind speed; and correlate the data so collected to energy expenditure and behaviour. Interface circuitry was also developed to connect sensors to the microprocessor. Successful paddock trials were carried out on all sensors except heart rate and wind speed.

Although the design of heart rate circuitry is straightforward, the electrodes proved to be a problem. An electrode jelly is required which, for Ag/AgCl electrodes, must contain chloride ions; these compounds all seem to be water-soluble, and thus not suitable for outside use. Thus non-invasive electrodes for field use would require a detailed further study on non-polarisable electrodes. Implanted electrodes were not ruled out, but would make the experiment slower and more troublesome due to the requirement for surgery.

To monitor wind speed the sensor should be small and robust, have a low power consumption, and be linear enough to resolve 2 ms^{-1} speeds from 0 $\longrightarrow$ 30 m/s. A search for a suitable manufactured product was unfruitful and various design methods also did not match the requirements. Methods tried were hot wire/thermistor bend anemonetry and weather vane anemonetry. The experiments were carried out using a large wind tunnel. Heating/cooling anemonetry had high power consumption but was very robust, and vane anemonetry has low power requirements but, as so far seen, cannot be very robust.

Work using the above equipment (without the heart rate or wind sensors) is continuing in Glensaugh.

b) Biomass meter

A capacitive biomass probe was constructed, as described by Vickery (1979).

The device was designed to reduce the very labour intensive current technique of measuring sward biomass (i.e. cutting, drying, weighing etc.).

By resting the probe in the sward, a reading of Capacitance, between the sward and the probe, is displayed. Each measurement takes only a few seconds, and so a very large number of readings could be gathered, whereas previously this would have been impractical.

The instrument, as built, has yet to undergo extensive field trials.

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Vickery, P.J., Bennett, I.L. and Nicol, G.R. 1979. Improved Electronic Capacitance meter for estimating herbage mass. Research Note, CSIRO, Armidale.

c) Peripheral interfacing to central computing facilities

Several projects have been undertaken in this category.

An interface has been built for the X-ray spectrometers to convert the output into parallel ASCll (a code readable to teletypes).

Further analytical services required analogue input lines to the PDP 11/03 computer, and a patchband array was constructed to switch the large number of incoming lines.

Many further data logging requirements have been foreseen, and an overall design philosophy to standardize internal equipment for this purpose has emerged, thus work under this heading in the near future is to develop a versatile 'in house' data logging system.

RED DEER

05001/05005: Identification of the practical problems associated with the application of domestic animal husbandry methods to red deer kept under semi-intensive conditions.

05001. The effect of herbage mass and vegetation type on the performance of red deer hinds and calves in lactation

J.A. Milne and A. Loudon (University of Edinburgh)

Information on the milk yield, calf growth rates or liveweight changes of hinds grazing improved species swards of different herbage mass in early lactation is necessary in developing suitable systems of production under upland conditions. This information has not yet been obtained nor is information on the milk production of hinds grazing hill vegetation available. An experiment was conducted from June to September 1981, with 30 hinds and their calves in which the milk yield and performance of red deer hinds were compared on the following three swards.

A A hill sward of mixed heather and *Agrostis/Festuca* vegetation, West Greenshiels, described by Grant, Hamilton and Souter (1981)

B An improved species sward maintained at 1000 kg DM/ha

C An improved species sward maintained at 2000 kg DM/ha

The stocking rate on sward A was 15 hinds/ha and on B and C 10 hinds/ha. Measurements were made of hind and calf weights at 2 week intervals and of milk yield of hinds on swards A and C by the calf-suckling technique at the same 2-weekly interval. Observations were also made of some aspects of grazing behaviour.

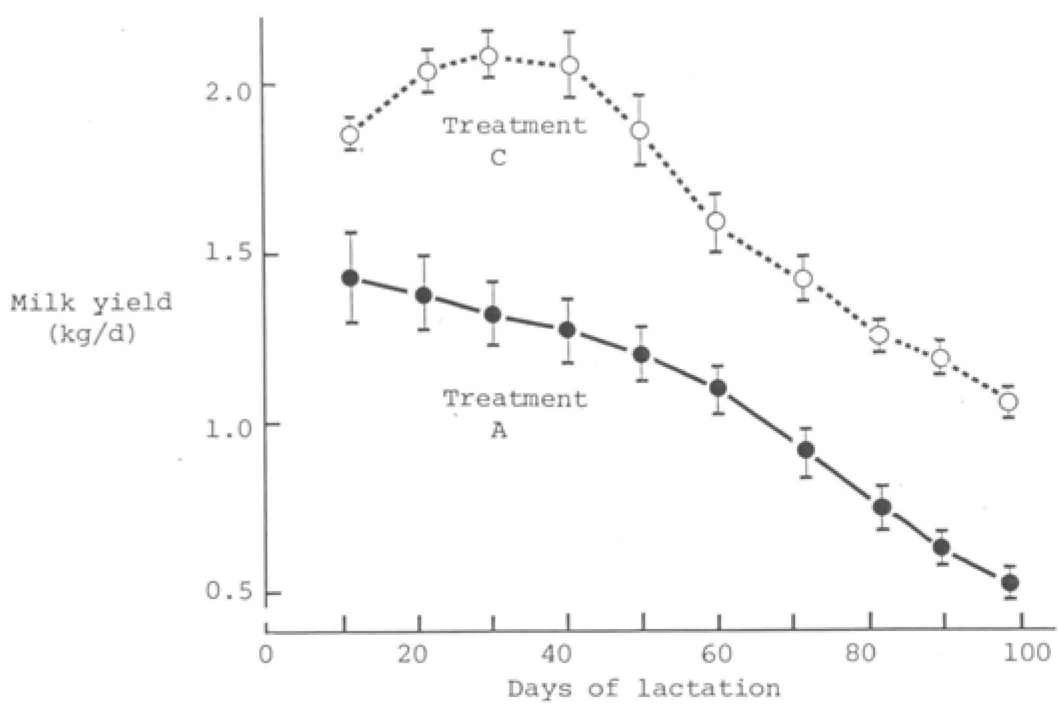

Figure 1 shows the mean lactation curves obtained from hinds on swards A and C. The yield and shape of the lactation curve were considerably different with milk yields being 60% higher and peak yields sustained longer on sward C than on sward A. The differences in milk yield were reflected in higher liveweight gains of calves on sward C (370 g/d) than on sward A (280 g/d) over the 100 days of lactation between birth and weaning. The liveweight gains of calves on sward B were intermediate (310 g/d). The weaning weights of calves from swards A, B and C were 34, 37 and 44 kg respectively. On all swards the hinds lost liveweight in the 1st 40 days of lactation but then gained liveweight at different rates so that at weaning the hind liveweights on swards A, B and C were 87, 86 and 81 kg respectively.

The biting rates and grazing times of hinds on swards B and C were similar (55 bites/min. and 5.7 h (only recorded over daylight hours) respectively) but on sward A the biting rates were much slower (33 bites/min.) and grazing times much longer (8.8 h) than on the improved species swards. The slower biting rates on the hill sward were presumably associated with diet selection from a heterogeneous sward and the longer grazing times with attempts to compensate for a slow biting rate.

The high levels of milk yield still being achieved on sward C at weaning suggest that it might be advantageous in terms of calf growth rate to delay weaning until after the rut and it is intended to examine this possibility in a further experiment.

REFERENCE:

Grant, S.A., Hamilton, W.J. and Souter, C. 1981. The responses of heather dominated vegetation in North-east Scotland to grazing by red deer. J. Ecol. 69: 189-204.

05005

1. Upland deer systems study

W.J. Hamilton, J. Eadie, T.J. Maxwell and L. Cranne

Two systems are currently being examined.

(A) spring and summer on sown pasture; rut on hill, further autumn grazing of sown pasture then wintered on hill area

(B) spring and summer on sown pasture; rut on sown pasture, further autumn grazing then wintered in small enclosure and hand-fed full requirements.

The progeny of both systems are weaned in late September/early October and wintered inside and run on sown pasture in their second summer (see p.C.50).

The hinds of both systems are stocked at 10 per ha on the sown pastures and there are 34 on each system. Each system has been allocated 0.77 ha of Hogg Park and 2.7 ha of Forestry Park. A further 2.8 ha of Hogg Park has been allocated for the use of young stock in their second summer.

Fodder conservation takes place on the Hogg Park section of each system provided an allowance of 80 kg DM herbage/hind remains available for grazing.

Fertiliser is applied in the spring when 20 cm soil temperature reaches 5.5°C. A total annual application of 144 kg of nitrogen per ha is applied to the grazed area and 112 kg of nitrogen per ha on the area for conservation.

The sown paddocks are stocked in the spring when herbage mass reaches 800 kg DM/ha and the end of the grazing season will be when herbage mass falls below 500 kg/ha.

Winter feed is adjusted so as to achieve a turnout weight in April of 80 kg. During 1980/81 the hinds were fed to lose weight during the winter after the completion of the rut; this amounted to between 5 and 10 kg for system A and 7 and 15 kg for system B.

The hinds were stocked on the area in the spring of 1980. Performance of the two herds is given in Table 1.

Table 1. Herd performance

		A		B	
		1980	1981	1980	1981
Calving (%)		100	97	100	94
Weaning (%)		85	88	88	82
Birth Wts.	Male	8.7	8.2	7.4	8.8
	Female	7.6	7.4	7.6	8.4
	Mean	8.1	7.8	7.5	8.7
Mean Wts.	Male	47.5	36.1	41.5	40.4
	Female	39.6	30.9	40.0	38.2
	Mean	43.3	33.8	40.7	39.4

The wintering cost of herd in 1980/81 was for herd A £23.88 and for herd B £5.12 per head.

05005

2. Wintering of deer calves

W.J. Hamilton, L. Cranna and T.J. Maxwell

In the production of venison from upland resources the overwintering of weaned calves for meat production or for further breeding in the following year requires that they be housed. The suitability and cost of diets designed to meet the nutrient requirements of weaned deer calves over this period are therefore being examined.

At weaning on 6 October 1980 57 calves from the Upland Systems Study were allocated to two groups of 29 (A) and 28 (B). To facilitate weaning both groups were housed for a period of 16 days and given a standard hay/concentrate diet, the second group (B), was then turned out to pasture until 4 December. At this time (9 December) groups A and B were further divided, calves being allocated by weight, to AL (15), AH (14), BL (14), BH (14). Groups AL and BL were given hay *ad libitum* and 700 g concentrate per head per day. The concentrate consisted of barley (85%), soya bean meal (10%) and a mineral urea mix (5%). The calves were turned out to grass on 24 April 1981 and grazed the same pasture until slaughter on 9 September. Two calves were removed (the lightest) from each group at turnout to reduce the stocking rate on the allocated paddock to an acceptable level.

A summary of the liveweights of the calves (not including those removed at turnout) is given in Table 1. The seasonal liveweight changes are given in Table 2.

Table 1. Mean liveweights of calves (kg)

	22/10	9/12	2/2	24/4	1/6	10/9
	Housed			Turnout		Slaughter
AL		43.3	44.6	52.8	54.6	69.3
	40.5					
AH		45.2	47.4	57.3	59.0	72.8
	At pasture	Housed		Turnout		Slaughter
BL		48.7	50.8	57.3	60.0	78.8
	41.0					
BH		48.8	50.9	60.0	62.8	77.8

Table 2. Seasonal liveweight changes (kg)

	Winter (housed)	Summer (at pasture)
AL	9.5	16.5
AH	12.1	15.5
BL	8.6	21.5
BH	11.2	17.8

The groups that were grazed until 4 December were some 4.0 kg heavier on 9 December than those housed from weaning. This difference persisted until turnout on 24 April.

The intake of hay by the calves given the high concentrate diet was between 250 and 300 g less per head per day than those calves given the low concentrate diet. This resulted nevertheless in a greater nutrient intake by the calves on the high concentrate diet and consequently greater liveweight gains over the winter.

The summer liveweight gains were inversely related to winter gain but only group BL fully compensated for its lower weight change in the winter when compared with BH.

The cost of wintering the farm groups was respectively AL, £26; AH, £30.50; BL, £20 and BH, £23 per head.