HFRO 234

HILL FARMING RESEARCH ORGANISATION

ANNUAL REPORT 1982

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HILL AND UPLAND PASTURE PRODUCTION

SYSTEMS STUDIES

Introductory note

The format of the 1982 Annual Report has been changed from previous years, and the report is arranged within the framework of the new ARC Information System. However, in order to allow a subject-based approach to be used in presenting the information, the programme unit structure has not been strictly adhered to. The titles of the programme units and the research objectives have been included in the relevant sections in the report, but omitted from the table of contents, for reasons of clarity.

Miranda Alcock
Information Officer/
Librarian.

Programme Unit 3: Factors affecting sheep performance in hill and upland environments.

1. REPRODUCTION

Research objective : Control of ovulation rate and embryo loss in ewes by manipulation of pasture and animal factors at mating (project no. 301).

1.1 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

This experiment is one of a series designed to examine the merits, if any, of providing different standards of nutrition during the pre-mating period to ewes of differing body condition. In 1980/81, the principle was to provide a high level of nutrition, in both quantity and quality, to half (group H) the Glensaugh NCC flock containing ewes in a wide range of body condition and to provide a low or maintenance level to the other half (group M). For details of how this was achieved and with what results, see 1981 Annual Report, p.A2.

The results of the 1980/81 experiment were sufficiently encouraging to justify further examination of the relative responses of fat and thin ewes to different pasture resources and there is a need to improve the monitoring of pasture amount and the objectivity of management decisions on how and when to use it. The experiment was therefore repeated on the same paddocks in 1981/82 with more detailed pasture monitoring and measurement of intake by ewes in different body conditions on the different pasture amounts.

Over the 6 weeks prior to mating, height and total mass measurements of pasture amount were carried out every 2 weeks. Height measurements only were carried out in alternative weeks. Regressions of mass on height were calculated at each time of measurement and herbage mass was estimated from the height in each alternate week on the basis of the regressions obtained from the week on either side. This gave two estimates for each alternate week which were, in general, quite different. It is therefore suggested that such a technique of herbage mass estimation based simply on height measurements and the use of regression equations derived at different times is not satisfactory at this time of year, particularly later in the period. This may be due to the regressions being derived from measurements of mass which were much more variable than those of height. It is also likely to be a function of decreasing density with decreasing height, particularly in swards in which growth has ceased, and may be due to a loss in tillers associated with senescence and decay. Since total mass measurements are also difficult at the low levels of pasture which obtain prior to mating, we have here an unresolved problem.

Each group grazed four paddocks for a mean 10.5 days (range 9-13) over the total 6-week period, and, using height measurements only, the H group started with a mean 5.79 cm of pasture (range 4.25-7.75) and finished with a mean 3.18 cm (range 2.50-4.00), while the M group started with a mean 3.51 cm (range 2.80-4.00) and finished with a mean 2.68 cm (range 2.25-3.35). This means that the H group appeared to be reducing pasture height by a mean 0.25 cm/day, while the M group appeared to be reducing it by only 0.08 cm/day.

On the basis of such total mass measurements as were made, the herbage mass in the paddocks rotationally grazed initially by group H ewes ranged, at the start of grazing, between 1600 and 2000 kg DM/ha (mean approx. 1800) and was eaten off to between 1200 and 1600 kg DM/ha (mean approx. 1400) in 9 to 13 days per paddock. Group M ewes followed Group H ewes and ate off the residual pasture to between 800 and 1400 kg DM/ha (mean approx. 1100) in the same periods.

Mean live weights (kg) and condition scores of the ewes initially ⩾ score 3- (F) and ⩽ score 2½ (T) on 16 October and on the high (H) and maintenance (M) pastures thereafter are given in Table 1.

Table 1

Mean live weights and condition scores

	No. of ewes*	16 Oct.	28 Oct.	10 Nov.	26 Nov.
FH	26	65.7 2.90	68.7 3.07	72.9 3.22	71.8 3.07
FM	28	65.7 2.95	69.3 3.03	68.2 2.89	68.9 2.91
TH	25	56.2 2.26	63.0 2.56	67.2 2.81	67.1 2.79
TM	25	56.2 2.32	63.4 2.51	62.6 2.54	63.2 2.59

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

Estimates of daily intakes (g) of DM, OM and DOM and associated digestibilities during the week prior to and including mating, based on faecal N levels derived from sample ewes dosed with chromic oxide, and using a ryegrass/clover regression of digestibility on faeces N (R.H. Armstrong, personal communication) were calculated, and are shown in Table 2.

Table 2

Estimates of daily intakes and associated digestibilities

	No. of ewes	DMI Total	/kg LW	OMI	DOMI	Dig. %
FH	11	778	11.4	662	426	64.5
FM	11	758	11.4	647	382	59.1
TH	11	1070	16.5	899	530	63.1
TM	11	804	13.0	683	410	60.1

Intakes were greater in the initially thinner ewes, particularly on high levels of pasture ($P<0.05$). Digestibilities were considerably lower on the maintenance levels of pasture, this being the residual stem and sheath after the top leaves had been eaten off by the group H ewes.

Mating took place between the 27 and 30 November and Table 3 shows the reprodutive performance of the ewes.

Table 3

Reproductive performance

	First mating			All matings		
	Lambing rate*++	Litter size+	% of ewes lambed	Lambing rate*	Litter size+	% of ewes lambed
FH	1.46	1.58	92	1.58	1.58	100
FM	1.18	1.50	79	1.43	1.48	96
TH	1.46	1.59	92	1.54	1.61	96
TM	1.20	1.43	84	1.24	1.41	88

* Per ewe mated + Per ewe lambing

++ Ewes lambing to later matings are included as barren

The responses were very similar to those in 1980/81, except that of the fatter ewes on a high level of pasture (FH), whose response was virtually identical to that of the thinner ewes on a maintenance level of pasture. Putting the results of the 2 years together, it is clear that the high level of pasture increased live weight and condition and the associated reproductive parameters, in particular lambing rate, in both condition classes of ewe, compared with the maintenance level of pasture ($F = 1.66$ and 1.44, respectively, P 0.05; $T = 1.57$ and 1.26, respectively, $P<0.05$). There was, however, very little difference in the reproductive responses of the fatter and thinner ewes on a high level of pasture, although the latter were still lighter and leaner at mating.

The fatter ewes on a maintenance level of pasture had an overall better reproductive performance than the thinner ewes on maintenance, although the differences were not statistically significant. Clearly, there are advantages of a high level of pasture to ewes of both condition classes but where high levels of pasture are limited, the best should be given to the leaner ewes, while the fatter ewes may be better able than the leaner to perform satisfactorily on poorer pasture.

The dynamic response to high level of pasture has been looked at in more detail, using data derived from this NCC flock over 4 years. This has shown that ewes in the intermediate condition score range of 2½/3- at 5 weeks before mating produced more (1.50; $P < 0.05$) lambs to first mating than did ewes in fat (≥ 3) and lean (≤ 2+) condition (1.26 and 1.26) and that this effect was more apparent in ewes on maintenance amounts of pasture. This analysis has been prepared for publication.

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

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

The study reported on in the 1981 Annual Report (p.A4) has been repeated on a larger scale at Hartwood with 242 Greyface ewes, two initial levels of herbage mass (a planned 1600 and 2000 kg DM/ha) and three replicates of each. In each replicate, 50% of the area was set-stocked at 12 ewes/ha (control) on 21 August while the other 50% (treatment) was sub-divided, half being closed off (saved) and the other half stocked at 24 ewes/ha (grazed). The saved areas were opened up on 13 October and mating took place from 26 October. The pastures were second year reseeds which had been grazed by sheep all summer and were fertilised with nitrogen in late August. Herbage mass was measured at intervals in the control, saved and grazed paddocks. Quantities of herbage mass (kg DM/ha) initially, at the time of opening up the saved areas and towards the end of the grazing phase of the study are shown in Table 1.

Table 1

Herbage mass quantities during the period of the experiment

Planned initial HM			1600				2000			
Replicate			1	2	3	Mean	1	2	3	Mean
Ewes/ha										
Date										
21 Aug.			1422	1464	1633	1513	2076	2240	1899	2072
13 Oct(	(Control	12	2125	1429	1686	1747	2119	2020	1493	1877
		(24	1178	924	921	1008	1897	1472	1290	1553
	(Treat.	(0	3494	3444	4614	3851	4752	4373	4020	4382
1 Dec.(	(Control	12	1217	899	1217	1111	1076	1098	1104	1093
		((24)	(1041)	(868)	(900)	(936)	(871)	(1031)	(1052)	(985)
	(Treat.	((0)	(1322)	(1163)	(1551)	(1345)	(1240)	(1809)	(1350)	(1466)
		(12	1182	1016	1226	1141	1056	1420	1201	1226

On 21 August, the achieved mean masses were nearer to 1500 and 2100 kg DM/ha than the 1600 and 2000 initially planned. Between 21 August and 13 October, herbage increase on the saved areas, and the change in herbage mass on the control and grazed areas, based on measurement of mass before and after grazing plus increase, are in Table 2.

Table 2

Changes in Herbage Mass

Initial HM		1500				2100			
Replicate		1	2	3	Mean	1	2	3	Mean
21 Aug.-13 Oct. Accumulation (kg DM/ha/day)		39	37	56	44	50	40	40	44
Change in herbage mass (kg DM/ewe/day)	@ 12 ewes/ha	2.2	3.2	4.6	3.3	4.1	3.7	4.0	3.9
	@ 24 ewes/ha	1.8	2.0	2.9	2.2	2.2	2.3	2.1	2.9

Since pasture growth continued for a period after 13 October but was not measured, estimates of change in herbage mass between then and 1 December are likely to be less than actual and are not given.

The mean patterns of change of herbage mass over the grazing phase of the study are shown in Figures 1 and 2. Net herbage production was high in the early stages in late August. The decline in herbage mass was very high in the early stages of use of the saved pasture in late October. With the control and grazed areas being set-stocked, 12 ewes/ha was too low a stocking rate to fully utilise the available growth of pasture in late August and September and a net herbage increase resulted. This was particularly the case on the initial 1500 kg DM/ha (1500 areas), in which there was more grass on 13 October than on 21 August, while this was not the case on the initial 2100 kg DM/ha (2100 areas). At 24 ewes/ha, the stocking rate was too high to allow a net herbage increase, except during the first 3 weeks on the 1500 areas.

The ewes this year were much heavier and fatter at the start of the experiment than they were in last year's study, approximately 65 kg and grade 2.9 compared with 55 kg and grade 2.2. Live-weight and condition recovery were also much slower (see Figures 1 and 2). In particular, the treatment ewes grazing at 24/ha on the 1500 areas gained very little compared to all other groups during the period 21 August to 13 October. When herbage mass fell below 1500 kg DM/ha, LW started to decline; in this year this occurred at the beginning of November in the control group.

Fig. 1. GF '81. Initial herbage mass of 1500 kg DM/ha

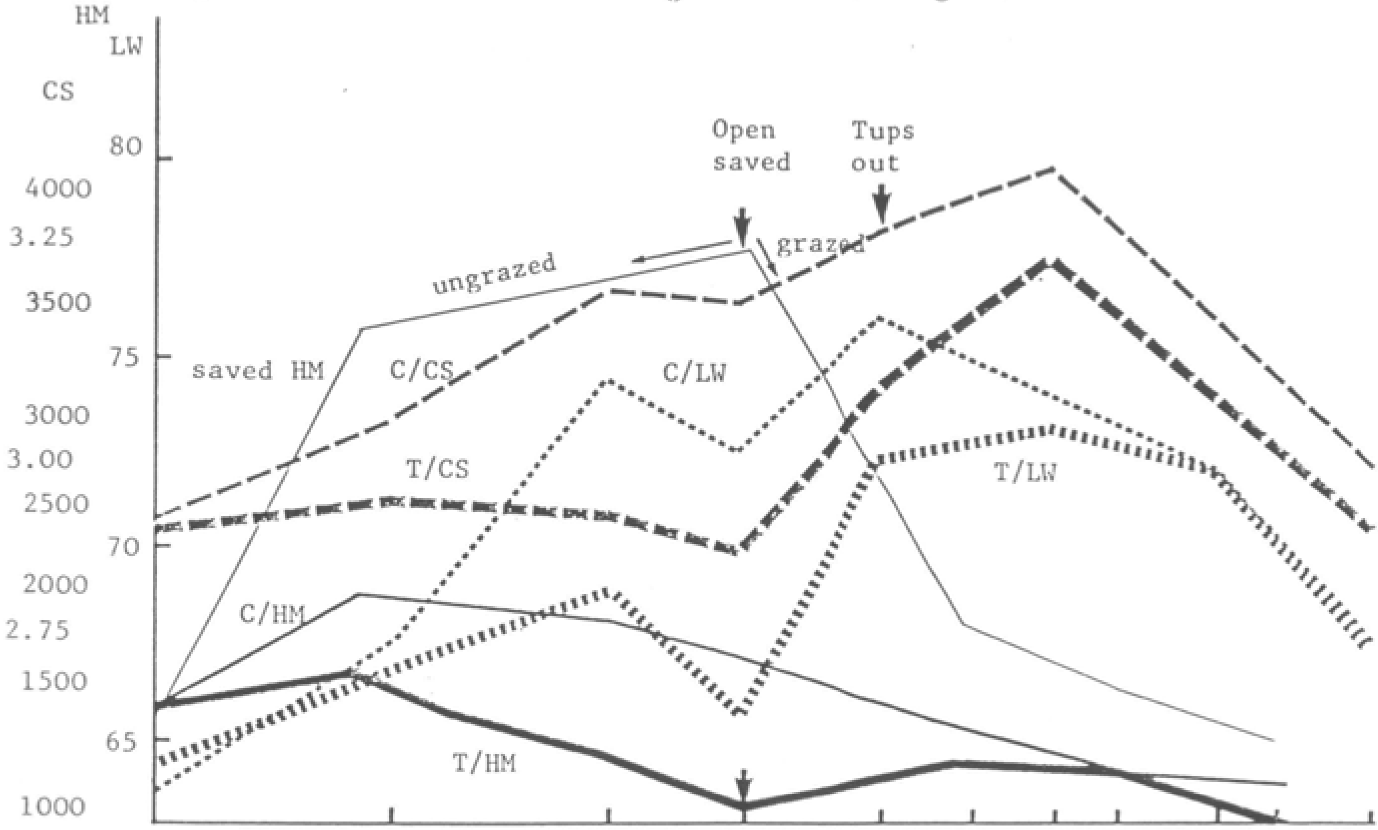
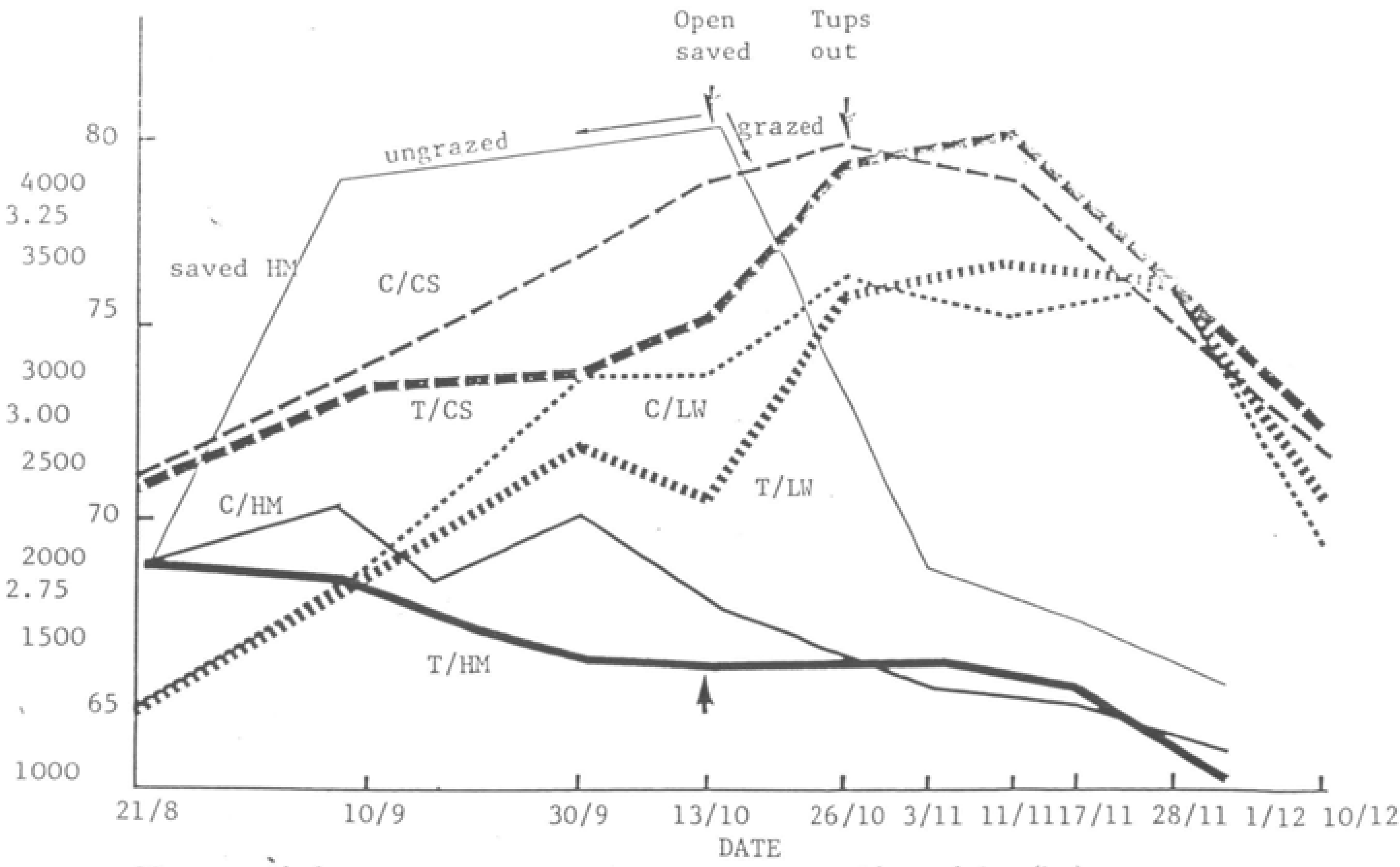


Fig. 2. GF '81. Initial herbage mass of 2100 kg DM/ha



CS = condition score, HM = herbage mass, LW = liveweight (kg)
T = treatment, C = control

The performance of the ewe is shown in Table 3.

Table 3

Reproductive performance of ewes

Initial HM		1500	2100	Combined
Litter size to first mating*	Control	2.00	2.00	2.00
	Treatment	2.13	1.80	2.01
	Combined	2.06	1.91	
Lambing rate to all matings+	Control	1.88	1.66	1.78
	Treatment	1.97	1.61	1.80
	Combined	1.92	1.64	

* Per ewe lambing + Per ewe at mating

Overall, there was no difference between the treatment and control groups in litter size to first mating or in lambing rate to all matings. There was, however, a difference in litter size to first mating between the treatment ewes on the 1500 and 2100 areas ($P < 0.1$) but no difference between the control ewes on these areas. This was associated with a significantly ($P < 0.05$) greater lambing rate in the treatment ewes on the 1500 areas than on the 2100 areas and, although the difference between the control ewes was not significant, the trend was in the same direction. As a result, ewes on the 1500 areas produced an overall significantly ($P < 0.05$) greater number of lambs than did ewes on the 2100 areas. This was almost entirely due to the adult ewes (2.07 and 1.70, respectively, $P < 0.01$) there being no difference in the gimmers (1.48 and 1.46, respectively).

These results suggest that, with ewes in such good condition as they were this year (mostly in the range 3 to 3½ at mating), the restriction associated with heavy stocking at 24 ewes/ha on pasture initially at about 1500 kg DM/ha, has produced a greater response to the later use of saved pasture than was the case with ewes which were on greater herbage mass and whose rate of recovery was not checked initially. One explanation for the poorer performance of the ewes on the 2100 areas is that they became too fat at mating and that excessive condition reduces ovulation rate and/or increases ova and embryo wastage. For an analysis of this effect see elsewhere in this Report (p. 11). This effect was also apparent according to the level of condition the ewes were in at 7 weeks before mating, lambing rate tending to be greater in the initially leaner ewes ($173 \leqslant 3 = 1.87$ and $67 \geqslant 3+ = 1.63$, $P < 0.1$) although removal of the gimmer age, which tended to be initially fatter than the adults, did reduce this difference ($151 \leqslant 3 = 1.93$ and $29 > 3+ = 1.83$). Nevertheless, the trend was still apparent in the adult ewes, as is shown in Table 4.

Table 4

Condition score and lambing rate in adult ewes

CS at 7 weeks before mating	≤ 2	3-	3	$\geq$3+
Lambing rate (no. of ewes)	2.25(12)	1.94(36)	1.89(103)	1.83(29)

The conclusion to be drawn from this study is that pasture management and utilisation should be designed to regulate body condition in the recovery period. If ewes are initially fat, only limited amounts of pasture should be offered initially in order to restrict the rate of recovery and then a boost may be provided by saved pasture utilised prior to and at mating. If ewes are initially lean, sufficient pasture must be made available to allow rapid recovery but the provision of saved pasture may then not be so necessary. Pasture offered should therefore depend on body condition. It may be better to control the pasture at a required level until such time as a nutritional boost is necessary from the saved area, when the previously grazed area can no longer sustain the optimum level of intake.

1.3 Herbage intake of ewes on ryegrass/clover pasture in the pre- and post-mating periods

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

In 1978 (see p.A2 in the 1978 Annual Report), a study was carried out on the effect of a potentially stressful experimental management before or after mating on ova loss in Blackface ewes. The management selected was daily handling, which gave an opportunity for preliminary examination of voluntary herbage intake of ewes in the pre- and post-mating periods. Two groups of 31 ewes were run in Eastrae throughout, on two approximately 5 ha paddocks of similar ryegrass/clover pasture. No pasture measurements were carried out. Daily handling for chromic oxide dosing and faecal sampling was carried out during the last 2 weeks prior to a synchronised mating in one group (TBM) and during the first 2 weeks after a synchronised mating in the other (TAM). Mating took place between 28 November and 1 December. Table 1 shows mean daily intake (g) and the digestibility of the ingested herbage which were calculated for two consecutive 5-day periods up to and including the day after mating for each individual ewe in group TBM and for two consecutive 5-day periods from the 5th day after the start of mating in group TAM. The calculations were based on faecal N and the regression equation of R.H. Armstrong (unpublished data) for ryegrass/clover pasture, namely

$$IF = 1.86 + 0.75N_1 - 0.16M$$

and using a month correction factor (M) of 7.

Table 1

Herbage intakes and digestibility in Blackface ewes

Group	Sampling period	DMI	OMI	DOMI	Dig. %
TBM	20-27 Nov.	845	664	499	75.2
	25 Nov.-2 Dec.	797	618	463	74.9
TAM	3-7 Dec.	744	531	372	69.8
	8-12 Dec.	746	539	364	67.6

Although the validity of using in Nov./Dec. a regression equation derived from pasture in the May to August growing season may be questioned, the results are nevertheless interesting. Intake was depressed during the week of actual mating compared with the previous week, although there was little difference in digestibility. This is a similar result to that obtained from North Country Cheviot ewes at Glensaugh in 1978 which were sampled over the same but earlier pre-mating periods, as shown in Table 2.

Table 2

Herbage intakes and digestibility in NCC ewes

Sampling period	DMI	OMI	DOMI	Dig. %
4-11 Nov.	1342	1101	833	75.9
9-16 Nov.	1217	985	735	74.7

Such a depression in intake may simply be due to the disturbance associated with seeking out the ram and with mating itself.

Post-mating intake in the present study was considerably depressed and may be related to the decline in digestibility, although paddock differences in sward structure and amounts of pasture available may well play a part in this.

The apparent difference in intake between the two studies is partly a function of live weight, the Blackface ewes being much lighter than the North Country Cheviot ewes, but even on a per kg live-weight basis the values in the present study are lower, as shown in Table 3.

Table 3

Comparison of herbage intake in NCC and BF ewes, pre- and post-mating

Breed	NCC		BF			
Sampling period	4-11Nov	9-16Nov	20-27Nov	25Nov-2Dec	3-7Dec	8-12Dec
gDMI/kgLW	18.1	16.4	15.1	14.0	13.5	13.3

This decline in intake with time is likely to be an expression of declining digestibility of the herbage or to be related to the differences in sward structure and pasture amount in the two studies. Certainly, live weight appears to decline in late November when DMI drops below 800 g/day and digestibility below 75%.

1.4 Fertility in East Friesland x North Country Cheviot ewes: Comparison of reproductive performance with that of pure-bred North Country Cheviot ewes on the same pastures

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

Part of a flock of North Country Cheviot (NCC) ewes was mated to East Friesland rams to produce cross ewes (EF x NCC) for studies on extended lactation. Over 2 years, comparison has been made of the reproductive responses of the pure-bred and cross Cheviot ewes in a study on the optimization of pasture-use by ewes in different body conditions in the pre-mating period. Two levels of pasture standing crop (equivalent to high and maintenance levels of nutrition) were provided over the 5 weeks prior to a synchronized mating, and live-weight and body condition responses were monitored. Data were available from the gimmer stage of two age groups of cross ewes and from the second year's production of the older, giving a total of 90 ewe records. These were compared with their pure-bred contemporary age groups, which gave 106 ewe records. All were mated with NCC rams.

Between-breed differences in body condition score are likely to be related to breed differences in the deposition of internal and external fat reserves. Since the cross ewes had consistently lower scores than did the pure-bred ewes, comparison at the same condition score is not justified. Pre-mating live weights (LW) were very similar in both cross and pure-bred ewes, ranging between 54 and 66 kg according to age and the level of pasture offered. Cross ewes had substantially higher lambing rates (LR) per ewe mated than did pure-bred ewes at all three lambings.

Table 1

Live weight and lambing percentages of crops and pure-bred ewes

		1st crop				2nd crop	
Year born		'79		'80		'79	
	Pasture	LW	LR	LW	LR	LW	LR
EFxNCC	H	64.3	1.71	61.8	1.77	65.8	1.75
	M	54.7	1.72	57.1	1.57	60.9	1.53
NCC	H	62.8	1.37	58.6	1.33	66.0	1.38
	M	54.3	1.06	55.8	1.10	63.5	1.35

The overall mean LRs were 1.68 and 1.27 for the EF x NCC and NCC ewes, respectively, associated with pre-mating mean LWs of 60.8 and 60.2 kg. LR in the EF x NCC ewes was less affected by LW and therefore pasture availability than it was in the NCC ewes. This is shown from the regression of mean LR on mean LW in the above six groups of ewes in each breed class. In the EF x NCC the following equation was derived:

$$LR = 0.0078LW + 1.2033 \quad (r = 0.33)$$

while in the NCC the equation was:

$$LR = 0.0283LW - 0.4351 \quad (r = 0.91)$$

From these equations, a change in LW of 5 kg can be expected to result in a change in LR of only 4 percentage units in the EF x NCC compared with 14 percentage units in the NCC.

Within limits, the EF x NCC ewe may therefore be a more consistent producer of lamb number than the NCC in a nutritionally variable pre-mating environment.

1.5 Body condition/lambing rate relationships in Greyface ewes

R.G. Gunn

It is well known that lambing rate in the ewe is increased by increasing body condition at mating. What is less well known is whether this principle applies over the whole range of body condition, particularly at the higher end, since it is often suggested that performance levels drop off in excessively fat ewes, although the evidence for this is difficult to find. However, in a recent experiment in which 180 adult Greyface ewes had individual scores $\geqslant 2.75$, a regression analysis was carried out on the mean lambing rates of the ewes in four condition score classes at mating:

CS at mating	No. of ewes	Lambing rate
⩾3.5 (3.56)	44	1.82
3.25	64	1.89
3.0	58	1.93
2.75	14	2.14

This produced the equation:

$$LR = -0.368\ CS + 3.10; \quad r = -0.93; \quad F = 11.947,$$

which gave a significant ($P < 0.05$) decline in lambing rate with increasing condition over this range.

An examination has therefore been carried out on the relationship between the body condition of individual adult Greyface ewes at mating and the number of lambs born to first mating over 8 years of system and component studies, a total of 843 ewe records. Mean lambing rates and the two parameters which produce them, litter size and barrenness, are shown in Fig. 1.

Lambing rate increased significantly ($P < 0.01$) from condition scores 2 to 3 but it was not possible to show the apparent decline from scores 3 to 4 to be significant. It is, however, clear that lambing rate peaks at about score 3 and greater condition will not increase it and may even decrease it. The parameter of importance here is barrenness (which includes ewes not holding to first mating) since the proportion of barren ewes increased significantly ($P < 0.001$) with increasing condition, particularly at the top and bottom of the range. This effect mirrors that of litter size in which the proportion of single lambs decreased significantly ($P < 0.001$) and that of triplets increased significantly ($P < 0.05$) with increasing condition, while the proportion of twins remained constant.

It is therefore concluded that there is no advantage in terms of lambing rate in having Greyface ewes in condition greater than score 3 at mating and that there may even be a disadvantage in terms of increased barrenness. No information, unfortunately, is available from this study on which aspect of barrenness, i.e. failure of oestrus, fertilization or embryo survival, is the more likely to be affected by higher levels of condition at mating.

Fig. 1. Mean lambing rates to first mating of GF ewes over 8 years, by condition score at mating. Ewes not holding to first mating are included as barren. Adult ewes only.

Research objective : Determine effects of nutrition on plasma FSH, LH, prolactin, progesterone and on ovulation and lambing rates (project no. 303).

1.6. Reproductive performance and endocrine status of Greyface ewes in moderately high and very high condition scores at mating

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

Recent experiments have indicated that Greyface (Border Leicester x Scottish Blackface) ewes in very good condition at mating (condition score = 3.5) have lower lambing rates than ewes in moderately good condition (C.S. = 2.75 to 3.0). The aim of this experiment was to determine the oestrous activity, ovulation rates and embryo survival rates of ewes with condition scores of 2.75 and 3.5 at mating and to characterise the associated patterns of secretion of FSH, LH and prolactin in the perioestrus period and of progesterone in the first month after mating.

In late August, 39 draft Greyface ewes with body condition scores of 1.75 to 2.75 were allocated, randomly within each condition class, to one of two initially similar groups. They were housed in individual pens and fed dried grass pellets and hay *ad libitum* until they achieved a target condition score of either 2.75 or 3.5, for the respective groups, or until mating. Thereafter they were offered a body condition maintenance ration of 12 to 18 g pellets/kg liveweight/head/day and 0.25 kg hay/head/day. All animals were weighed and condition scored weekly. The pattern of liveweight and condition score changes that were actually achieved during the experiment are summarised in Table 1.

Table 1

Mean (± s.e.) liveweight (kg) and condition scores of ewes at 10 and 5 weeks before mating, at mating and at slaughter

Target condition score	2.75	3.5
Liveweight		
10 weeks before mating	71.6±1.38	74.9±1.72
5 weeks before mating	71.6±1.41	81.3±1.92
Mating	63.9±1.09	83.7±1.72
Slaughter	65.6±1.19	79.6±1.54
Body condition score		
10 weeks before mating	2.33±0.055	2.47±0.058
5 weeks before mating	2.74±0.038	2.88±0.046
Mating	2.74±0.022	3.35±0.025
Slaughter	2.80±0.023	3.30±0.032

The ewes were synchronised in oestrus using intravaginal pessaries inserted for a 14 day period. On day 10 of the cycle following pessary withdrawal, they were injected with 0.4 ml of prostaglandin $F2_{\alpha}$(PG) and again at the same stage of the next cycle. The approximate time of oestrus onset following the first PG injection was determined so that the optimum time for frequent collection of blood samples at the next cycle could be determined. All ewes were mated at 12 to 24 hours after the onset of oestrus following the second PG injection.

Blood samples were collected at 15 minute intervals for 10 hours on day 9 of the cycle following the first PG injection and for 8 hours on the day after the second injection and on the following day for animals that had not shown oestrus. Samples were collected at 3-hour intervals for 30 hours from oestrus onset. These samples will be analysed for FSH, LH and prolactin to provide detailed hormone profiles for the perioestrus period. Samples were also collected between mating and slaughter for progesterone determination.

The ewes were slaughtered at approximately 4 weeks after mating and the reproductive tracts recovered and corpora lutea and embryos counted.

Table 2

Incidence of oestrus, ovulation rate and potential litter sizes in ewes in high (C.S. = 3.35) or moderate (C.S. = 2.74) condition at mating.

Condition at mating			
Mean condition score		2.74	3.35
No. of ewes in group		19	20
No. of ewes showing oestrus following second PG injection		19	16
No. of ewes pregnant at slaughter with 1 to 5 ovulations at time of mating	1	0	0
	2	11	2
	3	3	5
	4	1	2
	5	0	2
Mean ovulation rate of ewes pregnant at slaughter		2.33	3.36
No. of ewes with 1 to 3 embryos at slaughter	1	4	4
	2	10	3
	3	1	4
Mean potential litter size/ewe pregnant		1.80	2.00
Mean potential no. of lambs/ewe put to ram		1.42	1.10

The reproductive performance of the animals is summarised in Table 2. While ovulation rates at the time of mating could only be accurately determined in ewes pregnant at slaughter, examination of corpora abicantia indicated that all but one animal ovulated at this time and that the overall mean ovulation rate was similar to that of the pregnant ewes.

The results confirm previous observations of a reduced lambing rate in very fat ewes and provide some information on the causes. Although there was a significantly higher ($P < 0.05$) ovulation rate associated with the higher mean condition score (3.36 vs 2.33), the lambing percentage was reduced by the failure of 4 very fat ewes to show oestrus and possibly by increased embryo mortality. The latter is suggested by the fact that the rate of egg wastage in the pregnant ewes with a condition score of about 3.5 was higher than in the other pregnant ewes (40.9 vs 22.9%). However a more comprehensive understanding will be possible when post mating progesterone profiles have been determined as this will allow identification of cases of late embryonic death and pregnancy failure. Thus it will be possible to distinguish between total fertilisation failure or early embryo death and pregnancy failure after day 12. The progesterone profile will also show whether or not luteal insufficiency could be responsible for the reduced fertility of the fatter ewes.

Research objective: Increase ovulation and lambing rate of hill and upland ewes by passive immunisation against steroid hormones (project no. 305).

1.7. Ovulation rate and lamb production in ewes of two breeds and in two different levels of body condition, passively immunised against testosterone

S.M. Rhind, B. Morris (Dept. of Biochemistry, Univ. of Surrey), J.M. Doney, R.G. Gunn, W.F. Smith, A.D.M. Smith, I.D. Leslie and D.A. Sim

Until now, most of the work done on increasing the ovulation rate of ewes by passive immunisation against steroid hormones has involved Welsh Mountain ewes and the ovulatory response obtainable from other breeds has not been investigated. Furthermore it is not known whether or not the response is affected by the ewes' level of body condition at mating. The aim of this work was to investigate the ovulatory response and lambing rate following immunisation against testosterone of Greyface (Border Leicester x Scottish Blackface) and Scottish Blackface ewes on low or moderately high body condition at mating.

Sixty draft Scottish Blackface and 37 draft Greyface ewes were housed in early October and allocated randomly within each breed to one of two treatment groups. Ewes of one group were fed so that their mean body condition score was increased to 2.75 to 3.0 while the others were fed a restricted ration so that they declined in condition to a score of 1.5 or 1.75. Two weeks before mating ewes of each condition score group were allocated according to weight and body condition to one of two similar sub groups (see Table 1).

Table 1

Mean (± s.e.) liveweights (kg) and body condition scores at mating of ewes of each breed, condition score and treatment category

Target condition score	2.75/3.0		1.5/1.75	
Treatment	Anti-T serum	Control	Anti-T serum	Control
Greyface				
Liveweight	77.1±2.70	75.6±2.06	56.0±1.76	56.1±1.80
C.S.	2.86±0.073	2.89±0.061	1.65±0.041	1.53±0.050
Scottish Blackface				
Liveweight	65.7±1.78	65.1±0.041	44.7±2.59	47.0±1.21
C.S.	2.83±0.031	2.85±0.041	1.52±0.038	1.60±0.033

On 1 December, approximately one week before mating, ewes of one sub group from each breed/body condition category were injected intravenously with 25 ml of anti-testosterone serum (titre = 1:100,000). The dose given was the same as that used successfully by Dr R. Land of ABRO with Welsh Mountain ewes. The remaining ewes were injected with the same volume of 'blank' serum obtained from non-immunised wethers, and served as controls.

All ewes were synchronised in oestrus using intravaginal pessaries inserted for a 14 day period. They were mated between 6 and 10 December at the second oestrus following pessary withdrawal.

Approximately one week after mating, the ovaries of ewes were examined by endoscopy and the numbers of corpora lutea present were recorded. The results are given in Table 2.

Table 2

Mean (± s.e.) number of corpora lutea recorded by endoscopy in ewes of each breed/condition score and treatment group (no. of ewes successfully examined is given in parenthesis)

		Treatment	
Breed	Target condition score	Anti-T Serum	Control
Greyface	2.75/3.0	1.63±0.182(8)	1.33±0.167(9)
	1.5/1.75	1.33±0.167(9)	1.43±0.202(7)
Scottish Blackface	2.75/3.0	1.93±0.165(14)	1.47±0.215(15)
	1.5/1.75	1.14±0.143(14)	1.00±0.00(15)

Examination of the Greyface ewes in good condition was difficult because of the presence of large amounts of internal fat. It is likely that the ovulation rate of these groups in particular, was underestimated.

The ovulatory response of thin ewes was not significantly altered by treatment with anti-testosterone serum; however the ovulation rate of ewes of both breeds that were in moderately good condition was increased by this treatment and when the data from the two breeds was pooled, the increase was found to be statistically significant ($P < 0.05$).

Nineteen per cent of ewes returned to service within a month of mating. They were remated. There was no difference between treated and untreated ewes in the incidence of returns to service. The lambing rate for each group will be determined.

The results show that the ovulation rate of ewes of these breeds can be increased by immunisation against testosterone but the ovulatory response to anti-testosterone serum treatment, like that of the untreated animal is dependent on body condition and with the dose used, was absent in ewes in low condition. It remains to be determined whether a higher dose would stimulate additional ovulations in the thin animals.

2. PREGNANCY

Research objective: Develop and evaluate effective and safe means of determining foetal number in pregnant ewes (project no. 312)

2.1 Determination of foetal number in pregnant ewes

A.J.F. Russel, I.R. White and D.G. Fowler (NSW Dept. of Agriculture)

One of the major constraints to the application in practice of the results of research on the nutrition of the pregnant ewe is the inability to determine foetal numbers at some stage prior to the last 6-8 weeks of gestation. Various approaches to this problem, including the use of concentrations of a number of blood metabolites and hormones, have been examined (see earlier Annual Reports). For a variety of reasons, not least of which is their inability to provide an immediate result, these have been found unsatisfactory. Radiological techniques have been used successfully for experimental purposes, but again are not considered suitable for application in commercial enterprises.

In recent years attention has turned to the use of ultrasonic techniques and two main approaches have been examined. The first is based on the detection of foetal heartbeats or other foetal signals, using the Doppler and other principles of this type. This approach is considered to merit further investigation and work is continuing in collaboration with the Scottish Institute of Agricultural Engineering who are developing systems of signal processing and analysis on material collected and supplied by HFRO.

The second approach is the use of ultrasonic real-time scanning. Dr D.G. Fowler of the New South Wales Department of Agriculture pioneered the use of this technique for determining foetal numbers in sheep in Australia and visited HFRO during January and February 1983 to study its use on British sheep breeds and under UK conditons. The technique involves the examination of a bared area of the ewe's belly wth a linear-array transducer measuring approximately 10 x 1 cm. A real-time image is portrayed on a screen and with training it is possible to determine, firstly, whether or not the ewe is pregnant, and if so, to count the number of foetuses. This can be done wth a high degree of accuracy at any stage between 50 and 100 days of gestation.

Two instruments were used during the period of Dr Fowler's visit - an ADR Kranzbuhler 2130, which Dr Fowler had used previously, and a Linus from Fischer Ultrasound of Edinburgh. A number of different transducers were used with each instrument. Although considerably more than 1000 ewes were scanned during the course of the studies, a major part of the work was concerned with the training of an HFRO member of staff (IRW). A total of 833 ewes on four research stations were scanned by both DGF and IRW and the accuracy attained by IRW (assuming DGF to be correct) is shown in Table 1. Although the Linus instrument with the 3.5 Mz transducer was preferred by both operators, both instruments with a variety of transducers were used as part of the training programme. It can be seen from the results that the accuracy of determination of actual foetal numbers (i.e. 0, 1, 2 or 3) and of identification of singles and multiples (i.e 0, 1 and>1) improved rapidly from around 70 and 80% respectively after a minimum of instruction, to between 97 and 100% when using the Linus with a 3.5 Mz transducer. Final assessment of the accuracy of determination of foetal numbers and of the identification of singles and multiples will be made after lambing on the basis of actual numbers of lambs born. With practice DGF has shown that it is possible to maintain this accuracy at scanning rates considerably in excess of 150 ewes/hour. Lower rates of between 50 and 100 ewes/hour would still be regarded as eminently acceptable in practice.

The use of ultrasonic real-time scanning would appear to offer an accurate and immediate means of determining foetal numbers in pregnant ewes, at a rate and at a cost which would be acceptable in practice. From our experience to date the main limitation to the commercial use of the technique is the relatively high labour requirement for preparing the ewes and presenting them for scanning. Collaborative work is now beginning with the Scottish Institute of Agricultural Engineering with the objective of designing handling equipment to reduce the high labour requirement and improve the efficiency of the operation.

Alternative uses of the ultrasonic real-time scanning equipment are also being investigated. These include the diagnosis of pregnancy in suckler cows at 3-5 weeks post-mating, and the in vivo estimation of subcutaneous fat depth in sheep and cattle as indices of carcass and whole body composition.

Table 1

Accuracy of Foetal Number Determination

Date	Location	Breed	No. of Ewes	Instrument	Accuracy Foetal Number	Accuracy Single /Mult.
14.1.83	Hartwood	Greyface	32	ADR 3.5	0.69	0.81
17.1.83		"	32	Linus 3.5	0.75	0.81
18.1.83		"	31	Linus 3.5	0.77	0.94
19.1.83		"	31	Linus 3.5	0.81	0.94
7.2.83		Greyface & Blackface	56	Linus 3.5	0.79	0.84
9.2.83	HOM	Blackface	62	Linus 3.5	0.87	0.87
10.2.83		"	65	Linus 3.5	0.95	0.97
11.2.83		"	62	Linus 3.5	0.98	0.98
15.2.83	Glensaugh	North Country Cheviot & East Friesland x Cheviot	77	ADR 2.25 & 3.5	0.95	0.97
16.2.83		"	74	Linus 3.5	1.00	1.00
17.2.83		Blackface	44	Linus 3.5	1.00	1.00
21.2.83	Sourhope	Blackface	82	Linus 2.25	0.94	0.98
22.2.83		"	56	Linus 2.25	0.96	0.96
23.2.83		"	21	ADR 3.5	0.90	0.90
23.2.83		"	20	ADR 3.0	0.90	0.90
23.2.83		"	29	Linus 3.5	0.97	0.97
24.2.83		"	59	Linus 3.5	0.98	0.98

2.2 Economic assessment of the benefits following detection of foetal number in sheep

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

The potential savings following detection of foetal number in a sheep flock are based on the identification of barren ewes to save late pregnancy feeding and the identification of single, twin and triplet-bearing ewes so that late pregnancy feeding can be matched to their separate requirements. Single-bearing ewes are often over-fed in late pregnancy when the anticipated flock lambing percentage is greater than 100, identification of single bearing ewes can therefore save feeding costs. Twin and triplet-bearing ewes are often under-fed in late pregnancy and, as a consequence, a proportion of these lambs die in the first few days after lambing because they are too small to survive. Identification of multiple-bearing ewes allows late pregnancy feeding to be more closely matched to their requirements so that multiple lambs are heavier at birth with a better chance of survival. A further advantage of the identification of multiple-bearing ewes is that they can be given special attention at lambing in order to reduce the number of ewe and lamb deaths that occur with unattended, difficult births. The savings therefore come from lower feeding costs, better lamb survival leading to higher weaning percentages and more lambs sold and fewer ewe deaths. Consequently fewer lambs are retained as flock replacements and more lambs are sold or, if replacement stock are not kept, fewer replacement gimmers are bought in. A further potential benefit in some flocks is that ewes identified as barren at an early stage can be sold at a time when ewe prices are near their maximum.

An economic assessment of some of these effects on flock performance has been carried out by use of a specially written computer program. Two special attributes of the program are first that flock structure (numbers in age groups) is calculated year by year because alterations to ewe loss rate will affect structure, for example, a lower ewe loss rate will result in more cast ewes sold and fewer ewe lambs retained or gimmers bought. The second special attribute is that the number of ewes in single, twin and triplet bearing categories is calculated based on flock lambing percentage and percentage of barren ewes. This allows feeding costs to be calculated when foetal detection has been used and feeding adjusted to numbers of ewes in each lamb-bearing category. Comparisons can then be made when foetal number detection is not used; in this case the proportions of ewes in lamb-bearng categories are calculated as shown in Table 1.

Late pregnancy feeding requirements are based on the calculations shown in the MLC Booklet "Feeding the Ewe". It is assumed that a twin-bearing ewe will require 1.5 times the late pregnancy feeding of a single bearing ewe and a triplet twice that amount.

Table 2 shows the basic data used for gross margin calculations of three main flock types, hill, upland and lowland, the data in the table were derived from the SAC publication "Farm Management Handbook 1982/83" and the MLC Booklet "Feeding the Ewe". As shown in Table 2 ewe loss rate, lambing percentage and lamb loss rate are all varied in order to produce a set of results for the appraisal of each flock.

Table 3 shows the results for the hill flock. A base Gross Margin per ewe is shown for the range of lambing percentages 80-120 with ewe and lamb loss rates at 8% per annum. Below this are shown the increase in Gross Margin that would result from reducing lamb losses by one quarter or one half with similar reductions for ewe loss rate and adjustment of feeding levels all applied separately. Reductions in loss rates are applied where relevant. These are all effects that could result following identification of barren, single and multiple-bearing ewes between 50 and 100 days pre-lambing. The final row of Table 3 shows the sum of the effects. The values in Table 3 represent the amounts that could be paid per ewe for a foetal number detection service to break-even on the procedure. Any greater charge for the service would result in a net loss and any lesser charge in a net gain from using a foetal number detection service. On the basis of the best information currently available and scanning 400 ewes in a day, a service is likely to cost about £1.00 per ewe.

Savings are greater at higher lambing percentages because, at a fixed level of reduction of lamb losses more lambs are saved. Savings in feeding costs are greater at 80% lambing than at 100% because no barren ewes are fed. They are greater at 120% than 100% because, again, barren ewes are not fed and because single and twin-bearing ewes are fed at their required levels rather than all ewes being fed at a level which would satisfy the needs of a ewe bearing a lamb and a half. This latter effect, it is argued, will also result in the reduction of lamb losses.

Table 4 shows the set of results for the upland flock. Here, because there is a high proportion of twin-bearing ewes over the whole lambing percentage range, savings through reductions in ewe and lamb deaths can be relatively large. Savings in feeding costs diminish from 120-150% since Table 1 shows that in this range a non-detected flock is assumed to be fed at the 150% lambing level. Feed savings at 160% are consequently greater because a flock lambing at this level and for which foetal number detection was not carried out, would be fed as though all ewes were carrying two lambs.

Table 5 shows the set of results for the lowland flock. Savings here diminish rapidly as the 200% lambing level is approached since a higher and higher proportion of the flock will be carrying two lambs, the identification of them has less and less significance. A small proportion of triplet-bearing ewes might benefit from early detection.

In general it can be seen that flocks with lambing percentages in the range 120-180% gain the greatest economic advantages from the early detection of foetal number. This is because the proportions of both single and twin-bearing ewes in these flocks are relatively high (i.e. proportions in the range 0.2-0.8).

Table 1

Calculation of feeding costs when foetal number detection has not been used

	proportion of flock in lamb type	
Lambing %age	single	twin
< 100	1.0	0.0
100-150	0.5	0.5
> 150	0.0	1.0

Table 2

Data used in Gross Margin calculations of 3 flock types

	Hill	Upland	Lowland
a) Production data			
Flock number	400	400	400
Lamb crop/ewe	5	4	4
Flock replacement	retained lambs	gimmers bought	gimmers bought
Ewe loss rate (%)	4-8	2.5-5	2-4
Barren rate (%)	10	8	8
Lambing (%)	80-120	120-160	160-200
Lamb losses (%)	4-8	3.4-6.7	3.4-6.7
b) Prices (£)			
per lamb	27.43	37.72	40.07
per cast ewe	30.00	28.00	29.00
Wool per ewe	2.10	2.50	2.72
Wool per hogg	2.30	-	-
Subsidy + premium	8.25	6.25	2.00
c) Costs (£)			
Late pregnancy feeding*	3.45	6.60	6.60
Other variable costs+	4.50	8.53	8.47
per gimmer	-	58.00	65.00

* Feeding a single-bearing ewe; twin = single x 1.5; triplet = single x 2.0.
\+ Cost of grazing not included - hoggs wintered at home.

Table 3

Potential savings for gross margin (£/ewe) following the detection of foetal number in a hill flock

base GM using: Ewe loss rate 8.0%
Lamb loss rate to weaning 8.0%

		Lambing %age				
		80	90	100	110	120
base GM		20.38	22.88	25.44	27.07	29.63
lamb loss	6%	-	0.54	0.55	-	-
	4%	-	-	-	1.24	1.31
ewe loss	6%	-	-	0.75	0.75	-
	4%	-	-	-	-	1.50
adjust feed		0.70	0.35	0.19	0.87	0.70
total		0.70	0.89	1.49	2.86	3.51

Table 4

Potential savings in gross margin (£/ewe) following the detection of foetal number in an upland flock

base GM using: Ewe loss rate 5.0%
Lamb loss rate to weaning 6.7%

		Lambing %age				
		120	130	140	150	160
Base GM		24.12	27.64	31.15	34.66	36.55
lamb losses	5%	-	-	-	-	-
	3.3%	1.50	1.60	1.78	1.89	1.99
ewe losses	4%	-	-	-	-	-
	2.5%	1.19	1.20	1.23	1.23	1.21
adjust feed		1.26	0.94	0.61	0.29	1.61
total		3.95	3.74	3.62	3.41	4.81

Table 5

Potential savings - Gross Margin (£/ewe) following the detection of foetal number in a lowland flock

base GM using: Ewe loss rate 4.0%
Lamb loss rate to weaning 6.7%

		Lambing %age				
		160	170	180	190	200
base GM		34.92	38.65	42.38	46.12	49.85
lamb loss	5%	-	-	-	1.29	-
	3.3%	2.13	2.27	2.42	-	-
ewe loss	4%	-	-	0.52	-	-
	2.5%	1.07	1.05	-	-	-
adjust feed		1.60	1.28	0.95	0.63	0.29
total		4.80	4.60	3.89	1.92	0.29

3. LACTATION AND LAMB GROWTH

Research objective : Determine the inter-relationships between milk intake, herbage intake and growth of lambs at pasture (project no. 307).

3.1. Lamb growth; milk and herbage intake

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

Much of the work previously carried out at HFRO has been devoted to factors affecting milk supply. Experiments described in the 1980 Annual Report (p.A9) and the 1981 Annual Report (p.A12) showed that the use of artificially reared (AR) lambs at pasture permitted close individual control of milk intakes without apparently disturbing grazing behaviour.

In 1982 an improved field system for controlling individual milk intake by AR lambs was used in a full scale trial.

The major objective of the trial was to determine any difference in herbage intake associated with pasture quality at comparable levels of milk intake and to investigate interaction between pattern of milk intake, herbage consumption and live weight gain.

It was proposed that 40 male lambs from one genotype would be used. In the event a lower than expected lambing percentage and disease problems resulted in the use of groups with mixed breed structure and reduced treatment numbers.

Four groups of lambs were offered either a sustained (S) or normal milk intake (N) pattern on each of 2 contrasting pasture types:-

1. Improved pasture - Ryegrass/clover at Eastrae (E)

2. Unimproved pasture - Agrostis/Festuca, at House o' Muir (HOM)

The first three weeks were designated as a training period.

The target mean peak daily milk intake was 2000 g/day for all groups. Achieved peak intake was 1910 and 1904 g/day for lambs on the improved pasture (E)-S and (E)-N respectively, in the fourth week. The lambs on unimproved pasture reached a lower peak intake one week later, 1793 (HOM)-S and 1506 (HOM)-N g/day.

By the 12th week when this phase of the experiment terminated, mean intakes had been reduced to 1363 and 200 g/day (E), 1392 and 200 g/day (HOM for S and N groups, respectively.

In the 4th week all male lambs were fitted with harnesses and faecal collection bags for daily collection on 4 days each week. Mean faecal dry matter output increased progressively to weaning at 12 weeks. Analyses of faecal nitrogen content will be used to estimate the digestibility of ingested herbage and to compare the changes in total DOMI associated with nutrient source.

The results of these analyses are not yet available.

The liveweight gain of each lamb is shown in relation to its total milk intake over the 12 weeks (Figure 1). These results differ from data obtained in previous years. Whilst weight gain is clearly dependent on total milk intake within both lactation groups, the lambs in the normal lactation group show a higher live weight gain per unit of milk intake.

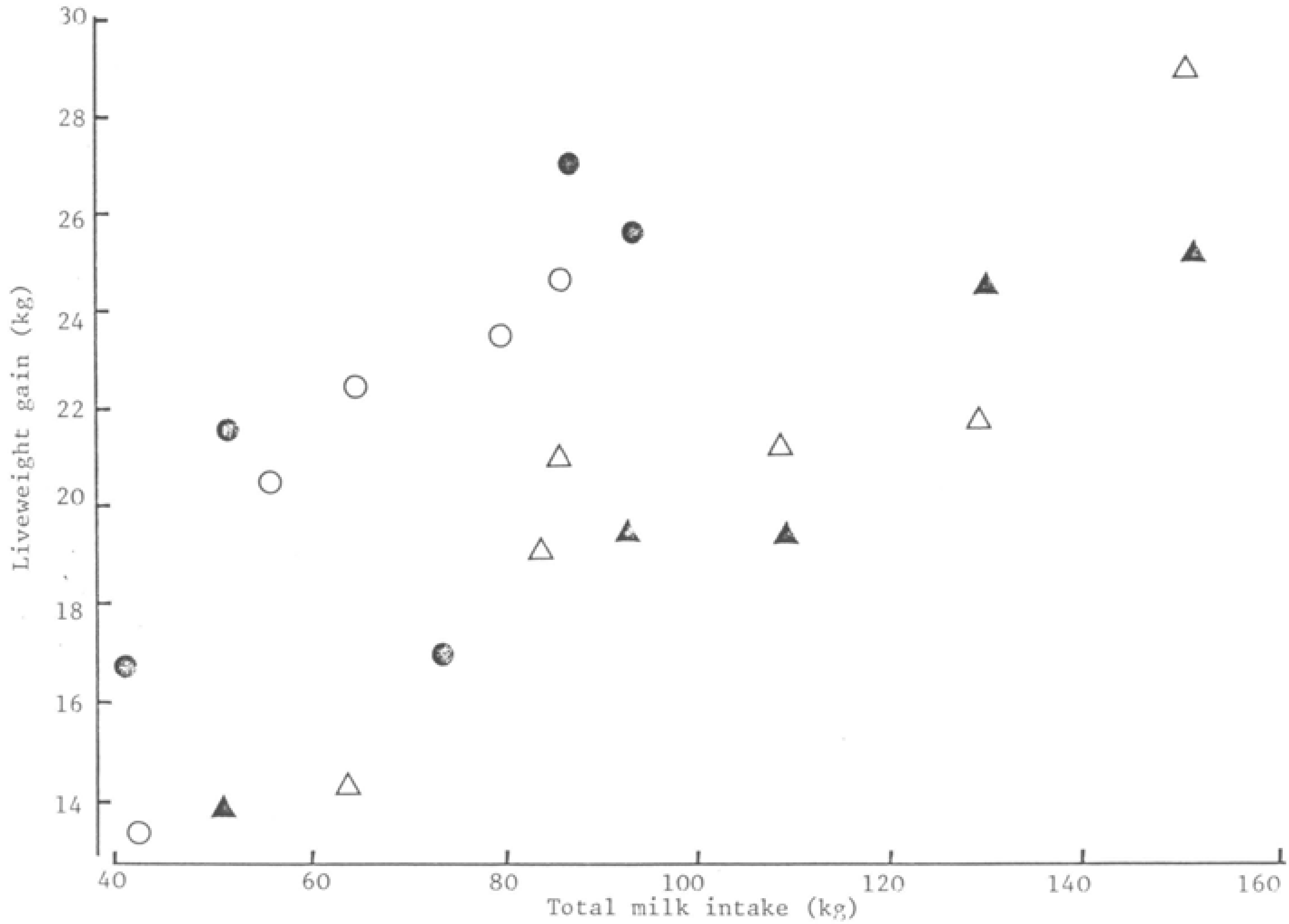


Figure 1. Individual lamb liveweight gain/total milk intake over 12 weeks

Eastrae-S ▲ HOM-S △

Eastrae-N ● HOM-N ○

Research objective: Define the endocrine status of lactating ewes in relation to milk production and changee in body composition (project no. 308).

3.2. Levels and pattern of milk supply of lactating ewes in relation to lamb demand and endocrine status as affected by season

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

During the early part of lactation a ewe produces milk at the expense of her own body tissue. This continues until a peak is reached and thereafter milk production declines as the ewe directs a greater proportion of nutrients towards her own body reserves. Work has shown that the level of milk production achieved during a particular lactation is influenced by the suckling intensity imposed by the lambs. It is well known that the lactation cycle is controlled hormonally, although the mechanisms by which this control is achieved is still under investigation.

It is the aim of this work to investigate the physiological mechanisms controlling milk production and the partitioning of nutrients throughout lactation by examining the hormone status of the ewe and relating this to body composition changes and milk yield at three stages of the year, with ewes lambing in October, January and April. It is hoped that the differing levels of prolactin associated with season will assist with the interpretation of other endocrine differences in relation to changes in nutrient partitioning.

The first experiment in this series has been completed. Ewes lambing in October were divided into two treatment groups, those rearing singles and those rearing triplets. These groups were achieved by cross fostering of lambs at birth. All ewes were fed at a fixed level of 3.5 kg dried grass, regardless of body size or number of lambs reared. Milk production, condition score and liveweights were recorded each week. Once a week blood samples were collected every 20 minutes for 2 hours before feeding in order to determine the overall change in the levels of hormones and blood metabolites throughout lactation. At three stages of lactation, approximately 2, 4 and 9 weeks after the onset of lactation, blood samples were collected every 15 minutes for 8 hours. This should give a detailed description of the pattern of hormone release at the various stages of lactation. The results of the experiments to date are summarised in Table 1. Analysis of insulin, cortisol, prolactin, growth hormone, thyroxine, tri-iodothyronine and blood metabolites are in progress.

Table 1

Summary of milk yield, milk composition, ewe liveweight and condition score change.

	Treatment	
	Single	Triplet
Peak milk yield kg	1.940	3.760
Milk fat %	7.9	7.8
SNF %	11.9	11.7
Ash %	0.90	0.88
Ewe liveweight change g/day		
Weeks 1-4	-100	-405
Weeks 4-9	+146	+ 17
Ewe condition score		
Week 1	2.67	2.44
Week 4	2.67	2.11
Week 9	2.75	2.17

The results show that an increase in the number of lambs reared causes an increase in milk production. This is achieved by metabolism of body reserves as indicated by the relative change in body weight and condition between the two groups. The majority of animals in the triplet group did not complete the experimental period due to teat damage perhaps caused by excessive demand of the lambs. In the second stage of the experiment, now in progress, ewes lambed in January with twin lambs being used instead of triplets in an attempt to avoid this problem. Twins verus singles will be used in the subsequent experiments in this series with ewes lambing in April and October 1983.

4. GENOTYPES

Research objective: Study the effectiveness of improved genotypes of hill sheep in utilising better hill pastures

4.1. Comparison of the performance of Blackface and crossbred ewes in improved hill conditions

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

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 genotypes, Border Leicester x Blackface and Texel x Blackface, with the pure bred Blackface ewes.

A summary of the lambing performance of the Finella flocks was given for 1976-1981 in last years Annual Report. The performance results from 1982 are given in Tables 1 and 2 which show the pre-mating weights of each age and breed group of ewes (November 1981), the number of lambs and the weaning weights of lambs by genotype. No Blackfaces were bed pure this year. A third were mated to Texel, a third to the Border Leicester and a third to the Dorset Down. All the cross-breds were mated to the Dorset Down.

The lambing performance for the cross-bred flocks was less than in previous years and also less than the Blackface flocks for the first time since 1976. This was associated with a lower liveweight at pre-mating.

The Dorset cross lambs were of a similar weight from all three breeds of ewe.

Table 1

Mean ewe bodyweights (kg)

BREED	Premating November 1981					Weaning, August 1982				
	Mid Finella		West Finella		Mean	Mid Finella		West Finella		Mean
BLACKFACE										
Born 1976	-		53.0	(1)	53.0	-		50.0	(1)	50.0
1977	63.9	(13)	55.8	(7)	61.1	56.5	(13)	46.4	(7)	53.0
1978	58.4	(25)	53.7	(21)	56.3	55.2	(22)	45.1	(19)	50.5
1979	55.9	(21)	50.1	(26)	52.7	54.2	(18)	46.7	(26)	49.8
1980	50.3	(21)	41.2	(22)	45.6	50.1	(22)	45.2	(22)	47.6
ALL AGES	56.5	(80)	49.1	(77)	52.9	53.7	(75)	45.9	(75)	49.8
TEXEL x BLACKFACE										
Born 1976	-		-		-	-		-		-
1977	59.6	(10)	57.3	(5)	58.8	60.4	(8)	40.7	(3)	55.0
1978	58.0	(10)	56.3	(9)	57.2	56.3	(10)	51.1	(9)	53.8
1979	56.3	(10)	53.1	(11)	54.6	58.2	(10)	55.2	(11)	56.6
1980	51.5	(11)	47.6	(12)	49.5	55.8	(11)	47.9	(12)	51.7
ALL AGES	56.2	(41)	52.7	(37)	54.5	57.5	(39)	50.4	(35)	54.1
BORDER LEICESTER x BLACKFACE										
Born 1976	-		-		-	-		-		-
1977	66.2	(10)	58.7	(6)	63.4	61.0	(8)	47.0	(5)	55.6
1978	62.0	(11)	58.9	(8)	60.7	64.6	(11)	54.2	(8)	60.2
1979	60.1	(6)	52.0	(8)	55.5	58.4	(5)	54.9	(7)	56.4
1980	53.1	(10)	43.5	(10)	48.3	57.8	(10)	50.0	(10)	53.9
ALL AGES	60.4	(37)	52.3	(32)	56.6	60.9	(34)	51.8	(30)	56.6

Table 2

Mean lamb bodyweights (kg) with lambing and weaning percentages

Genotype		Ewes to tup	Lambs born	Lambing %	Combined lambing %	Heft	Weaning weight	Combined weaning wt.	Lambs weaned	Weaning %	Combined weaning %
Dam	Sire										
BF	Texel	27 27	38 34	140.7 125.9	133.3	MF WF	27.4 23.1	25.3	36 (2) 33 (2)	133.3 122.2	127.8
BF	B. Leic.	28 25	37 33	132.1 132.0	132.1	MF WF	29.4 25.0	27.2	34 (2) 31	121.4 124.0	122.6
BF	Dorset Down	26 25	37 30	142.3 120.0	131.4	MF WF	29.7 24.8	27.5	35 (4) 28 (2)	134.6 112.0	123.5
Texel x BF	Dorset Down	41 37	42 40	102.4 108.1	105.1	MF WF	29.9 27.5	28.8	42 (3) 38 (4)	102.4 102.7	102.6
B. Leic. x BF	Dorset Down	37 32	40 29	108.1 90.6	100.0	MF WF	29.0 25.6	27.7	39 (1) 28 (3)	105.4 87.5	97.1
TOTALS		159 146	194 166	122.0 113.7	118.0	MF WF	29.1 25.2	27.3	186 (12) 158 (11)	117.0 108.2	112.8

5. LAMB FINISHING

Research objective : Growth and body composition of lambs on grass or forage crops in relation to intake and growth before weaning (project no. 309)

5.1. Finishing of lambs on forage crops

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

A preliminary trial of the effect of a number of factors (type of crop, stocking rate, breed of lamb, sex, type of rearing and weight and condition at weaning etc.) on the finishing of lambs on forage crops was carried out at Hartwood in 1981 (Ann. Rep. 1981, p.A23).

In 1982 two of these factors - live weight at weaning and treatment between weaning and introduction to forage crop - were examined in greater detail using castrated male lambs of a single breed (Blackface) and a single type of forage crop (rape). In the preliminary trial many lambs remained unfinished when the crop was used up and they required a further period of concentrate feeding. It was decided to introduce some form of supplementary food during the forage crop period as a third factor in the 1982 trial.

At weaning in August a group of 252 Blackface lambs were selected from two farms, Glensaugh (Gl) and Lephinmore (Le), in two weight classes, 18-22 kg (L) or 27-32 kg (H). On transfer to Hartwood they were allocated, within farm of origin and weight classes, to one of four groups to receive two levels of pre-forage crop treatment and two levels of supplement during the crop grazing period.

Pre-forage crop treatment. Two pasture types were provided; a good quality aftermath with a high herbage mass and a low quality pasture wth a low herbage mass. These were intended to provide, respectively, a high rate of liveweight gain (G) or maintenance of existing liveweight (M). The lambs remained on these pastures for 6 weeks.

Forage crop treatent. In October the lambs were transferred to 6 ha of rape fenced into 6 x 1 ha replicates. Initial forage mass on each replicate was measured and the number of lambs for each was determined on the basis of uniform availability of forage per head. One group of lambs (randomly allocated to 3 replicates) was offered up to 400 g/day/head of a rolled barley supplement (S) and the second group (3 replicates) were given no supplement (N). Despite bringing the lambs of the S group to the feeding troughs daily, the full allowance of supplement was never consumed, maximum intakes being 100 g/day. The mean forage crop mass when the lambs were transferred was estimated as a little over 4 tonnes DM/ha (as compared with 4.8 t/ha in the previous year). This gave an individual initial allowance of around 100 kg DM/head.

Lambs were weighed and condition scored at weekly intervals and were sent for slaughter on reaching the set criteria of a minimum weight (37.5 kg) and condition score (2.75). All carcasses were individually weighed and graded after slaughter.

Forage crop mass was measured 3 weeks after introduction of the lambs and again, 4 weeks later, when the crop was considered as exhausted. The results are shown in Table 1. There was considerable variation amongst replicates.

Table 1

Mean forage crop mass (kg DM/ha) and individual allowance (kg DM/lamb) of supplemented and unsupplemented groups at start of grazing after 3 weeks and at end of crop (7 weeks)

	Supplement group		Non-supplement group	
	Mass	Allowance	Mass	Allowance
Pre-stocking	4171	99.5	4180	99.6
3 weeks	2377	59.1	2185	54.8
End of crop	954	26.9	965	30.6

The lambs were removed for slaughter when they reached the set criteria of weight and condition. No lambs finished in the first 6 weeks before introduction to the forage crop. By the end of the forage crop period only 44 lambs (17.5%) were finished to the required standard. All lambs sent for slaughter were graded and classified, mainly, as 3L. Table 2 shows the distribution of the finished lambs according to the 4 treatment classifications.

Table 2

Number and percentages of lambs finished by end of forage crop

a) Farm of origin	Glensaugh (Gl)	Lephinmore (Le)
No.	11	33
%	9.7	23.9
b) Initial weight class	Light (L)	Heavy (H)
No.	1	43
%	0.8	33.3
c) Pre-crop treatment	Maintenance (M)	Gain (G)
No.	14	30
%	11.4	23.4
d) Supplement level	No supplement (N)	Supplement (S)
No.	21	23
%	16.7	18.4

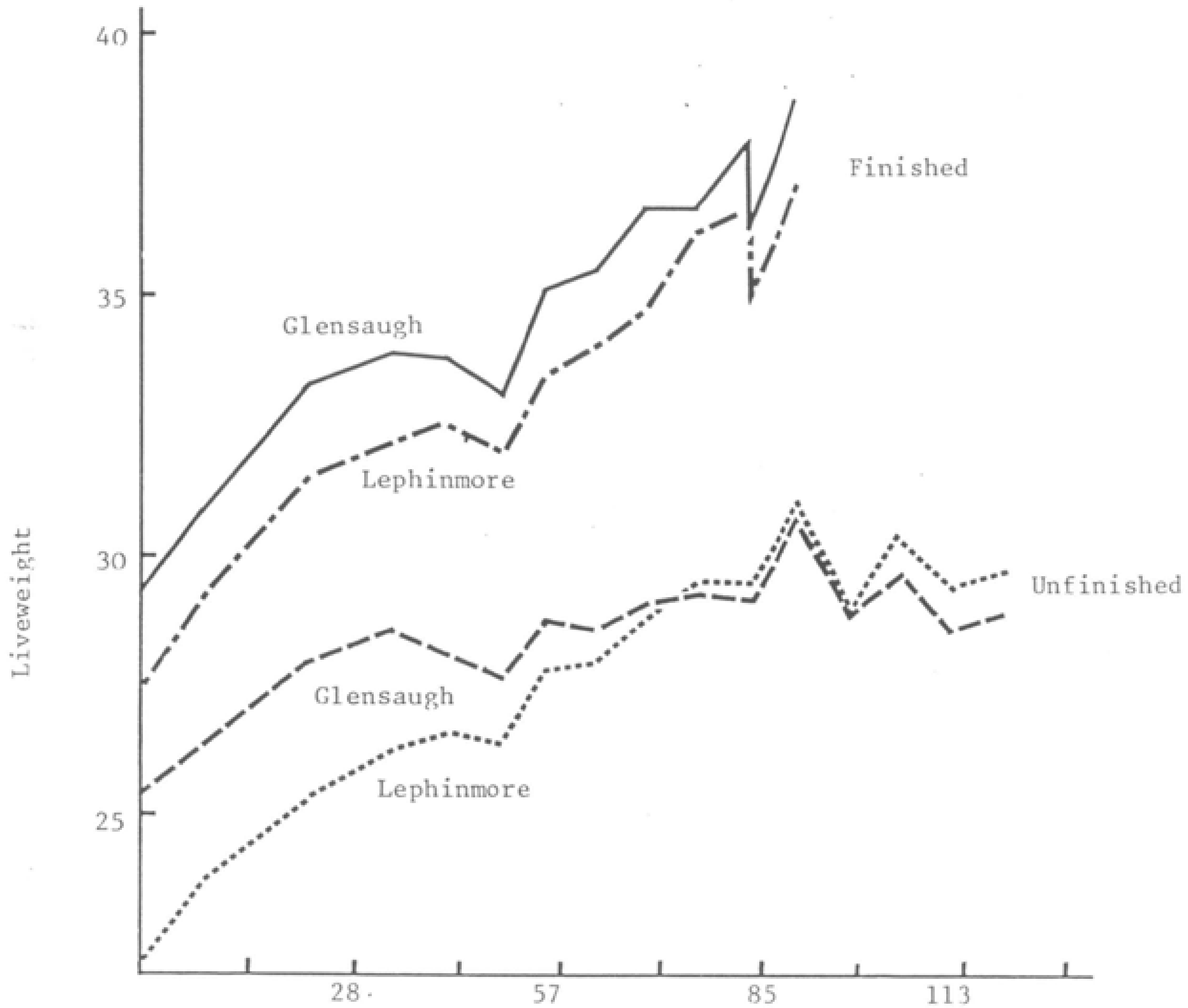


Figure 1. Liveweight of finished and unfinished lambs

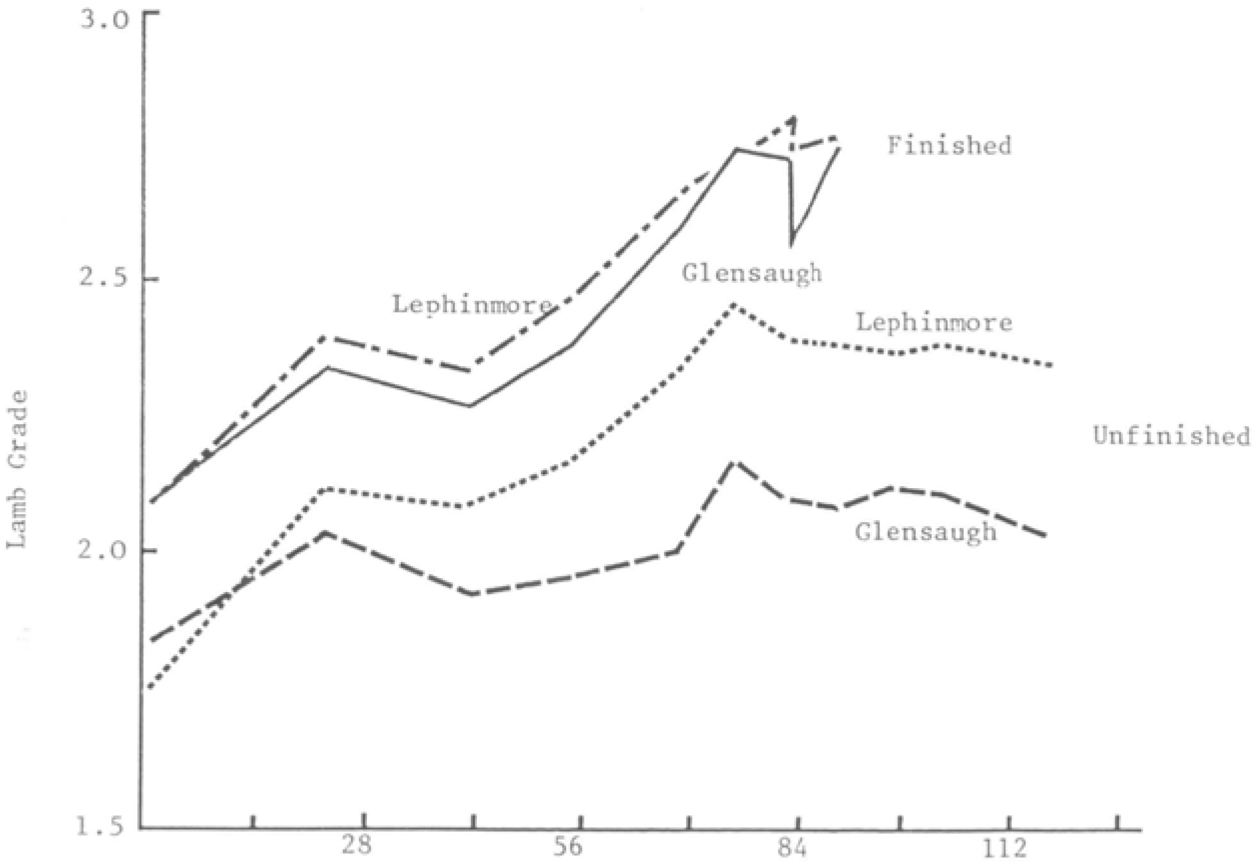


Figure 2. Body condition scores of finished and unfinished lambs

It can be seen that a much higher proportion of lambs from Lephinmore were finished as compared with those from Glensaugh despite a lower initial mean weight (23.3 and 25.8 kg, respectively, for L and G lambs). This result may reflect differences in mature weight of the two types of Blackface sheep; at Lephinmore the ewe flock has been bred to rams of the Lanark and Newton Stewart types whilst at Glensaugh, the flock is derived from the larger, Perth type.

Not surprisingly, all but one of the finished lambs came from those in the heavier initial weight group (H) but even in this group only one third of the lambs were finished. Pre-crop treatment had some effect, with more than twice as many lambs from the live-weight gain treatment (G) being finished as compared to the maintenance group (M) despite the fact that differences in live-weight gain during the pre-crop treatment were not as great as intended (3.6 kg and 2.6 kg, respectively, for G and M groups). Finally, there was no difference in the numbers of lambs finished in the supplemented or unsupplemented groups. This is probably a reflection of the low intake of supplement by the lambs to which it was offered.

Analysis of liveweight and condition score of unfinished lambs at the end of the crop period showed that these originating from Glensaugh were heavier than those from Lephinmore (29.8 ± 0.55 and 28.9 ± 0.37 kg, respectively) but had significantly lower condition scores (2.03 ± 0.043 and 2.35 ± 0.034, respectively). Irrespective of liveweight 66% of Glensaugh lambs were below 2.5 in condition score compared with only 29% of Lephinmore lambs.

Mean liveweights and condition scores throughout the whole period are shown in Figs. 1 and 2, respectively, according to farm of origin. These results all suggest that lambs of the strain represented by Glensaugh, being of higher potential mature size, were able to increase in weight but could not put on condition as rapidly as the Lephinmore lambs. It appears that the latter lambs, with lower potential mature size, reached the finishing phase of growth at relatively lower liveweights.

These facts have implications for the allocation of lambs of different strains and liveweights to different finishing systems and, indeed, for the pre-weaning treatment of the different strains.

5.2. Finishing systems for Blackface lambs

T.J. Maxwell, D. McFarlane and A.R. Sibbald

The objective of this study was to investigate the finishing attributes of Scottish Blackface lambs from the Isle of Lewis, and provide the Highlands and Islands Development Board with objective information on animal performance and financial costs and returns in relation to its involvement in lamb marketing co-operatives.

Four hundred and fifty lambs were selected from the Isle of Lewis at the beginning of September and grazed on grass until they started their finishing treatment. Lambs were allocated to systems which aimed to (i) finish the lambs by Christmas; (ii) finish lambs by end of February; (iii) finish lambs March/April. This report concerns the lambs from group (i) only.

The health status of the lambs was established at the start and during the period of the study. The programme of preventive medicine and the results of veterinary examination are reported under a separate heading on page 38.

The lambs were finished on three treatments as follows:

(i) Grass then rape (77 lambs)

(ii) Grass then rape + barley supplement (70 g/day) (78 lambs)

(iii) Grass then housed and given 920 g/head/day of a dried grass/lucerne/sugar beet pulp pellet (78 lambs)

All lambs stocked on rape were given an allowance of 120 kg DM/lamb. A fourth group of lambs for comparison from the Pentlands (House o' Muir Research Farm, HFRO) was stocked on rape only, i.e. equivalent to group (i).

Tables 1, 2 and 3 summarise the physical performance of each group of lambs from arrival to slaughter and Table 4 summarises the gross margin analysis on a per 100 lamb basis for each 'finishing' system.

The initial weights of the HIDB lambs were slightly less than the Pentland lambs and they were less fat. The mean weight at slaughter was similar for all groups, as was the carcass weights. The lambs finished earliest on rape only, then rape + supplement and lastly from the shed. The proportion 'finished' before Christmas was highest from the House o' Muir lambs on rape (87%) then HIDB lambs on rape (Table 3). Table 3 also shows that the initial mean weight of HIDB lambs arriving at Hartwood and which finished before Christmas was a little over 1 kg greater than those which didn't finish. The difference, across all treatment groups including House o' Muir lambs was 1.6 kg which was significant ($P < 0.001$). This confirms earlier conclusions that Blackface lambs have to be at least 27 kg in weight and condition score 2.0 on arrival at the farm in September if they are to finish before Christmas.

The gross margin analysis shows that rape only was the most profitable system and more so for HIDB lambs on rape only but only because they were bought more cheaply as stores, 61 p/kg as compared to 81 p/kg.

Carcasses have been graded 3L and 3H on the MLC classification. Sample carcasses from each of the groups will be dissected fully to assess tissue composition at slaughter. An initial slaughter group (slaughtered as stores on arrival) was used to provide an estimate of body composition at that time.

Table 1

Early Finished Lambs

	HIDB	HIDB	HIDB	HoM
	Grass then rape	Grass then rape+ barley	Grass then housed, green keil	Grass then rape
Nos. lambs	77	76	77	30
Initial weight (kg)	26.4(0.27)	26.7(0.29)	26.6(0.29)	27.9(0.57)
Weight of grass (kg)	29.0	29.4	28.6	29.2
Initial condition score	1.99(0.02)	1.96(0.03)	2.00(0.02)	2.12(0.03)
Days to slaughter (from 14.9)	97 (1.2)	100 (1.4)	108 (1.5)	96 (1.8)
Slaughter liveweight (kg)	33.9(0.31)	33.4(0.30)	33.5(0.37)	33.1(0.60)
Slaughter condition score	2.57(0.02)	2.49(0.02)	2.43(0.02)	2.56(0.04)
Gain - grass (kg)	2.6	2.7	2.0	1.3
Growth rate g/d)	72	75	56	36
Gain - 'finishing' system (kg)	4.9	4.0	4.9	3.9
Growth rate g/d	80	63	68	65
Total gain (kg)	7.5	6.7	6.9	5.2
Growth rate g/d	77	67	63	54
Carcass weight (kg)	14.3(0.16)	14.4().17)	14.3(0.16)	14.4(0.38)
Killing out (%)	42.2(0.29)	43.0(0.31)	42.7().25)	43.3(0.51)
Food conversion kg fresh food/kg gain group basis			12:1	
Gross Margin per lamb	£7.08	£6.20	£0.33	£3.82

Table 2

Liveweight gain on treatment - main finishing period (i.e. 42 days (g/day)

First 14 days	-10	-16	-5*	-15
Second 14 days	186	243	164	257
Third 14 days	164	150	78	157

Table 3

Number, initial mean weight (kg on arrival at Hartwood) and condition score of lambs finished before Christmas on treatment and those finished after Christmas

		Before Christmas	After Christmas
HIDB Rape	Nos.	62 (79%)	15
	kg	26.6	25.6
	CS	2.00	1.94
HIDB Rape + suppl.	Nos.	52 (67%)	24
	kg	27.2	25.5
	CS	2.02	1.82
HIDB Shed	Nos.	33 (43%)	44
	kg	27.4	26.0
	CS	2.05	1.96
House o' Muir Rape	Nos.	26 (87%)	4
	kg	28.5	24.3
	CS	2.13	2.10
All lambs	Nos.	173 (66%)	87
	kg	27.3	25.7
	CS	2.04	1.92

Table 4

Early finished lambs : Gross margin analysis per 100 lambs

	HIDB	HIDB	HIDB	HoM
	Grass then rape	Grass rape+ suppl.	Housed Green Keil	Grass then rape
Output				
Fat lambs*	2728	2726	2746	2813
less store lambs**	1614	1614	1614	2025
	1114	1112	1132	788
Variable costs	£	£	£	£
Veterinary costs (Flukamide + vaccine)	50	50	50	50
Transport and levy	65	65	65	65
Grazing (25p/lamb)	25	25	25	25
Rape (£105/ha)	266	262		266
Barley (£105/t)		35		
Green Keil (£145/t)		54	902	
Hay (£65/t)			58	
Total variable costs	406	491	1100	406
Gross margin	708	621	32	382
Per ha (Rape)	279	248	-	150
Per Lamb	7.08	6.2	0.32	3.82

* There were only very small differences in price of lamb per kg which averaged £1.95 per kg.

** HIDB lambs bought for £0.61 per kg
House o' Muir lambs bought for £0.81 per kg

Veterinary aspects

A. Whitelaw, A.R. Fawcett and I.A. McDonald

The study included an examination of the health status of the lambs on arrival and at entry to the trial, and the construction of a veterinary health programme. Health surveillace continued during the trial and examination of representative numbers of lambs was carried out at slaughter.

An initial sampling on arrival for the following parameters was carried out. Packed cell volume (PCV) expressed as a percentage, Gluthathione peroxidase (GPSX) expressed as units per ml of red blood cells, plasma copper concentrations (Cu) expressed as micrograms per 100 ml, Serum Vitamin B_{12} concentrations (B_{12}) expressed as picograms per ml, and Serum Glutamic oxaloacetic transaminase estimations (SGOT) expressed as units per litre.

Faeces samples were examined for worm egg counts, WEC p.g. and for the presence of fluke eggs (Fl). The results are presented in Table 1.

Table 1

Normal range	28-30	> 42	60-160	400	< 60		
	PCV	GPSX	Cu	B_{12}	SGOT	WEC	Fl
$\bar{m}$	33.3	26.1	79.2	929	86	286	-

A group of lambs selected for slaughter at the commencement of the trial provided both pre-slaughter and post-slaughter data.

Prior to slaughter blood samples were taken for biochemical analysis and serological examinations. Plasma copper concentrations, Gluthathione peroxidase concentrations, serum vitamin B_{12} estimations are expressed as in Table 1, Plasma pepsinogen concentrations (PEP) are expressed as international units/litre. Serum Calcium Magnesium and Phosphorus estimations, Ca, Mg and P are expressed as millimoles per litre.

Serological examinations were carried out for louping-ill (L.I.) and Parainfluenza$_3$ Virus (PI_3). Faeces samples were examined for worm eggs expressed as worm eggs per gram (WEC) and for the presence of liver fluke (Fl) + or -. In addition pooled heparinised blood was injected into susceptible lambs to check for evidence of Tick-borne fever infection. Table 2 shows the mean values obtained.

Table 2

Normal Range	42 GPSX	2.1-2.8 Ca	0.78-1.3 Mg	0.9-2.5 P	400 B_{12}	0.2-0.4 PEP	60-160 Cu	WEC
m HIDB (15)	16.5	2.6	1.05	2.17	275	0.41	98	267
m HOM (6)	17.0	2.4	1.02	2.48	206	0.32	110	875

	L1	Pl_3	F1	TBF
HIDB	-	-	-	+
HOM	-	1/6 AT 1/16	-	-

A post mortem examination of these lambs was subsequently carried out on viscera; intestinal tract, (total worm counts), the liver, which was examined for pathological changes, the lungs, which were examined for evidence of respiratory disease, and the kidneys which were examined for pathological changes.

Table 3 tabulates the findings.

Table 3

	$\bar{m}$ Abomasal worms	$\bar{m}$ Small intestine worms
HIDB(15)	3572	786
HOM(6)	966	616
	Number with evidence of lung lesions	
HIDB(15)	6/15	
HOM(6)	3/6	
	Number with evidence of liver lesions	
HIDB(15)	12/15	
HOM(6)	0/6	
	Number with evidence of kidney lesions	
HIDB(15)	0/15	
HOM(6)	0/6	
	Number with cardiovascular lesions	
HIDB(15)	1/15	
HOM(6)	0/6	

The range of abomasal worm counts was 13,700 to nil in the HIDB lambs and 3,700 to nil in the HOM lambs. The range of intestinal worm counts was 1,800 to nil in the HIDB lambs and 1,400 to nil in the HOM lambs. The presence of Haemonchus contortus in the HIDB lambs contrasted with their absence in the HOM lambs. Ostertagia circumcincta was the predominant abomasal parasite in both HIDB and HOM lambs and Trichostrongylus vitrinus was the predominant worm in the small intestine.

Lung lesions were evident in lambs of both groups, showing non suppurative consolidation of varying numbers of lobes. Liver lesions were present only in the HIDB lambs and showed two pathological forms (i) small microabscesses present in the subcapsular tissue, showing calcification and believed to be associated with tick pyaemia; (ii) invasive tracts in the subcapsular tissue indicative of invasion by immature liver flukes.

These findings were used as a basis for the construction of a veterinary health programme.

In summary the initial findings were of normality of plasma copper concentrations, a low parasite burden, depressed selenium levels and adequate vitamin B_{12} levels. The findings in the group selected for slaughter, from the pre- and post- slaughter examinations confirmed an adequate copper, calcium, magnesium and phosphorus status, low selenium and vitamin B_{12} status, moderate worm burdens, no evidence of adult fluke burdens but evidence of migrating immature flukes. The occurrence of previous exposure to tick infestation was indicated by the positive tick-borne fever transmission and the presence of microabscesses in the liver probably resulting from tick pyaemia. The evidence of respiratory disease in some of the lambs was confirmed by histopathology to be of atypical pneumonia suggesting a viral/microplasma origin and there was additional evidence of parasitic insult such as Muelleris species.

The health programme which was instituted was as follows:

(i) Primary and secondary clostridial vaccination six weeks apart (Covexin, Wellcome Laboratories).

(ii) All lambs dosed with fenbendazole with Selenium and Cobalt (Panacur, S.C. Hoechst U.K.) thereafter at monthly intervals.

(iii) All lambs dosed twice with rafoxanide (Flukanide, MSD Agvet) at a six-week interval. This was instituted because of the findings at slaughter of damage by invading immature liver flukes.

(iv) All lambs were given 2 g cupric oxide needles because previous experience had shown the tendency of lambs folded on rape to become hypocupraemic.

(v) Lambs were also dipped to remove ectoparasites, and run through a footbath.

(vi) Subsequent to the introduction of a new pasteurella vaccine (Ovipast, Hoechst) all lambs were vaccinated during the trial.

(vii) Monitoring. In October sera from 408 lambs were stored for future reference.

In November samples taken from representative lambs on different treatments showed satisfactory elevations of their selenium and vitamin B_{12} status and continuance of adequate copper status. Faeces samples were negative for worm egg counts. In January 1983 further sera were taken from the lambs to constitute 'paired' samples with those taken in October 1982.

The losses at the time of writing have been very low, two due to trauma and four from other causes not investigated, out of a total of over 400 lambs.

Examinations of finished lambs at slaughter. Because of difficulties that might arise when examinations interfere with production line slaughter the results of these are of a general nature.

On 12.1.83, an examination of the viscera of 60 HIDB lambs at slaughter; the results are summarised in Table 4.

Table 4

Lesions liver	7/60
Lesions lungs	18/60
Lesions both organs	21/60
No lesions	15/60

The lesions were similar to those found at the initial slaughter, i.e. consolidated lesions in the lobes of the lung and calcified microabscesses in the liver.

Lungs from lambs undergoing carcass evaluation have been sent for histopathological examination and the results will be linked with paired sera examinations. As a general comment the extent of lung consolidation present in a proportion of lambs could be considered capable of affecting growth rates adversely. The liver lesions would have a minimal effect, most being calcified.

The low mortality of 1.3%, including two animals from trauma, reflects upon the effectiveness of the veterinary programme, which in turn was based on the initial screening procedures indicating potential problems.

6. MINERAL NUTRITION

Research objective: Investigate methods of preventing hypocuprosis and cobalt deficiency in sheep (Project No. 313)

6.1. Further studies on the use of cupric oxide needles in the prevention of hypocuprosis

A. Whitelaw, R.H. Armstrong, E. Skedd, A.R. Fawcett, A.J. Macdonald and J. Mackenzie

6.1.1 A study of hypocuprosis in South Country Cheviot lambs grazing reseeded pasture

Previous studies (Whitelaw et al, 1983) indicated that the induced hypocuprosis producing ill-thrift, manifesting particularly in poor fleece quality and inferior liveweight gain initially seen in Scottish Blackface lambs (Whitelaw et al, 1979) would also affect lambs of the South Country Cheviot breed. Weiner et al (1969) demonstrated differences in copper status between the Scottish Blackface, Cheviot, Welsh Mountain breeds and their crosses. In 1982 a study was undertaken using South Country Cheviot lambs grazing the improved reseeded pastures at Alderhope and Fasset. The objective was to examine the degree to which this breed was affected by induced hypocuprosis.

Twin-bearing ewes (30) and their lambs (60) were introduced to the pasture just after lambing. Twin lambs were balanced by birth weight and sex and one twin received oral cupric oxide needles (1 g) whilst its sibling was untreated.

Table 1

Mean plasma copper concentrations μg/100 ml

	13/5	3/6	1/7	11/8
Treated lambs	66.2	104.4	95.2	80.2
Control lambs	62.5	53.1	32.8	18.5
Ewes	50.2	68.6	49.2	36.0

Table 2

Weight gains Marking-Weaning kg

Treated lambs	15.84
Control lambs	15.51

Table 3

Copper concentrations mg/kg DM

Treated lambs	593.8
Control lambs	19.8

The degree of hypocupraemia encountered in the control lambs was less than has been consistently seen in Blackface lambs in previous studies. The difference in liveweight gains between treated and control lambs was also of a lower order than previously experienced with Blackface lambs and whilst the liver copper values of the control lambs were deficient this was not so marked as in previous years. However the liver copper values of the treated lambs were very satisfactory. Certain reservations must be made about this study. Because the area of new reseed created for copper studies was limited in this year a comparison between South Country Cheviot and Scottish Blackface lambs in the same year in sufficient numbers was not possible. The indications are that the rate of depletion of copper reserves in the South Country Cheviot breed produced by molybdenum and sulphur induced copper deficiency is less marked than in the Scottish Blackface. This would accord with a recent study (Woolliams and others, 1982) where the authors examined the accretion of copper in the liver in a range of breeds. A further study using sufficient numbers of both Cheviot and Blackface lambs in the same season is indicated and the increase in reseeded area available for copper studies in 1983 should enable this to be done.

References

Weiner, G. et al (1969). The concentration of minerals in the blood of genetically diverse groups of sheep. I: Copper concentration at different seasons in Blackface, Cheviot, Welsh Mountain and crossbred sheep at pasture. Journal of Agricultural Science, Cambridge 72, 93-101.

Whitelaw, A. et al (1979). A study of the effects of copper deficiency in Scottish Blackface lambs on improved hill pasture. Veterinary Record 104, 455-460.

Whitelaw, A. et al (1983). Use of cupric oxide needles in the prophylaxis of induced copper deficiency in lambs grazing improved hill pastures. Veterinary Record 112, 382-384.

Woolliams, J.A. et al (1982). The effect of breed of sire on the accumulation of copper in lambs, with particular reference to copper toxicity. Animal Production 35(2), 299-307.

6.1.2 Evaluation of cupric oxide needles on commercial farms

Assistance was given in the implementation of two trials to evaluate the effectiveness of a commmercial cupric oxide needles capsule.

One site did not have a copper problem (although the owner stated that he had)! The capsules were well tolerated and no problems ensued. No differences between treatment and control lambs were observed.

The second site had lambs exhibiting typical ill-thrift related to land improvement and characterised by severe hypocupraemia in the lambs at the onset of the trial. Treated lambs showed benefits in fleece texture, liveweight gains, plasma and liver copper values compared with control lambs which continued to exhibit ill-thrift, severe hypocupraemia and at slaughter deficient copper levels. There were no problems with the administration of the commercial capsules and the farmer was enthusiastic about the response obtained.

6.1.3 Use of cupric oxide needles for the prevention of swayback in lambs

Following the demonstration in 1981 of the value of administering cupric oxide needles (4 g) to ewes in mid-pregnancy to prevent the occurence of swayback in their offspring, a further study was carried out in 1982 to look at the administration of cupric oxide needles in the pre-tuppng period, thus utilising the long term response obtained with this therapeutic agent.

Group 1 Ewes (28) were given 4 g cupric oxide needles in the pre-mating period (13 November 1981).

Group 2 (28) Ewes were given 4 g cupric oxide needles during pregnancy (11 February 1982)

Group 3 Ewes received no copper.

All ewes were confined on the improved pasture used in the 1981 study. On 13/11/81 samples were taken from ewes in Group 1 as being representative of all three groups. On 11/2/81 samples were taken from Group 1 ewes and from Group 2 ewes the latter being representative of groups 2 and 3.

Table 1

Mean plasma copper concentrations μg/100 ml

	Group 1 Ewes	Group 2 Ewes	Group 3 Ewes
13/11/81 Pretupping	43.0	43.0	43.0
11/2/82 Mid-pregnancy	97.8	51.1	51.1
8/6/82 'Marking'	70.4	95.2	26.8
	Group 1 lambs	Group 2 lambs	Group 3 lambs
8/6/82 'Marking'	71.0	90.0	44.9
	No Swayback	No Swayback	3 cases 'Delayed Swayback'

The results show that Group 1 ewes given cupric oxide needles in the pretupping period were normocupraemic both in mid-pregnancy and at the marking gather approximately 1 month after parturition. Group 2 ewes were normocupraemic at the marking gather whilst Group 3 ewes were hypocupraemic at all three sampling dates and were severely hypocupraemic at the marking gather, i.e. approximately 1 month post lambing.

The lambs from Group 1 and 2 were normocupraemic, with the group 2 lambs having a higher plasma copper concentration, reflecting the shorter interval since the administration of copper to their dams. Group 3 lambs from undosed ewes were hypocupraemic and 3 clinical cases of delayed swayback occurred in this group.

The results must be seen against a low swayback incidence forecast. December 1981 and January 1982 had high snow cover necessitating feeding. This is reflected in the slighter higher mean plasma copper concentrations of the group 2 and 3 ewes in February. The influence of feeding because of snow cover would reduce the number of potential swayback cases from the group 3 ewes. However the results do indicate that the longevity of response obtained with cupric oxide needles should allow these to be administered at an earlier period than pregnancy when most parenteral copper compounds are administered.

7. NUTRITION SUPPLEMENTATION AND METABOLISM

Programme Unit 6: Effect of nutrient supply and supplement on the digestion, metabolism and performance of grazing sheep.

Research objective: Establish the amount, type and method of feeding of the supplement to give ewes in mid-pregnancy grazing different vegetation types.

7.1 The effect of method of feeding and the type of the supplement given to ewes grazing a predominantly heather hill in mid-pregnancy

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

In two previous experiments (Ann. Rep. 1980 p.A38 and 1981 p.A41) mid- pregnancy supplementation was found to increase birthweight by approximately 10% even though the ewes were fed adequately in late pregnancy. In the experiment reported here a comparison was made again between supplementation and when no supplement was given in mid-pregnancy. Each treatment was replicated twice. In previous years a conventional supplement was given in late pregnancy. In this experiment in late pregnancy a conventional supplement was compared with a supplement higher in amounts of rumen-undegradable protein. The experiment was designed so that interaction between mid-pregnancy and late- pregnancy could be examined. The study was carried out on 4 plots of 25 ha each on Birnie Hill, Glensaugh with each plot containing 20% *Agrostis/Festuca* species and 80% heather by area. Each plot was grazed by approximately 50 Scottish Blackface ewes.

The composition of the supplement in the two previous experiments had been of barley and urea to supply 2 MJ ME/day and 6 g N/day. The ruminal NH_3 and plasma concentration had been extremely low (2-4 mM) and it was considered that a vegetable protein source might provide a more efficient source of N to the rumen microbes. A comparison was made within each supplementation treatment between N supplied as urea or vegetable protein. The supplement was given as a feed block and incorporated into the suppplementation comparison was a study of the effect of block placement on either *Agrostis/Festuca* or heather areas on ruminal NH_3 and plasma urea concentrations.

The between-day and between-animal variation in supplement intake has been found to be high in the previous experiments. The effect of size of area and the placement of feed blocks in containers on these parameters was also examined. A comparison was made between an area of 25 ha and one of 190 ha of similar vegetation grazed at similar stocking rates and with the amount of feed block per bite being offered. A comparison was made also within the supplement treatments between feed blocks placed in containers and without containers.

Considerable between-year variation in ewe liveweight loss in the previous 2 years had been observed. One possible reason for this was differences in the herbage mass of Agrostis/Festuca present in the two years and the effect that may have on diet quality. A small-plot experiment was conducted in which the changes in in vitro OM digestibility of extrusa samples from oesophageal-fistulated sheep were measured during the period from January to March with two different initial herbage masses and at a similar grazing pressure to that found on the main experimental site.

Lamb birth weight was increased significantly ($P < 0.05$) by mid-pregnancy supplementation which also reduced the liveweight loss in mid-pregnancy (see Table 1). The composition of the supplement in late pregnancy had no effect on lamb birthweight.

Table 1

The effect of mid-pregnancy supplementation on lamb birth weight (lambing percentage - 110%) and ewe liveweight loss

	No supplementation	Supplementation	SE of mean
Lamb birthweight (kg)	3.25	3.59	0.077
Ewe liveweight loss (g/d)	-207	-68	6.1

The mechanisms whereby these responses have been obtained in lamb birthweight are not understood. It is now considered that the effect of plane of nutrition in mid-pregnancy on placentation and foetal growth is more important than previously recognised but whether the response obtained was due to the energy or protein supplied by the supplement is not known. This aspect will be examined in an experiment in 1983.

The results of the effects of nitrogen source and site of block placement on ruminal NH_3 and plasma urea concentrations are given in Table 2.

Table 2

Ruminal NH_3 and plasma urea concentrations as affected by N source and block placement

	No supplement	Supplement				SE of mean
Location of supplement	-	Agrostis/Festuca		Heather		
Source of N	-	Veg.Protein	Urea	Veg.Protein	Urea	
Rumen NH_3 (mM)	3.74	5.05	3.85	2.31	3.75	0.280
Plasma urea (mM)	1.53	2.10	2.34	1.53	1.70	0.094

When the feed blocks were placed on the *Agrostis/Festuca* area, the concentration of rumen NH_3, when N was supplied by vegetable protein, was significantly ($P < 0.01$) higher than when urea formed the N source. When feed blocks were placed on heather the opposite finding was observed. N source had no effect on plasma urea concentration but values were higher when the feed blocks were located on *Agrostis/Festuca* rather than heather. Rumen NH_3 and plasma urea values were generally low and their use did not appear to aid an interpretation of the efficiency of use of the N source. The samples were collected once daily for logistical reasons and the choice of sampling time in relation to the grazing behaviour of the sheep may provide a possible explanation of the results.

Between-animal and between-day variation in supplement intake was high in all comparisons (see Table 3). Between-day variability with containers was reduced for the first three weeks of feeding but thereafter was similar to that found without the use of containers. Between-day variability was lower on the larger area but between-animal variation was higher with a larger proportion of animals not consuming feed-block.

Table 3

Between-day and between-sheep variability in intake of supplement

Area of plot (ha)	Use of container	Mean intake (g/d)	Coefficient of variation(%) Between-day	Between-animal
25	No container	193	97	37
	Container	193	90	43
187	Container	164	48	70

The effect of the higher level of herbage mass of *Agrostis-Festuca* was to increase OM digestibility by between 5 and 10 digestibility units and this difference was maintained throughout the January to March period. The OM digestibility on the low herbage mass declined from 0.50 in January to 0.42 by the end of February and then rose sharply during March to 0.55 as new growth appeared. From these results it would appear that the degree to which the hill is grazed during the previous year can have an important effect on the quality of herbage ingested the following winter.

Research objective: Identify nutrient limitations in late pregnancy and to provide supplement to remove these limitations (project no. 602).

7.2. The importance of dietary glucogenic energy supply in late pregnancy.

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

As indicated in the 1981 Annual Report (p.A34) a series of investigations has been initiated with the objective of assessing the relative needs of ewes in late pregnancy for absorbable amino acids, glucogenic energy (GLE) and metabolizable energy (ME) as a step towards being able to define the composition of supplements that should be given to pregnant ewes at pasture.

The results of the experiment described in last year's Annual Report, in which two diets of similarly high GLE content were fed to Blackface ewes over the last 8 weeks of pregnancy, indicated that at an estimated 90% of ME requirement, there were responses in ewe nitrogen (N) retention and lamb birth weight due to additional absorbable amino acids. However since the GLE content of both diets was probably higher than of many practical rations, this experiment could not conclusively answer whether the supply of GLE could ever be limiting in commercial practice. The purpose of the experiment desribed below, was to answer whether dietary GLE supply could limit lamb birth weight and ewe N retention when absorbable amino acid supply was adequate.

As in the previous experiment, the study was conducted as separate production, metabolism and digestion trials. Three diets based on hay, sugar-beet pulp and fish meal, of similar ME content were compared. Two of the diets were isonitrogenous but differed in GLE content by incorporation of either sodium acetate and butyrate ("low GLE" diet) or of sodium propionate ("high GLE" diet). The third diet also contained sodium propionate but had a higher fish meal content ("high protein" diet).

In the production trial 20 ewes, equal numbers carrying single and twin lambs, received each diet at an estimated 60% of ME requirement (ARC, 1980) for the last 8 weeks of pregnancy. They were individually penned and fed twice daily. Each week blood samples were taken and the animals were weighed. Lamb birth weights were measured and milk production was determined 24-48 h after lambing.

In the metabolism trial 4 sheep from each treatment, taking part in the production trial, and an additional 4 rumen-fistulated pregnant ewes were housed in metabolism crates for two weeks. Blood CO_2 and plasma glucose production rates were determined in all sheep. In addition ruminal acetate, propionate and butyrate production rates were estimated in the rumen fistulates, whereas in the other sheep, plasma glycerol, 3-hydroxybutyrate and tyrosine production rates were determined. The activities of a number of enzymes involved in glucose and fat metabolism were determined in biopsy samples of liver and adipose tissue from the sheep which were not fistulated (conducted in conjunction with H. Dove). Digestibility of OM and N balance was determined in 20 of the sheep used in the metabolism trial.

In the digestion trial 12 sheep with rumen, abomasal and ileal cannulae were allocated across the three diets and fed at levels spanning those given to the ewes in the production trial. Flow rates of OM, non-ammonia N and microbial N were estimated at the abomasum and ileum using ^{51}Cr-EDTA and ^{103}Ru-phenanthroline as dual-phase markers and ^{35}S to label microbial protein synthesised in the rumen. Ruminal methane production rate was measured using (^{14}C)-methane.

Results available from the production and metabolism trials are summarised in Table 1. Increasing dietary GLE and protein caused significant increases in lamb birth weight and N retention in the ewes (low GLE diet vs. high protein diet). Changing GLE or protein in the diet had no significant effect on ewe live-weight change or milk production in early lactation. However, the nature of the diet had some profound effects upon metabolism in the animals, as assessed by plasma metabolite concentrations, plasma metabolite production rates and tissue enzyme activities.

The low GLE diet caused considerably higher plasma 3-hydroxybutyrate concentrations than the two diets of high GLE content at similar ME intakes. Plasma NEFA concentrations were similarly high for all diets. Although plasma glucose concentrations did not differ significantly, glucose production rates were significantly increased by increasing dietary GLE content, and were further increased by increasing dietary protein content. The low GLE diet caused higher plasma glycerol production rates than the other diets. Plasma tyrosine production rate was not affected by diet, but the metabolism of this amino acid in the liver may have masked any effect of changes in the amino acid supply from the gut. The lower glucose production rate from sheep receiving the low GLE treatment is reflected in the lower activity of glucose-6-phosphate dehydrogenase (G-6-PDH) in the liver and adipose tissue. The activity in adipose tissue of isocitrate dehydrogenase (ICDH) was similarly reduced.

The results of this experiment indicate that at low ME intakes and with adequate dietary protein it is possible that GLE supply to ewes in late pregnancy can limit lamb birth

Table 1

Summary of results of 1982 Late Pregnancy Experiment

		Treatment	
	Low GLE Diet	High GLE Diet	High Protein Diet
Lamb birth weight (kg) (combined singles and twins data)	5.11^{a}	5.57^{ab}	5.74^{b}
Ewe Lwt. Change (kg) (- 6 weeks to post lambing)	-5.16	-4.89	-4.45
Milk production (kg/d) (24-48 h post lambing)	1.98	1.93	2.04
†*N retention (g/d)	5.22^{a}	5.42^{a}	7.77^{b}
† Plasma concentrations (mM)			
3-Hydroxybutyrate	3.70^{a}	0.73^{b}	1.02^{b}
NEFA	1.66	1.44	1.37
Glucose	1.82	2.08	2.08
Urea	3.00	3.31	4.24
†*Metabolite production rates (gC/d)			
Blood CO_2	255.7	229.0	251.2
Plasma glucose	44.5^{a}	54.3^{b}	62.0^{c}
Plasma glycerol	12.4^{a}	6.7^{b}	7.0^{b}
Plasma tyrosine	6.3	5.9	6.7
† Enzyme activities (units/mg protein)			
*Liver: GOT	4.38	2.60	3.08
G-6-PDH	0.13^{a}	0.15^{b}	0.13^{a}
ICDH	4.08	4.38	4.25
**Adipose tissue: GOT	0.28	0.51	0.45
G-6-PDH	0.09^{a}	0.18^{b}	0.19^{b}
ICDH	0.61	0.91^{b}	0.99^{b}

Values with different superscripts differ significantly ($p < 0.05$) ($p < 0.001$ for 3 hydroxybutyrate).

† 2 weeks (approximately) before lambing.

* 12 non-fistulated sheep: 6 twin-bearing, 6 single-bearing.

** 6 non-fistulated sheep bearing single lambs.

weight. The reduction in glucose production rates and the high plasma 3-hydroxybutyrate concentrations when the dietary GLE level is reduced suggests that there is a shortage of glucogenic citric-acid cycle intermediates. The higher glycerol entry rate suggests an increase in the rate of lipolysis in adipose tissue, whereas the adipose-tissue enzyme activities imply a reduction in fat tissue synthesis, with no evidence of any adaptation in the ability of the adipose tissue to depend upon relatively less glucose for the supply of reduced NADP for long chain fatty acid synthesis.

Reference

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

Research objective: Identify the amount and type of supplement to feed to ewes in relation to pasture supply in early lactaction (project no. 603).

7.3. Influence of herbage mass and supplementary feeding on nutrient flow and performance in lactating Greyface ewes

H. Dove, J.A. Milne, C.S. Lamb, H. McCormack and A. Spence

In previous experiments increases in herbage mass in early lactation have resulted in increases in estimated digestible OM intake by Greyface ewes and in lamb growth rates. Presumably the improved performance reflects an increase in the supply of nutrients for ruminal and intestinal absorption but it is not known whether the response is due to protein supply, energy supply or both. This information is important to acquire in relation to defining the composition of supplements that require to be offered in early lactation. There is evidence from indoor experiments that an increased protein supply in early lactation will increase milk production and lamb growth rate. The extent to which the high levels of N in spring herbage can be captured by the rumen microbes is not known and whether this source will supply sufficient protein when an energy supplement is provided or whether an undegradable protein source is required. An experiment was conducted at Hartwood in 1982 to examine these issues.

Ninety-six Greyface ewes (75 twin-bearing) which lambed in early May were allocated to the following 4 treatments imposed in the first 7 weeks of lactation:-

LO Herbage mass maintained at 1000 kg OM/ha - no supplement

LE Herbage mass maintained at 1000 kg OM/ha - energy supplement

LP Herbage mass maintained at 1000 kg OM/ha - protein supplement

HO Herbage mass maintained at 1600 kg OM/ha - no supplement

The treatments were replicated four times. From the end of feeding to weaning at 14 weeks all the ewes were grazed at a herbage mass of 1600-2000 kg OM/ha. The energy supplement was molassed sugar beet pulp and the protein supplement was 50% molassed sugar beet pulp and 50% formaldehyde-treated soya bean meal. Each supplement was offered at a level of 600 g/d. On all replicates measurements were made of lamb growth rate and ewe liveweight change. On one replicate measurements were also made of herbage intake and milk yield on 3 occasions during the supplementary feeding period. On the same replicate on the same occasion measurements, using 12 lactating ewes fitted with rumen and abomasal cannulae and carrying portable infusion pumps, were made of non-ammonia-N (NAN) flow at the abomasum and of microbial protein production in the rumen.

The available results from the replicate with the detailed measurements are given in Table 1. These results show that the energy supplement tended to increase ruminal microbial production over the LO treatment and that the LP treatment produced a higher and significant ($P < 0.05$) increase

Table 1

Lamb performance, milk yields and digesta flows in 1st 7 weeks of lactation when supplements were offered.

	LO	LE	LP	HP	SE of mean
Lamb LW gain (g/d)	254	308	331	274	12.5
Milk yield/ewe (g/d)	2048	2133	2846	2580	11.04
Microbial protein production rate in rumen (g N/d)	41.3	46.9	53.2	40.0	4.59
NAN flow at abomasum (g/d)	44.2	55.1	68.8	47.9	4.31

over the LO treatment. As would be expected NAN flows at the abomasum increased in the same way as ruminal microbial protein production with the greater amounts on the LP treatment reflecting the use of a rumen-degradable protein source. Milk yields and lamb growth rates followed the same pattern suggesting that increasing milk protein precursors increased milk yield and lamb growth rate, although the energy absorption data is not yet available to confirm this conclusion.

The lamb LW gain data for all 4 replicates does not show the same degree of difference between the LE and LP treatments (3 out of the 4 replicates produced a positive response to the LP treatment) although there is a clear difference between the LO and the LE and LP treatments (see Table 2). Table 2 also shows the lamb growth rates from the end of the feeding period to weaning.

Table 2

Lamb growth rates and weaning weights from all replicates throughout the experiment

	LO	LE	LP	HO	SE of mean
Birth to end of feeding (g/d)	258	291	299	272	7.0
End of feeding to weaning (g/d)	243	225	205	254	7.8
Weaning weight (kg)	28.4	30.2	29.5	30.0	0.62

The LW gain of lambs from end of feeding to weaning was lower on those treatments where supplements were fed than where no supplement was given. A similar finding was also observed in a previous experiment. The reason for this compensation in lamb growth is not known, but may be associated with earlier rumen development in those lambs receiving less milk. There was no evidence of milk yield changing in ranking between treatments after supplementation stopped. Consequently there was no significant difference in weaning weight between the treatments even though considerable amounts of supplement had been offered in early lactation. The implication of this finding is that the minimum amount of supplement, consistent with the establishment of an adequate lactation, should be given in the spring and that herbage masses of 1500 kg OM/ha should be achieved as early in lactation as possible. However this assumes that it is not possible to sustain the higher lamb growths achieved in early lactation with supplemented ewes later in lactation. Although there was some advantage from the results of this experiment and of a previous experiment in the feeding of a supplement with a higher rumen undegradable protein source at relatively high levels of feeding, the feeding of such a supplement would not be economically justified. There may be a greater advantage at lower levels of feeding and this will be examined in a future experiment.

Research objective: Identify factors influencing the supply of nutrients from milk and herbage to the lamb at pasture (project no. 604).

7.4. The digestibility of components of milk and herbage throughout the period when lambs are receiving both feeds

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

In order that contributory factors affecting the growth of lambs at pasture can be better understood it is important that the concurrent intakes of both herbage and milk can be determined. Furthermore, the digestibilities of milk and herbage, and possible interactions between the two, can have a considerable influence on the nutrient supply to the lamb.

There is thus a need to be able to make separate estimates of milk and herbage digestibility when lambs are receiving both feeds. Although a regression approach (Hodge, 1966), in which faecal organic matter (OM) output is related to milk and herbage OM intakes, has been used to obtain milk and herbage OM digestibilities (Hodge, 1966; Penning and Gibb, 1979), the need for quadratic and interaction terms in the regression equation to be statistically non-significant limits its general application. An alternative approach is to obtain independent digestibilities of components peculiar to either milk or herbage when both are fed. In the indoor experiment described below, the digestibility of milk was estimated from the apparent digestibility of [^{3}H]-milk fat and [^{3}H]-milk protein when labelled ewe's milk was incorporated in the diet. The herbage digestibility was measured as the digestibility of fibre components from herbage (ADF, NDF and cellulose).

Eight male lambs, initially aged 2 weeks, were offered ewe milk replacer, containing skimmed cow's milk and butterfat (298 g crude protein/kg DM; 266 g fat/kg DM) at two declining feeding levels, for four consecutive 21-day periods. After the first period and for a fifth period when no milk replacer was offered, the lambs were given free access to fresh ryegrass/clover herbage which was cut daily. Ewe's milk containing ^{3}H-labelled fat and protein was incorporated into the liquid feeds for the final 10d of each of the first four periods and faeces were collected over the final 5d of each period. The radioactive ewe's milk was obtained by injecting intravenously into separate ewes at peak lactation either 10 mCi [^{3}H] acetate, 5 mCi glycerol tri-[^{3}H]-oleate or 5 mCi [^{3}H] lysine; the 24-hour milk output was freeze-dried and the milks were combined before adding to the lamb milk replacer. The ^{3}H levels in lipid extracts and residues from soxhlet determinations of feeds and faeces were used to obtain respective digestibility values for [^{3}H]-milk fat and [^{3}H] milk protein. The apparent digestibilities of total dietary OM, fat and N and also of fibre fractions (ADF, NDF and cellulose) were also determined. *In vitro* OM digestibility was estimated on the herbage offered each day.

The level of milk intake within each period had no effect on digestibility or herbage intakes. For this reason the results given in Table 1 are the mean values combined over the two milk intakes for each period.

In the first period, when no herbage was offered, [^{3}H]-milk fat digestibility was not significantly different from total dietary fat digestibility; however, [^{3}H]-milk protein digestibility was significantly higher ($p < 0.05$) than total dietary N digestibility, suggesting that the endogenous material in the faeces contained less ^{3}H than N. There was a progressive increase in herbage intake with time, although intakes were lower than anticipated. As expected, the apparent digestibilities of total dietary OM, fat and N progressively declined, as the proportion of herbage in the diet increased.

The digestibilities of [^{3}H]-milk fat and [^{3}H]-milk protein progressively declined by a small but highly significant extent with period. Although statistically non-significant, changes in the digestibilities of ADF, NDF and cellulose reflected changes in *in vitro* OM digestibility of the herbage with each period.

Table 1

Intakes and digestibility of milk replacer and herbage in lambs aged from 4 to 16 weeks

	1	2	3	4	5	Significance
Age (wk)	4	7	10	13	16	-
Milk Intake (gOM/d)	306	264	205	143	-	-
Herbage Intake (gOM/d)	-	9.6	27.1	87.9	204.0	$p < 0.01$
Apparent digestibility (%):						
[^{3}H]-milk fat	99.4	99.3	98.9	97.6	-	$p < 0.001$
[^{3}H]-milk protein	98.5	98.4	96.6	96.1	-	$p < 0.001$
Total dietary fat	98.9	98.0	95.7	88.7	37.1	$p < 0.001$
Total dietary N	96.8	95.8	90.1	85.5	71.6	$p < 0.001$
Total dietary OM	98.5	97.5	93.5	89.5	76.5	$p < 0.001$
Acid detergent fibre (ADF)	-	79.8	64.6	79.3	75.5	NS
Neutral detergent fibre (NDF)	-	81.2	66.4	78.8	76.3	NS
Cellulose	-	90.5	78.7	90.6	87.3	NS
In vitro digestibility of herbage	-	76.6	71.6	76.7	70.7	-

These results suggest that there is a small reduction in milk digestibility but no evidence of change in herbage digestibility with advancing age and increasing herbage intake.

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Research objective: Establish supplement strategies for finishing lambs grazing pasture or forage crops in the autumn (project 605).

7.5 The use of supplements in the finishing of lambs grazing rape

J.A. Milne, H. Dove and H. McCormack

Responses in LW gain to the grazing of rape by finishing lambs have been found to be in the order of 60-80 g/day when leaf is grazed and less when rape stem is ingested. From a knowledge of the intakes by lambs and the composition of rape leaf and stem, it can be predicted that lamb growth rates are likely to be limited by ME supply rather than the amount of protein absorbed although growth rates achieved in practice have been somewhat less than would be predicted. In some finishing systems growth rates of greater than 100 g/d might be desirable. An experiment was conducted to test the hypothesis that to achieve lamb growth rates greater than 100 g/d the feeding of a predominantly energy supplement, barley, should suffice by comparing the following treatments, when lambs grazed either rape leaf or rape stem continuously for a period of 6 weeks.

A. No supplement

B. 275 g DM rolled barley

C. 275 g DM rolled barley + 50 g DM soya bean meal

Two experimental sites were used. On one site, measurements were made of liveweight gain and carcass energy and protein gains. Thirty Scottish Blackface castrate male lambs of approx. 28 kg were allocated to each treatment on either the leaf or stem crops. A representative group of 18 lambs were slaughtered at the start of the experiment in mid- October and 10 lambs/treatment at the end of the experiment to determine carcass protein and energy gains. On the other site in the same field 6 lambs/treatment of similar liveweight were used. Measurements were made of intake of rape leaf and stem and of supplements. These results are not yet available. Four rumen-fistulated ewes were also used in an incomplete Latin Square design to examine the degradability in the rumen of N of the rape leaf and stem using the dacron bag technique with the following 4 treatments:

LF Rape leaf - fresh

LE Rape leaf - from oesophageal fistula extrusa samples

SF Rape stem - fresh

SE Rape stem - from oesophageal fistula extrusa samples

The design was repeated on 2 occasions during the main experiment. The DM disappearance rates obtained give an indication of the rate at which N from the plant becomes available to the rumen micro-organisms.

The DM disappearance curves from dacron bags are illustrated in Figure 1. The rate of DM disappearance was greater from rape leaf than stem whilst that from extrusa samples was faster than that from fresh material. The difference between leaf and stem presumably reflects the more fibrous nature of the latter. The more rapid initial disappearance from the extrusa samples is probably related to the effects of chewing. When N values become available rumen degradability values for N will further aid the interpretation of the production results given below in Table 1.

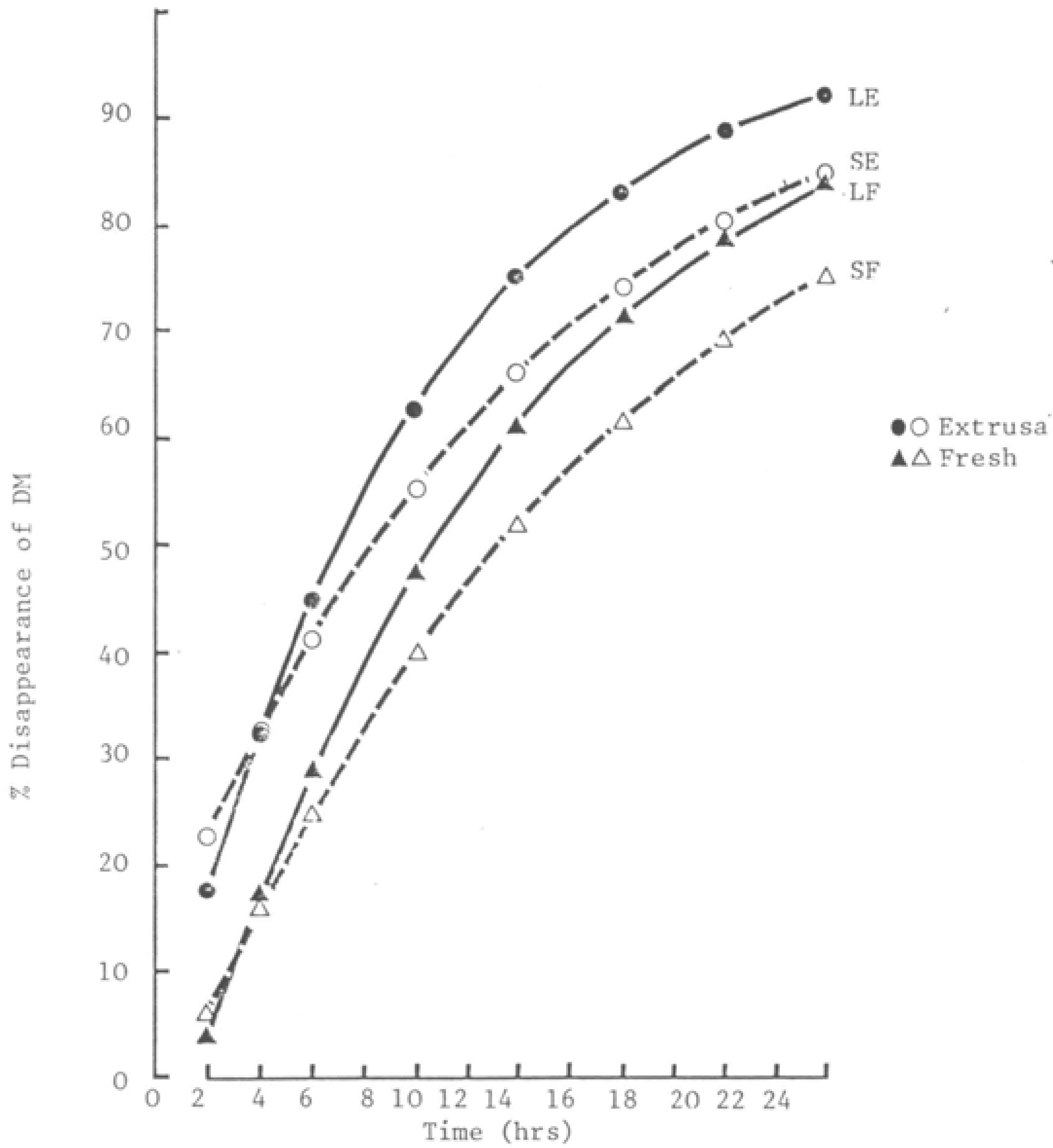


Figure 1. Fitting of disappearance curves using OPTIMIZE in GENSTAT

Table 1

Liveweight, energy and protein gains of lambs grazing the rape crop and when given supplements

	Rape Leaf			Rape Stem			SE of mean
Supplement	A	B	C	A	B	C	
Liveweight gain (g/d)	167	157	198	118	116	141	8.9
Protein gain (g/d)	21	21	23	11	11	17	-
Total Energy gain (MJ/d)	2.43	2.46	2.60	1.80	1.68	1.95	-
% fat in carcass	23.0	23.5	22.6	22.2	23.3	22.0	-

The liveweight gain of lambs on both leaf and stem when supplement C (barley + protein supplement) was offered was significantly ($P < 0.05$) higher than on treatments A and B. This was reflected in higher carcass weights and higher protein gains. However, total energy gains were not significantly different between treatments. In part this was due to the higher fat content in the carcass of the lambs given supplement B (barley), although there was also differences in the composition of the non-carcass components. These results are taken to indicate that a supplement of barley alone does not provide a suitable supplement for finishing lambs in that lamb growth rates were not increased over unsupplemented animals and a fatter carcass was produced. The addition of a small amount of a rumen degradable protein supplement increased liveweight gains and produced a leaner carcass.

Research objective: Develop methods of measuring short-term changes in the fat and protein tissues of the ewe in pregnancy and lactation (project no. 607)

7.6. Methods of measurement of short-term changes in the rate of fat mobilisation of the pregnant ewe

S. Wilson, J.A. Milne and H. McCormack

It is now well established that the body condition of the ewe has a significant effect upon overall production performance. For example, the ewe's body reserves can be used to support foetal growth during pregnancy and also to supply precursors for milk synthesis in the early stages of lactation. In addition, body condition prior to mating has a significant effect on lambing percentage. Although the importance of the body condition of the ewe is recognised the amount of quantitative information available on rates of change in her fat content is very limited. One of the principal reasons for this is the lack of suitable methods for estimating _in vivo_ the rate of change in the fat content of the ewe's body over fairly short periods of time.

The approach adopted initially has been one of using _in vivo_ techniques in attempting to construct models of adipose tissue metabolism (including lipolysis and lipogenesis) in ewes in late pregnancy, which was chosen as a time when short-term fat changes are important, whilst at the same time conducting a search for metabolic indices which would be useful for predictive purposes. This search was centred upon various metabolites found within the adipose tissue itself rather than on the more conventional plasma metabolites which have been examined, with only limited success, in the past.

The objectives of this preliminary experiment conducted with six monotocous Scottish Blackface ewes in late pregnancy fed two levels of dried grass (i.e. 700 g and 1500 g) to promote two different rates of adipose tissue loss, were as follows: (a) to determine the rate of lipolysis by measuring the plasma irreversible loss (ILR) rates of FFA (Palmitate) or glycerol, using (^{14}C)-labelled tracers; (b) to explore the possibility of using the much cheaper (^{3}H)-labelled tracers for the same purpose; (c) to determine the rate of lipogenesis by measuring the incorporation rate of (^{14}C) acetate (acetate is the major precursor for lipogenesis in ruminants) into adipose tissue and (d) to explore the potential of using the activity of lipogenic enzymes (G-6-PDH; ICDH, acetyl Co-A carboxylase) as indices of rate of lipogenesis, and the concentration of cyclic-AMP (an activator of the major lipolytic enzyme - hormone sensitive lipase) as an index of rate of lipolysis. The ewes were housed in metabolism crates and fed by continuous feeder from day 100 of gestation. Isotopic infusions and fat biopsy samples were taken between days 115 and 130 of pregnancy.

In ewes fed the lower intake, rates of lipolysis, when determined with the palmitate and glycerol tracers, were 65 and 15% higher respectively than in the ewes fed the higher intake. There was some evidence to suggest that even at four weeks before term, the rate of lipolysis was increasing very rapidly (by 30-40% in three days). Before any conclusion can be drawn from this, the possibility of an artefact caused by the "stress" of handling and sampling procedures on the animals would have to be eliminated. In ewes fed both diets the rates of lipolysis determined with the glycerol tracers were 2-3 times higher than when determined with the palmitate tracers. This suggested that there was extensive re-esterification of FFA to triacylglycerols within the adipose tissue. The requirement for glucose for synthesis of glycerol-phosphate needed for this re-esterification could account for up to 15-20% of the glucose ILR in late pregnancy. There was evidence to suggest that a significant proportion of the circulating triacylglycerols, which were originally thought to be derived mainly from lipids absorbed from the G.I. tract, were in fact synthesized from circulating FFA. The proportion of the circulating FFA which was used for synthesis of triacylglycerols was affected by level of intake (high intake 20%, low intake 14%).

The (^{3}H)-labelled tracers gave similar estimates for glycerol and FFA ILR to those obtained using the (^{14}C)-labelled tracers. The use of these cheaper (^{3}H)-labelled tracers would enable measurements to be made on more animals and would allow simultaneous infusions of (^{14}C)-labelled tracers (e.g. (^{14}C)- acetate, ($^{14}CO_2$) whilst determining an FFA or glycerol ILR. It could also enable similar measurements to be made with cattle where the cost of using (^{14}C)-labelled FFA and glycerol is prohibitive.

Preliminary results from assays of enzymes associated with lipogenesis (ICDH and G-6-PDH) have been encouraging (conducted in conjunction with R.W. Mayes). Large differences were seen in the activity of both enzymes between levels of intake, but there were also some large differences between animals given the same intake. Further assessment of their suitability as indices of fatty acid synthesis will be possible when measurements on the rate of incorporation of (^{14}C) acetate into adipose tissue become available. The activity of acetyl Co-A carboxylase and the concentration of cyclic AMP in adipose tissue have still to be determined.

The experimental approaches which have been identified from this preliminary experiment as potentially fruitful will be followed up in further experiments in 1983.

Programme Unit 4: Factors affecting beef cow and calf performance in hill and upland environments.

Research objective: Study relationships between the effects of pre- and post-weaning nutrition on performance of weaned suckled calves (project no.407)

1. Nutrition and performance of weaned suckled calves

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

The first experiment concerned with the nutrition and performance of weaned suckled calves was carried out at Glensaugh. It was conducted using 60 weaned calves of two genotypes (Charolais crossed from either Hereford x Friesian or Blue-Grey cows), 36 of which were heifers and 24 steers, drawn in equal numbers from the autumn and spring calving herds at Hartwood. During the winter the weaned calves were allocated to one of three levels of feeding designed to give growth rates of approximately 0.25, 0.5 or 0.75 kg/day. Each calf was offered 16 kg of silage plus a variable quantity of mineralised barley.

In mid-May the cattle were turned-out to one of two herbage masses, on which the average herbage masses over the grazing season were 1800 or 2900 kg DM/ha. Due to drought the experiment had to be terminated prematurely in mid-August.

Results are given in Table 1. Winter live-weight gains were close to the set targets. At turn-out there was a considerable loss in weight, which was affected by both winter feed level and summer herbage mass. The cattle on the high herbage mass gained considerably more weight ($P < 0.001$) during the grazing season, presumably because of a higher herbage intake. Winter nutrition also affected live-weight gains in summer ($P < 0.05$), whereby the lower the live-weight gain in winter, the higher the summer live-weight gain. On three occasions herbage intake was measured on the 30 cattle which grazed the high herbage mass and the enhanced performance at pasture following feed restriction in winter appears to be associated with higher herbage intakes per kg live-weight.

A second experiment similar in design to the first began in November 1982. Sixty-four Charolais cross weaned suckled calves were transferred from Hartwood to Glensaugh and were allocated to one of three levels of feeding designed to achieve growth rates of 0.2, 0.5 or 0.8 kg/day. In May it is hoped to turn-out half the cattle on to a sown ryegrass sward and half to an indigenous *Agrostis/Festuca* sward. Measurements of live weight, condition score, ultrasonic fat depth and herbage intake will be made.

Table 1

Effect of winter feed level and summer herbage mass on performance of weaned suckled calves.

	Winter feed level			Summer herbage mass	
	Low	Medium	High	Low	High
Winter Phase					
Live weight at start (kg)	279	279	286	-	-
Live weight before turn-out (kg)	325	367	406	-	-
Winter live-weight gain (kg/day)	0.311	0.581	0.792	-	-
Summer Phase					
Live weight 9 days after turn-out (kg)	318	347	378	348	348
Live weight at end	420	440	464	431	431
Summer live-weight gain (kg/day)	1.226	1.124	1.030	0.996	1.25
Mean herbage OM intake (g/kg LW) (high herbage mass only)	17.7	16.1	15.9	-	16.1

Research objective: Improve the accuracy of determining nutrient requirements and in vivo changes in body composition in beef cows (project no.402)

2. Sources of variation in the body condition scoring of suckler cows

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

An exercise in the body condition scoring of suckler cows was conducted at Hartwood in May 1982 with the objectives of comparing the standards of two centres (HFRO and ESCA) using the system in practice, of examining within and between-operator sources of variation, and of assessing the effect of previous experience and training.

Nine participants from 3 centres (HFRO, ESCA and ARCUS) took part in the study. All four from HFRO and two from ESCA had previous experience of condition scoring suckler cows, the third ESCA participant had experience of condition scoring dairy cows, and the two ARCUS participants had never conditioned scored animals before, although both were familiar with the concept and had previously observed it being done.

Forty-eight cows (24 Blue Grey and 24 Hereford Friesians) were scored by each participant, once in the morning, and again in the afternoon without reference to the mornings' scores. A discussion of standards, using cows not included in the exercise, was held after the morning session and prior to the afternoon session.

It was apparent during the discussion on standards that there was a difference between those used in practice by HFRO and ESCA. Later analysis of the results showed that all HFRO participants scored almost all cows higher than did all ESCA participants, there being a clear linear trend with the HFRO scores averaging 0.5 units per cow higher than ESCA scores. HFRO scores ranged from 1.0 to 3.0 compared with 0.5 to 2.75 for ESCA scores.

All the experienced scorers showed good consistency between morning and afternoon scores. One participant from HFRO and one from ESCA had within-operator correlations of greater than 0.9 with largest differences between pairs of scores of 0.5 units and mean differences over all 48 cows of 0.00. Within-operator correlations for the other participants were: HFRO, 0.82, 0.85 and 0.89; ESCA 0.78 and 0.86; and ARCUS, 0.40 and 0.65. In general all four HFRO participants scored very similarly to each other, and one of the HFRO participants was the individual to whom most participants scored most similarly. The results also suggested that some training and previous experience was required to condition score cows consistently and to the same standard as individuals using the technique frequently. Further statistical analysis of the results are being conducted.

Research objective: Study the relationship between winter nutrition and grazing management in lactating beef cows (project no.404)

3. A study of factors affecting production from grazing beef cows and calves.

J. Hodgson, A.J.F. Russel, I.A. Wright, R.A. Hetherington, T.K. Whyte and E.A. Hunter (ARCUS)

The results of earlier grazing experiments with suckler cows and calves have shown that performance at pasture, assessed primarily in terms of milk production and calf growth rate, is affected by nutrition both prior to and following turnout. Spring-calving cows relatively poorly fed in early lactation, when turned out to high quality pasture, produced more milk and gained weight and condition more quickly than did cows which previously had been better fed. Their calves also grew more quickly at pasture. This superior performance at pasture was associated with higher herbage intakes. It has also been shown in more recent work that differences in level of nutrition after turnout, achieved by creating differences in herbage height and mass, also affected herbage intake and performance. These responses in milk yield and calf growth rate to changes in nutrition at pasture have been observed up to more than the sixth month of lactation.

It is probable that the effects of nutrition prior to turnout on performance at pasture are mediated through an influence of body composition on voluntary intake, the hypothesis being that voluntary intake is inversely related to the level of body fat. An experiment was conducted during the 1982 grazing season to test this hypothesis and to provide more detailed quantitative information on the factors affecting the performance at pasture. The main factors examined were level of nutrition prior to turnout (post-partum nutrition in November/December calving cows, and pre- and post-partum nutrition in March/April calving cows), body composition at turnout and during the grazing season (estimated from ultrasonic measurements of subcutaneous fat depth and from condition score), level of nutrition at pasture (created by regulating sward height), stage of lactation and genotype.

The levels of nutrition imposed prior to turnout in mid-May were designed to create, in a balanced fashion, a range in body condition at turnout. During April and early May 16 cows (8 Blue Grey and 8 Hereford Friesian), which had calved in November/December and been mated in February/March were fed to either gain or lose 0.5 condition score. Thirty-two March/April calving cows (16 of each genotype) were fed prior to calving to achieve similar changes in body condition, and after calving half of each group were switched from the high to low treatments and vice versa, again in a balanced fashion.

The grazing phase comprised two consecutive 8 week periods. Two contrasting herbage allowances (managed by adjusting the number of non-experimental animals to maintain sward surface heights of 3-4 cm (low treatment) and 8-10 cm (high treatment)) were maintained under continuous stocking management throughout both periods. Twenty-four cows (8 November/December calvers and 16 March/April calvers) were allocated to each treatment in Period I, after which the earlier calving cows were withdrawn, and the later calving cows reallocated to pasture treatments in a balanced fashion.

Analysis of the data has only recently begun. It appears at this stage that the level of feeding to the spring-calving cows in late pregnancy affected both cow and calf weight at parturition, with the higher level of feeding resulting in heavier cows and calves. Both Autumn and Spring calving cows showed a considerable increase in milk yield at turnout.

Programme Unit 5: The husbandry of red deer.

Research objective: Studies on the utilisation of upland pastoral resources in whole systems of deer meat production (project no. 502).

1. Uplands Systems Study

W.J. Hamilton, T.J.Maxwell and J. Eadie

In 1979 a study was initiated to explore the possibility of farming red deer more intensively on upland sown pasture. It was recognised that economic viability would depend not only upon high levels of animal performance but also on low winter feed costs; the study therefore was essentially concerned with comparing two different wintering systems, one, System A, including a hill outrun on which herds would be mated and then wintered, and the other, System B, where hinds were wintered in a paddock of approximately 3 ha and where they were fed a controlled ration of hay and concentrates. These latter hinds were mated on the sown pasture area.

Each of the herds comprised 34 hinds having access to 3.4 ha of permanent sown pasture. The results presented refer to two complete production years viz. 1980/81 and 1981/2.

Table 1

The mean live-weight (kg) of the hinds throughout the annual cycle for the two years.

		Oct.	Dec.	Jan.	Feb.	Mar.	May.	Aug.
System A	1980/81	86.3	88.3	83.0	83.7	80.6	91.5	89.7
(hill)	1981/82	84.8	85.4	81.2	82.6	80.8	93.2	86.5
System B	1980/81	88.6	87.5	87.3	83.1	80.0	86.8	89.6
(paddock)	1981/82	89.5	87.6	84.6	85.2	82.1	90.4	88.6

The average liveweight for both systems in each of the years at the time of the rut was 88.0 and 89.0 kg in 1980 and 1981 respectively. Liveweight loss in winter was controlled where necessary in both herds by feeding additional hay and concentrate as required to achieve a liveweight of 80.0 kg by the end of March.

Reproductive performance differed between the two herds; the weaning percentages of the hill wintered calves were 82 and 73 in the two years while those of the paddock wintered calves were 88 and 100 respectively. The lower weaning percentages of the hill wintered group were mainly due to losses at and around calving, the reasons for which cannot be adequately explained though they may be linked to a significantly earlier calving.

The growth rates of the calves tended to be greater from the hinds wintered on the hill. From birth to weaning growth rates for both systems were around 300 g/day.

Table 2

The performance of the two systems in each of the two years.

Wintering System	1980/81 System A (hill)		1980/81 System B (paddock)	1981/82 System A (hill)		1981/82 System B (paddock)
No. of Hinds	34		34	34		34
Birth date (day no.)	162	**	171	148	**	159
Nos. Calves Weaned	28		30	25		34
Weaning Percent	82		88	73		100
Birth Weight Calves (kg)	8.7	**	7.8	8.5	NS	8.3
Calf Growth Rate to Weaning (g/day)	315	(p=0.052)	293	319	NS	306
Wean Weight (kg)	39.5	**	33.8	43.6	***	38.5
Out per hectare sown pasture (kg/ha)	326		299	321		386

Relative to the level of nitrogen application and levels of pasture production, the level of performance (output/ha) estimated at the stocking rate of 10 hinds/ha equated with similar stocking rates with sheep on the same area.

The cost of wintering the hinds on the hill was £ 4.40 and £8.97 in 1981 and 1982 respectively whereas on the enclosed area cost of wintering was £21.70 and £23.00. The hill wintered stock provided a better economic return than hinds wintered on the paddock. The returns from the sale of venison would have to increase very considerably relative to winter feed costs to overcome the higher costs of winter feeding on the latter system.

Research objective: the nutrition of hind and stag calves in their first winter in relation to their subsequent performance at pasture (project no. 503).

2. The effect of different wintering regimes on the performance of red deer calves to 16 months of age

J.A. Milne, H. McCormack and C. Thomson

Red deer calves weaned from hinds grazing hill or upland swards in September will differ in weaning weight by approximately 10 kg (35 v 45 kg). How should these calves be treated in their first winter so that they achieve acceptable liveweights by the end of the following summer's grazing when they would be used for breeding or slaughtered? For breeding, a liveweight of 75-80 kg requires to be achieved.

There are 3 periods when dietary manipulation can take place. Firstly, in a period of grazing from September to housing in November, secondly, from December to April when the calves will be housed and, thirdly, at pasture in the summer. In the housing period it is important to minimise feeding costs and therefore any expression of compensatory growth during the following summer requires to be exploited. This aspect of dietary manipulation was examined in the experiment described below.

Forty-eight calves of high (45 kg) and low (38 kg) weaning weight in mid-September were allocated according to sex to 2 planes of nutrition (High (H) and Low (L)) imposed throughout the autumn and winter. In the autumn the planes of nutrition were obtained by grazing the calves on sown-species swards maintained at 1000 (L) or 2000 (H) kg DM/ha. Supplementary feeding was given to both groups from November 1st and the animals were housed on November 11th, 1981. At housing the H plane animals were offered a complete diet (Diet AA6) *ad libitum* until December 21st. From then until March 11th, 1982 the H plane animals received a level of feeding to maintain liveweight after which they were offered the complete diet *ad libitum* until turnout to pasture on May 5th. The L plane animals received the complete diet at a level to maintain liveweight throughout the indoor feeding period. From turnout to pasture until the end of the experiment, in the middle of September, the calves grazed the same perennial ryegrass/white clover sward. Because of the dry summer weather conditions at Glensaugh herbage masses were low from mid-June onwards and supplementary feeding at pasture was given during August and September. The calves were weighed at 3-weekly intervals and measurements of intake were made daily during the indoor feeding period.

At pasture in the autumn the H and L planes of nutrition had gains of 124 and 85 g/d respectively. In November the calves appeared under stress and 3 calves died from Yersinia infection. The calf growth rates were low in comparison to those obtained before weaning. The winter planes of nutrition produced gains of 132 (H) and 10 (L) g/d. Before and after the period of winter maintenance feeding *ad libitum* intakes and liveweight gains were similar. Energy requirements for maintenance and liveweight gain during this period were estimated to be 490 KJ/kg $W^{0.75}$/d and 5.5 MJ/kg LW gain. The turnout liveweights of the groups are given in Table 1.

Table 1

Effect of liveweight at weaning and plane of autumn and winter nutrition on calf liveweight and liveweight gain in their second summer.

	Plane of nutrition				
	High		Low		
Liveweight at weaning	High	Low	High	Low	SE of mean
Liveweight at turnout on 5.5.82 (kg)	58.6	52.6	50.0	44.2	1.76
Liveweight gain from turnout to 16.9.82 (g/d)	119	108	134	139	9.4
Liveweight gain from 26.5.82 to 16.9.82 (g/d)	149	127	132	145	11.1
Liveweight at 16.9.82 (kg)	76.7	68.4	69.4	62.8	2.86

When the liveweight gains from turnout to the end of the summer grazing are compared for the two planes of winter nutrition there is evidence of some compensatory growth with a benefit of 20 g/d in favour of these animals which had received the L plane of nutrition in winter. However when the first 3 week period of grazing is excluded in an attempt to remove gut fill effects then there is no evidence of compensatory growth with mean liveweight gains of 138 and 139 g/d respectively for the H and L planes of winter nutrition. There was no effect of weaning weight on liveweight gain in the autumn, winter or subsequent summer so that there were large differences of up to 15 kg in liveweight at the end of the calves second summer between treatments reflecting differences in weaning weight and winter plane of nutrition.

The lack of compensatory growth (excluding the 1st 3 weeks after turnout) may have been due in part to low herbage masses in the summer limiting herbage intake and the experiment will be repeated in 1983 at higher herbage masses in the summer.

The implications of the results of the experiments are that to avoid the need for high levels of winter feeding high weaning weights and liveweight gains from autumn grazing are required. High weaning weights are a function of calving date, weaning date and liveweight gain between these two dates. The extension of weaning date into the rutting period would appear the most likely option in terms of improving autumn growth rates of the calf.

GOATS

Programme Unit 8: Factors affecting goat performance in hill and upland environments

A.J.F. Russel, S.A. Grant, G.R. Bolton, I.R. White, L. Torvell, V.A. Doughty, D.R. Campbell, R.W. Mayes and T.J. Maxwell.

Introduction

The results of a small-scale pilot study conducted in 1981 on the grazing of certain types of vegetation by goats were sufficiently encouraging to merit more detailed investigation in the following year. The main findings of this second year's work are summarised below. On the basis of these two years' results it was considered that, in certain types of hill sheep management systems, grazing by goats might be beneficial to sheep production. If this conclusion were to be confirmed by further work and goats were to be grazed with sheep on certain types of hill it is likely that marketable products would also be sought from the goats. The continuation of the grazing studies together with the initiation of research on goat production clearly involved more measures than could readily be incorporated in existing programmes, and in late 1982 DAFS approved proposals for a goat research programe and undertook to provide funding for a period of three years. Facilities for this work have now been created at Glensaugh and a programme of research with a herd of some 200 animals, and supported by two new appointments, is now being initiated.

As far as goat products are concerned, it is considered that although milk is the main goat product in the UK this form of production is not appropriate in the context of hill farming. Consequently the main emphasis is being placed on meat production and on an assessment of the feasibility of fibre production.

1. Further studies on the possible use of goats in hill sheep grazing systems (project no. 801)

AJFR, SAG, GRB, LT, VAD and IRW

A preliminary study of the plant species grazed by sheep and goats stocked separately on a mosaic reseed at Lephinmore indicated that goats might have a use in certain types of sheep production systems. Their role would be as an aid to management of the varied plant communities of hill land and particularly in the maintenance and further improvement of reseeded pastures. The investigation conducted in 1981 was in the nature of a pilot study and the level of botanical monitoring was kept to a minimum. The goats used were yearling Anglo Nubians which had not previously grazed on hill land, and it was considered in hindsight that they were not particularly well suited to the wet climatic conditions of a hill farm in the west of Scotland. Despite these limitations the results were encouraging and further work using both feral goats and domesticated British Saanen goats, and incorporating more comprehensive botanical measurements, was undertaken at Lephinmore during the 1982 grazing season.

1.1 The utilisation of improved and indigenous pasture components within fenced plots by grazing sheep and goats

SAG, GRB, LT and VAD

Two plots, each 1 ha in extent and each composed of 0.5 ha improved pasture as a single block and 0.5 ha *Calluna-Eriophorum* blanket bog, were grazed by sheep or goats from early June until early September. The plots were stocked with 15 Scottish Blackface wether sheep and with 26 feral female and castrate male goats, the total weight of stock on the two plots being approximately the same (ca 850 kg). In mid-August stock numbers were reduced to 9 sheep and 12 goats (total weights of ca 475 kg) and the study was concluded in early September.

The plots were characterised by recording the floristic composition (percentage cover and percentage specific frequency) of the improved pasture component in May and July and of the *Calluna* dominant and *Eriophorum* dominant components of the indigenous vegetation in July.

The improved pasture was rush infested with frequent tussocks of *Juncus effusus*. Records of the percentage frequency of grazed leaves of grasses, clover and rushes were collected on five occasions, at two or three weekly intervals. The individual tiller of grasses, stolon of clover or a bunch of 10-15 rush stems was used as the unit of measurement and the plots were sampled by walking transects at intervals along which a point quadrat frame (to locate the grass tillers) or a small quadrat (to locate the clover stolon or bunch of rush stems) were placed. The results are summarised in Table 1.

Table 1

Utilisation of Improved Pasture by Sheep and Goats

% Frequency of Grazing. (Grazed leaves in each category as a percentage of leaves observed in that category)

SHEEP PLOT	14 June	28 June	19 July	9 August	30 August	Mn&SE
Grass	40.9	61.2	47.3	49.3	34.7	46.7±4.4
Clover	26.7	62.7	44.0	46.4	31.1	42.2±6.3
Rushes	0.2	0.6	12.1	17.0	20.5	10.1±4.2
GOAT PLOT						
Grass	17.3	39.4	14.4	23.1	22.2	23.3±4.3
Clover	10.3	17.9	9.6	21.8	11.5	14.2±2.4
Rushes	10.1	53.5	89.7	95.4	95.6	68.9±16.6

From Table 1 it can be seen that

a) goats graze less grass and clover compared with sheep

b) goats graze proportionately less clover than grass while sheep have a similar percentage frequency of grazing for these components

c) goats readily graze the rushes while sheep avoid grazing them to any extent

A more detailed examination of the data also show differences in behaviour between sheep and goats with respect to species selection within the grasses. Sheep preferentially grazed Lolium perenne when grasses were classified into L. perenne, Poa annua or other grasses while goats grazed all three classes to a similar extent.

Utilisation of the indigenous pasture was recorded on two occasions, in July and September. Grazing of Eriophorum vaginatum tussocks was observed in the Eriophorum dominant area and the grazing of Calluna in the Calluna dominant area. The results, which are summarised below (Tables 2 and 3), clearly demonstrated that the goats grazed the indigenous vegetation to a greater extent than did the sheep and that the difference in behaviour was most marked in July when availability of grass on the improved pasture was high.

Table 2

Utilisation of Indigenous Pasture by Sheep and Goats

Grazing of Eriophorum vaginatum tussocks.
100 tussocks observed, percentage in denominated categories shown

	Tussocks ungrazed	Tussocks disturbed but not def.grazing	Tussocks with def. grazing	Summer only, No. flowers remaining per tussock
7 July				
SHEEP	82	13	5	5.9
GOATS	24	13	62	1.2
15 September				
SHEEP	3	13	84	
GOATS	9	15	76	

The majority of tussocks grazed by sheep were very lightly grazed having less than 10% of the leaves grazed while the majority of tussocks grazed by goats were severely grazed, about half having 50% or more of the leaves hard grazed or drawn.

In the first trial herbage mass was measured on 28 May and again on 9 July and floristic composition (percentage cover and percentage specific frequency) was recorded on 30 June. The low mass plots were grazed by sheep from early May and the experimental animals, 2 Scottish Blackface wether sheep and 5 British Saanen goats (each treatment totalling some 105 kg animal live weight) introduced to the respective plots at the beginning of June. At the same time the high mass plots were stocked with 3 Blackface sheep and a further 5 British Saanan goats. Records of the frequency of grazed leaves of grasses and rushes (for technique see item 1.1) were collected on 7 June, 21 June and 12 July. The results, summarised in Table 4 confirm the readiness with which goats will graze the rushes compared with sheep and also show that the herbage mass of grass has an influence - the less the amount of grass the more the rushes were grazed by the goats. Where rushes were grazed by sheep the species grazed was usually Juncus acutiflorus rather than Juncus effusus.

Table 4

The influence of herbage mass of grass on the frequency of grazing of grasses and rushes by sheep and goats. (Grazed leaves in each category as a percentage of leaves observed).

	7 June	21 June	12 July
SHEEP			
LOW MASS (600-800 kg DM/ha)			
grasses	48.7	58.3	47.1
rushes	1.8	9.5	0
HIGH MASS (2370-2400 kg DM/ha)			
Grasses	22.9	53.0	40.5
rushes	0	0	0
GOATS			
LOW MASS (900-1680 kg DM/ha)			
grasses	46.3	39.1	30.9
rushes	6.9	48.9	76.9
HIGH MASS (1830-2400 kg DM/ha)			
grasses	8.0	40.3	34.8
rushes	6.2	17.0	41.6

The plots used to compare the effect of cutting versus no cutting of rushes were small and much more variable in their rush content and in their floristic composition than was desirable for comparison of treatment effects. For example Juncus effusus had nearly three times the cover on the 'rushes cut' goat plot (11.0%) compared with the sheep plot (4.5%). By contrast on the 'rushes uncut' plots, Juncus effusus cover was very high on the sheep plot (23.5%) but low on the goat plot (8.0%). Juncus acutiflorus also had appreciable cover on the 'uncut' plots but had low cover (6.0%) on the sheep plot and high cover (22.5%) on the goat plot. Each plot was stocked with either 2 sheep or 2 goats (total live weight per plot ca 75 kg).

The results are summarised in Table 5. There were no differences in percentage of rushes grazed in relation to the treatment (cut vs uncut) though the mean grazed heights, recorded at the end of the trial on 7 September, were less on the 'cut' compared with the 'uncut' plots. The sheep avoided grazing *Juncus effusus* but readily grazed *Juncus acutiflorus*; the goats readily grazed both rush species.

Table 5

The percentage frequency of grazed rush stems on plots grazed by sheep or goats and with rushes cut in late spring or rushes uncut (grazed stems in each category as a percentage of stems observed).

SHEEP	25 May	23 June	26 July	17 Aug.	Mn grazed height,cm.(7Sept)
RUSHES CUT					
J. effusus	0.5	0.7	1.6	4.1	44.5 + 3.1
J. acutiflorus*	24.4	83.8	29.5	34.2	
RUSHES UNCUT					
J. effusus	2.0	0	5.2	10.1	59.9 + 3.7
J. acutiflorus*	3.6	30.4	21.2	80.0	
GOATS					
RUSHES CUT					
J. effusus	24.7	71.1	93.1	93.4	23.4 + 1.0
J. acutiflorus*	ND	ND	ND	ND	
RUSHES UNCUT					
J. effusus	4.4	64.3	87.8	95.0	35.0 + 1.5
J. acutiflorus*	46.2	45.6	85.7	91.3	

ND = No data
**J. acutiflorus* was more local in its distribution than *J. effusus* and the sample size very small compared with *J. effusus.*

Faecal material from the animals used in these studies was also collected for plant cuticle analysis.

2. The effect of nutrition on fibre production of goats (project no. 803)

AJFR and IRW

Nothing is known of the effects of nutrition on fibre production of Scottish feral goats, although there are reports in the literature of such effects in goats in other countries. In general these reports indicate that fibre production will respond to improvements in nutrition. The particular interest in our context is in the production of the cashmere undercoat of feral goats. These fibres, produced by the secondary follicles, are thought to grow most actively in the autumn-winter period and are known to be shed in the spring. It is reasonable to assume that the growth of these fibres will be affected by the level of nutrition, and particularly by the concentration and degradability of dietary protein, although it must be borne in mind that the evidence from work on British breeds of sheep indicates that they do not show any appreciable wool growth responses to nutrition over the winter period.

Against this background of virtually no factual information an investigation was conducted over the period from September 1982 to March 1983 to study the pattern of fibre production in different genotypes and sexes of goats and to examine the effects of level of nutrition, including dietary protein type and allowance, on fibre production.

A total of 38 goats were used in the study. Groups I-III each comprised 6 coloured feral castrate males; Group IV, 6 British Saanen castrate males, Group V, 6 coloured feral females; Group VI, 5 white feral females from Holy Isle; and Group VII, 2 white feral females and 1 white entire feral male from North Wales.

Group I were fed an approximately maintenance allowance of hay throughout the entire period. Group II received a mixture of hay and a concentrate diet based on cerals and soyabean meal at a level of approximately 1.67 x maintenance. Groups III-VII were offered a mixture of hay and a concentrate diet based on cereals and fishmeal at the same level of energy intake as Group II. All allowances were calculated on a metabolic body weight basis, and the majority of animals were individually fed.

All animals were weighed, condition scored and blood sampled fortnightly. Fibre production was estimated by clipping 10 cm^2 patches at intervals of six weeks. These fibre samples are presently being evaluated in terms of production of coarse and fine fibres and diameter of fine fibres. Full results are not yet available, but it is clear at this stage that fibre diameters are well within the strict cashmere classification, most samples being in the 13-16 micron range (cashmere being less than 20 micron). The fine fibres appear to grow rapidly in the autumn and the early winter, but visual assessment suggests that growth ceased in the late winter, probably during February.

The female goats did not appear to exhibit natural oestrus, but responded to treatment with progestagen pessaries, and at least some were mated by the white feral male. Seven of the 13 females are known to be pregnant and the kidding may give some indication of the inheritance of colour, white being the colour which commands the highest price.

It is proposed to examine the feasibility of harvesting cashmere by shearing in the spring.

3. The comparative digestion of roughages by sheep and goats

The literature on the digestive physiology of sheep and goats contains reports which claim that goats digest fodder, and particularly low quality roughages, to a greater degree than do sheep. In view of our recent interest in the possible use of goats in certain types of hill sheep grazing systems, two studies were conducted with the objectives firstly, of ascertaining whether differences in the digestibility of roughages could be demonstrated between the two animal species, and secondly, of identifying the probable origins of any such differences.

3.1 The *in vitro* digestion of forages using rumen liquor from sheep and goats.

DRC, AJFR and IRW

Comparisons of the *in vitro* OM digestion of 20 standard forages by rumen liquor obtained from sheep and goats were made in a series of three separate evaluations using a split-plot design. The rumen liquors were obtained on each occasion from 3 animals of each species, all animals having been fed the same pelleted dried grass diet. The forages used comprised two *Trifolium* samples, and three samples of each of the following species: *Lolium*, *Nardus*, *Molinia*, *Eriophorum*, *Tricophorum* and *Agrostis/Festuca*. Previously determined *in vitro* OM digestibilities ranged from 0.2800 to 0.8122.

There was little or no effect of source of rumen liquor on the OM digestibilities of the highest quality forages (the 2 *Trifolium* samples and the best *Lolium* and *Agrostis/Festuca* samples). On the other samples differences ranged from 0.01 to 0.05, but no discernible pattern of consistent superiority of sheep or goat rumen liquor was evident. Over all 20 samples the OM digestibility estimated with sheep rumen liquor was on average 0.03 higher than that obtained using the goat liquor.

3.2 The assessment of the nutritive value of ensiled willow and poplar and their comparative digestion by sheep and goats

AJFR, RWM and IRW

Preliminary studies had shown that the current season's growth of poplar was readily consumed by sheep when chopped and fed either fresh or after ensiling in polythene bags. The quantity of material available for these preliminary studies was insufficient for an *in vivo* evaluation of its nutrient content, but the sheep ate it avidly. Intakes were of the order of 2 kg/day (approximately 650 g DM/d). *In vitro* estimates of OM digestibility were 0.508 and 0.449 for the fresh and ensiled materials respectively, giving estimated energy contents of 7.25 and 6.51 MJ ME/kg DM. These figures must, however, be regarded as very tentative because of the lack of appropriate standards for the *in vitro* determinations.

If this type of material has a potential as fodder for ruminant livestock it is likely to be for winter-feeding and with this in mind an experiment, using 8 Blackface wether sheep, was undertaken to determine *in vivo* the nutritive value of ensiled poplar and willow material harvested at two dates.

Some of the material was fed in the same study to 4 castrate British Saanen goats to examine the comparative digestion of this type of feeding stuff by two animal species. Estimates of *in vivo* digestibility and rate of passage were made on both sheep and goats.

The experiment was successfully completed with all animals taking readily to the diets. The analytical work is now in progress.

GRAZING STUDIES

1. HILL SWARDS

Research objective : Grazing control and manipulation in hill swards (project no. 203).

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

S.A Grant, G.R. Bolton, L. Torvell and V.A. Doughty

The long term study at Lephinmore investigating the effect of different levels of utilisation of blanket bog by grazing sheep was brought to a close prematurely as a consequence of the Organisation's loss of the Lephinmore field station in 1982. The timing has proved unfortunate as changes in the response of the vegetation to management have appeared comparing recent years with the earlier years of the study.

The study consisted of a stocking rate experiment with three stocking rates being provided at each of three sites. The plots at each site were 0.1 ha in extent and the seasonal pattern of grazing was consistent with that of the unimproved hill in a two-pasture management system. One site was treated as though it were part of an off-wintering system (OWS) and two sites as though they were part of a year round grazing system (YRGS). Stocking rates in grazing days per hectare per annum were 136, 296 and 484 (OWS) and 237, 494 and 810 (YRGS) respectively on the low (L), intermediate (I) and high (H) treatments.

Grazing treatments were begun in August 1971 and terminated in July 1982. Floristic composition (% cover) was recorded annually each July and harvests to record above ground biomass of higher plants were made at three yearly intervals.

Prior to 1980 plant cover and productivity were unaffected comparing L and I treatments though there was clear evidence of of damage attributable to over grazing on the H treatment plots. Recent changes in response trends on H and I plots however, perhaps initiated as early as 1980 but only becoming markedly apparent by 1982, suggest a change in the sensitivity of the bog ecosystem in terms of its tolerance to utilisation by grazing sheep. Figures 1 and 2, showing the changes with time in % cover (means of three sites) of heather and of ground bare of higher plants respectively, illustrate this point.

The reasons for the apparent change in response of blanket bog vegetation to given utilisation levels were thought to be associated with climatic variation and its effects on both the vigour of growth of the bog species and on their ability to withstand grazing and treading damage. Rainfall data from Lephinmore show that the period May 1971-April 1979 was drier than average and was characterised by both drier summers (May-October rainfall) and less

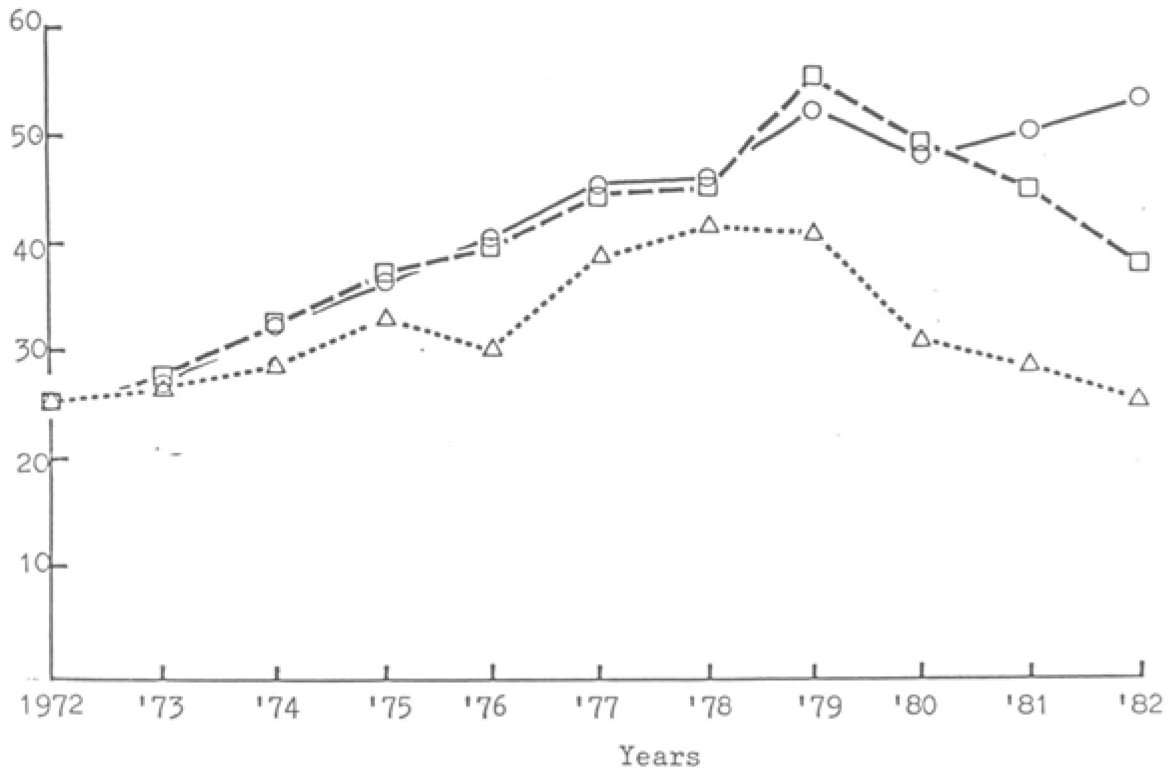


Figure 1 Blanket Bog. Trends over time in % heather cover. Means of three sites, △ ,High; □ , Intermediate; and O, Low stocking.

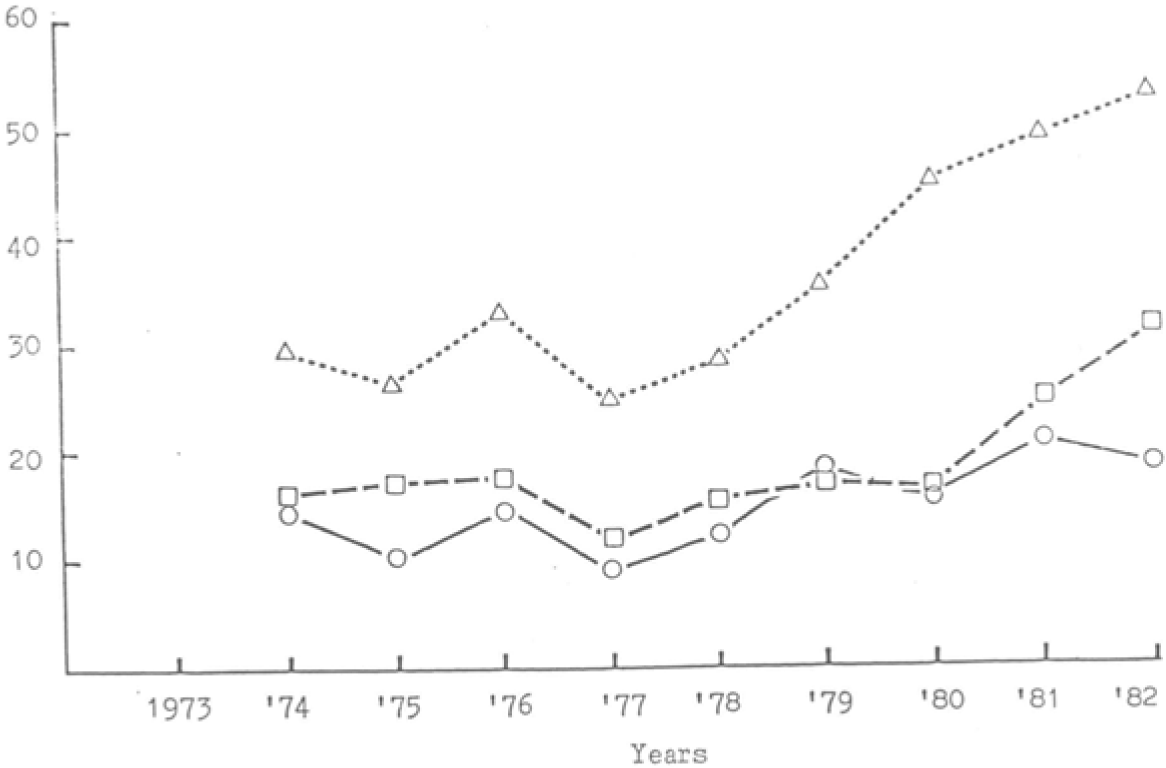


Figure 2 Blanket Bog. Trends over time in % bare peat or moss Means of three sites, △ ,High; □ , Intermediate; and O, Low stocking.

total rainfall per annum than the period May 1979-October 1982, which was wetter than average. Data from the Younger Botanic Garden at Benmore, about 14 Km distant, show that the winters from 1971/72 to 1975/76 inclusive were relatively mild compared with more recent winters. Climatological data summarising these trends are given in the Table 1 below.

Table 1

Climatic Trends* 1971-1982

	RAINFALL (mm) May-October	RAINFALL (mm) May-April	Days Air frost	No. months Mean T 4
1971-72	589	1590	47	1
1972-73	670	1558	41	1
1973-74	633	1757	47	0
1974-75	735	1830	40	0
1975-76	687	1767	40	0
1976-77	637	1707	59	3
1977-78	744	1683	57	2
1978-79	771	1723	80	4
1979-80	826	1799	61	2
1980-81	958	2022	69	1
1981-82	882	1927	55	2
1982-	866	-	-	-

* The rainfall data are from Lephinmore and the periods of time at low temperature from the Younger Botanic Garden.

The timing of the change in the vegetation response coincides remarkably closely with the change in the rainfall pattern from drier than average to wetter than average years. Heather is known to grow less vigorously in wet conditions. A possible additional contributory factor is the increasing age and woodiness of the heather which, as well as reducing the plants tolerance to grazing, could be expected to increase its susceptibility to trampling damage. Trampling damage is not necessarily immediately evident and many bruised stems appear normal until the first occasion of serious internal moisture deficit, such as may occur on a windy day in winter when the ground is frozen.

As mentioned previously the premature ending of grazing treatments in this experiment is unfortunate as the opportunity to distinguish whether the recent damage associated with the intermediate stocking levels was a permanent or temporary phenomenon has been lost. It could be reasoned that a utilisation level which on average was about level with the tolerance of the vegetation, in good years would allow a build up of cover and biomass while in bad years loss of cover and biomass would occur, with the status quo being maintained in the long term. Alternatively, the change in community structure during the good years, particularly the ageing of the heaths, may reduce tolerance of grazing and more permanent changes in the community may be initiated when the climate becomes less favourable.

1.2 Input-Output Experiments at Sourhope

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

A series of progressively more comprehensive improvement treatments were applied to three contrasting hill pasture types at Sourhope commencing in 1969 (Annual Report 1974, p.22). The objectives of these long term experiments included the assessment of the effects of treatment upon nutrient recyling, herbage production, digestibility, herbage intake, sheep live-weight changes during grazing and carrying capacity measured as sheep-grazing-days.

All treatments at each site were grazed simultaneously by mature Cheviot wether sheep for two periods of four weeks each between May and August, and for one period of three weeks in October or November. Stocking rates in each grazing period were set to equalise herbage mass per sheep and to graze all plots to a target of 560 kg DM/ha herbage mass at the end of the grazing period. The carrying capacity of each treatment was expressed as grazing-days/ha.

Herbage production was determined by harvesting a series of random quadrat samples during the grazing period (Annual Report 1974, p.93).

During the grazing periods the live weights of individual sheep were recorded weekly.

The amount of herbage ingested during grazing (expressed as organic matter intake), individual intake and organic matter digestibility were calculated as follows:

The organic matter intake (OMI) was calculated from the intake factor (IF) and faecal organic matter output (FOM) using OMI = FOM x IF

IF was calculated from the equation

$$IF = 0.75\ (FN) - 0.12\ (M) + 1.66$$

where (FN) is the faecal N% and (M) is a monthly correction factor (Armstrong and Eadie, 1977).

The individual intake was calculated from OMI and grazing days (GD):

$$\text{individual intake} = OMI/GD$$

The organic matter digestibility (OMD) was calculated from IF using the relationship:

$$IF = 100/(100 - OMD)$$

The data presented in this report was obtained in two recording years for each site:

Site 1 - 1971 and 1974
Site 2 - 1972 and 1975
Site 3 - 1973 and 1976

and has been recalculated from data presented in previous annual reports (1974 and 1977).

Table 1

Mean OMD values of herbage from five improvement treatments on three sites

Site	Treatments 1	2	3	4	5	Site Means
1	0.684	0.697	0.686	0.701	0.714	0.696
2	0.664	0.663	0.659	0.692	0.713	0.678
3	0.678	0.675	0.674	0.698	0.728	0.691
Treatment Means	0.676	0.678	0.673	0.697	0.718	

SED between site means (n = 10) = 0.005
SED between treatment means (n = 6) = 0.007
SED between site.treatment means (n = 2) = 0.011

The mean OMD value for site 1 was not significantly different from site 3, but both sites were significantly ($P < 0.05$) higher than site 2.

There was a significant ($P < 0.01$) effect of treatment. There were no significant differences between the overall means for treatments 1, 2 and 3 while there was a significant ($P < 0.05$) increase on treatment 4 and a further significant ($P < 0.05$) increase on treatment 5.

There was no significant site.treatment effect and no significant differences between means for treatments within sites.

The mean organic matter intake (OMI) (Table 2) on site 1 was significantly ($P < 0.01$) higher than sites 2 and 3. There was no significant difference between sites 2 and 3.

Table 2

Organic matter intake (kg/ha) for five pasture improvement treatments on three sites

Site	Treatment 1	2	3	4	5	Site Means
1	3710	4290	4253	4482	5852	4518
2	2692	2563	2452	4382	4718	3361
3	3071	3240	3470	4207	4818	3761
Treatment Means	3158	3365	3392	4357	5129	

SED between site means (n = 10) = 230
SED between treatment means (n = 6) = 297
SED between site.treatment means (n = 2) = 514

There were no significant differences between the overall means for treatments 1, 2 and 3. There was a significant ($P < 0.05$) increase on treatment 4 and a further significant ($P < 0.05$) increase on treatment 5. There was no significant difference in mean OMI between any treatment within a site.

Table 3

Individual sheep intake (kg OM/day) from five improvement treatments on three sites

Site	Treatment 1	2	3	4	5	Site Means
1	1.444	1.492	1.462	1.492	1.439	1.466
2	1.271	1.252	1.213	1.490	1.519	1.349
3	1.361	1.325	1.316	1.482	1.492	1.395
Treatment Means	1.359	1.357	1.330	1.488	1.483	

SED between site means (n = 10) = 0.048
SED between treatment means (n = 6) = 0.062
SED between site.treatment means (n = 2) = 0.106

The mean individual sheep intake (Table 3) for site 1 was significantly ($P < 0.05$) greater than for site 2. Site 3, however, was not significantly different from sites 1 and 2.

There was no significant difference in overall individual intake means between treatments.

Although there were no significant differences between means of treatments within sites the site.treatment interaction was significant ($P < 0.05$).

Table 4

Carrying capacity (days) of five pasture improvement treatments on three sites

Site	Treatment 1	2	3	4	5	Site Means
1	2570	2841	2861	3000	4028	3060
2	2297	2092	2090	2999	3177	2531
3	2288	2503	2664	2792	3259	2701
Treatment Means	2385	2479	2538	2930	3488	

SED between site means (n = 10) = 140
SED between treatment means (n = 6) = 181
SED between site.treatment means (n = 2) = 304

The mean carrying capacity (Table 4), expressed as grazing days, was significantly ($P < 0.01$) greater on site 1 than on sites 2 and 3. There was no significant difference in mean grazing days between sites 2 and 3.

While there was no significant difference in mean grazing days between treatments 1, 2 and 3 there was a significant ($P < 0.05$) increase on treatment 4 and a further significant ($P < 0.01$) increase on treatment 5. The treatment effect was significant ($P < 0.01$).

The site.treatment interaction was not significant and there were no significant differences beteen treatments within sites.

Table 5

Sheep live-weight changes (kg) from five improvement treatments on three sites

Site	Treatment 1	2	3	4	5	Site Means
1	+2.75	+3.85	+0.30	+3.20	+6.20	+3.26
2	-0.95	-0.75	+1.10	+3.95	+5.10	+1.69
3	-3.70	-4.60	-1.35	+3.45	+8.25	+0.41
Treatment Means	-0.63	-0.50	+0.02	+3.53	+6.52	

SED between site means (n = 10) = 1.498
SED between treatment means (n = 6) = 1.934
SED between site.treatment means (n = 2) = 3.350

There were no significant effects or interactions in sheep live-weight changes (Table 5).

Also there were no significant differences between any of the means.

However, the mean weight gains for treatments within sites tended to be greater, but not signficantly, on the oversown treatments (4 and 5) than on treatments 1, 2 and 3.

Reference

Armstrong, R.H. and Eadie, J. (1977). The growth of hill lambs on herbage diets. Journal of Agricultural Science, Cambridge v.88 p.683-692.

2. SOWN SWARDS

Research objective: Herbage production and utilisation of enclosed swards (project no. 204).

2.1. The effect of change in sward management on herbage production of continuously stocked swards.

S.A. Grant, G.T. Barthram, L. Torvell and V.A. Doughty

In May 1982 plots (replication x 2) managed to maintain high (H) herbage height and mass (6.0 cm, 2250-2500 kg OM/ha) or low (L) herbage height and mass (3.0 cm, 1250-1500 kg OM/ha) since May of the previous year were split to provide four sub-plots per replicate; on two sub-plots management was maintained as before (HH and LL treatments) and on two management was changed (HL and LH treatments). Measurements to establish production per tiller, tiller population density and production per unit area were made immediately prior to the management change and at weekly intervals for a period of six weeks after treatments began.

The data are currently being processed and have yet to be statistically analysed. However the patterns of response over time of the two main components of sward production, production per tiller and tiller population density, are shown in Fig. 1.

On HL compared with HH swards there was a small drop in lamina growth per tiller (ryegrass tillers) and an initial reduction in tiller numbers before the numbers began to rise in week 5. The data suggest a more modest reduction in production on HL plots than that which was observed in a similar experiment conducted in autumn (Bircham, 1981). When grazing pressure was relaxed on the previously hard grazed swards (LH treatment) lamina growth per tiller increased to match, or even exceed, that of HH tillers by week 3; decline in tiller population to match population densities on HH sub-plots took 5 to 6 weeks. The time lag between these two adjustments together with, for ryegrass tillers, the initially high proportion of efficient young leaf and low losses to senescence suggest a temporary advantage of LH management over other managements. In autumn, in a similar experiment, Bircham (1981) also found increased growth on LH swards. However, measurements were made over a two week period commencing 30 days after management change and at this time the increased growth was offset by increased senescence.

In the current experiment, *Poa* tillers were very frequent and out-numbered *Lolium* on some plots. Their response to management was less clear cut than *Lolium* because of initial variation among sub-plots before treatments were imposed. However, it was clear that *Poa* was much less productive than *Lolium*; lamina growth per tiller averaged only 0.4 to 0.5 that of *Lolium* but senescence losses were high averaging between 0.9 and 1.8 that of Lolium so that net growth was only 0.2 to 0.4 that of *Lolium*. Clearly swards invaded by *Poa*, during the main reproductive phase at any rate, suffer a substantial production penalty in terms of leaf growth.

Reference

Bircham, J.S. 1981. Herbage growth and utilisation under continuous stocking management. Ph.D. Thesis, University of Edinburgh.

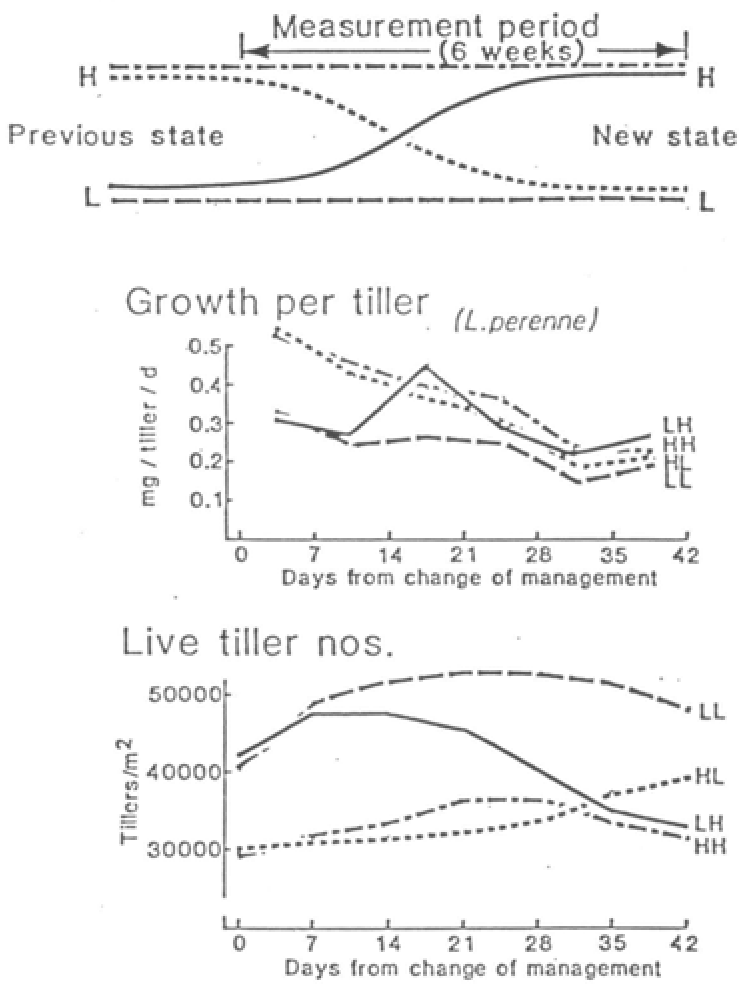


Figure 1. Changes in production per tiller and tiller population density in different management regimes.

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

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

The mixed grazing project described in the Annual Report for 1981 (p.A61) was continued throughout the 1982 grazing season. The results described for 1981 were confirmed, swards grazed by cattle alone maintaining tiller populations and rates of herbage growth and net production lower than those on swards grazed by either sheep alone or sheep and cattle in combination. The project has now been terminated, the final measurements on both swards and minerals being made in September 1982.

This work has now been written up as a Ph.D. thesis (Arosteguy, 1982). The main conclusions are as follows:

There is little reason to expect that net herbage production will be higher under mixed grazing than under grazing by either sheep or cattle alone. At similar grazing pressures cattle-grazed swards would be expected to have lower tiller densities than sheep-grazed swards and this in turn will result in a depression in net herbage production. However, the addition of sheep to a cattle-grazing system should result in the maintenance of tiller density and consequently net herbage production at levels close to those expected from sheep-grazed swards. When swards are intensively grazed mixed stocking does not appear to result in a greater efficiency of herbage utilisation than is achieved by either sheep or cattle grazing alone. The evidence demonstrated almost complete overlap in the diets selected by sheep and cattle. There is therefore no reason to expect that mixed species grazing management will result in synergistic effects upon herbage production and utilisation, though there is evidence of the existence of competitive advantages to sheep in the maintenance of herbage intake under limiting sward conditions.

In this study attention was concentrated principally upon the reaction of the sward to variations in grazing management. Though herbage production and utilisation are clearly no better under mixed grazing than grazing by sheep alone, the production advantages of cattle-grazed swards may contribute towards the greater animal output observed elsewhere from mixed grazing than from single-species grazing systems.

Reference

Arosteguy, J.C. (1982). The dynamics of herbage production and utilisation in swards grazed by cattle and sheep. Ph.D. Thesis, University of Edinburgh.

2.3. The estimation of rates of tiller turnover

G.T. Barthram

Rates of ryegrass tiller appearance and disappearance were estimated in two grazing experiments during 1981.

In experiment G14 eight randomly chosen groups of approximately 20 tillers per treatment were surrounded by a wire loop which was pegged to the ground. The pseudostem of each tiller was then marked with orange paint (Winfield silk vinyl) from a syringe and the number of marked tillers recorded. Six days later turfs containing the marked tillers were moved indoors and the numbers of surviving marked tillers, and any new (unmarked) tillers were recorded. Pairs of observations were made on 16 occasions between 10 June 1981 and 27 October 1981.

For experiment G14, 12% of the total number of pairs of observations were incorrect, with more marked tillers recorded as present per group on day 6 than were recorded as marked on day 0. Most of these errors (36%) were from the short dense 2 cm tall sward, with 26% from the 3 cm, 18% from the 4.5 cm and 20% from the 6.0 cm tall swards. It is quite possible that there are as many undetected errors. Some operators made more errors than others, but all operators made fewer errors with experience and when recording in dry weather.

The results from the groups of tillers where errors were not detected were similar for all grazing treatments with appearance rates of about 2.3 and disappearance rates of about 1.5 tillers per 100 tillers per day in June falling to near zero in September and October.

In the second experiment (G13; Arosteguy, 1982) the above method was used during the first three weeks of August. A second method of observation was used in addition from the beginning of August until the end of September. The second method involved marking five tillers on each of four randomly located transects per plot with a wire loop and recording at weekly intervals the presence/absence of the tiller and the number of daughters produced. Each new daughter was marked with a loop of differently coloured wire one week after detection.

The two operators with the lowest numbers of detectable errors in experiment G14 also made the measurements in the second experiment. There the swards were grazed by cattle and sheep either alone or in combination. The results of the two methods of observation showed slight differences (Table 1), with the rates derived from the tiller group technique being of the same order as those obtained using the same technique in experiment G14.

Table 1

Results from two techniques used to assess rates of ryegrass tiller appearance and disappearance during the first three weeks of August 1981 (from Arosteguy, 1982). Rates are tillers per 100 tillers per day.

technique		tiller groups			single tillers		
grazing species+		C	S	C+S	C	S	C+S
Tiller appearance rate							
herbage mass	1600	1.2	1.1	1.2	1.7	5.5	1.7
(kg OM/ha)	1900	0.9	1.4	2.3	2.9	2.6	1.9
	SE$\bar{x}$			0.40			1.0
Tiller disappearance rate							
herbage mass	1600	0.9	0.4	0.6	1.7	0.2	0.5
(kg OM/ha)	1900	0.3	0.6	0.3	0.2	0.0	0.5
	SE$\bar{x}$			0.23			0.2

+ C = cattle
  S = sheep

Arosteguy suggests that the single tiller technique needs a longer measurement interval than the tiller group technique. Unfortunately this may reduce the usefulness of the technique when tiller population density is changing rapidly, although the problem may be overcome by using a larger sample. Compared with the tiller group technique the single tiller technique is more liable to sampling bias and the result is more likely to be distorted because of the repeated sward disturbance. Sward disturbance probably has no effect on the results of the tiller group technique because the time required for the effects to become apparent is greater than the measurement interval, but this technique can suffer from unacceptably high operator error. If this problem can be overcome then the technique would appear to be the more reliable of the two.

Reference

Arosteguy, J.C. 1982. The dynamics of herbage production and utilisation in swards grazed by cattle and sheep. Ph.D. Thesis, University of Edinburgh.

2.4. Demonstration plots

J. Hodgson, W.G. Souter, G.T. Barthram with T.J. Maxwell

A set of four plots was set up on a sward dominated by perennial ryegrass in oder to demonstrate the "sward target" approach to grazing management (Biennial Report 1979-81, p.169). The plots were stocked with Blackface ewes and their lambs at lambing in early May and were maintained at sward surface heights of 2.5 cm, 3.5 cm, 4.5 cm and 6 cm respectively (equivalent to herbage masses of 800, 1200, 1600 and 2000 kg OM/ha), by adjusting sheep numbers under continuous stocking, until the lambs were weaned in early August.

The numbers of animals involved were relatively small, but records were maintained of stocking rates, ewe weight changes and lamb growth. The plots provided a useful focal point for discussion with visitors on many aspects of grassland management, one group of local farmers returning on three occasions during the summer to see them. The approach will be repeated in 1983.

3. FORAGE CROPS

Research objective : Control of forage consumption and grazing efficiency of forage crops (project no. 209).

3.1. The intake and performance of weaned lambs on rape 'leaf' and 'stem' in relation to crop condition and lamb size

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

The poor performance of lambs grazing Brassica crops has been variously ascribed by researchers elsewhere to metabolic disease or high water content, probably as a consequence of depression of herbage intake. The metabolic problems are anaemia (due to non-protein sulphur contents of herbage), 'goitre' (due to thiocyanates), and copper deficiency, which may also exaggerate the anaemia problem.

However most investigations have not involved measurements of intake, and no critical indoor work has been published.

A pilot experiment at HFRO (Annual Report, 1981 p.A64) showed that herbage organic matter digestibility (OMD) was usually over .80, but intakes were very low, whether by pen-fed or grazing lambs. The experiment suggested that intake (OMI) of stem declined more rapidly than did OMD as stems were grazed down, possibly due to physical toughness. Indirect evidence also suggested that leaf petiole was of higher potential OMD and intake than was lamina.

It has been claimed that the size of lambs influences their response to rape.

The experiment reported here was carried out to examine the influence of components of the rape plant, and of lamb size, on herbage intake and on lamb performance. A grazing experiment was conducted in concert with investigations into the effects of energy and protein supplementation (J.A. Milne, H. Dove) and into copper supplementation (A. Whitelaw), at Hartwood using a crop of 'Lair' giant rape. A small intake/digestibility trial was conducted concurrently using harvested herbage indoors in which hand-separated plant components were fed separately to individually penned lambs.

a) Herbage intake/digestibility trial

Herbage was cut daily by Allen Scythe and separated into four main components; lamina, petiole, upper stem (2/3) and lower stem (1/3). These four components and a sample of whole crop were chopped into lengths (≃ 1½") and each fed (after a preliminary period of 7 days) separately to one of 5 individually penned lambs over 5 successive 9-day periods in a latin square design.

Herbage was offered daily to 10% excess; faecal collections were made on the last 6 days of each period (in two 3-day sub-periods). Samples of herbage were cold stored each day for subsequent aggregation within feeds x periods and analysis for DM, Ash, S.M.C.O., thiocyanate, reducing sugars and mineral contents and *in vitro* digestion of organic matter (IVOMD). Other sub-samples were subsequently fed to fistulated lambs to determine relationships of IVOMD (extrusa) to IVOMD (feed) and then to OMD, for use as *in vitro* digestion standards for grazing study samples. Faecal samples were weighed and analysed for DM and Ash content.

b) Grazing experiment

The two crop treatments were 'leaf' and 'stem'; leaf being the ungrazed crop, whereas stem was created by preliminary grazing which removed most of the leaf. Subsequently, during the three consecutive 2-week periods, a leader:follower system was adopted so that leaf in period 1 became stem in period 2 and so on. Lambs were moved so that they stayed on leaf or stem throughout the three periods.

Plots for intake measurement lambs were 0.13 ha (replicated twice) and those for performance lambs were 0.30 ha (unreplicated) so that herbage allowance (assuming equivalent herbage mass) was equal, at a stocking rate of 100/ha.

The lambs were Blackface, either 'light' (21-25 kg liveweight) or heavy (29-36 kg); the intermediates being allocated to the associated supplementation experiment (J.A. Milne/H. Dove). Intake and performance groups were of 12 and 30 lambs respectively (each being composed of equal numbers of light or heavy lambs). All lambs were put on the crop on 28th September, then on to treatment plots on 11th October; thereafter they were moved twice at approximately 2-week intervals on the leader:follower system until 22nd November.

As part of the investigation by the veterinary section (A. Whitelaw) into the effect of copper, half the performance lambs and all indoors and intake lambs, were dosed with copper oxide needles. Lambs were also dosed for worms at the start, then blood sampled and weighed at fortnightly intervals.

Oesophageal-fistulate lambs were allocated to intake treatments (one per plot, but run in pairs) to provide samples of extrusa for diet digestibility and composition estimates.

Herbage intake was estimated by standard procedures from faecal output (by chromic oxide dilution) and digestibility (from *in vitro* digestion estimates on samples of the extrusa).

Estimates of carcase, energy and protein gain will be made from a representative number of animals slaughtered at the start and from each treatment performance group at the end.

Estimates of herbage mass (and litter) and its composition were made by cutting nine 60 x 40 cm quadrats to ground level on each plot at the beginning and end of each period. Sub-samples of this herbage will be analysed as will the herbage from the indoor trial.

Results

a) Indoor intake and digestibility trial

The assessment of potential intake indoors may be invalid because of possible differential effects of the chopping on plant components. However there are significant differences between OMI of some components (Table 1), notably the high level of petiole and low levels of lower stem and lamina. While intakes of stem may have been influenced by chopping, it is unlikely that low intake of lamina, or high intakes of petiole, were so influenced. The differences shown here will have great significance on performance if they obtain in practice. The data also show no significant additive effects between components on digestibility or intake.

Table 1

The composition of herbage offered, with digestibility, intake and digestible organic matter intake (g/hd/day).

	Lamina	Petiole	Upper Stem	Lower Stem	Whole Crop
Composition+	23.2	22.6	31.9	22.4	100
OMD	.847	.892	.865	.771	.838
IVOMD	.818	.917	.880	.774	.884
OMI	467	694	651	534	635
DOMI	396	619	563	412	532

+% (DM) of whole crop cut to ground level

Note : the table excludes data from one lamb which scoured on 2 feeds.

b) Grazing experiment

The liveweight gain of performance lambs (Table 2a) was greater than in 1981; though this may have been due to soiling as a consequence of the very wet conditions throughout the experiment.

Gains of lambs grazing leaf were much greater than those on stem; in addition those of the light lambs were slightly greater than of heavy lambs especially on leaf, though not significantly so. Since gains of the intake lambs (Table 2b) closely reflected those of the copper-dosed performance lambs it seems that intake was not being affected by dosing and handling. The superiority of light over heavy lambs was statistically significant when intake and performance lambs were combined.

There was a trend towards greater liveweight gain of copper dosed lambs grazing leaf over the last two weeks of the experiment which approached statistical significance.

Diet composition (Table 3) was determined by separation of eight extrusa samples (taken from 2 pairs of lambs on each of two days) during the measurement week on the intake plots.

These show that the attempts to partition the crop into leaf components or stem were largely successful, at least during the measurement week.

Detailed comment on the relationships between diet composition, intake, performance and crop parameters awaits completion of chemical analysis. However it seems likely that the superior performance on leaf was largely due to high intrinsic potential of petiole relative to that of lower stem.

Table 2

Liveweight gain (g/hd/day) of lambs on grazing expt.

a) Performance lambs (28/9/82 -22/11/82)

	LEAF			STEM			
	Light	Heavy	Mean	Light	Heavy	Mean	Grand mean
Copper	186.0	158.8	172.4	116.7	100.1	108.0	140.2
Control	159.5	132.2	145.8	105.6	107.8	106.4	126.1
	172.7	145.5	159.1	110.8	103.6	107.2	

S.E. of differences of means :

Crop	10.02
Wt. class	10.02
Copper	10.04
Crop x Wt.	14.16
Crop x Copper	14.18

b) Intake lambs (28/9/82 - 19/11/82) (All copper):

LEAF			STEM			
Light	Heavy	Mean	Light	Heavy	Mean	Grand mean
177.0	161.2	169.1	116.2	107.3	111.8	140.4

S.E. of differences of means :

Crop	12.41
Wt. class	11.59
Crop x Wt. class	16.98

Note : means quoted are approximate because of unequal numbers.

Table 3

Diet composition (% in DM)

	'LEAF'				'STEM'			
	Diet identified	Lamina	Petiole	Stem	Diet identified	Lamina	Petiole	Stem
Period								
1	99.0	61.5	37.1	1.4	92.4	0.2	14.0	84.6
2	99.1	60.3	35.8	3.8	93.5	0.2	1.4	97.4
3	96.4	26.2	66.2	7.5	87.4	0.1	1.2	95.8
Mean	98.2	49.3	46.6	4.2	91.1	0.2	5.5	92.6

Note : Individual components are expressed as a proportion of total identified components. Weeds were never more than 1%.

Comparison of herbage intake and performance of lambs grazing swedes or cabbage:

At the end of the rape experiment 24 lambs were taken from the intake groups. These were allocated on the basis of previous treatment and liveweight class to crops of swedes (Doon Major) or cabbage (Early Drumhead) at equal herbage allowance. Diet composition and digestibility and intake were estimated as usual, and liveweight and grades recorded for 2 weeks.

No herbage intake or digestibility data is yet to hand, though since the cabbage crop was depleted much more rapidly than the swedes, it is likely that intake of cabbage was greater.

Liveweight changes (g/head/day) were +68 and −9 for cabbage and swedes respectively.

There were no differenes in lamb tooth loss or firmness between the crops.

Programme Unit 1: Factors affecting production of herbage from hill and pasture.

1. SOIL CHEMISTRY

Research objective: Understand the origins of acidity in hill and upland soils so that lime requirements can be predicted (project no. 101).

1.1 The determination of exchangeable aluminium

K. Logan, M.J.S. Floate and A.D. Ironside

The total exchangeable acidity (H^+ + Al) of a soil is determined by titrating a 1M KCl leachate with 0.02M NaOH to an equilibrium endpoint (HFRO Annual Report, 1981 p.C35). The aluminium component of the acidity, exchangeable Al (exch. Al), was complexed with NaF and the acidity due to H^+ alone measured by backtitration. Exch. Al was then calculated by difference between total exch. acidity and exch. H^+ acidity.

Since this procedure was time consuming, a comparison was made with the direct measurement of exch. Al by colorimetry. The Al in 1M KCl leachates was determined using continuous flow analysis with Alizarin Red as the coloured complexing agent (Lancaster and Balasubramaniam, 1974). Results for exch. Al in 20 samples measured by colorimetry (Al_c) are compared in Table 1 with values obtained by tritration (Al_t).

Al_c is consistently higher than Al_t, but values for Al concentration by both methods are significantly related (R = 0.995). In the colorimetric procedure, the determination of Al was made at pH 4.2 where all Al present reacts with Alizarin and, for the conversion of the measured Al concentration to equivalents, one mole of Al is assumed to equal 3 equivalents. The Al determined by titration can be in several forms depending on soil pH and, since Al_t is measured as base equivalents, this does not presume the valency of Al.

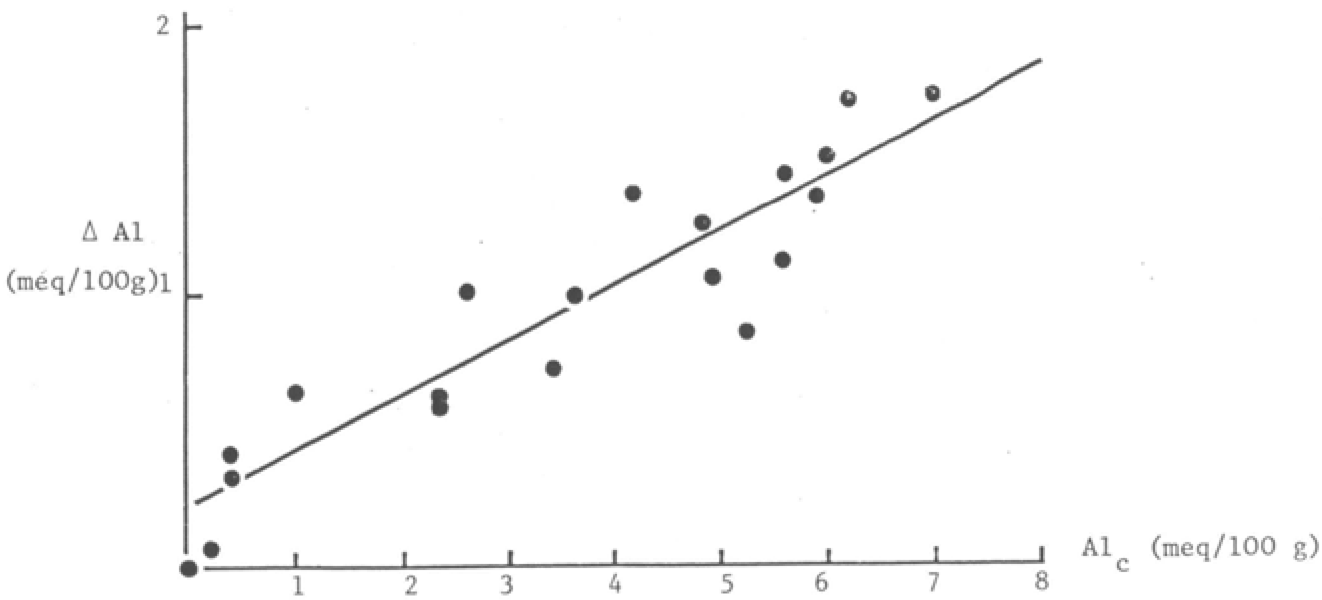


Figure 1. Relationship between exch. Al by colouration and Δ Al.

It was therefore expected that as soil pH increased from 4 to 6, causing an increase in the proportion of lower valence Al forms, the difference (ΔAl) between Al_t and Al_c would increase. However, although ΔAl varied with pH (R = 0.86), ΔAl decreased with increasing pH. ΔAl did increase with increasing Al concentration (R = 0.93), shown in Fig. 1, suggesting that the recovery of Al by titration decreased as Al concentration increased. Al_t is calculated by difference between exch. acidity and exch. H^+ and, since the recovery of exch. acidity decreases with increasing Al concentration, this can be partly explained.

Reference

Lancaster, L.A. and Balasubramaniam, R. (1974). An automated procedure for the determination of aluminium in soil and plant digests. Journal of the Science of Food and Agriculture v.25, p.381-386.

Table 1

Comparison of colouration and titration techniques for the determination of exch. Al

Sample (meq/100 g)	Al_t (meq/100 g)	Al_c (meq/100 g)	Al pH	Soil
85	4.52	5.89	1.37	4.51
81	3.87	4.93	1.06	4.62
12	4.49	6.21	1.72	4.67
22	4.50	6.01	1.51	4.67
83	3.55	4.81	1.26	4.68
82	4.46	5.58	1.12	4.71
18	5.29	7.01	1.72	4.73
16	4.15	5.60	1.45	4.78
96	4.39	5.25	0.86	4.81
17	2.83	4.20	1.37	4.82
21	1.59	2.62	1.03	4.91
93	1.71	2.35	0.64	4.94
95	1.74	2.35	0.61	4.96
20	2.62	3.61	0.99	5.00
80	2.70	3.43	0.73	5.19
15	0.09	0.43	0.34	5.31
14	0.38	1.03	0.65	5.42
19	0.15	0.23	0.08	5.56
89	0	0.43	0.43	5.67
79	0	0	0	6.00

1.2. 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 10 composite soils was determined at varied pH using buffered Ba solutions, and that the change in CEC from the native to the target pH of 5.5 (Δ CEC) was closely related to lime requirement to pH 5.5 (LR) measured in the laboratory. The range of soil types in the study has been increased and now includes a total of 30 soils with different liming histories, described in Table 1.

Results for CEC measured at different pH levels are given for the 30 soils in Table 2. For each soil there is a highly significant correlation between CEC and pH ($R > 0.9$), illustrated by the regression equations in Table 3. Comparison of slope of regression (m) with loss on ignition (%LOI) data has shown that the change in CEC with pH increases with increasing organic matter content ($R = 0.94$).

To establish the CEC of a soil in its native state, CEC was measured in unbuffered Ba solution. However, as the determination proceeds, the pH of each subsequent extract tends to increase, causing enhanced CEC values so that native CEC cannot be measured directly. CEC at any pH can be calculated by interpolation from the regression of CEC v. pH. The pH at which CEC is measured is the pH of the final extract, i.e. 0.025 M $MgSO_4$ solution, hence, for CEC purposes, the native pH of a soil is best represented by its pH in $MgSO_4$ solution. Native CEC is therefore defined as the CEC at the pH of a soil in 0.025 M $MgSO_4$ solution, and is calculated from the regression of CEC v. pH.

Since native CEC varies with liming history, CEC is significantly correlated ($R = 0.91$) with LR. The regression equation relating these values, given in Table 4,

$$LR = 1.119\ \Delta CEC + 1.482$$

was then used to calculate from ΔCEC, the amount of lime which each soil theoretically required to achieve an increase in pH to 5.5. Each soil was treated with lime additions equal to CEC and to 1.119 ΔCEC + 1.482, and the pH due to each treatment measured after 2, 4, 24 and 48 hours. A t-test performed on the attained pH values showed that the ΔCEC lime addition resulted in pH significantly lower than the target, but that lime additions calculated from the regressions produced, after 48 hours, pH values not significantly different ($P < 0.05$) from pH 5.5. Hence, this function of Δ CEC seems to offer a good basis for the prediction of lime requirement.

It is well known that laboratory values for LR do not always agree with the field pH response to lime. This is illustrated by observations from the Stanhope liming trial. Although calculations from the measured Δ CEC of unlimed Stanhope soil indicated an LR of 1.5 tonne/ha, this lime rate only increased the soil pH to about 4.8. This discrepancy can be explained by poor mixing of lime and soil, low temperatures, runoff, leaching and the presence of micro-organisms as opposed to the ideal laboratory conditions.

Table 1

Characteristics of soil samples used in the acidity study

Sample No.	Location	Rate and year of lime application (t ha^{-1})	Sampling date	Soil type
1	Sourhope, Fasset	0	1981	brown forest
2	Sourhope, Fasset	5.0 + 5.0(1970+1976)	1981	brown forest
3	Llansannan, A	0	1974	peaty podsol
4	Llansannan, A	6.75(1952)	1974	peaty podsol
5	Llansannan, A	6.75+6.75(1952+1958)	1974	peaty podsol
6	Dirrington	0	1966	peaty podsol
7	Bogrie	0	1966	peaty podsol
8	Sourhope, Fasset	6.3 + 6.3(1971+1977)	1981	thin peaty podsol
9	Sourhope, Fasset	0	1981	thin peaty podsol
10	Stanhope	0	1975	brown forest
11	Glensaugh	6.25(1978)	1981	peaty podsol
12	Glensaugh	6.25(1978)	1981	peaty podsol
13	Glensaugh	6.25(1978)	1981	peaty podsol
14	Glensaugh	6.25(1978)	1981	peaty podsol
15	Llansannan, A_o	0	1974	peaty podsol
16	Llansannan, A_o	6.75(1952)	1974	peaty podsol
17	Llansannan, A_o	6.75+6.75(1952+1958)	1974	peaty podsol
18	Spartleton	0	1966	peaty podsol
19	Sourhope, Gairs	0	1981	peaty podsol
20	Sourhope, Gairs	6.3 + 6.3(1970+1976)	1981	peaty podsol
21	Glensaugh	6.25(1979)	1981	peaty podsol
22	Glensaugh	6.25(1979)	1981	peaty podsol
23	Glensaugh	6.25(1979)	1981	peaty podsol
24	Redesdale	0	1982	peat
25	Redesdale	2.5 (1969)	1982	peat
26	Redesdale	5.0 (1969)	1982	peat
27	Redesdale	7.5 (1969)	1982	peat
28	Lephinmore	0	1982	deep peat
29	Lephinmore	5.0 (1972)	1982	deep peat
30	Lephinmore	5.0 + 5.0 (1972+1977)	1982	deep peat

Table 2

Summary of results of CEC (meq/100 g) measured in buffered solutions, related to the pH of the $MgSO_4$ extract (in brackets)

Sample No.	Buffer pH 2.0	Buffer pH 2.5	Buffer pH 3.5	Buffer pH 4.0 & 5.0	Buffer pH 5.5 & 6.0	Buffer pH 6.4 & 7.0	Buffer pH 8.0
1	8.6(3.18)	-	12.3(4.41)	13.9(4.69)	-	21.7(6.62)	-
2	10.0(3.18)	-	16.3(4.46)	18.1(4.69)	-	24.5(6.51)	-
3	5.4(2.69)	-	12.5(3.99)	17.4(5.63)	23.7(6.46)	23.3(7.02)	21.9(7.80)
4	5.1(2.72)	-	15.1(4.08)	19.1(5.58)	26.5(6.39)	30.6(6.99)	30.4(7.81)
5	5.9(2.71)	-	12.8(4.01)	18.1(5.62)	23.4(6.39)	27.0(7.07)	29.9(7.92)
6	-	3.6(2.61)	7.6(3.94)	15.3(5.62)	18.6(6.32)	21.7(6.94)	28.5(7.86)
7	-	7.4(2.74)	12.2(4.19)	18.4(5.65)	28.7(6.51)	34.3(7.09)	36.2(7.94)
8	8.8(3.19)	-	12.1(4.37)	13.8(4.67)	-	23.3(6.48)	-
9	14.3(3.18)	-	20.6(4.44)	22.3(4.66)	-	46.9(6.58)	-
10	4.4(3.26)	6.0(3.50)	10.4(4.60)	10.7(4.71)	18.3(6.18)	20.3(6.29)	32.4(7.57)
11	11.2(3.34)	-	19.2(4.50)	32.9(4.99)	-	52.7(6.61)	-
12	13.6(3.34)	-	26.2(4.64)	34.9(5.00)	-	60.8(6.62)	-
13	21.8(3.43)	-	36.8(4.49)	42.0(4.91)	-	72.3(6.62)	-
14	21.1(3.36)	-	34.9(4.45)	45.9(4.91)	-	80.8(6.66)	-
15	3.1(2.79)	-	19.8(3.96)	47.0(5.74)	62.1(6.37)	72.2(6.98)	83.0(7.81)
16	10.4(2.76)	-	28.4(4.03)	54.6(5.77)	66.3(6.33)	77.0(6.98)	88.4(7.82)
17	15.8(2.75)	-	29.8(4.13)	48.6(5.84)	62.3(6.37)	69.4(7.02)	75.2(7.76)
18	-	11.4(2.74)	30.6(4.05)	52.6(5.67)	74.4(6.43)	83.6(6.95)	98.2(7.82)
19	-15.5(2.70)	-	33.2(4.47)	40.4(4.75)	-	82.2(6.53)	-
20	-26.4(2.68)	17.9(3.22)	37.1(4.45)	47.0(4.74)	-	83.4(6.49)	-
21	23.6(3.32)	-	41.5(4.59)	54.9(4.90)	-	92.4(6.59)	-
22	24.9(3.37)	-	41.7(4.43)	53.9(5.02)	-	91.8(6.60)	-
23	25.1(3.32)	-	48.5(4.51)	64.4(4.99)	-	105.1(6.60)	-
24	18.2(3.32)	21.0(3.51)	38.6(4.66)	40.2(4.74)	74.4(6.24)	76.8(6.26)	-
25	12.7(3.30)	14.8(3.50)	35.6(4.72)	38.5(4.76)	63.0(6.20)	62.2(6.27)	-
26	15.2(3.31)	18.6(3.50)	42.0(4.75)	42.5(4.78)	70.3(6.22)	68.7(6.27)	-
27	16.4(3.34)	18.9(3.50)	45.5(4.83)	45.9(4.90)	72.7(6.22)	72.3(6.26)	-
28	18.5(3.17)	19.9(3.27)	23.4(3.46)	44.7(4.46)	79.8(6.23)	-	-
29	19.7(3.14)	21.6(3.26)	23.4(3.45)	49.7(4.50)	84.7(6.28)	-	-
30	24.2(3.25)	26.2(3.37)	52.4(4.52)	56.9(4.56)	84.8(6.25)	88.0(6.27)	-

Table 3

Regressions for CEC v. $MgSO_4$ extract pH for 30 samples, where CEC = m pH + c

Sample	Slope, m	Constant, c	Correlation coefficient, R	%LOI
1	3.86	-4.12	1.00	14.4
2	4.32	-3.11	0.99	15.7
3	3.57	-2.59	0.95	15.7
4	5.17	-7.78	0.98	17.5
5	4.63	-6.50	1.00	15.3
6	4.65	-9.89	0.99	16.4
7	6.04	-11.47	0.98	16.1
8	4.52	-6.62	0.99	14.7
9	9.92	-20.72	0.97	24.9
10	6.06	-16.60	0.98	20.7
11	13.15	-34.90	0.98	39.1
12	14.63	-37.83	0.99	52.6
13	15.93	-34.22	1.00	63.1
14	18.47	-43.80	0.99	64.9
15	16.34	-43.77	1.00	68.4
16	15.69	-33.91	1.00	67.4
17	12.40	-19.80	0.99	56.4
18	17.35	-38.87	0.99	65.3
19	25.51	-82.58	1.00	73.6
20	26.11	-80.88	0.96	84.6
21	21.44	-50.90	0.99	76.8
22	20.96	-48.67	1.00	83.3
23	24.71	-59.17	1.00	86.8
24	19.87	-50.26	0.99	90.5
25	17.21	-44.66	1.00	89.6
26	18.51	-46.06	1.00	89.6
27	19.44	-48.82	1.00	88.9
28	20.22	-46.00	1.00	93.7
29	21.14	-47.39	1.00	94.1
30	20.61	-41.51	1.00	91.9

Table 4

pH in $MgSO_4$ solution, native CEC, CEC at pH 5.5, ΔCEC and lab. lime requirements for 30 samples

Sample No.	pH in $MgSO_4$ solution	native CEC (meq/100g)	CEC at pH 5.5 (meq/100g)	ΔCEC (meq/100g)	lab. LR (meq/100g)
1	4.41	12.9	17.1	4.2	6.0
2	5.82	22.0	20.6	-1.4	0
3	3.74	10.7	17.0	6.3	16.2
4	4.02	13.0	20.6	7.6	14.7
5	4.51	14.4	19.0	4.6	6.1
6	3.55	6.6	15.7	9.1	13.9
7	3.79	11.4	21.7	10.3	16.8
8	4.41	13.3	18.2	4.9	5.6
9	3.82	17.2	33.8	16.6	25.4
10	3.81	6.5	16.7	10.2	13.3
11	4.87	29.1	37.4	8.3	3.7
12	5.07	36.4	42.7	6.3	2.3
13	4.69	40.5	53.4	12.9	14.2
14	4.35	36.5	57.8	21.2	22.0
15	3.50	13.4	46.1	32.7	59.2
16	4.11	30.6	52.4	21.8	27.5
17	4.70	38.5	48.4	9.9	12.1
18	3.46	21.2	56.6	35.4	54.8
19	3.51	7.0	57.7	50.7	52.0
20	4.00	23.6	62.7	39.1	31.7
21	4.20	39.2	67.0	27.9	31.9
22	4.25	40.4	66.6	26.2	35.5
23	4.33	47.8	76.7	28.9	34.8
24	3.56	20.5	59.0	38.5	48.4
25	4.39	30.9	50.0	19.1	20.3
26	4.49	37.1	55.8	18.7	17.4
27	4.69	42.3	58.1	15.8	12.6
28	3.40	22.8	65.2	42.4	46.7
29	3.93	35.7	68.9	33.2	32.6
30	4.47	50.6	71.8	21.2	18.5

1.3. Lime response and lime maintenance on Linhope acid brown soil at Stanhope

M.J.S. Floate, K. Logan and A.D. Ironside

The objectives and design of this experiment have been described in annual reports for earlier years (1975 p.64;1981 p.C38). Herbage yield data, provided in Table 1, illustrate the increase in production due to original and maintenance lime applications. Statistical analysis has shown that the treatments can be separated into four groups (a, b, c and d), within which there is no significant difference (95%) between yields. Although there is some overlap, differences between lime rates are beginning to show in 1982.

Table 1

Total herbage DM yields for 1982 and relative yields for 1980, 1981 and 1982 from original and maintenance lime treatments at Stanhope

Treatment	Lime Applied (tonne/ha)	1982 DM Yield (kg/ha)	Statistical Group	Relative Yield ($\%\ L_2$)		
				1980	1981	1982
L_0	0	1810	a	60	55	48
$L_{\frac{1}{4}}$	0.6	2439	ab	85	77	65
$L_{\frac{1}{2}}$	1.3	2627	b	86	85	70
$L_{\frac{3}{4}}$	1.9	2698	b	92	87	72
L_1	2.5	3048	bc	98	86	81
L_2	5.0	3738	cd	100	100	100
L_0+M	2.5	3594	bcd	76	88	96
$L_{\frac{1}{4}}$+M	1.3	2883	b	88	88	77
$L_{\frac{1}{2}}$+M	2.5	3424	bc	97	89	92
$L_{\frac{3}{4}}$+M	3.8	3676	c	101	90	98
L_1+M	5.0	3885	cd	99	109	104
L_2+M	10.0	4350	d	115	110	116

Since 1975, excluding data from years when accidental grazing occurred, annual production has steadily declined. This can probably be explained by deficiencies of N and K, since calculations suggest that previous fertiliser applications were too small. It is proposed to rectify this in 1983 by increasing the fertiliser rates.

The decrease with time of the relative yields of the original treatments was more pronounced in 1982, with production within 80% of the original 5 tonne/ha lime rate for L_1 alone. Apart from $L_{\frac{1}{4}}$+ M, which decreased to 77% L_2, the relative yields of all maintenance treatments were equal to or greater than L_2, suggesting that the effectiveness of $L_2$2 is beginning to decline. This suggestion is supported by the decrease in the proportion of clover on L_2 plots from 30- 40% in 1981 to 20-30% in 1982.

Data in Table 2 show that clover was only retained at more than 20% of the sward on plots where pH had not dropped below 5. The anomaly of L_0 + M, with pH 5.2 and clover less than 10%, can be explained by the decrease in pH of L_0 + M with time to a minimum of 4.1 in 1980, which may have been too low for maintenance lime to effect a recovery. The persistence of ryegrass was also only evident at more than 20% on L_2 and on the plots with higher maintenance lime rates.

Table 2

Effects of lime on soil pH and on ryegrass and clover persistence at Stanhope in 1982

Treatment	pH	Clover %	Ryegrass %
L_0	4.5	0-10	0-10
$L_{\frac{1}{4}}$	4.5	0-10	0-10
$L_{\frac{1}{2}}$	4.7	0-10	0-10
$L_{\frac{3}{4}}$	4.5	0-10	0-10
L_1	4.7	0-10	0-10
L_2	5.0	20-30	20-30
L_0+M	5.2	0-10	10-20
$L_{\frac{1}{4}}$+M	4.6	10-20	0-10
$L_{\frac{1}{2}}$+M	4.8	10-20	10-20
$L_{\frac{3}{4}}$+M	5.1	20-30	20-30
L_1+M	5.4	20-30	10-20
L_2+M	6.2	30-40	30-40

The effect of lime on soil acidity was assessed by the measurement of pH, exchangeable acidity (exch. acidity) and exchangeable aluminium (exch. Al). Since improved methods for the determination of exch. acidity and exch. Al, equilibrium titration and colorimetry (Annual Report 1982,p.C35) respectively, were employed in 1982, the analysis of samples from all preceding years was reported using these techniques.

The effect of lime on soil pH over time is best illustrated by Fig. 1. After the initial rise in pH in 1975 and 1976 due to the original lime applications, the pH of all plots decreased as the effect of the treatments decreased until 1981. Maintenance lime was applied to half of each plot in 1980, after soil sampling, so a pH rise was expected in 1981 for the relimed plots. However the pH increase was also evident for plots which received no maintenance lime. This cannot be explained by the migration of maintenance treatments or by liming operations near the site. Statistical analysis is required to prove whether or not this pH change was outwith the normal seasonal variation. Because of the 1981 increase, the pH for none of the plots had declined, by 1982, as far as the pretreatment pH of 3.8.

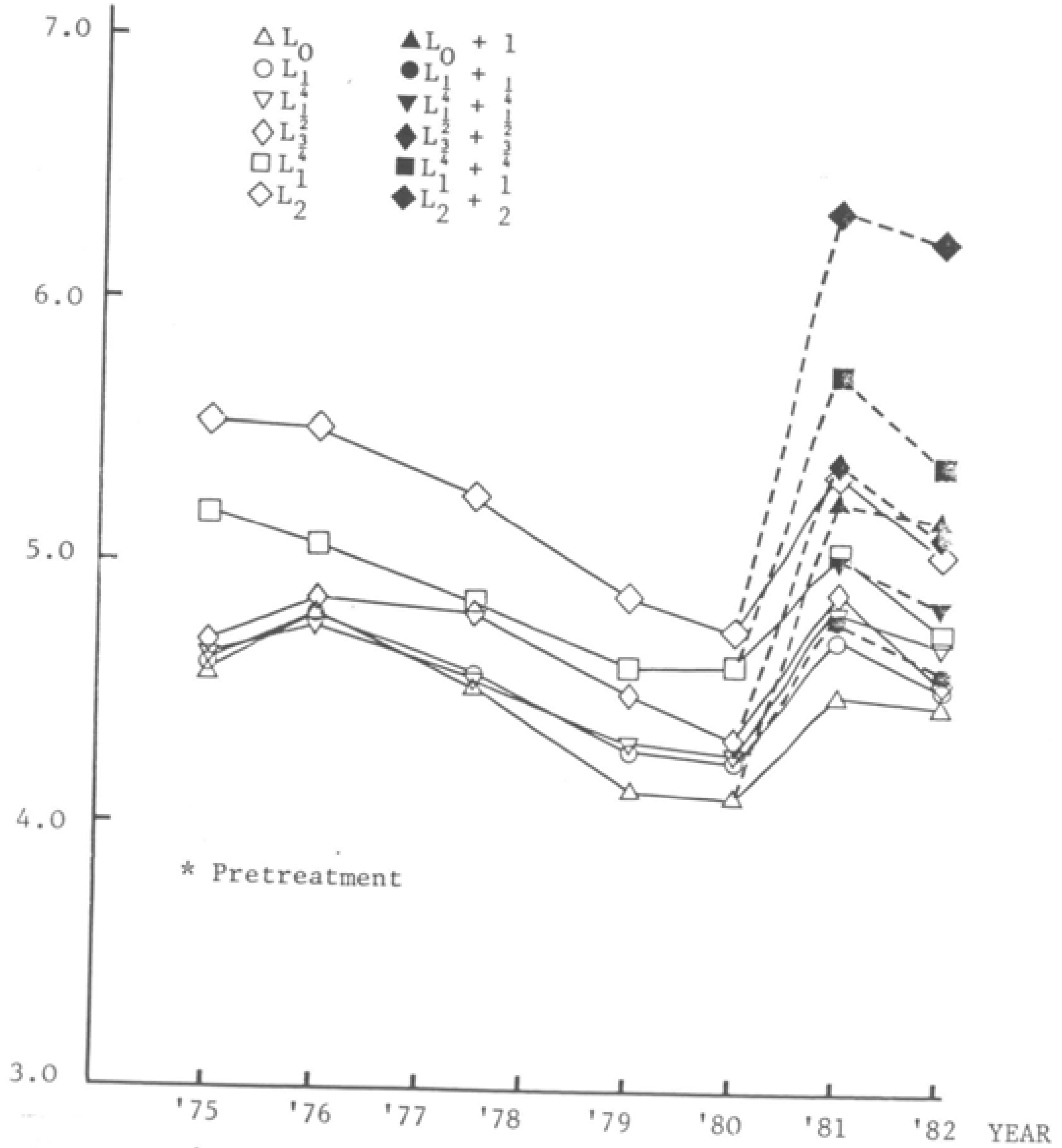


Figure 1. Effect of lime on soil pH over time

As exch. Al was always about 90% of exch. acidity, exch. Al and exch. acidity followed the same trends. Fig. 2 shows the decrease in exch. acidity with increasing lime rates, and its subsequent increase with time for original treatments only. Although there was considerable seasonal variation, the sudden decrease in 1981 corresponding to the pH increase, is evident.

The nature of the relationship between the soil pH and exch. acidity is best illustrated by Fig. 3. Exch. acidity fell off rapidly in the lower pH range and started to level off at about pH 5.3. Above this pH, exch. acidity was less than 2 meq/100 g, implying that neither H^+ nor Al was easily displaced by 1M KCl solution and were therefore probably inactive towards plants (McLean, 1965).

The soil will be sampled in 1983 prior to an increased rate of fertiliser application. Further harvests will be taken and it is hoped that by 1983, treatment differences will be significant.

Reference

McLean, E.O. (1965). Aluminium : Methods of Soil Analysis II Agronomy Monograph 9. Amer. Soc. Agron. 979.

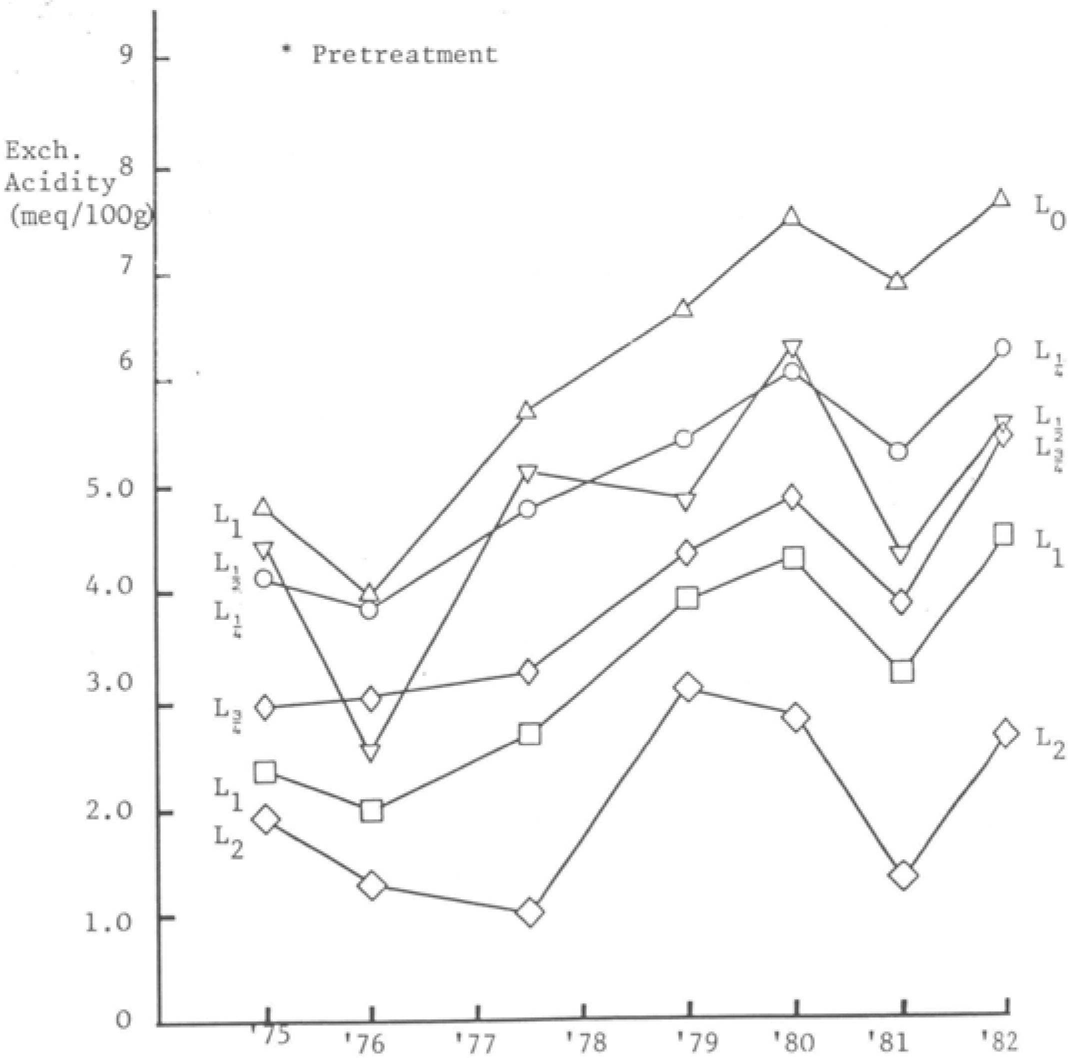


Figure 2. Effect of lime rate on exch. acidity over time

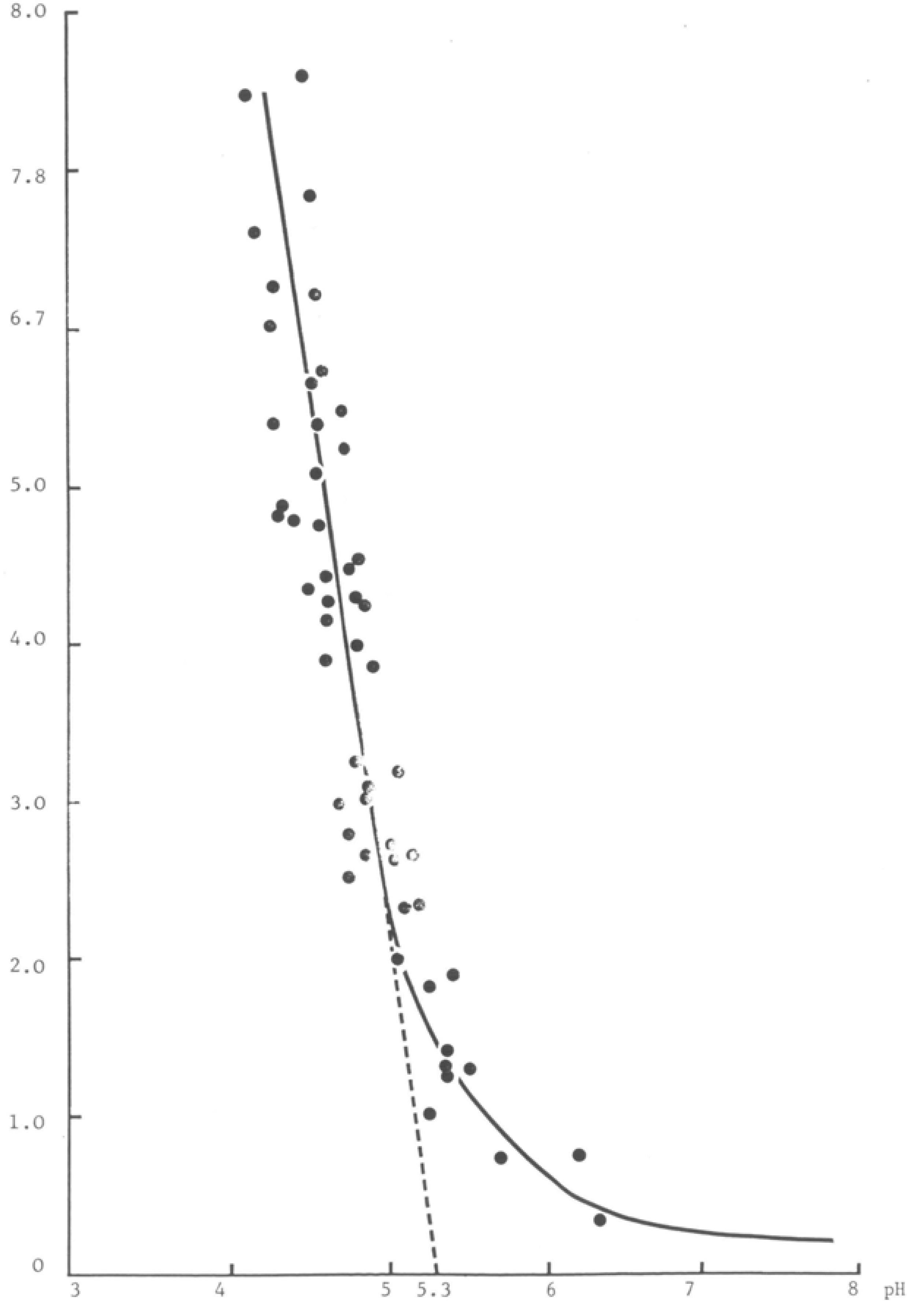


Figure 3. Relationship between pH and exch. acidity (IMKCl)

2. PLANT NUTRITION : MAJOR ELEMENTS

Research objective : Determine the response of hill and upland pastures to additions of lime and fertilisers (project no. 103).

2.1 Response to P fertiliser at Hartwood

M.J.S. Floate, K. Logan, G.R. Bolton and A.D. Ironside

The objective of this experiment was to quantify the response of an established, reseeded (1980) ryegrass-clover pasture on Rowanhill soil of low P status to incremental additions of P fertiliser.

The site was prepared on Reservoir field in spring 1982. Treatment of 0, 20, 40, 80 and 160 kg P/ha were applied to 4 replicate blocks at 2 levels of nitrogen, 100 and 200 kg N/ha; each N level was split into 3 equal treatments applied on 14/4/82, 23/6/82 and 19/7/82. The entire area was treated with 80 kg K/ha so that K would be non-limiting.

Five harvests were taken and the dry matter yields, presented in Tables 1 ans 2, show that the maximum annual yield attained was 11.6 tonne DM/ha. Statistical analysis showed no significant difference between P treatments for all harvests except the first, when the yield from the highest P application was significantly (95%) greater than from all other levels of P. For the first harvest alone, production at N200 was significantly (95%) greater than at N100 for all levels of P. Data for P uptake are not yet available and await the determination of herbage P content.

It is proposed to continue in 1983 with further N applications, in the hope that P will become exhausted in the lower P status plots and significant differences between treatments will be shown.

Table 1

Dry matter yields (tonne/ha) of 5 harvests at 5 rates of P at 100 kg N/ha

Harvest Date	P_0	P_{20}	P_{40}	P_{80}	P_{160}	SED (df)
26/5/82	1.87	1.96	2.04	1.82	2.39	0.17 (24)
17/6/82	1.79	2.03	1.84	1.62	1.76	0.21 (24)
16/7/82	1.69	1.71	1.80.	1.61	1.92	0.13 (24)
26/8/82	3.03	3.06	2.89	2.89	3.00	0.15 (24)
14/10/82	1.39	1.43	1.44	1.29	1.31	0.14 (24)
Total	9.77	10.19	10.01	9.23	10.38	0.60 (24)

Table 2

Dry matter yields (tonne/ha) of 5 harvests at 5 rates of P at 200 kg N/ha.

Harvest Date	P_0	P_{20}	P_{40}	P_{80}	P_{160}	SED (df)
26/5/82	2.77	2.51	2.53	2.87	3.01	0.17 (24)
17/6/82	1.65	1.56	1.60	1.73	1.61	0.21 (24)
16/7/82	2.03	1.95	1.97	2.03	2.09	0.13 (24)
26/8/82	3.13	3.16	3.10	3.46	3.22	0.15 (24)
14/10/82	1.40	1.32	1.43	1.48	1.49	0.14 (24)
Total	10.98	10.50	10.63	11.57	11.42	0.60 (24)

2.2. Lime and fertiliser applications needed to establish ryegrass/white clover swards on the Rowanhill soil series at Hartwood

A. Rangeley, G.R. Bolton and P. Newbould

A laboratory experiment with the Rowanhill soil from Hartwood described in the previous report (1981, p.C3) indicated a big response in growth of both ryegrass and white clover to additions of phosphate and some benefit to white clover from lime at low levels of added phosphate. A fully replicated experiment was set up to test these observations in the field and also to look at the effect of 'starter' dressings of nitrogen fertiliser. The following treatments were applied to 2 x 2 m plots in triplicate:-

LIME	0 and 5 t/ha as ground magnesium limestone
NITROGEN	0, 40, 80 and 160 kg N/ha as nitrochalk
PHOSPHATE	0, 40, 80 and 160 kg P/ha as superphosphate

All these treatments were supplied with 80 kg K/ha as muriate of potash. The opportunity was also taken to examine the plant responses to additional potassium fertiliser and to inoculation of the white clover with Rhizobium with selected treatments only. The experiment was conducted in Dipper field. Lime was applied on 13/5/82, fertilisers on 20/7/82 and the seeds 25 kg/ha S23 Ryegrass and 5 kg/ha Grasslands Huia (white clover) were sown on 11/8/82. Seedling counts were made on 17/9/82 and 21/10/82 and herbage was sampled on 25/10/82. Soil, root and nodule samples were taken on 2-3/11/82. All the plots had a high population of weeds and in an attempt to control these without too much damage to the young clover seedlings Acumen (BASF UK Ltd) a new herbicide formulation containing bentazone and MCPB was used on 26/9/82.

At the first count (17/9/82) there were on average 276 white clover and 1120 ryegrass seedlings per m^2; none of the treatments affected these numbers significantly although there was a trend for the numbers of white clover seedlings to decrease with increasing phosphate addition. Following the application of the herbicide the average number of white clover seedlings decreased by 40% to 167 per m^2. As at the first count lime and nitrogen were without significant effect but the number of seedlings established at the higher levels of phosphate was significantly less than at low levels i.e. $198/m^2$ at P0 compared to $151/m^2$ at P160 (LSD (P = 0.01) = 37).

Herbage from the central m^2 of each plot was cut, frozen, thawed, separated into grass and clover, dried and weighed. For ryegrass, lime depressed production, while both nitrogen and phosphate markedly increased production. For white clover lime tended to increase production while nitrogen increased production slightly and phosphate markedly. There was a significant interaction between the effects of N and P. Since there was no significant interaction between lime and other treatments mean results for both lime treatments are shown in Table 1.

Table 1

The effect of nitrogen (as nitrochalk) and phosphate (as superphosphate) on production of herbage (g DM/m^2) of ryegrass and white clover grown for 10 weeks in Rowanhill soil at Hartwood.

Mean results for two levels of lime 0 and 5 t magnesium lime/ml/ha are shown.

	NITROGEN (kg N/ha)	PHOSPHATE (kg P/ha) 0	40	80	160
Perennial Ryegrass	0	9.2	39.0	37.4	68.5
	40	14.9	37.9	48.5	78.7
	80	12.6	54.4	60.6	80.5
	160	23.6	71.8	111.0	106.8
		LSD (P = 0.05) = 21.8			
White Clover	0	0.003	0.145	0.050	0.023
	40	0.007	0.082	0.120	0.235
	80	0.022	0.123	0.157	0.220
	160	0.008	0.207	0.398	0.205
		LSD (P = 0.05) = 0.109			

Production of both plants but especially white clover is low because of the late time of sowing and the effects of the herbicide. However, there is clear evidence that the establishment and growth of both plants benefited from moderate applications of nitrogen and phosphate. The maximum production of both plants was determined with 160 kg N and 80 kg P added per ha. The effect of these treatments on shoot nutrient content, and particularly the nitrogen fertiliser on nodulation and fixation by white clover has yet to be assessed. Further analysis of existing samples is required and the assessment of winter survival will be made by further measurements in spring 1983.

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

A. Rangeley, P. Newbould and J. Leask

Investigations into the disappointing establishment and growth of white clover in the mosaically-arranged patches of improved pieces of heather moor on the Cairn hill at Glensaugh, as described in this report, were described in the last annual report (1982, p.C2). Small plot trials on reseeds of two acres (sown in 1978 and 1979) were set up to explore the matter further. The treatments applied to the existing swards were as follows:-

No treatment;

Complete (lime 5 t/ha, N 40 kg/ha in spring, summer and autumn, trace elements, Rhizobium, and potassium (100 kg/ha));

Complete + extra N (1 x 40 + 3 x 80 kg N/ha);

Complete - N;

Complete - Rhizobium;

Complete - Rhizobium and N;

Complete - Trace elements;

Complete - K

Herbage cut from 2 quadrats (0.4 x 3.6 m) in each plot (2 x 4 cm) was sampled on four occasions - 31 May, 30 June, 11 August and 4 October. Separation into grass and white clover is not yet complete so only a limited amount of information on production is available; no chemical analysis has been done as yet.

At the time of each harvest the nitrogen fixation by white clover was assessed on complete and untreated plots only using the acetylene reduction technique.

There was no significant difference between the plots at either site (1978 and 1979). It is interesting that the rates of acetylene reduction were similar in spring than those recorded for hill pastures previously (Haystead and Marriott, personal communication), but these fell rapidly after May and were lower than those measured elsewhere, probably due to drying out of the surface layers of the soil.

During the course of the experiment it was noted that the clover plants were infected with pepper spot disease (*Leptosphaerilia trifolii*); for the 1978 site 7% of plants were infected on 15/4/82 and 48% on 23/6/82. To investigate the importance of this disease to production a fungicide TILT (CIBA-GEIGY) was applied to half the area of each complete treatment plots. No evidence has been found to suggest that the fungicide application was of any benefit. Towards the end of the growing season it was noted that ryegrass leaves were affected by fungi. Analysis by the Pathology Department of the East of Scotland College of Agriculture indicated the main one to be *Drechslera* (probably *D. festucae*) but *Fusarium nivale* and *Rhizoctonia* were also present. It is not known if these fungi were primary causes of the poor growth of grass in the plots or whether they infected the plant after they had been affected by lack of nutrients or water, or some other cause.

Table 1

The effect of nitrogen, Rhizobium, trace elements and potassium on production of herbage (grass/ white clover) (kg DM ha-1) from swards of two ages on Cairn Hill, Glensaugh

	1978 Site		1979 Site	
	Harvest			
	1	2	1	2
Treatment*	31/5/82	30/6/82		
Untreated	629	651	210	397
Complete-R-N	675	791	187	451
Complete-N	839	978	235	424
Complete-K	874	952	261	343
Complete-R	1182	1109	400	478
Complete-TE	1210	1035	491	475
Complete	1117	1063	423	427
Complete+N	1110	1514	409	927
LSD (P = 0.05)	365	206	169	237

N applications:40 kg N ha-1 on 14/4/82

To + N plots 80 kg N ha-1 on 4/6/82

Complete = 5 t lime, 40 kg N, trace elements, *Rhizobium*, 100 kg K (per ha).

Separation of grass and clover in the herbage samples is not complete but the total herbage production data for the first two sampling occasions at each site are shown in Table 1. It is evident that all treatments with added N have led to increased production and that lack of potassium may lead to a depression in production.

In the absence of weight data for white clover, it is of interest that a white clover ground cover visual scoring system carried out by two operators with no knowledge of the treatments on 10 August indicated that clover content declined in the presence of nitrogen and in the absence of K at both sites. On the 1978 site the percentage cover for the treatments without N was 28-39%, with N was 18-21%, without K was 11% and with additional N was 8%. Similar trends though at a much lower level of cover, 0-9% were found at the 1979 site.

These data, incomplete though they are, suggest that lack of available N and K in the soil are the prime determinant of herbage prodution on this soil type. This despite evidence for fixation by white clover when it is present. The need to understand why decomposition of organic matter, and mineralisation and transfer to nitrogen is poor in this soil type is evident. It is hoped to continue the trial for a further year and to expand work on factors that inhibit the turnover of N in these soils in the near future.

2.4 The effect of pattern of N application on herbage mass (kg DM/ha) in June, August and October on the mosaic reseeds

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

In conjunction with the more detailed study reported in the preceding section, a trial comparing the amount and timing of applications of nitrogen on the production of grass and clover on the mosaic reseeds in both the 1978 and 1979 blocks was carried out.

The treatments were as follows:

Treatment	Nitrogen application kg N/ha April	June	August	Replicates
1	40	0	40	2
2	40	0	40	5
3	0	0	40	2
4	40	0	0	2
5	0	40	40	2
6	0	40	0	2

All the treatment areas, except those of treatment 1, also received 2½ tonnes/ha magnesium limestone, 100 kg/ha of potassium, plus *Rhizobium* and trace elements.

Response to the treatments was measured in terms of herbage mass (kg/ha) of areas which had been caged after the application of the nitrogen fertiliser for a period of five weeks. At the time of the first measurement, herbage mass of the areas outside the cages were also measured. These data were used to provide a covariate to reflect differences in plant density between treatment sites, all sites having been managed in a similar way up to that time with the exception of fertiliser application.

Herbage mass measurements were made on 7 June, 12 August and 7 October. In Table 1 the herbage mass measurements for 7 June are presented; those treatments receiving nitrogen in April were compared with those receiving no nitrogen.

Table 1

Effect of April application of 40 kg N/ha on herbage mass (kg DM/ha) on 7 June

Treatments	Herbage mass
N applied (2+4)	2709a
N applied but no lime or K(1)	2164b
No N applied (3+5+6)	1989b

Common subscripts are not significantly different at $P < 0.05$.

In Table 2 treatments receiving nitrogen in June (40 kg N/ha) were compared with those receiving nitrogen in April (40 kg N/ha) and with those receiving no nitrogen in either April or June.

Table 2

Effect of June application of 40 kg N/ha on herbage mass (kg DM/ha) on 12 August

Treatments	Herbage mass
N applied June (5+6)	2386a
No N applied April or June (3)	2043b
N applied April (2+4)	2358a
N applied April but no lime or K(1)	2083b

Common subscripts are not significantly different at $P < 0.05$.

After the final application of N was made in August, herbage masses of all treatments were measured on 7 October and in Table 3 treatments have been ranked from highest to lowest herbage mass.

Table 3

Effect of all applications of N (each 40 kg N/ha) on herbage mass (kg DM/ha) on 7 October

Treatments	Herbage mass
N applied June and August (5)	2165a
N applied April and August (2)	1993b
N applied June (6)	1774c
N applied April (4)	1625d
N applied April and August but no lime or K (1)	1500d
N applied August only (3)	1369e

Common subscripts are not significantly different at $P < 0.05$.

An April application of N gave a significantly higher herbage mass by June (700 kg DM more than no N) but only if lime, potassium, trace elements and Rhizobium were also present (Table 1). An application of N in June gave no greater response than N applied in April by 12 August provided lime, potassium, trace elements and Rhizobium were present (Table 2). The extent of the response to N applied in August appeared to depend on how recently nitrogen had been applied previously and also whether lime, potassium, trace minerals and Rhizobium were present. There was a difference of 800 kg DM/ha between the June plus August application and the August only application. Within the constraint of a total annual application of 80 kg N/ha, (two applications of 40 kg N/ha), and provided that pH status has been corrected and that potassium, trace minerals and Rhizobium have been added, the results suggest that an application of N in late April and again in early August would meet the requirement for herbage in spring and autumn on the mosaic reseeds.

3. PLANT NUTRITION : TRACE ELEMENTS

Research objective: Understand the soil and plant factors which influence the content of Cu, Mo and S in herbage from improved hill pastures (project no. 104).

3.1 Reconnaisance survey of reseeded pastures

C.C. Evans, P. Newbould, G.J. Baillie, J. Wood (ARCUS), J.C. Holmes (ESCA), J. Frame (WSAC) and G.J. Copeman (NOSCA)

Observations of ill-thrift in sheep confined to hill pastures, which have been improved by reseeding after application of lime and fertilisers have been made at HFRO research stations and elsewhere. Investigations have shown that this was due to copper deficiency which may be treated successfully by provision of copper supplements to the animal.

Examination of the trace element status of these improved pastures has shown significant increases in the molybdenum and sulphur concentration of the herbage. These elements are known to be antagonistic to Cu absorption during ruminant digestion and in high amount they can induce copper deficiency. The consequential need to assess the possible extent to which hill land improvement reduces the nutritional availability of copper in grazing ruminants was outlined in the 1981 Annual Report (p.C42).

In collaboration with the three Scottish Colleges of Agriculture and the ARC Unit of Statistics the field sampling part of a reconnaisance survey was carried out during August and September 1982 after advice on site selection had been obtained from the DAFS Agricultural Inspectorate and the Scottish Soil Survey (MISR).

The scale of the survey has been influenced by logistical considerations relating to the availability of qualified sampling staff and the number of samples and estimations requiring trace chemical analysis. It was decided that a fully randomised approach was impractical and that a stratified scheme be adopted. In the event ninety (90) recently reseeded sites on commercial hill farms were sampled - thirty (30) from each Agricultural College area. More than one series of samples were taken from a few sites where changes in soil characteristics were encountered and readily delineated. In addition a number of reseeds on HFRO Research Stations were sampled for purposes of comparison.

The main criterion for site selection was according to soil classification. Approximately equal numbers of sites from five soil categories commonly found on hill land were included - peat, well drained podsol, poorly drained podsol, well drained brown earth and poorly drained brown earth (non-calcareous gleys). A subsidiary factor was the age of reseed since establishment, but within each soil type some randomisation of choice was possible from a relatively large preliminary list of potentially suitable sites.

Detailed site descriptions were recorded through interviews with the owner or occupant as well as on-site observation by sampling staff. Sites were located throughout Scotland from the Border counties to Caithness and many soil associations with large geographical/area distributions were included. The sampling of many sites in the East and particularly the North College areas was delayed until well into September due to the prolonged summer drought. Even then a few sites had either to be revisited or substituted altogether due to unsatisfactory sward conditions.

The statistical variability of results from the Alderhope reseeds was used to determine a standardised sampling scheme which was used throughout. This involved the collection of 6 herbage samples each being composited from 6 sub-samples (6 x 6 sampling points per reseed). Similarly each of 6 soil samples were taken, each of which was constituted by the bulking of 12 individual soil cores (6 x 12 soil cores per reseed). All samples of soils and herbages have been fully prepared for analysis and await assay at HFRO.

3.2. Influence of lime and phosphate on soil/plant relationships of copper molybdenum and sulphur in hill pastures:

R.M. Paynter, P. Newbould and K.A. Smith (ESA)

a) Preliminary assessment of a range of soils

During the winter of 1981/82 small soil samples were collected from 12 improved and 12 adjacent unimproved hill pasture sites. The samples were analysed for pH, %C, SO_4^{2-}-2, and extractable Al, Cu, Mo and P. On the basis of these analyses 9 soils representative of the 24 were chosen for use in future work (see Table 1).

In the summer of 1982 bulk samples of the 9 soils selected for study were collected and prepared for use in pot experiments.

b) Experimental work

Experiment 1. An experiment in the glasshouse using soil in 12.5 cm dia. pots to investigate the effects of three different soil pHs (natural, 5.0 and 7.25) on the Cu, Mo and SO_4^{2-}-2 status of the soils, and also on the levels of these nutrients in the shoots of perennial ryegrass (S23) grown in them. The following quantities (kg/ha) of the major nutrients were added to each pot to ensure good growth, 60 N, 48 P and 60 K. Three of the soils are being studied in more detail by using two additional pHs (4.25 and 6.25) with more frequent soil analysis for additional plant nutrients.

Table 2

The effect of contrasted soil pH on production of herbage (g DM per pot) of perennial ryegrass after 5, 9 and 13 weeks growth respectively in 9 soils

Harvest / Soil	1	2	3	1	2	3	1	2	3
pH	Natural			5.0			7.25		
1	0.47	0.90	0.99	0.73	1.04	1.13	0.89	1.60	1.54
2	0.07	0.16	0.26	0.85	1.07	1.18	0.31	1.22	1.47
3	0.95	0.84	0.55	0.98	0.92	0.60	0.82	1.21	1.04
4	0.14	0.54	0.86	1.19	1.21	1.14	0.62	1.59	1.25
5	0.25	0.45	0.57	0.87	1.33	1.20	0.81	1.42	1.35
6	0.71	1.01	0.54	1.33	1.18	0.83	0.93	1.40	0.81
7	1.19	1.25	0.74	1.53	1.80	1.31	0.36	1.71	2.03
8	0.56	0.97	0.47	1.29	1.43	0.92	0.07	0.04	0.12
9	0.98	1.29	0.87	1.04	1.42	1.03	0.82	1.70	1.70

SED (78 df) 1st harvest 0.068
2nd harvest 0.091
3rd harvest 0.068

Table 1

Main characteristics of soils selected for detailed study

Soil No.	Location	Soil association	Soil series	Soil type	Drainage status	pH	%C	Extractable Al (mg/100g)	Extractable Cu (ppm)	Extractable Mo (ppm)	Extractable P (mg/100g)	SO_4^{2-} - S (ppm)
1	Carron Vall.	Darleith	Myres	Peaty gley	Poor/very poor	3.7	3.7	91.6	4.3	0.006	0.89	27.6
2	Glensaugh/ Birnie	Strichen	Fungarth	Cultivated brown for. soil	Free	3.5	12.5	77.1	5.5	0.020	0.50	45.7
3	Glensaugh/ West Finella	Strath-finella	Strath-finella	Humus iron podzol on deep till	Free	4.2	6.5	46.3	0.9	0.299	0.38	4.7
4	Hartwood	Rowanhill	Rowanhill	Non-calcareous gley	Poor	3.3	6.7	26.7	2.1	0.068	0.13	8.5
5	House o' Muir	Bernersyde	Bernersyde	Brown for. soil	Free	3.6	12.2	82.9	2.5	0.013	0.75	15.7
6	Lephinmore		Peat		Poor/very poor	4.0	38.9	4.0	4.2	0.004	4.7	24.4
7	Sourhope I	Sourhope	Sourhope	Brown for. soil, low base status	Free/ intermediate	3.5	9.3	20.3	2.5	0.009	0.61	2.0
8	Sourhope II	Sourhope	Cowie	Peaty podzol	Free with peaty top	3.2	22.5	37.4	1.0	0.042	1.3	13.6
9	West Linton					4.8	3.7	18.6	0.8	0.016	0.32	4.6

Three harvests of the shoots were taken (after 5, 9 and 13 weeks growth) and the soil and herbage samples are awaiting analysis. Dry weight data for the herbage is available (Table 2) and shows highly significant differences between soils, between lime levels and within soils at different lime levels.

Experiment 2. An experiment is in progress to study the effect of different soil pHs upon the growth and nutrient content (Cu, Mo, SO_4^{2-}-2) of a grass (PRG S23) and a legume (white clover, Grasslands Huia) grown separately in three soils (Nos. 2, 4 and 8). Three pHs are being investigated (4.5, 5.5, 6.5) and two methods of lime placement - evenly mixed throughout the soil or a surface application to the top 30% of soil. No results are available as yet.

3.3. Copper, molybdenum and sulphur concentrations in herbages - routine pasture analysis

C.C. Evans and G.J. Baillie

The analysis of herbage samples collected from improved and unimproved pastures from Sourhope and House o' Muir during 1981 are now completed and are shown in Table 1.

Table 1

Elemental concentrations and estimates of absorbable dietary copper of herbage from improved and unimproved pastures sampled during 1981

Sampling Date	S g/kg	Cu mg/kg	Mo mg/kg	Absorbable Dietary Cu* mg/kg DM (a)	(b)
1. Alderhope					
(a) Improved					
13/5	3.1±0.20	3.7±0.34	2.9±0.16	0.11±0.010	0.03±0.005
13/8	3.3±0.07	5.7±0.20	3.3±0.10	0.16±0.007	0.03±0.003
(b) Unimproved					
13/5	1.7±0.06	6.8±0.36	1.2±0.11	0.32±0.016	0.25±0.012
13/8	1.8±0.07	5.4±0.18	1.0±0.07	0.26±0.008	0.20±0.011
2. Fasset					
Improved					
13/8	3.9±0.08	7.2±0.29	2.7±0.21	0.19±0.010	0.04±0.006
3. House o' Muir					
(a) Improved					
27/5	3.3±0.07	8.4±0.35	1.9±0.09	0.28±0.012	0.10±0.008
(b) Unimproved					
27/5	1.8±0.06	7.5±0.18	1.0±0.08	0.36±0.006	0.27±0.005

* Estimated from the S, Mo and Cu using relationships based on either feeding semi synthetic diets (a) or fresh herbage (b)

The concentrations of S, Cu and Mo and estimated absorbable dietary copper (AD_{Cu}) are consistent with results from Sourhope found previously. The higher S and Mo concentrations in the improved herbage being reflected in lower AD_{Cu} values which are much below the minimum Cu requirement for pregnant and lactating ewes or for optimal growth rates in young lambs. It has now been established (Refs. 1-3) that the absorption of Cu from fresh herbage is considerably less efficient than from semi synthetic cereal based diets. When adjustments are made for this (Table 1(b)) a serious copper deficiency is indicated in animals which graze the improved pasture. Here the AD_{Cu} of 0.03- 0.04 mg Cu/kg DM are approximately 20% of the dietary Cu requirement for young growing lambs (~ 0.20 mg Cu/kg) and only about 5% for pregnant or lactatng ewes (0.5-0.7 mg Cu/kg). Estimates of AD_{Cu} in the indigenous pastures indicate sufficient dietary Cu for growing lambs but are somewhat low for lactating ewes.

The AD_{Cu} level in herbage from the recently created reseed on Fassett hill is approximately the same as those calculated for the Alderhope unit. This is to be expected bearing in mind their close proximity. The marginally higher Cu and lower Mo levels of the House o' Muir improved herbage (when compared with Sourhope) is reflected in the slightly higher but still inadequate AD_{Cu}.

References

1. Trace Element Deficiencies in Ruminants. Report of a Study Group 1982, Published by the Scottish Agricultural Colleges.

2. Suttle, N.F. 1980, Proc. Nutr. Soc., 39, 63A.

3. Suttle, N.F. (Personal Communication).

4. NITROGEN FIXATION AND TRANSFER

Research objective: Determine the factors which influence nitrogen fixation and transfer by white clover in hill and upland pastures (project no. 105).

1. Uptake and release of ammonia in clover-grass canopies

A. Haystead and C. Marriott

Two simulated sward experiments were set up to study the possible significance of gaseous transfer of ammonia within a plant canopy (see HFRO Annual Report 1981, C24). Clover and grass plants were grown in individual small containers in perlite in the first experiment and in Levingtons compost in the second. The plants were grouped, alternating grass and clover plants to form a simulated sward; there were 27 plants of each species in the perlite simulated swards and 10 of each in the Levingtons compost swards. In the control sward grass plants were alternated with fallow pots.

Three levels of cutting were imposed on the swards at harvest; lax (8-9 cm herbage left above rooting medium), intermediate (5 cm herbage left) and close (2-3 cm herbage left). The grass in the control sward was also subjected to close cutting. There was one simulated sward for each treatment. Different cutting regimes were used because we were interested in the possible interaction between sward height and ammonia release and uptake.

^{15}N labelled ammonium nitrogen (100 ppm N as $(^{15}NH_4)_2SO_4$, 95 Atom % ^{15}N was supplied throughout the experiments to the clover and fallow pots. A small amount of nitrate nitrogen (as KNO_3) was supplied to the grass plants growing in perlite to prevent them from becoming nitrogen deficient.

Three harvests were taken from the perlite experiment and six from the Levingtons compost experiment, for determination of dry weight, total N and ^{15}N abundance. ^{15}N enrichment of grass N above the enrichment of grass N in the control treatment would indicate gaseous transfer of ammonia from clover to the neighbouring grass plants. Underground transfer of nitrogen was not possible because the grass and clover plants were growing in separate containers. The dry weight data are presented in Tables 1 and 2.

Table 1

Grass and clover dry weights (g) - Perlite experiment (sown 5.4.82)

Cutting treatment	1st harvest 16.8.82		2nd harvest 15.9.82		3rd harvest 1.10.82			
	Grass Shoots	Clover Shoots	Grass Shoots	Clover Shoots	Grass Shoots	Grass Roots	Clover Shoots	Clover Roots
lax	0.93	0.71	1.26	4.91	18.51	27.75	13.13	13.91
inter-mediate	1.92	2.43	1.53	6.53	12.27	23.41	14.61	15.04
close	3.33	5.44	1.80	5.98	9.08	20.89	8.25	10.50
grass only - close	3.33	-	1.73	-	10.70	27.17	-	-

Initially the treatments were ranked lax, intermediate, close, in order of increasing yield, but this order was reversed by the final harvests. The cumulative yields from all harvests (Table 3) are greatest in the lax cutting treatment, followed by the intermediate then close cutting treatments. The difference is especially marked in the Levingtons compost experiment, where the high frequency of close cutting proved a severe limitation to plant production.

Table 2

<u>Grass and Clover Dry Weights (g) Levingtons Compost Experiment (sown 17.8.82)</u>

Cutting Treatment	1st harvest 15.9.82		2nd harvest 22.9.82		3rd harvest 30.9.82		4th harvest 11.10.82		5th harvest 22.10.82		6th harvest 4.11.82			
	Grass Shoots	Clover Shoots	Grass Shoots	Clover Shoots	Grass Shoots	Clover Shoots	Grass Shoots	Clover Shoots	Grass Shoots	Clover Shoots	Grass Shoots	Clover Shoots	Grass Roots	Clover Roots
lax	0.12	0.03	0.40	0.29	1.29	1.47	1.87	1.81	1.13	1.25	7.35	6.55	5.36	2.35
intermediate	0.77	0.34	0.93	0.68	1.41	1.61	1.27	1.64	0.58	0.75	3.78	5.42	4.39	2.33
close	1.01	0.44	0.86	0.60	1.42	1.45	1.04	1.07	0.54	0.97	1.74	2.28	2.07	1.00
grass only - close	0.43	-	0.44	-	1.24	-	1.70	-	0.90	-	2.06	-	2.49	-

Table 3

Cumulative yields, g DM, from all harvests

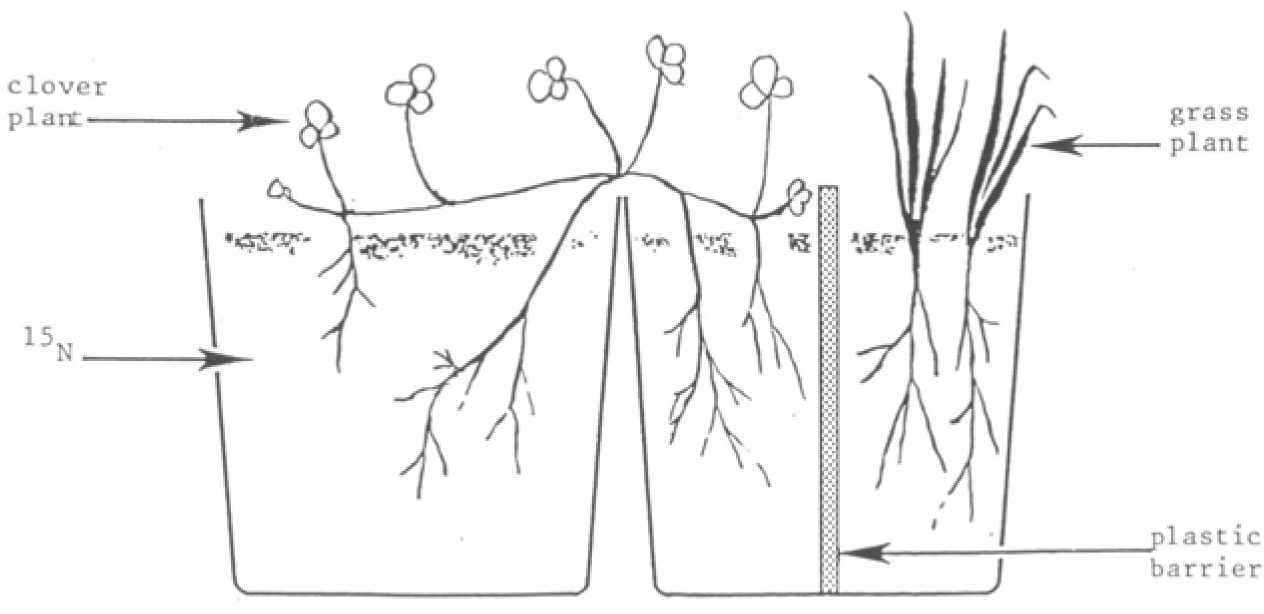
Experiment	Cutting Treatment	Grass Herbage	Clover Herbage	Total Herbage	Total Herbage + Roots
Perlite	lax	20.70	18.75	39.45	81.11
	intermediate	15.72	23.57	39.29	77.74
	close	14.21	19.67	33.88	65.27
	grass only - close	15.76	-	15.76	42.93
Levington Compost	lax	12.16	11.40	23.56	32.46
	intermediate	8.74	10.44	19.18	26.93
	close	6.61	6.81	13.42	16.70
	grass only - close	6.77	-	6.77	9.26

Plant material has been sent to A. Haystead for total N and ^{15}N analysis.

4.2. The role of vesicular arbuscular mycorrhizas in the associated growth of pasture legumes

A. Haystead, C. Marriott and A. Rangeley

Another experiment has been carried out to determine the possible effect of common mycorrhizal infection of the roots of associated pasture species on nitrogen transfer from a nitrogen-fixing legume to a non-fixing legume. An association of Trifolium repens and Lolium perenne inoculated with Glomus was studied, using a modified technique to that described in HFRO Annual Report for 1981, p. C22. The plants were grown in perlite in 4" square pots, with the root system of a clover stolon cutting divided into two adjacent pots. In one pot there was the clover plant only; in the other pot there was a plastic barrier halfway across the pot with 4 grass plants growing on the other side of the barrier. A diagram of this arrangement is shown below:



There were three barrier treatments and in each treatment there were mycorrhizal inoculated plants (+M) and uninoculated plants (-M), each with 4 replicates. The barrier treatments were:

1) Complete barrier. No root contact was possible and there was no possibility of underground transfer in either +M or -M treatments.

2) 60 m nylon mesh barrier. Again no root contact was possible. The possible routes of transfer were diffusion of nutrients through the soil solution (the only route for -M plants), diffusion across a reduced distance due to the presence of mycorrhizal hyphae or direct connection of the root systems by fungal hyphae.

3) No barrier. Root contact was possible in this treatment and the routes of transfer were the same as in the 60 m nylon mesh treatment.

^{15}N labelled ammonium nitrogen (100 ppm N as $(^{15}NH_4)_2SO_4$. 98.1 Atom % ^{15}N) was watered on to the pots containing only clover. Using this technique we intended to label the nitrogen of the whole clover plant without allowing the grass plants direct access to the source of ^{15}N. Thus enrichment of the grass N would reflect transfer of nitrogen from the clover plant. The experiment was watered throughout with Dart and Pate (1959) nutrient solution, and a small amount of KNO_3 was supplied to the grass plants when they appeared pale green.

Table 1

Dry matter yields of grass plants (g)

Treatment	1st Harvest 16.9.82 Shoots	2nd Harvest 11.10.82 Shoots	Final Harvest 28.10.82 Shoots	Roots
+M no barrier	0.0430	0.1638	0.2635	0.3490
mesh	0.0463	0.1982	0.2907	0.3604
complete barrier	0.0342	0.1919	0.3047	0.3274
$\bar{x}$ (+M)	0.0412	0.1846	0.2863	0.3456
-M no barrier	0.0451	0.2159	0.4000	0.4815
mesh	0.0412	0.2006	0.3546	0.4052
complete barrier	0.0504	0.2050	0.3320	0.3720
$\bar{x}$ (-M)	0.0456	0.2072	0.3622	0.4196
LSD 5%	0.0158	0.0377	0.0764	0.0631

Three harvests were made - 76, 101 and 118 days after sowing the grass. At present dry weight data only are available; in Table 1 the dry weights (freeze dried) of the grass plants are presented. The dry matter of grass herbage and root material was greater in the -M treatment throughout the experiment but the difference was significant only for the final harvest of root material. As in the previous experiment the level of mycorrhizal infection of grass roots was low.

From a visual assessment the plants in the +M treatment appeared darker green. This awaits confirmation from the total N data which will be provided by A. Haystead. He will also analyse the samples for ^{15}N enrichment.

Reference

DART, P.J. and PATE, J.S. 1959. Nodulation studies in legumes. 3. The effects of delaying inoculation on the seedling symbiosis of barrel medic, Medicago tribuloides Desr. Aust. J. Biol. Sci. 12, 427-44.

4.3. Nitrogen economy of white clover plants

C. Marriott

In the first experiment in the nitrogen economy studies of white clover plants (HFRO Annual Reports 1977, p. C38 and 1980, p.C17) it was found that there was a much reduced level of nitrogen in defoliated plants, even 21 days after defoliation. There was a greater rate of increase in plant nitrogen in control plants grown with either ammonium or nitrate nitrogen - 2.44 mg N d^{-1} for control plants compared with 1.44 mg N d^{-1} for defoliated plants grown with NH_4-N and 2.39 mg N d^{-1} compared with 1.67 mg N d^{-1} for NO_3-N grown plants. In the period prior to defoliation 98% of the nitrogen in the clover plants was derived from fixation of atmospheric nitrogen. The source of the nitrogen increment in the post-defoliation period - either fixed N or mineral N - could not be determined. A second experiment was therefore planned to distinguish between the two sources of nitrogen.

White clover plants (S184) were grown from stolon cuttings in 4" pots of perlite and were inoculated with an effective strain of Rhizobium. Dart and Pate nutrient solution was supplied to the plants and only small amounts of unlabelled NO_3-N and NH_4-N (less than 5 mg N) were given. In addition plants were grown without a supply of mineral N - i.e. relying completely on fixation of atmospheric nitrogen. Acetylene reduction assays 60 days after setting up the experiment showed that nitrogen fixing activity was not significantly different in the three sets of plants (Table 1). All plants were actively fixing nitrogen and at harvest were seen to be well nodulated.

Table 1

Acetylene reduction assays 60 days after experiment set up. 3 plants/treatment measured.

	$\mu mol\ C_2H_4 h^{-1} pl^{-1}$ (±SE)
NH_4 plants	20.31 ± 3.35
NO_3 plants	16.96 ± 2.03
NO-N plants	16.99 ± 3.92

Ninety-eight days after the stolon cuttings were established half the plants in each regime were subjected to defoliation i.e. removal of all fully expanded leaf material. At the same time the plants were given ^{15}N labelled nitrogen according to the previous mineral nitrogen regime. Ammonium nitrogen was supplied as 95.6 Atom % ^{15}N ammonium sulphate and nitrate nitrogen as 95.2 Atom % ^{15}N sodium nitrate. The plants were harvested at intervals after the defoliation treatment was imposed and the material was dissected into mature leaves - laminae and petioles, young leaves - laminae and petioles, stolons, growing tips and nodulated roots. An attempt was made to remove nodules from the root system but because of their large number (over 1000 per root system) it was not possible to continue separating them. The plant parts were freeze dried to provide dry weight data and were analysed for total N and ^{15}N content.

Further acetylene reduction assays were carried out at harvest of the plants in the no N treatment. Dry weights, total nitrogen content and acetylene reduction data from these plants are presented in Table 2.

Table 2

Dry weights, total N content and acetylene reduction data - No N treatment

		Harvest days after defoliation			
		0	5	10	14
Dry Wt. g	Control	13.260	17.085	17.054	-
	Defoliated	9.128	12.269	13.035	-
	LSD 5%	4.173	11.342	1.736	-
mg N	Control	336	414	475	-
	Defoliated	225	333	373	-
	LSD 5%	31	241	79	-
C_2H_4 $\mu mol.h^{-1}.pl^{-1}$	Control	8.64	8.64	11.62	14.75
	Defoliated	7.54	8.16	8.94	13.65
	LSD 5%	4.09	14.97	7.62	4.30

The reduction in dry matter was significant only at the harvest 10 days after defoliation. The reduction in N content was significant except at the 2nd harvest but there was no significant reduction in acetylene reducing activity. These are surprising results, since removal of such a large proportion of leaf material would be expected to have a significant effect on photosynthetic assimilate production and hence on nitrogen fixation. A linear regression analysis of the total nitrogen data showed no significant difference in the rate of increase of plant nitrogen (13.87 mg N d^{-1} in control and 15.16 mg N d^{-1} in defoliated plants) confirming the acetylene reduction data.

The %N data in the first and second experiments were in broad agreement but there was a lower %N in the stolons in the second experiment (Table 3). The total N content of all plant parts except young leaf tissue in the NO_3 treatment and young leaf tissue and growing tips in NH_4 grown plants was significantly less ($P < 0.05$) in defoliated plants. The active growing tissues are areas of priority for N supply in the post-defoliation period.

Table 3

Stolon material %N - mean over all harvests

	Expt 1	Expt 2
NH_4	2.39	1.84
NO_3	2.67	1.74

The dry weight, total N and ^{15}N content of whole plants are presented in Tables 4a and 4b. There is a significant reduction in plant dry matter ($P < 0.001$), total N ($P < 0.001$) and ^{15}N ($P < 0.05$ for NH_4 plants and $P < 0.001$ for NO_3 plants) in the defoliated treatment. Linear regression analysis was used to compare the rates of increase of the data in the 21 day period following defoliation (Table 5). There was a smaller rate of increase in dry matter, total N and ^{15}N in defoliated plants grown with ammonium nitrogen but the difference for nitrate plants was not as large. Indeed the rate of increase in plant ^{15}N was greater in defoliated plants grown with nitrate.

Using the values for plant ^{15}N content, the amounts due to fixation of atmospheric nitrogen and uptake of mineral nitrogen were calculated (Tables 6a and 6b). Fixation of atmospheric nitrogen accounted for over 98% of the plant nitrogen. There was no difference in the rate of uptake of ammonium nitrogen in the post defoliation period (0.06 mg N d^{-1}) but the rate of uptake of nitrate nitrogen was greater in defoliated plants (0.04 mg N d^{-1} in control plants and 0.08 mg N d^{-1} in defoliated plants). The rate of increase of fixed N was greater in control plants grown with nitrate nitrogen (Table 7). The results from the ammonium grown plants agree with those from the first experiment, where defoliation caused a decrease in fixation of nitrogen; the results from the nitrate grown plants agree with those from the no N treatment, where there was no reduction in fixation of nitrogen, in fact an apparent increase.

Table 4a

Dry weight, total N and ^{15}N data for control (C) and defoliated (D) plants - NH_4 plants (n = 3)

		Days after defoliation 0	5	10	14	21	LSD 5%	1%
Dry Weight g	C	12.279	10.152	11.708	16.682	19.704	2.613	3.580
	D	7.746	9.270	10.167	11.551	14.042		
Total N mg	C	302.2	291.0	280.5	399.4	494.2	80.3	110.0
	D	201.5	224.2	266.6	269.6	342.5		
^{15}N µg	C	1128	1349	1280	2222	2979	390	
	D	751	1102	1533	1753	2446		

Table 4b

Dry weight, total N and ^{15}N data for control (C) and defoliated (D) plants - NO_3 plants (n = 3)

		Days after defoliation 0	5	10	14	21	LSD 5%	1%
Dry Weight g	C	10.150	12.072	12.871	16.520	19.787	3.653	5.005
	D	6.567	6.081	7.422	11.634	13.703		
Total N mg	C	245.9	330.6	307.9	360.4	496.0	77.3	105.9
	D	176.2	168.2	196.4	269.8	375.7		
^{15}N µg	C	917	1565	1691	2014	2884	286	392
	D	656	881	1234	1860	2844		

Table 5

Linear regression analysis of dry matter, total N and ^{15}N of control (C) and defoliated (D) plants

		NH_4 plants Dwt	N	^{15}N	NO_3 plants Dwt	N	^{15}N
C	Slope	0.419	9.758	90	0.465	10.635	87
	Intercept	9.909	255.9	890	9.628	242.8	944
	R^2	0.779	0.723	0.870	0.804	0.787	0.930
D	Slope	0.259	6.528	80	0.386	9.959	106
	Intercept	8.143	195.6	719	5.219	137.0	436
	R^2	0.842	0.809	0.976	0.866	0.862	0.950

Table 6a

Mineral N and fixed N content of control (C) and defoliated (D) plants - NH_4 plants

		Days after defoliation			
		5	10	14	21
Mineral N as % of total N	C	0.10	0.09	0.20	0.25
	D	0.13	0.22	0.30	0.36
mg mineral N	C	0.29	0.25	0.80	1.23
	D	0.29	0.58	0.81	1.23
mg fixed N	C	290.71	280.25	398.60	492.97
	D	223.91	266.02	268.79	341.27

Table 6b

Mineral N and fixed N content of control (C) and defoliated (D) plants - NO_3 plants

		Days after defoliation			
		5	10	14	21
Mineral N as % of total N	C	0.11	0.19	0.20	0.22
	D	0.16	0.27	0.34	0.42
mg mineral N	C	0.36	0.58	0.72	1.09
	D	0.27	0.53	0.92	1.58
mg fixed N	C	330.24	307.32	359.68	494.91
	D	167.93	195.87	268.88	374.12

Table 7

Linear regression analysis of fixed N in control (C) and defoliated (D) plants grown with NH_4-N and NO_3-N, 5-21 days after defoliation

		NH_4 plants fixed N	NO_3 plants fixed N
C	Slope	13.92	10.96
	Intercept	192	236
	R2	0.937	0.881
D	Slope	7.00	13.39
	Intercept	187	84
	R2	0.971	0.982

A closer analysis of the defoliation treatment was made in an attempt to explain the different responses of nitrogen fixation (Table 8).

Table 8

Analysis of defoliation treatment

	Removed leaves as % of original leaves	% of DM	% of N	Number of young leaves remaining
1st expt	45-52	30-35	> 30	42-54
2nd expt				
No N	55	27	28	180
NH_4-N	56	28	31	156
NO_3-N	60	32	33	129

There were no significant differences in the defoliation treatment in terms of % leaf, % DM or % N removal. The number of leaves per plant at the start of the experiment varied, leaving a different number of young leaves after defoliation. Contrary to what one might have expected, there was no trend of decrease in nitrogen fixation with reduced number of young leaves. This is an area which could be investigated further, using treatments imposing different severities of defoliation - ranging from removal of fully expanded leaf material to removal of all leaf tissue. Further work is needed using plants that depend more heavily on mineral nitrogen, for a more detailed assessment of how mineral nitrogen uptake and assimilation is affected by defoliation.

4.4. 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 to work in this project was described in HFRO Annual Reports 1980 (p.C20) and 1981 (p.C25). Experiments during 1982 have concentrated on three main aspects.

4.4.1. Estimations of relative effectiveness of indigenous Scottish strains of Rhizobium trifolii in association with Trifolium repens cv New Zealand Grasslands Huia (NZGH).

Following the earlier work where strains of Rhizobium trifolii were selected from a series of hill soils and characterised by relative growth responses, intrinsic antibiotic resistance and symbiotic efficiency, similar experiments were conducted in 1982 in an attempt to reduce the variability produced by the symbiotic association. As in 1981 (HFRO 1981 Annual Report, p.C25) where dry weight of nodulated white clover plants was significantly correlated with percentage nitrogen content and acetylene reduction (nitrogen fixation) by the root systems, plants of cultivar NZGH were grown under bacteriologically controlled conditions and inoculated with single strains of R. trifolii (12 strains isolated from the Cleish Hills, Fife, two originally supplied by ESCA and stocked at HFRO, and two strains from the Rothamsted collection of Rhizobium).

Surface sterilised seeds were sown directly into autoclaved test tubes containing a filter paper "wick" and 10 ml of a "simplified nutrient solution" (SNS) which contained:

$CaCO_3$	0.6 g
$CaCl_2$	0.2 g
$K_2 H_2PO_4$	0.2 g
$Na H_2 PO_4$	0.2 g
$MgSO_4.7H_2O$	0.2 g
Fe Na EDTA	1.0 ml stock containing 32.86 g/l
Trace elements	1.0 ml stock (Gibson, 1963)
Deionised water	1 litre

After 60 days growth at 20°C day-, 15°C night-temperatures, with a 15 hr daytime period, the plants were removed from the tubes and dry weights, nodule fresh weight per plant and total nodule number per plant were recorded. From this data the mean nodule fresh weight for each plant was extrapolated, and an analysis of variance was carried out using a "Genstat" program for a randomised block design. In all these measurements significant differences existed between strains. Dry weight data were also compared against uninoculated controls. The results are shown in Table 1.

The main conclusion to be drawn from this data is that generally the effectiveness of the symbiotic association as monitored by the dry weight of the host plant is limited by the total nodule mass on the roots. That is to say, that, as a generalisation, the greater the amount of nodule material produced, as a result of infections by Rhizobium, the greater the amount of fixed nitrogen (which limits growth) that will be produced. However, there appears to be a major exception to this rule and that is the standard effective strain RCR221 (also known as TA1). This strain appears to initiate a larger number of smaller nodules than is the norm for the other effective strains which usually form larger nodules. In this case an 'effective' strain is defined as being significantly different than uninoculated controls when considering the mean dry weight of the host plant. However, defining 'ineffective' strains still remains a problem as variability in host responses to infection with CL03, CL10, CL12, CL33 and CL35 has produced an intermediate result which is neither significantly different to the mean dry weight of uninoculated plants or the standard 'ineffective' strain RCR10, and the defined effective strains, CL21, CL56, P3, FA6 and RCR221.

Table 1

Relative effectiveness (nitrogen fixation effiency) expressed as mean dry weight per plant, mean nodule fresh weight per plant (mean nodule mass), mean number of nodules per plant and extrapolated mean nodule fresh weight, for 16 strains of Rhizobium trifolii in assocation with white clover, cv. NZGH, grown under totally enclosed, bacteriologically controlled conditions for 60 days

Strain	Mean dry weight (mg/plant)	Mean nodule mass (mg/plant)	Mean number of nodules per plant	Mean nodule fresh weight (mg)
CL03	14.3	3.61	10.84	0.34
CL10	18.3	3.85	11.33	0.36
CL12	18.2	5.04	11.59	0.69
CL21	36.6	10.17	9.21	1.55
CL24	5.1	1.92	12.95	0.11
CL25	5.7	1.90	8.02	0.33
CL27	3.6	1.15	9.62	0.57
CL33	14.1	4.54	17.67	0.35
CL35	16.7	4.47	21.03	0.26
CL56	35.4	10.02	5.58	2.14
CL66	4.4	0.36	11.45	0.03
CL96	4.5	0.95	7.49	0.13
P3	41.4	10.99	10.34	1.13
FA6	67.8	14.09	15.62	1.01
RCR10	3.7	1.41	12.26	0.16
RCR221	53.9	5.52	18.63	0.36
Uninoculated	4.4	0.00	0.00	0.00
LSD	31.0	8.64	20.18	1.64

Correlation coefficients   Degrees of freedom = 150

1) Dry wt x nodule mass $r = 0.8461$ $p<0.1\%$

2) Dry wt x number of nodules $r = 0.2953$ $p<1.0\%$

3) Dry wt x extrapolated nodule fresh weight $r = 0.4605$ $p<0.1\%$

Finally, the fact that, taking the data as a whole and disregarding the mean measurements, production of dry weight is also significantly correlated to the number of nodules produced, suggests that the overall performance of a strain could be improved by stimulating the number of successful infections in a root system. Experiments utilising plant growth hormones in an attempt to encourage nodulation will be started in the near future to further investigate the validity of this statement.

Reference

GIBSON, A.H. 1963. Physical environment and symbiotic nitrogen fixation. 1. The effect of root temperature on recently nodulated Trifolium subterraneum L. plants. Aust. J. Agric. Res. 15, 37-49.

4.4.2. Relative competitiveness between strains of Rhizobium trifolii for nodulation of Trifolium repens cv New Zealand Grasslands Huia under controlled conditions.

a) Multiple strain comparisons

Three experiments to compare relative nodulation success (relative competitiveness) were conducted concurrently using the 'Filter Paper Wick' technique for plant culture (section 4.4.1). Each group of plants was grown for 60 days at 20°C day temperature, 15°C night temperature, 15 hr day time, and received an inoculum of a mixture of five or six randomly selected strains (approximately 10^7 cells ml^{-1} of each strain). A further treatment effect was produced by addition of nutrient solutions made up to four different pHs, i.e. 5.0, 5.5, 6.0, 6.5 by the addition of 0.1 N HCL or 0.1 N Na OH after autoclaving. The strains in each inoculum 'cocktail' were:

Experiment 1 : CL03, CL24, CL25, CL33, RCR10

Experiment 2 : CL10, CL12, CL27, CL35, CL96

Experiment 3 : CL21, CL56, CL66, P3, FA6, RCR221

The tubes were arranged in a randomised block design and nodules were selected for study from the crown position (top of the root) and randomly from the rest of the root system. Identification of 100 nodules per pH x 'cocktail' treatment was carried out by replicated plating of isolated colonies on to a number of yeast-Mannitol agar plates containing low levels of key antibiotics. The resistance patterns of growth ('finger-prints') thus produced by each isolate were compared with those produced by pure cultures of each strain (Josey et al, 1979; HFRO 1980 Annual Report, p.C20).

Watering of the plants with nutrient solutions (SNS) of different pH values had no significant effects on the number of nodules occupied by each strain in any of the three experiments. A significant interaction between the position of the nodules and the strains that occupied them was also absent from two out of the three experiments, being only recorded for experiment 3.

Table 2

Relative nodulation success of each strain compared to other strains in the same experiment. Figures given are the percent of nodules that produced identifiable isolates, occupied by each strain. the least significant difference (LSD) (P = 0.05) for each experiment area also given.

EXPERIMENT 1

Strain	CL03	CL24	CL25	CL33	RCR10	LSD
% occupancy	19.97	18.29	15.87	28.52	17.98	12.28

EXPERIMENT 2

Strain	CL10	CL12	CL27	CL35	CL96	LSD
% occupancy	21.10	28.00	16.00	20.80	14.20	13.61

EXPERIMENT 3

Strain	CL21	CL66	P3	FA6	CL56	RCR221	LSD
% occupancy	9.92	13.70	20.89	25.90	11.44	18.27	11.91

It can be seen from the data in Table 2 that there are no major differences between the majority of strains when inoculated in approximately equal proportions on to clover plants grown in bacteriologically controlled conditions. In summary then the only significant differences that existed were:

Experiment 1 : Significantly more nodules were formed by CL33 than by CL25.

Experiment 2 : Both CL12 and CL35 occupied significantly more nodules than CL96.

Experiment 3 : FA6 occupied significantly more nodules than CL21, CL56 and CL66. However in this latter case there was a significant interaction between the position of the nodules and the strains occupying them. Considering this interaction the only significant difference recorded in this experiment was that FA6 occupies more crown nodules than CL21.

However, because of variability in intrinsic antibiotic resistance patterns, much of which may possibly be attributed to mixed infections/nodulation by two or more strains, between 34% to 50% of nodules could not be reliably identified even using 'cluster analysis' techniques. This meant that, on average, the above data, and subsequent tentative conclusions, were based on only 60-61% of the total number of nodules analysed. It was therefore obvious that if reliable information was to be obtained concerning competition between strains of Rhizobium trifolii, especially under field conditions, an alternative and more exact method of identification must be used. It was therefore decided to screen some of the above strains for spontaneous mutations to higher levels of antibiotics.

After careful single colony picking and re-streaking on high level antibiotic plates, together with tests for stability of the phenotype after repeated nodulation, isolation, reinfection and re-isolations the following strains were selected for further competition trials:

CL03/E102 : a spontaneous mutant of CL03 resistant to 25 mg l^{-1} (YM agar) erythromycin (mutation rate $\approx 10^{-7}$)

CL25/S3 : a spontaneous mutant of CL25 resistant to over 80 mg l^{-1} (YMA) streptomycin (mutation rate on 50 mg l^{-1} streptomycin 10^{-5} - 10^{-6}

CL56/K302 : a spontaneous mutant of CL56 resistant to 40 mg l^{-1} kanamycin and over 80 mg l^{-1} streptomycin mutation rate on 25 mg l^{-1} kanamycin < 10^{-5}

Also used in subsequent experiments was the strain HP3; a rifampicin resistant (50 mg l^{-1} YMA) mutant of P3 supplied by Professor A.J. Holding, Queens University, Belfast, and also found to be resistant to 40 mg l^{-1} kanamycin, but not to streptomycin or erythromycin.

Before use the above strains were also tested against their parent strains for changes in symbiotic effectiveness as measured by dry weight production using the 'Filter Paper Wick' technique. No significant differences between the mutants and their parents were recorded.

b) Multiple ratio comparisons

Assuming that infection sites on white clover root systems are a finite limited resource, then strains of R. trifolii in a mixed inoculum can be judged to be competing for this resource. In an attempt to investigate this assumption a series of concurrent experiments, using the antibiotic resistant mutants previously described, were set up. Plants of white clover cv NZGH were grown in the bacteriologically controlled conditions produced by the 'Filter Paper' technique (section 4.4.1) and 'watered' with SNS nutrient solution at four different pHs (section 4.4.2a). Once germinated the plants were inoculated as described below and arranged in a randomised block design in a growth chamber (section 4.4.1). The replicate plants received one of the combinations of two strains at one of the nine ratios:

Strain combinations:

CL03/E102 v CL25/S3

CL03/E102 v CL56/K302

CL03/E102 v HP3

CL25/S3 v HP3

CL56/K302 v HP3

Ratios of strains supplied in the inoculum (total of 10^7 cells ml^{-1} were 20:1; 15:1; 10:1; 5:1; 1:1; 1:5; 1:10; 1:15; 1:20; or expressed as a proportion of strain A/strain B. 20, 15, 10, 5, 1, 0.2, 0.1, 0.0675, 0.05.

After 60 days growth as many nodules as possible per tube (up to 20, each tube contained 2 plants) were excised from the roots and crushed on to yeast-Mannitol agar plates. The isolated colonies were then spotted on to selective agar plates containing the appropriate levels of antibiotics and the presence or absence of growth after four days incubation at 27°C was recorded. Comparisons between CL25/S3 and CL56/K302 were not made are both as resistant to streptomycin and so any comparison based solely on resistance to kanamycin would not include mixed infections, and so would under-estimate the relative infection rate of CL25/S3. In fact it was found that overall up to one third of all nodules analysed in other comparisons were multiply infected, though there was significant variation between the comparisons.

The aim of these experiments was to produce a relative competitive index based on an equilibrium point where the input ratio (ratio of strains in a dual inoculum) equals the output ratio (ratio of infections caused by each strain in the inoculum).

As was expected, as the resource does not determine survival, a case of stable equilibrium between strains competing for infection sites was obtained. This is analogous to the case of competing annual plants in stable equilibrium described by De Wit (1960) cited in Krebs (1978), and can be expressed graphically with vector arrows indicating resulting trends.

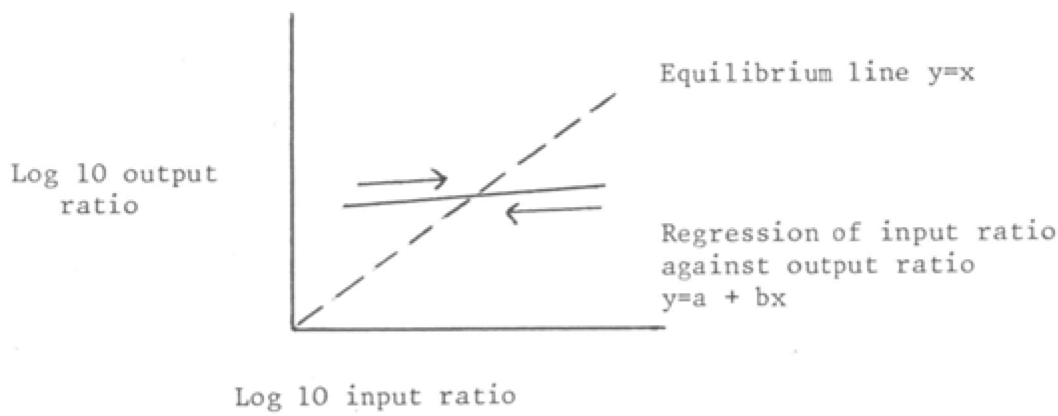


Figure 1. Input-output diagram to illustrate outcome of competition for nodulation by R. trifolii strains infecting white clover cv NZGH.

When the slope of the fitted regression line is < 1 a case of stable equilibrium or coexistence arises with the equilibrium ratio, where the input ratio = output ratio, being at the intercept of the regression line with the line y = x.

Expressed algebraically

where y = Log 10 output ratio $\left(\frac{\text{No. infections by strain A}}{\text{No. infections by strain B}}\right)$

and x = Log 10 input ratio $\left(\frac{\text{No. cells of strain A in inoculum}}{\text{No. cells of strain B}}\right)$

then Log 10 Equilibrium Ratio Xe = $\frac{a}{(1-b)}$

The significance of these relationships can be found using standard t-tests on the regression functions.

If a (intercept of the fitted regression with line X=0) is not significantly different from zero then the equilibrium ratio is deemed to be 1, i.e. a 1:1 input ratio results in a 1:1 output ratio, signifying equal relative competiveness between the two strains in the inoculum.

If b (slope of fitted regression) is not significantly different from 1, then the fitted line is deemed to be parallel to the line y=X and equilibrium is not reached (= competive exclusion of one strain by another).

N.B. in all comparisons b was significantly greater than zero and the regression line was significant at 5% probability level.

Table 3

Extrapolated equilibrium ratios between strain comparisons of Rhizobium trifolii competing for nodulation of white clover cv NZGH under bacteriologically controlled conditions with original inoculum concentration of $1x10^7$ cells ml^{-1}

Strain compar.	Slope b of regress. line	Significance P < 5.0% against b=1	Log 10 equil. point Xe	Significance P < 5.0% against a=o	Equil. ratio
CL03/ E102xCL23/ S3	0.182	b<1	-0.486	a≠o	0.33
Cl03/E102x CL56/K302	0.437	b<1	-0.240	ns a=o	1.0
CL03/E102x HP3	0.284	b<1	-0.220	ns a=o	1.0
CL25/S3x HP3	0.528	b<1	0.528	a≠o	3.38
CL56/K302x HP3	0.570	b<1	-0.121	ns a=o	1.0

This shows that under bacteriologically controlled conditions with a total inoculum concentration of 107 cells ml^{-1} i.e. adequate numbers of viable cells for optimal nodulation by even the least represented strains, the only real differences in competitive ability exist between the strains CL03/E102 and CL25/S3 and between CL25/S3 and HP3 with CL25/S3 being the least competitive in both comparisons. Thus, if equal opportunities for nodulation are to be presented, then under the conditions influencing these experiments CL25/S3 must be 3-4 times more abundant in an inoculum than both CL03/E102 and HP3.

As with the earlier multiple strain comparisons the pH of the nutrient solution had no effect on the outcome of the competition.

References

JOSEY, D.P. et al 1979. Strain identification in Rhizobium using intrinsic antibiotic resistance. J. Appl. Bact. 46, 343-350.

KREBS, C.J. 1978. Ecology : the Experimental Analysis of Distribution and Abundance. 2nd edition, Harper International, New York.

WIT, C.T. de 1960. On Competition. Versl. Landbouwk, Onderzoek No. 66, Wageningen, Netherlands.

4.4.3. Effects of lime level and inoculum type on rhizosphere and soil populations of introduced strains of Rhizobium trifolii in competition with naturalised strains for nodulation of white clover plants in a newly sown, pure sward.

A lime x inoculum-type factorial experiment was set up on the 1978 reseed site on the Cairn Hill at Glensaugh farm in 1982. This was designed to test the abilities of marked strains both ineffective and effective in nitrogen fixation/symbiotic functioning, to compete amongst themselves and with naturalised populations of R. trifolii for nodulation of white clover. To produce a pure, young clover sward, the designated plots (2mx2m) were desiccated with a sprayed application of Paraquat (Gramoxone 100) solution three weeks prior to sowing. Two weeks after desiccation the dead vegetation was removed and half the plots received an application of 5 tonne/ha which was incorporated to a 10 cm depth by rotavation (all plots similarly rotavated). One week later the plots/seed beds were levelled by forking and raking and seed of white clover cv New Zealand Grasslands Huia (NZGH) was sown at five times the recommended agricultural rate for a pure sward. This was done in an attempt to reduce patchiness during germination and thus produce a dense but even clover sward capable of out-competing colonising plants from external sources.

Inoculation of the plots was with equal amounts of the four antibiotic mutants described earlier (section 4.4.2). Two methods of inoculation were employed both of which supplied approximately $3x10^5$ cells cm^{-2} of each strain. Half the plots received the inoculum as a spray of diluted late log phase cultures. The other plots received a granular peat based inoculum prepared 12 hours previously. This latter method involved mixing the inoculum with milled peat and methyl cellulose so that the seed was evenly coated. Excess peat inoculum was then mixed with washed autoclaved sand to enable even distribution on the plots.

Samples were collected in June and October of 1982. Sampling involved the selection of five random 4.5in diameter soil cores per plot. For each of these, 10 randomly selected nodules were excised from the clover root system. The roots were washed in a weak NaCl solution plus Decon 90 detergent (previously autoclaved) to remove the rhizosphere material. Soil which had previously been sieved from the roots was also collected.

Isolates obtained from the excised nodules were spotted on selective (antibiotic) agar for identification whilst serial dilutions of both the rhizosphere material and soil were over-plated with selective media.

a) Lime effects

Generally speaking lime had little or no direct effects on any of the rhizobia, introduced or indigenous, and its effects on these strains were only recorded as an interaction with the inoculum treatment. Also at the first sample date the lime treatment had had no significant effect on the soil pH. Nevertheless, by the time the second samples had been taken the overall differences between pH measurements had become significant, despite great variability between plots and a pH gradient across the blocks.

Table 4

Effect of lime level on the mean pH measurements of samples collected in October 1983

Lime level	0	5 t/ha
Mean pH	5.82	6.15

LSD = 0.14

b) pH effects

As lime had little or no effect on individual rhizobia strains and there were large differences between pH measurements even within a plot, it was decided to see if the pH of the sample had any effect on nodulation, or the rhizosphere and soil populations of the various strains. This was done by regression analysis.

From the first set of samples the only effect of pH was a -ve regression with nodule occupancy by total marked strains. That is to say, as increased. By the time the second set of samples was taken this effect has become insignificant but pH was having an effect on various soil and rhizosphere populations.

Table 5

List of significant relationships between pH measurements and some rhizosphere and soil populations as monitored by regression analysis for each soil core measurement with a significance level of P<5.0% from second set of samples.

Strain	Population	Relationship with pH
CL03/E102	Soil	+ve
CL25/S3	Rhizosphere	-ve
Indigenous	Soil	+ve
Total rhizobia numbers	Soil	+ve

c) Inoculum effects

Table 6

List of overall effects of type of inoculum (spray or peat based) on the nodulation and soil and rhizosphere populations which are consistent over both sample dates

Strain	Population	Significance	Effect
CL03/E102	Nodules	ns	-
	Rhizosphere	ns	-
	Soil	ns	-
CL25/S3	Nodules	P < 1.0%	Peat inoculum increased nodulation
	Rhizosphere	P < 5.0%)	Peat inoculum tends to increase both populations but grand means are not significantly different
	Soil	P < 5.0%)	
CL56/K302	Nodules	ns	-
	Rhizosphere	ns	-
	Soil	ns	-
HP3	Nodules	P < 5.0%	Peat inoculum increases nodulation but only in limed plots
	Rhizosphere	P < 1.0%)	Peat inoculum increased both populations
	Soil	P < 1.0%)	
Indigenous Rhizobia	Nodules	P < 1.0%	Peat based inoculum decreased nodule occupancy by indigenous rhizobia

As an indication of the representation of the different marked strains in the nodules and ex-planta populations, Table also shows the interaction between inoculum type and strain representation in the first set of samples. However, the figures given for percentage nodule occupancy are further confounded by an interaction with lime levels. In this case liming at 5 t/ha tends to reduce nodule occupancy of all the strains in plots receiving the peat-based inoculum (figures are not given as the reduction of each strain is insignificant).

Table 8

Effect of inoculum type on overall means for total marked strains in the soil populations at the first sampling date

Inoculum	Mean log 10 cells/g marked strains in soil	LSD
Spray	4.300	0.308
Peat	4.654	

Table 7

Representations of all four marked strains as mean percentage occupancy in nodules, and mean log 10 ex-planta populations at the first sampling date, and the effects of inoculum type on these results

Strain		CL03/E102	CL25/S3	CL56/K302	HP3	LSD	
Population (mean % nodules mean log 10 ex-planta populations	Inoculum					a) when comparing within inoculum	b) when comparing across inoculum
Nodules mean % Occupancy	Spray	8.00	11.12	2.87	2.73	13.26	15.08
	Peat	6.83	21.63	6.45	2.87		
Rhizosphere Log 10 cells g^{-1} Material/dry wt.	Spray	8.033	7.265	7.572	6.099	0.584	0.851
	Peat	7.661	7.822	7.192	6.296		
Soil Log 10 cells g^{-1} Soil dry wt.	Spray	3.988	4.867	5.021	3.325	0.601	0.711
	Peat	4.587	5.091	5.073	3.863		

Taking tables 7 and 8 together, the following assertions can also be made for the relative successes of different strains up to the first sampling date (June 1982).

1. In the soil peat-based inoculum produced greater numbers of marked strains per gram of dried soil.

2. Rhizosphere populations of a strain may be up to 10,000 times greater than the corresponding soil population (CL03/E102, sprayed plots).

3. The standard effective strain HP3 was always significantly less abundant in both ex-planta populations than the other three marked strains but despite this it is only significantly less abundant in the nodules than CL25/83 in the peat inoculated plots.

4. When considering sprayed inoculum alone CL03/E102 was significantly less represented in the soil than CL25/S3 and CL56/K302, but greater stimulation in the rhizosphere reversed this situation relative to CL25/S3.

d) Time effects

Table 9 below, indicates that the above difference between CL25/S3 and HP3 nodule occupancies may well be insignificant by the time of the second sampling.

Table 9

Changes in mean percentage nodule occupancy for CL25/S3 over the two sampling dates

	Sample 1	Sample 2	LSD
Mean % nodules containing CL25/S3	16.4	5.0	6.6

Generally though there was no significant change in the number of nodules occupied by marked strains (considering all four together). Nevertheless, there were changes in the ex-plant populations with an increase in the soil populations of marked strains corresponding to a proportional decrease in the rhizosphere (Table 3.7).

Table 10

Changes in the soil and rhizosphere populations of total marked strains ove the two sample dates

	Sample 1	Sample 2	LSD
Mean rhizosphere numbers Marked srains (log 10 cells/g dry wt)	8.356	7.895	0.334
Mean soil numbers of marked strains (log 10 cells/g dry wt)	5.449	5.844	0.324

e) Inter- and intra-strain effects

Some indication of between strain interactons, particularly concerning strains CL25/S3 and CL03/E102 (these two strains were shown to compete for nodulation under controlled conditions - Section 4.4.2b) were obtained via a correlation matrix of all comparison means. Some stable correlations were also recorded for intra-strain comparisons. Surprisingly though, there were no consistent correlations over time between nodule occupancy, and either of the two ex-planta populations, for any single strain. This suggests that nodulation of the plants by marked strains was an early event in the history of the sward and mainly occurred before the soil populations reached stability.

A further set of samples is due to be collected from the same sites in May 1983 in an attempt to monitor over-winter survival of the marked strains and a more rigorous analysis of edaphic conditions will be made to elucidate any consistent trends or relationships found.

5. PASTURE GROWTH AND UTILISATION

Research objective: Understand how to maximise utilised herbage production in grazed hill and upland grass and grass/clover swards (project no. 106).

5.1. The growth rate of intermittently grazed swards

J. King, E. Sim and V.A. Doughty

In 1981 a report was given of the results of an experiment carried out on a rotationally grazed pasture, to compare rate of net canopy photosynthesis and hence growth-rate, during a single regrowth and grazing period (HFRO Annual Report 1981, p.C12).

In 1982 the experiment was repeated and measurements made of several 21 day/7 day regrowth/grazing cycles. The results showed clearly that net photosynthesis was higher over most of the regrowth period than it was while the sward was being grazed down. Growth-rate and senescence rate also differed between the two parts of the rotational cycle. Figure 1 shows that leaf elongation rate per tiller per day fell steeply as herbage mass was grazed down and over much of the range was lower than that of the regrowing sward. In contrast the senescence rate in the grazed sward was higher than in the regrowing sward.

The data for net photosynthesis from both the 1981 and 1982 rotational grazing experiments has been analysed along with data from three other experiments carried out in 1979 and 1980 and which were subjected to continuous stocking.

These continuously stocked experiments were all of one kind. A series of three or four swards were grazed to maintain a range of herbage heights of from 2 to 6 cm, producing a range of steady-state swards in which herbage mass ranged from 1000 to 3000 kg OM/ha and Leaf Area Index (LAI) from LAI 1 to 5. In all the experiments measurements were made of LAI and of net canopy photosynthesis at a constant light intensity (400 Wm^{-2} 400-700 nm)on turf samples removed from the field plots and taken to the laboratory. For all the results reported here, sampling did not take place until the grazing treatment had been in operation for some weeks so that the swards had time to adapt their growth-form and reach an equilibrium state in relation to the various grazing treatments.

The relationship of net photosynthesis to LAI was examined by regression analysis and the results have been summarised in Figures 2 and 3.

Figure 2 shows the relationship of Pnc to LAI for swards in the process of being grazed, either to maintain a herbage mass in a continuously stocked system or to reduce herbage mass from a high to low level in a rotational system. Figure 3 shows the relationships between Pnc and LAI for rotationally stocked swards in the regrowth phase and also while being grazed from high to low mass.

From these results several conclusions can be drawn:

a) On grazed swards Pnc was directly related to LAI whereas on swards in the regrowth phase the relationship was curvilinear and probably asymptotic.

b) On grazed swards Pnc and therefore potential growth-rate was higher, especially below LAI 3.5 where stocking was continuous and a steady-state was being maintained, than when the sward was being grazed down from high to low mass.

The superiority of the continuously stocked sward extended over the full LAI range from 1 to 5 in two experiments (E2 + 3) but in one Experiment (E1) only up to LAI 3.5.

c) On rotationally grazed swards Pnc during the regrowth phase was higher than that in the grazing phase.

These results can be accounted for in the following ways:-

i) Linear and curvilinear relationships for Pnc and LAI

The linear relationship between Pnc and LAI in grazed sward arises from the sequence of events illustrated in Figure 4. Pnc of an individual tiller is severely reduced by defoliation but during regrowth increases with LAI towards an asymptote. If no further grazing occurs the results is a curvilinear relationship. If further defoliation occurs the sequence is repeated. Thus, at any given moment in a grazed pasture the tillers will be found at all stages in the grazing/regrowth cycle, some newly defoliated and others in various stages of regrowth.

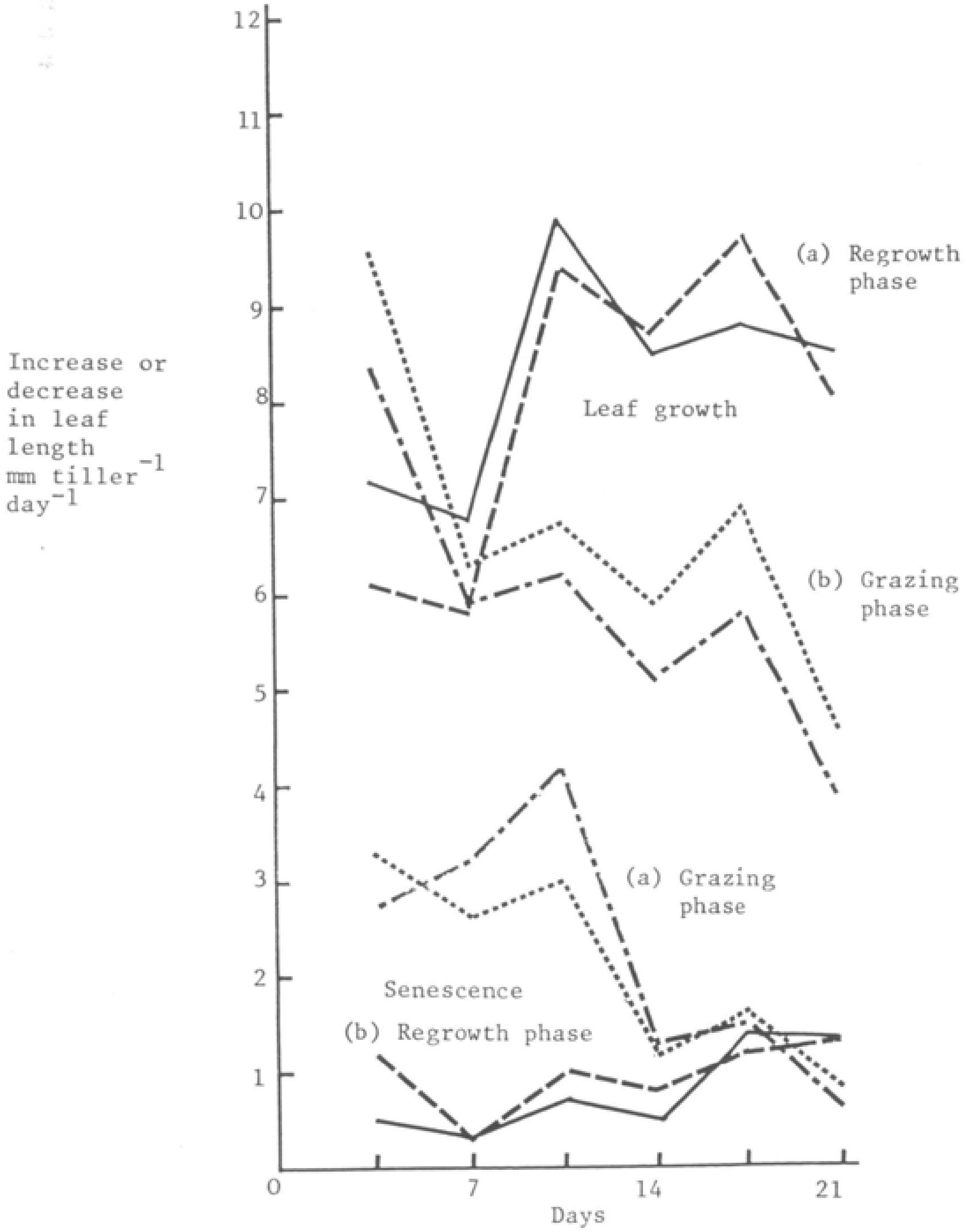


Figure 1. Increase in leaf length due to growth and decrease due to senescence for leaves of a rotationally grazed sward (a) in the regrowth phase
(b) being grazed down from high to low mass

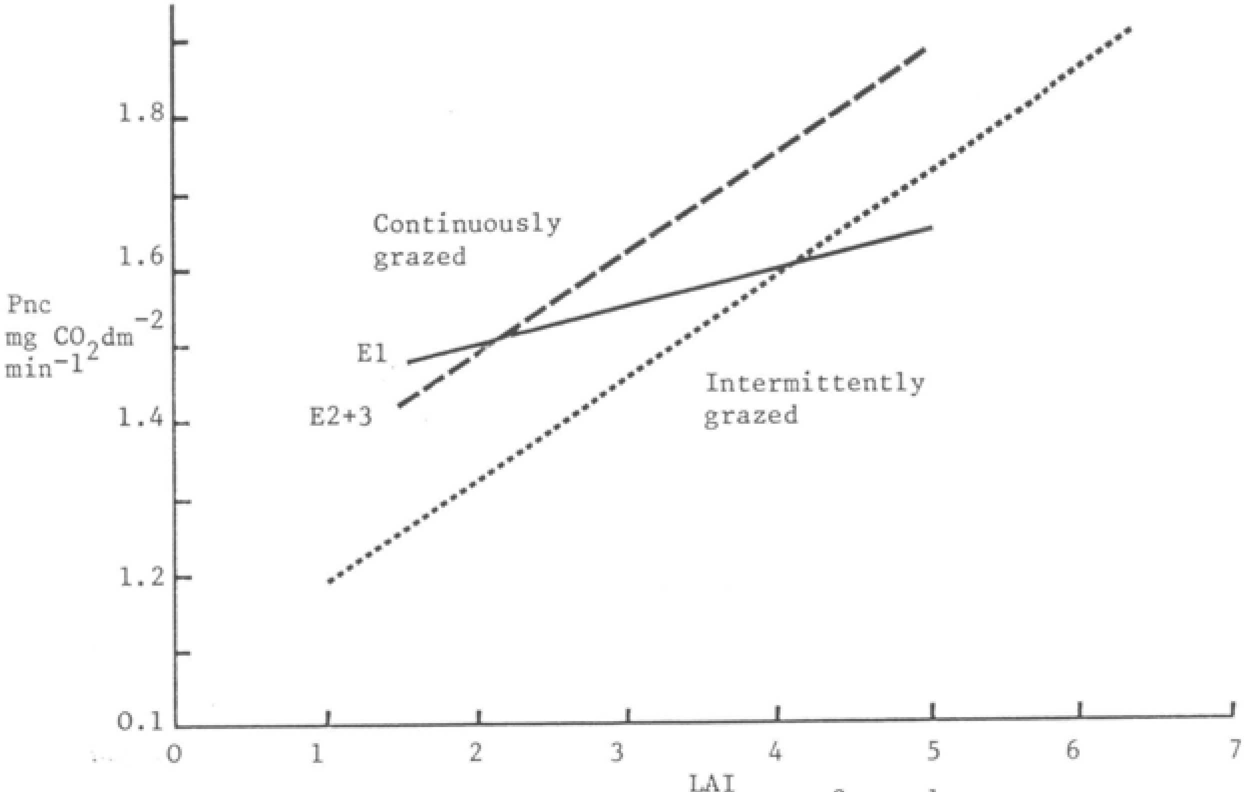


Figure 2. Relationship of Pnc (at 400 Jm^{-2} sec^{-1}) to LAI for continuously and intermittently (rotationally) grazed swards

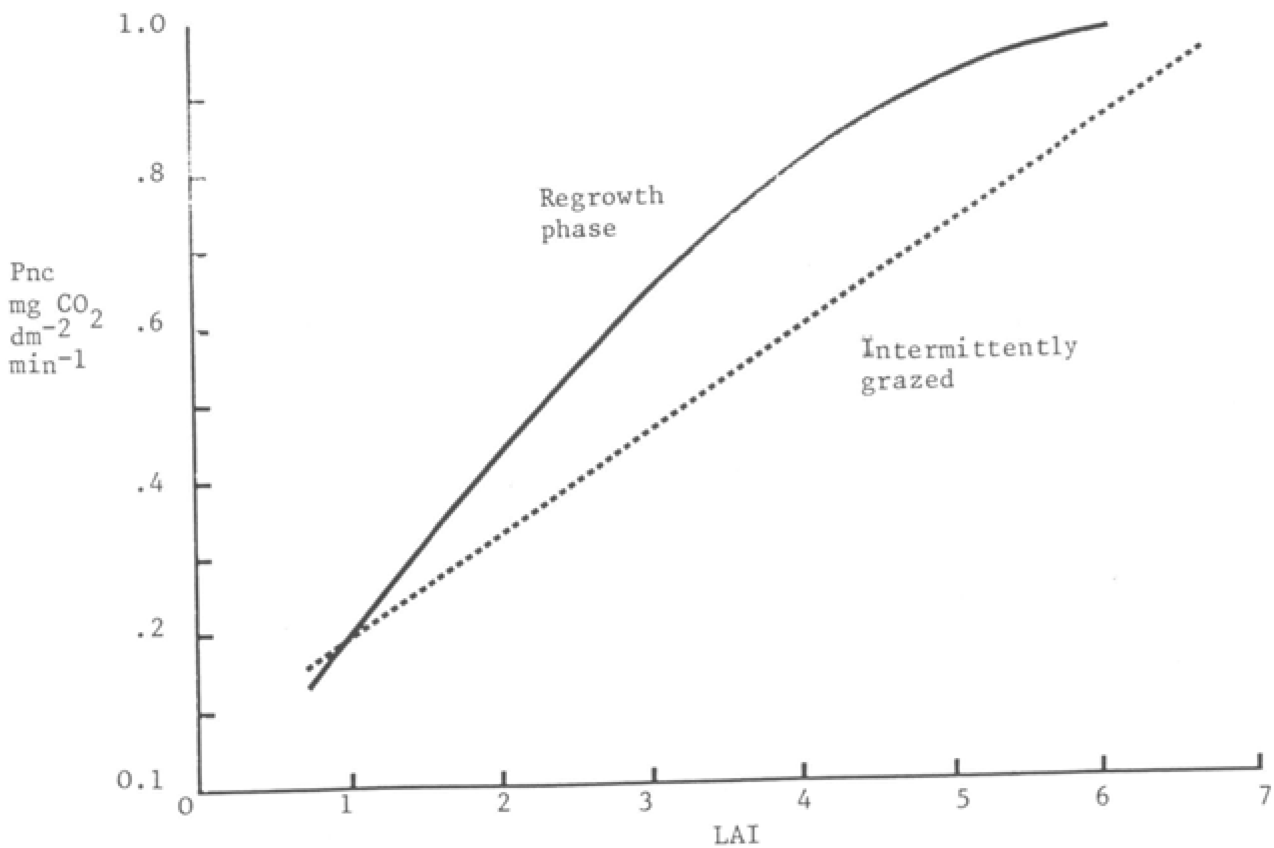


Figure 3. Relationship of Pnc to LAI for rotationally grazed swards (a) in the regrowth phase. (b) while being grazed down intermittently from high to low mass.

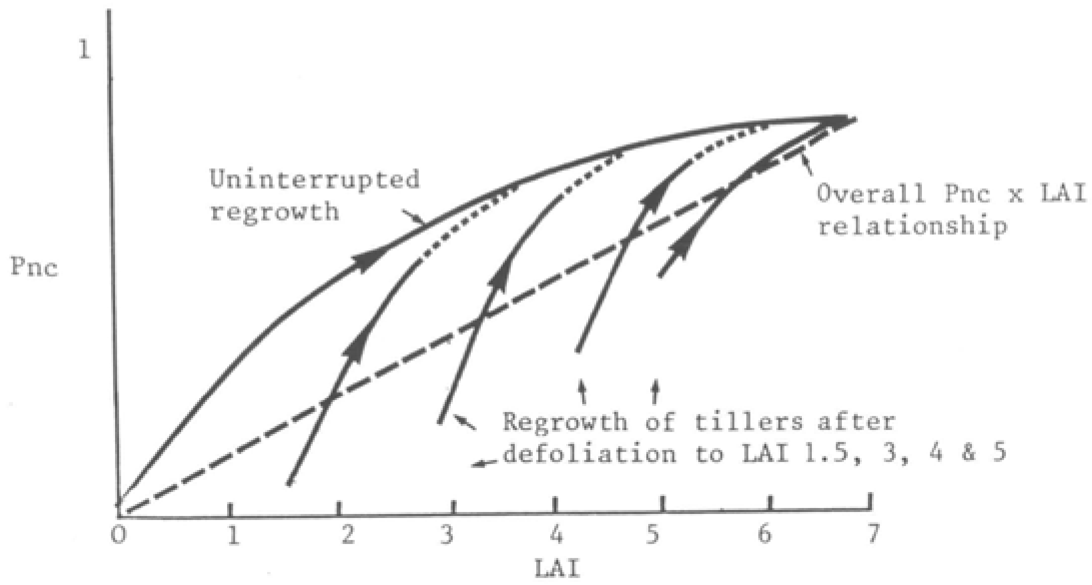


Figure 4. Relationships of Pnc to LAI for uninterrupted regrowth of a sward, regrowth of tillers grazed to various levels of LAI and for a grazed sward

This gives an overall relationship between Pnc and LAI which is linear and in which the mean value of Pnc at any given LAI is intermediate between the values for the newly defoliated and fully regrown tillers.

A grazed sward will therefore always have a lower photosynthetic rate than an ungrazed one at the same LAI unless some compensatory changes occur in the former.

ii) Compensatory adjustments by the grazed swards

These take place on pastures continuously grazed to maintain a low herbage mass and LAI. Data from the present and other experiments shows that such swards develop high tiller densities and prostrate leaves and since the swards cast little shade the photosynthetic efficiency of the young leaves developed in the bright light environment is high (Woledge, 1978). The result is that such swards have a higher growth potential than swards with lower tiller densities and erect leaves of lower efficiency. The latter set of properties are characteristic of rotationally grazed swards.

At LAI < 3.5 therefore a continuously grazed pasture that has had time to develop the requisite growth-form should always have a higher growth-rate than a rotational pasture. Above LAI 3.5 the position is less clear. The greater part of the data available indicates that the superiority of the continuously stocked sward extends up to LAI 5, possibly because defoliation on such swards is necessarily light so that the effect of defoliation on Pnc discussed under (i) above does not occur. Some data, however, suggests that the photosynthetic potential, and presumably also growth-rate, of such high mass swards may sometimes be low with no advantage over the rotationally grazed sward.

Although the differences in photosynthetic potential which have been described are fairly well attested it is not clear what these differences represent in terms of dry matter production and intake. To obtain this information it will be necessary to carry out a comprehensive grazing experiment in which measurements of net photosynthesis, growth-rate and intake are measured simultaneously.

Reference

WOLEDGE, J. 1978. Annals Bot., v. 42. p.1085-1089.

5.2 Seasonal patterns of grass production

D.E. Suckling

In the exploitation of grassland a knowledge of the level of grass production which can be expected and the way in which that production varies within the year and from year to year is an important aid to planning efficient forage use.

To examine this more closely thirty sites have been set up throughout Europe under the coordination of the Grassland Research Institute to monitor the production of cultivars of Timothy and Ryegrass under similar conditions of management. At the same time meteorological records will be made so as to correlate grass production to meteorological factors.

H.F.R.O. is contributing to this joint effort by establishing plots at Hartwood to examine the response of two cultivars of ryegrass (Cropper and Perma) and one cultivar of white clover (Huia) grown under the conditions suggested by the G.R.I. The plots were established in 1982 and harvesting will begin in spring 1983. Plots will be cut every four weeks throughout the growing season and samples will be kept for mineral and digestibility analysis.

New plots will be set up yearly for several years and the experiment repeated to give a knowledge of the way in which production varies from year to year. G.R.I. will coordinate all the results in order to attempt to predict the potential for grass production under standard conditions for particular areas.

SYSTEMS STUDIES

Programme Unit 7: Systems studies in ruminants.

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 the hills and uplands. In order to make extrapolation of the findings to other situations possible, field scale studies are being carried out in the widely different but limited range of environments represented by the three research stations where the essential biological monitoring and control over their management can be maintained.

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

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

Systems modelling and the application of mathematical and computing techniques are 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, date of lambing, levels of pasture production, individual animal performance and flock output.

1. HILL SHEEP : YEAR ROUND GRAZING SYSTEMS

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 systems.

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 three 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.

Research objective: The evaluation of improved systems of sheep production from grassy hills (project no. 701).

1.1 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 1A.

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 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. 1981	Cast	Deaths	Gimmers Bought Into Flock	Hoggs Born 1982	Ewes & Gimmers Nov. 1982
674	119	16	144	174	683

Total Stock Numbers

	1969	1970	1971	1972	1973	1974	1975
NCC	175	210	260	269	300	295	292
SCC	223	241	254	259	273	305	309
TOTAL	398	451	514	528	573	600	601

	1976	1977	1978	1979	1980	1981	1982	1983
TOTAL	620	621	623	622	631	649	674	683

Sheep Year 1981-82

a) Winter feeding

N.E. Hairney Law (4 crop, 3 crop, 2 crop ewes)

14.12.81 Feeding commenced because of severe weather Hay 450 g/head/day.

16.12.81 Feed blocks introduced.

22.12.81 S.B.P. introduced at 227 g, hay reduced to 227 g.

14.1.82 Hay increased to 380 g, S.B.P. to 350 g.

19.1.82 Hay feeding only stopped.

16.2.82 Hay re-introduced at 190 g.

19.3.82 Ewebol cobs introduced at 350 g, hay remaining at 190 g, S.B.P. feeding stopped.

9.4.82 Ewebol cobs increased to 420 g, hay remaining at 190 g.

Concentrate feeding continued through lambing, and super ewebol pencils (18% protein) fed to all twin nursing ewes (at 450 g/head/day) till the 3rd June.

	DEC.	JAN.	FEB.	MAR.	APR. (1-16 inc.)	APR. (17-30)/ MAY
Colborn Blocks (kg)	260	540	680	800	400	200
S.B.P. Pencils (kg)	1000	3525	3500	2250	-	-
Hay (kg)	2295	1642	877	2092	1012	67
Ewebol Cobs (kg)	-	-	-	1550	2200	2088
Super Ewebol Pencils (kg)	-	-	-	-	-	2313

Auchope (1 crop ewes and gimmers)

14.12.81	Feeding commenced because of severe weather Hay 560 g/head/day.
16.12.81	Feed blocks introduced.
23.12.81	S.B.P. introduced at 235 g, hay reduced to 280 g.
12.1.82	S.B.P. increased to 310 g, hay increased to 420g.
19.1.82	Hay feeding only stopped.
2.2.82	S.B.P. reduced to 235 g.
16.2.82	Hay re-introduced at 140 g, S.B.P. remaining at 235 g.
21.3.82	Ewebol cobs introduced at 310 g, hay increased to 175 g., S.B.P. feeding stopped.
1.4.82	Hay feeding stopped.

Concentrate feeding continued through lambing, and super ewebol pencils fed to all twin nursing ewes (450 g/head/day) till the 3rd June.

	DEC.	JAN.	FEB.	MAR.	APR. (1-16 inc.)	APR (17-30)/ May
Colborn Blocks (kg)	200	460	340	480	360	120
S.B.P. (kg)	675	2650	2125	2022	-	-
Hay (kg)	2205	1665	652	1777	-	22.5
Ewebol Cobs (kg)	-	-	-	1175	1600	1425
Super Ewebol Pencils (kg)	-	-	-	-	-	775

Hoggs (NE Hairney Law and Auchope) (151)

1.12.81 Hoggs started on ewe and lamb mix, then onto green keil. Hay fed as required during periods of snow cover. Sugar beet nuts, grass nuts and low protein pencils were given during the last weeks of feeding.

	DEC.	JAN.	FEB.	MAR.
Ewe and lamb mix (kg)	50	-	-	50
Green Keil (kg)	750	1550	1400	-
Hay (kg)	742	1080	1260	697
Low Protein Pencils (kg)	-	-	-	575
Grass nuts (kg)	-	-	-	125
Sugar Beet Nuts (kg)	-	-	-	700

Total feed consumption (kg) and costs per head

	Ewes and Gimmers(674)	Hoggs(151)
Hay	21.2	25.0
Colborn Blocks	7.2	-
S.B.P.	26.3	4.6
Ewebol Cobs and Pencils	14.9	3.8
Super Ewebol Pencils	4.6	-
Grass Nuts	-	0.8
Ewe and Lamb Mix	-	0.7
Green Keil	-	24.5
Cost per Head	£8.49	£5.82

b) Lambing Performance

Ewes to Tup	674
Tup Eild	37
Kebs	3
Ewe losses to lambing	3
Total lambs born (alive and dead)	881 (130.7%)
Total lambs marked	833 (123.6%)
Total lambs weaned	811 (120.3%)

c) Lamb Weights (kg)

Birth weights, singles	4.2
twins	3.5
Marking weights, singles	10.5
twins	7.4
Weaning weights, singles	25.0
twins	24.6

d) Wool Production (kg)

Total (ewes and gimmers)
1315 kg (674 ewes)
= 2.0 kg average fleece weight

e) Ewe Body Weights (kg) 1981/82

	Nos.	Pre-Mating Nov.81	Pre-Feeding	Pre-Lambing	Marking	Weaning	Pre-Mating Nov.82	Nos
4crop	102	67.1	66.2	63.9	62.0	60.7	65.1	108
3crop	115	66.1	66.0	64.5	62.5	61.5	62.9	126
2crop	138	61.1	60.1	58.1	58.6	59.3	60.4	163
1crop	165	56.9	55.6	56.1	55.9	56.8	54.6	142
Gimm.	154	52.1	47.2	47.3	48.1	50.1	49.4	144
All Ages	674	59.8	58.0	57.1	56.7	57.2	58.1	683

Summary of Production and Performance 1968/82

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

	1968	1969	1970	1971	1972	1973	1974
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	-	-	-	-	-	-	-

	1975	1976	1977	1978	1979	1980	1981	1982
NCCxSCC	58.0	53.6	57.7	59.1	58.1	59.9	59.9	58.1

g) Production Data

	Stock Nos.	Weaning %	Total Weight Lamb Weaned	Total Weight Wool (inc. Hoggs)
1969	398	84.7	7786	850
1970	451	86.7	9188	1017
1971	518	102.5	14177	1253
1972	528	104.7	14046	1369
1973	573	99.5	14193	1561
1974	600	91.5	14329	1454
1975	601	102.7	16042	1535
1976	620	108.5	17902	1543
1977	621	106.9	17596	1503
1978	623	105.1	16470	1523
1979	622	113.3	17837	1601
1980	631	118.2	19471	1887
1981	649	104.0	17905	1610
1982	674	120.3	20149	1590
1983	683	110.5	19486	1723

1.2 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. During 1982, the following applications were made. Reseeds A1 and A4 received 125 kg of potassium muriate on 5th October, and A4 received 5 tonnes per hectare of ground magnesium limestone on May 19th.

Sheep Stocks and Livestock Reconciliation

Ewes and Gimmers Nov. 81	Cast	Deaths	Gimmers brought into flock	Hoggs born 1982	Ewes and Gimmers Nov.82
275	57	8	71	80	281

Sheep Year 1981/82

a) Winter Feeding

Ewes and gimmers

14.12.81	Hay feeding started to ewes at 450 g/head/day
16.12.81	Ewes started on feed blocks.
22.12.81	Ewes started on sugar beet pulp at 227 g/head/day. Hay reduced to 227 g/head/day.
11.1.82	Beet pulp and hay both increased to 302 g/day.
17.1.82	Hay reduced to 227 g/day.
20.3.82	Commence feeding ewebol cobs at 272 g/head/day Stopped feeding S.B.P. pencils.

25.3.82 Hay feeding stopped.

6.5.82 Ewebol pencils introduced to ewes nursing twins and increased to 450 g/head/day.

30.5.82 All feeding to ewes finished.

	DEC.	JAN.	FEB.	MAR.	APR. (1-16 inc.)	APR. (17-30)	MAY
S.B.P.(kg)	650	2675	2275	1550	-	-	-
Feed Blocks (kg)	207.5	225	337.5	337.5	180	225	-
Ewebol Cobs (kg)	-	-	-	800	1400	750	250
Super Ewebol Pencils(kg)	-	-	-	-	-	-	1200
Hay (kg)	2092.5	2317.5	1260	1215 -	-	450	67.5

Hoggs

1.12.81 Hoggs started on ewe and lamb mix, then onto green keil. Hay fed as required during snow cover.

25.3.82 Hoggs finished on feed

Total Feed (74 hoggs)

Hay (kg)	1364
Ewe and Lamb mix (kg)	24.0
Green Keil (kg)	2196
Grass Nuts (kg)	83.5
Sugar Beet Pulp (kg)	83.5

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

	Ewes and Gimmers (275) (kg)	Hoggs (74) (kg)
Hay	26.9	18.4
Feed Blocks	5.5	-
Beet Pulp Cubes	26.0	1.1
Ewebol Cobs	11.6	-
Super Ewebol Pencils	4.4	-
Grass Nuts	-	1.1
Ewe and lamb mix	-	0.3
Green Keil	-	29.7
Total Cost per Head	£ 7.80	£ 5.21

b) Lambing Performance

Ewes to tup	275
Tup Eild	17
Kebs	0
Ewe losses to lambing	7
Total lambs born (alive and dead)	385 (140.0%)
Total lambs marked	364 (132.4%)
Total lambs weaned	360 (130.9%)

c) Lamb Weights (kg)

Birth weights,	singles	4.2
	twins	3.4
Marking weights,	singles	12.4
	twins	8.2
Weaning weights,	singles	29.7

twins 26.3

d) Wool Production (kg)

Total (ewes and gimmers) 498.1 kg (275 ewes and gimmers)

Average weight 1.8 kg.

e) Ewe body weights (kg) 1981/82

	Nos.	Pre-Mating Nov.81	Pre-Feeding	Pre-Lambing	Marking	Weaning	Pre-mating Nov.82	Nos
4crop	45	61.6	58.3	61.5	53.3	56.1	61.4	41
3crop	48	62.6	60.0	62.4	56.1	59.4	62.4	48
2crop	52	61.6	60.8	64.4	57.5	61.0	59.9	52
1crop	57	58.6	56.4	60.1	54.5	57.9	57.5	69
Gimm.	73	56.6	51.3	54.5	50.1	54.7	51.8	71
All Ages	275	59.8	56.8	60.0	54.0	57.6	57.9	281

Summary of Production and Performance (1972-82)

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

1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
54.4	51.8	55.7	54.5	55.3	56.8	58.3	56.9	59.8	59.8	57.9

g) Production Data

	Stock Nos.	Weaning %	Total Weight Lamb Weaned	Total Weight Wool (inc. Hoggs)
1973	217	112.9	6615	493
1974	222	109.0	6534	490
1975	242	116.6	7981	560
1976	255	106.3	7751	542
1977	272	112.9	8934	536
1978	259	97.3	7056	501
1979	266	115.0	8325	469
1980	269	128.6	9394	586
1981	266	127.1	9878	610
1982	275	130.9	9892	590

Research objective: The evaluation of improved systems of sheep production from Calluna Moorland (project no. 703).

1.3 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, 17.2 hectares of the Redstone Hill were enclosed and divided into two approximately equal areas. In one of the areas (south) four half ha square reseeds and in the other (north) four half ha rectangle reseeds were created. In this way, artificial mosaics of reseeded grassland was set up within the callunetum. 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 k/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 15.7 hectares on Thorter hill was enclosed, 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 (83 kg N/ha) of compound fertiliser (22:11:11) was applied to the Redstone Hill reseed in May 1979 and 125 kg/ha (32.5 kg N/ha) of Nitrochalk in July.

In 1980 and 1981 a similar dressing of compound fertiliser was applied to all the mosaic reseeds during May.

A long term monitoring programme was initiated in September 1979 on the Redstone Hill reseed. This programe 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.

During 1982, differential applications of nitrogen, lime, potassium, trace elements and Rhizobium were applied to randomly selected reseeded areas on an experimental basis in association with Dr Anne Rangeley (see p.).

Sheep Stocks and Livestock Reconciliation

Ewes and Gimmers Nov.81	Cast	Deaths	Gimmers brought into flock	Hoggs born 1982	Ewes and Gimmers Nov. 82
263	57	15	68	73	259

Sheep Year 1981-82

a) Winter Feeding

Block feeding was used for the first time on the Cairn. Blocks were widely distributed over the hill and were used by the ewes until snow covered most of the feeding sites. Hay and concentrate feeding was then introduced. Concentrate feeding was increased from 220 g/head some six weeks before lambing to over 450 g at lambing.

The total amount of concentrates given to the ewes was 32 kg costing 5.18 and 55.8 kg of hay costing 3.35 giving a total cost of 8.53 per ewe.

Hoggs

Concentrates		Hay	
Dates	g/head/day	Dates	g/head/day
10th Dec. - 30th April	249	8th Dec. - 10th April	811

Total feed and cost per head

	Ewes and gimmers		Hoggs	
	kg	£	kg	£
Concentrates	32.0	£5.18	34.9	£5.54
Hay	55.8	£3.35	98.9	£5.93
Total cost		£8.53		£11.38

b) Lambing Performance

Ewes to Tup	263
Tup Eild	24
Kebs	5
Ewe losses to lambing	4
Total lambs born (alive & dead)	299 (113.7%)
Total lambs marked	262 (199.6%)
Total lambs weaned	239 (90.6%)

c) Lamb Weights (kg)

Birth weights, singles	3.9
twins	3.2
Marking weights, singles	16.3
twins	14.1
Weaning weights, singles	25.8
twins	23.3
All lambs	24.8

d) Wool Production (kg)

Ewes and gimmers total = 478 kg

Average wt. (all ages) = 1.8 kg

e) Ewe Body Weights (kg) 1981/82

	Nos.	Pre-mating Nov.81	Pre-Feeding	Pre-Lambing	Marking	Weaning	Pre-mating Nov.82	Nos
6crop	-	-	-	-	-	-	62.5	1
5 crop	8	57.1	52.0	52.6	53.7	52.4	57.0	8
4 crop	29	55.9	51.6	56.0	56.1	51.2	57.3	12
3 crop	35	55.9	49.9	55.7	56.3	51.8	52.9	48
2 crop	54	55.0	49.6	54.9	56.8	50.9	52.9	56
1 crop	63	53.0	47.8	52.6	56.4	51.4	46.5	66
Gimmers	74	43.7	39.0	40.2	46.8	43.3	43.5	68
All Ages	263	51.6	46.5	50.4	53.7	49.1	49.1	259

Summary of Production and Performance (1972-82)

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

1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
52.8	51.8	55.8	50.0	47.5	51.3	54.0	56.7	57.5	51.6	49.1

g) Production Data

	Stock Nos.	Weaning %	Total Weight Lamb Weaned	Total Weight Wool (inc. Hoggs)
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
1982	263	90.9	5927	596

2. HILL SHEEP · OFF-WINTERING SYSTEMS

Research objective: The evaluation of improved systems of sheep production based on off-wintering with and without land improvement (project no. 704).

2.1 On a grassy hill - Sourhope/Rigg and Gairs

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

Land Resources

The Rigg and Gairs are two similar units, each of 101 ha, each traditionally stocked with 130-140 ewes and gimmers. Both sheep stocks are inwintered for the same length of time in the same wintering house. On the Gairs Unit a substantial area of improved pasture has been made available. An area of 15 ha of *Agrostis-Festuca* pasture was enclosed and limed and slagged early in the winter of 1969/70. During the summer of 1971 this was oversown with clover. Further in the spring of 1971, 10 ha of *Molinia-Nardus* grass heath at 450 m received 6.35 tonnes lime and 1.65 tonnes slag per ha. It was later sprayed with Paraquat, rotavated and direct reseeded in mid-July with 380 kg per ha of high phosphate compound. This area was grazed for the first time in the autumn of 1971. In 1975, ground magnesium limestone at 6.3 tonnes/ha and super-slag (16% P_2O_5) at 0.88 tonnes/ha was applied to the Gairs reseed. Gairs reseeds received applications of potassium muriate in November 1982 (E1 125 kg/ha, E2 187.5 kg/ha). In addition E1 received 7.5 tonnes/ha of ground magnesium limestone.

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 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 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. 1981	Cast	Deaths	Gimmers brought into flock	Hoggs born 1981	Ewes and Gimmers Nov. 1982
Rigg	261	43	7	63	66	274
Gairs	281	55	7	64	77	283
Total	542	98	14	127	143	557

Total Stock Numbers

	1969	1970	1971	1972	1973	1974	1975
RIGG							
S.C.C.	205	205	238	278	279	298	234
B.F.	-	-	-	-	-	-	65
GAIRS							
S.C.C.	209	207	233	260	279	297	240
B.F.	-	-	-	-	-	-	65

	1976	1977	1978	1979	1980	1981	1982
RIGG							
S.C.C.	152	93	40	-	-	-	-
B.F.	128	191	231	264	266	260	274
GAIRS							
S.C.C.	165	111	45	-	-	-	-
B.F.	132	199	230	271	272	281	283

Sheep Year 1981-82

a) Winter Feeding

Ewes and gimmers

Because of severity of early winter, feeding to all ewes and gimmers commenced on 13.12.81, and continued until housing.

Feed for December and January till housing:-

Hay	8.8 kg per head
Ewebol cobs (14% protein)	4.0 kg per head
Sugar Beet Pulp Pencils	0.3 kg per head
High energy rumevite blocks	0.7 kg per head

Rigg ewes and gimmers housed 15.1.82
Gairs ewes and gimmers housed 18.1.82

Commence on ration of:-

Concentrate	120 g
Hay	570 g
S.B.P.	230 g

29.1.82 All Rigg and Gairs ewes and gimmers, diet altered to:-

Concentrate	120 g
Hay	680 g
S.B.P.	280 g

17.3.82 Concentrate ration increased to 180 g.

1.4.82 Concentrate ration increased to 240 g.

8.4.82 Concentrate ration increased to 400 g.

12.4.82 Concentrate ration increased to 450 g.

12.4.82 All Rigg and Gairs late lambers out of shed. Early lambers lambed in sheds.

Concentrate feeding continued through lambing, and super ewebol pencils fed to ewes nursing twins at 450 g per head, until end of May.

Total Feed (kg) 542 ewes and gimmers

	Pre-lambing	Post-lambing	Total	Per Head
Hay	40320	4635	44955	82.9
S.B.P.	13245	2218	15463	28.5
Ewebol Cobs and Pencils	11300	3023	14323	26.4
Super Ewebol Pencils	-	1810	1810	3.3
Feed Blocks	360	-	360	0.7

Total weight dry matter per head 141.8 kg
Cost per head £11.96

Hoggs (137)

1.12.81 Hoggs started on ewe and lamb mix, then onto Green Keil.

Feed for December and January till housed:-

Hay	6.7 kg per head
Green Keil	6.7 kg per head
Ewe and lamb mix	0.3 kg per head

Housed 26.1.82 Ration 370 g Green Keil
370 g Hay

This ration equivalent to amount being fed outside during snow cover prior to housing.

2.3.82 Hay increased to 450 g.

5.4.82 Hoggs out of shed.

Total Feed kg		Per head
Hay	5692.5	41.6
Grass Nuts	275	2.0
Ewe and Lamb Food	50	0.4
Green Keil	5150	37.6

Total dry matter per head 81.6 kg
Cost per head £7.43

b) Lambing performance

	Rigg	Gairs
Ewes to Tup	260	281
Tup Eild	13	18
Kebs	0	0
Ewe Losses to lambing	1	3
Total lambs born	322 (123.8%)	356 (126.7%)
Total lambs marked	306 (117.7%)	326 (116.0%)
Total lambs weaned	305 (117.3%)	315 (112.1%)

c) Lamb Weights (kg)

		Rigg	Gairs
Birth weights,	singles	4.4	4.6
	twins	3.5	3.6
Marking weights,	singles	10.1	10.1
	twins	9.7	8.3
Weaning weights,	singles	28.0	30.5
	twins	31.5	28.9

d) Wool Production (kg)

Fleeces not weighed in age groups:-

Rigg (260 e+g) 406.7 kg
= 1.6 kg Average fleece weight

Gairs (281 e+g) 246.0 kg (summer shorn)
= 0.9 kg Average fleece weight

(219 e+g) 107.6 kg (January shorn)
= 0.5 kg Average fleece weight

e) Ewe Body Weights (kg)

RIGG:

Ages	Nos.	Pre-Mating Nov.81	Pre-Feeding	Pre-Lambing	Marking	Weaning	Pre-Mating Nov.82	Nos.
4crop	38	59.0	56.8	57.6	50.5	54.8	58.9	38
3crop	41	61.2	58.9	60.6	54.8	58.3	61.4	44
2crop	50	59.9	59.4	62.3	56.0	59.2	58.3	59
1crop	59	56.7	54.1	56.2	50.6	55.9	52.3	70
Gimm.	72	50.6	49.2	51.3	46.0	49.7	50.3	63
All Ages	260	56.7	54.9	56.9	50.9	55.0	55.5	274

GAIRS:

Ages	Nos.	Pre-Mating Nov.81	Pre-Feeding	Pre-Lambing	Marking	Weaning	Pre-Mating Nov.82	Nos.
4crop	49	61.6	57.6	61.1	52.6	55.8	57.6	45
3crop	49	59.1	55.7	59.8	51.5	56.3	57.6	51
2crop	54	57.9	53.4	58.0	50.5	57.4	58.7	59
1crop	60	57.0	52.7	57.1	50.4	59.1	53.9	64
Gimm.	69	51.5	49.9	53.0	47.2	53.6	49.1	64
All Ages	281	57.0	53.5	57.4	50.2	56.4	55.1	283

Summary of Production and Performance 1969-1982

f) Pre-mating Ewe Body Weights (kg)

	1969	1970	1971	1972	1973	1974	1975
RIGG							
S.C.C.	48.3	49.7	51.5	51.2	50.6	50.0	51.8
B.F.	-	-	-	-	-	-	-
GAIRS							
S.C.C.	49.9	50.5	51.9	53.5	52.9	54.1	53.8
B.F.	-	-	-	-	-	-	-

	1976	1977	1978	1979	1980	1981	1982
RIGG							
S.C.C.	53.8	55.6	55.6	-	-	-	-
B.F.	48.5	52.1	55.0	56.9	54.9	56.7	55.5
	52.4	54.0	55.1				
GAIRS							
S.C.C.	56.6	56.7	59.0	-	-	-	-
B.F.	48.5	51.5	55.1	58.0	57.2	57.0	55.1
	54.7	54.4	55.7				

g) Production Data

	RIGG				GAIRS			
	Stock Nos.	Weaning %	Total Wt. Lamb Weaned	Total Wt. Wool	Stock Nos.	Weaning %	Total Wt. Lamb Weaned	Total Wt. Wool
1970	205	83.0	3706	402	209	83.0	3581	461
1971	205	87.0	4432	534	207	96.0	5246	524
1972	238	100.0	5712	641	233	91.4	5176	634
1973	278	87.8	5324	732	260	93.1	5675	752
1974	279	91.0	6155	680	279	87.0	6394	766
1975	311	89.6	6257	670	305	87.2	6381	732
1976	299	90.6	6640	674	305	99.0	7943	738
1977	290	105.2	8218	567	297	109.4	9248	643
1978	284	105.6	7920	525	310	111.9	9542	624
1979	271	121.0	8519	521	275	127.2	9956	512
1980	264	121.6	9020	530	271	129.9	10102	552
1981	266	118.4	9299	503	272	121.0	9962	531
1982	260	117.3	8996	519	281	112.1	9392	516
1983	274	125.9	9534	522	283	126.9	11118	515

3. UPLAND SHEEP SYSTEMS

Research objective: Study systems of upland sheep production (project no. 705).

3.1 Upland Sheep Systems Experiment

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

On the basis of experiments carried out since the conclusion of the last Systems experiment in 1977 it is now possible to draw some tentative conclusions about the sward conditions that ought to be achieved within the context of whole systems of sheep production.

The objective of the reported experiments was to assess the decision rules required to achieve two herbage profiles throughout the grazing season resulting from setting targets of herbage mass at

(a) start of grazing

(b) closure for conservation (May for 1st cut)

(c) closure for conservation (July for 2nd cut)

and their effect on the performance of Greyface ewes stocked at either 10 or 15 ewes per ha (from lambing to post-mating).

The experimental design therefore was of four treatments, high and low herbage mass profiles, each at two stocking rates, each treatment being replicated three times. All the replicates had been sown out to grass the previous year, one had been sown under spring barley.

This experiment was a prelude to setting up a final version of a systems experiment in October 1982 to last for a minimum of four years.

(a) Start of grazing

Ewes were grazed either immediately after lambing on their allocated area and given 600 g supplementation, fed until herbage mass reached 750 kg DM/ha (low herbage mass profile), or were grazed only when their allocated area had reached a herbage mass of 750 kg DM/ha and the accumulated degrees by which the daily 100 mm soil temperature exceeded 5.5° reached 15° (high herbage mass profile). These latter ewes were maintained on a sacrifice area and given supplementary feed until they were allocated to their summer grazing areas.

(b) Closure for conservation (1st cut)

Areas were closed for conservation for the low herbage mass treatment when

(i) herbage mass reached 1250 kg DM/ha before 20 May

(ii) not before the accumulated degrees by which the daily 100 mm soil temperature exceeded 5.5°C reached 23

(iii) only if 0.25 of the treatment area could be closed at any one time based on weekly herbage mass estimates

and for the high herbage mass treatment when

(i) herbage mass reached 1600 kg DM/ha before 20 May and

(ii) not before the accumulated degrees by which the daily 100 mm soil temperature exceeded 5.5°C reached 23

(iii) only if 0.25 of the treatment area could be closed at any one time based on weekly herbage mass estimates.

(c) Closure for conservation (2nd cut)

Areas were closed for conservation for the low herbage mass treatment to maintain 1600 kg DM/ha on grazed area and on the high herbage mass treatment 2000 kg DM/ha on grazed area.

Nitrogen was applied on three occasions. The first application when 100 mm soil temperature reached 5.5°C, was 82 kg N, 41 kg P and 41 kg K per hectare. The second application on 15 May, was 56 kg N per hectare as Nitram and a third application of 35 kg N per hectare as Nitram on 1 July.

The ewes were wintered on rough fields and fed from mid-December. They were given 5 kg silage/ewe up to 4 weeks before lambing. Concentrates were introduced 6 weeks before lambing at 250 g/head; a barley and a protein balancer giving a mix of 15% CP was used; concentrate inputs were adjusted in relation to plasma 3-OHB levels. Immediately prior to lambing concentrate feeding had increased to 850 g/head. From 4 weeks prior to lambing 0.75 kg of hay and 0.5 kg sugar beet pulp was also given. Cost of feeding up to lambing was £11.79 per ewe.

Herbage mass and height measurements were taken throughout the period of the experiment. Regressions relating herbage mass and height were constructed for each of the three replicates in a three weekly rotation (i.e. one replicate each week). Each week height measurements were taken for all plots.

Table 1

Results of main treatment effects up to 24.6.82

Amount of herbage	Low		High	
Stocking Rate	Low	High	Low	High
Premating liveweight	72.0	70.0	74.0	70.5
Lambs reared per ewe	166.0	169.1	170.2	154.3
Twin Lamb Growth Rate 0-27 days g/day	310	270	296	255
Twin Lamb Growth Rate 28-55 days g/day	335	317	303	310
Twin Lamb Growth Rate 56-87 days g/day	234	231	291	309
Percent lambs sold fat by weaning	22	31	10	11
Mean Growth Rate of all lambs to day 87	316	308	312	301
Lamb Output kg/ha	500a	767b	513a	659c
Lamb Output kg/ewe	50.0a	51.1a	51.3a	43.9b

Table 1 gives a summary of the results of the main treatment effects up to 24 June before lambs were subsequently drawn for slaughter. All lambs were weaned on 13 July and the output data relate to all lambs up to weaning. There were no significant differences in the growth rate of lambs. There were significant differences in output per hectare between high and low stocking rate as would be expected. The significantly lower output per hectare and output per ewe of the high stocking rate and high pasture amount is attributable to a lower proportion of lambs reared per ewe.

A summary of the amounts of herbage available to the grazing ewe on each of the treatments is presented below in Table 2.

Table 2

Herbage masses kg DM/ha (grazed areas)

Herbage Profile	Low		High	
Stocking Rates	Low	High	Low	High
Pre-conservation (1st cut)	1050	1050	1250	1200
During conservation (1st cut)	2466	1502	2842	1730
Post-conservation/ weaning (1st cut) Pre-conservation (2nd cut)	3054	2400	5270	2162
Post-conservation (2nd cut)	3520	2512	3407	3027
Pre-mating	1993	1420	1791	1427

The data show that the decision rules used did not achieve the specific herbage masses required at the appropriate time. It was concluded that in order to achieve better control it would be necessary

(i) to take account of growth of herbage i.e. make assumptions on the basis of estimation of intake and between week measurements of herbage mass

(ii) to close areas less than 0.25 of the treatment paddock

(iii) to cut the areas for conservation much earlier in the second conservation period

(iv) to apply nitrogen on four occasions rather than three and ensure that the last application is made after the second period of conservation.

Table 3

Weight at mating (kg) October 1982 and weight changes during mating (g/day)

Amount of herbage	Low		High	
Stocking Rate	Low	High	Low	High
Weight at mating kg	65.9	67.7	70.1	68.2
Weight change g/day	-101	-137	-97	-147

The low amounts of herbage available at the point of mating and the fact that ewes were grazed on only half their total potential grazing area (for statistical and logistical reasons any treatment area within a replicate comprised two paddocks only one of which was used for mating at any one time) resulted in substantial weight losses during mating which took place from 23 October. Weight of ewes at mating and the weight losses during the period 23 Octobr to 30 November are given in Table 3. Concentrate feed was offered to ewes on areas with inadequate herbage mass. The ewes were removed from their grazed areas on 1 December. During the period of mating severe poaching occurred and herbage was badly contaminated by soil. It has been concluded that in future, treatment paddocks within replicates will not be divided. Division will only take place with temporary electric fencing during periods of conservation otherwise the area will be grazed as a whole. It has been agreed that such an arrangement can be handled statistically.

As a result of this preliminary study it has been possible to construct a set of decision rules and provide an experimental design which should achieve the desired treatment objectives.

3.2. Upland Sheep Systems - Conservation closure area, decision rules

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

In pasture based systems of sheep production there is a need to control sward conditions within specified limits to achieve required levels of animal performance and sward productivity. This is particularly so in early and mid-lactation when there is also a need to control reproductive growth in the sward and provide for winter forage as hay or silage.

Under grazing, to maintain a sward at a given herbage mass requires that all new net herbage production be ingested by sheep. It is therefore appropriate, on the basis of a prediction of ewe intake during lactation, and of herbage growth rate, to adjust the number of ewes and/or proportion of an area to be grazed such that herbage intake is equivalent to net herbage production. In practice there is a fixed flock size and so adjustment must be made in the proportion of the whole pasture area that is to be grazed.

Net herbage growth can be estimated from the relationships derived by Bircham (1981), see Fig. 1, and these may be adjusted to represent lower or higher growth according to season and rate of fertiliser application. Animal intake can be predicted from a knowledge of sheep breed stage of lactation and number of lambs per ewe.

In practice it is unlikely that a precise proportion of the whole pasture area can be fenced for grazing, it is reasonable therefore to calculate that proportion to the nearest eighth.

A computer program has been written which calculates, for ranges of herbage growth potential and animal intake at two stocking rates, the proportion in eighths to allocate to grazing to maintain a specific level of herbage mass. Table 1 shows these results. The program also calculates the effect on herbage mass if the grazing animals maintain their level of intake, since allocations to the nearest eighth will mean either a surplus or deficit of net herbage growth. These results are shown in Table 2.

This procedure will be used to determine the areas for conservation on the Greyface Systems Study at Hartwood.

Reference

Bircham, J. (1981). Herbage growth and utilisation under continuous stocking management. Ph.D. Thesis, University of Edinburgh.

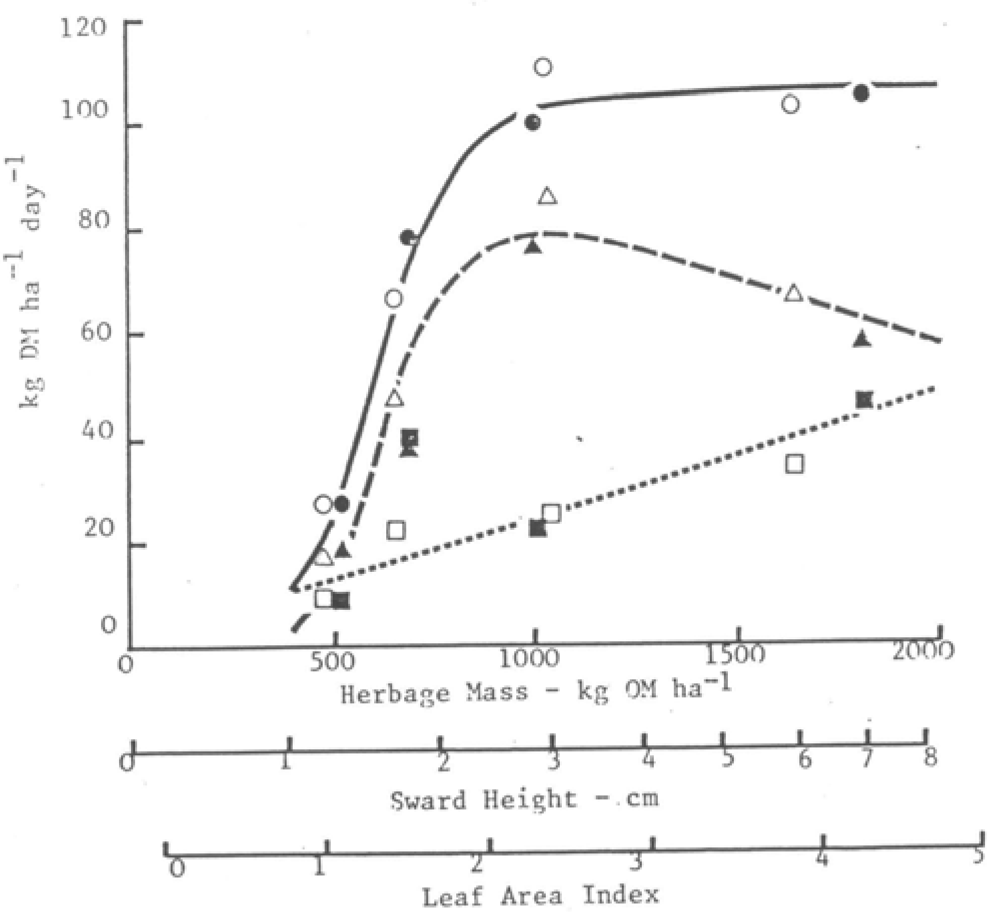


Figure 1. The relationships between total growth (●——○), senescence (▲– –△) and net production (■····□); and herbage mass, herbage height and LAI work using the logistic model for total growth (base herbage growth in Tables 1 and 2).

Table 1

Proportion (in 8ths) of total pasture area to be allocated to GRAZING for a range of Herbage Growth Rate, Standing Crop, Stocking Level and Ewe/Lamb unit intake requirement. Grazing area allocated to NEAREST 8th.

Standing Crop (kg DM ha^{-1})		750		1000		1250		1500		1750	
Stock Rate (ewes ha^{-1} overall)		10	15	10	15	10	15	10	15	10	15
	Ewe/lamb Intake (kg DM d^{-1} $unit^{-1}$)										
70% G	2.0	5	7	3	5	3	5	4	6	4	7
	2.5	6	7	4	6	4	6	5	7	5	8
	3.0	7	*	5	7	5	8	6	7	7	*
80% G	2.0	4	6	3	4	3	4	3	5	3	5
	2.5	5	7	3	5	3	5	4	6	4	6
	3.0	6	7	4	6	4	6	5	7	5	8
90% G	2.0	3	5	2	3	2	4	3	4	3	4
	2.5	4	6	3	4	3	4	3	5	3	5
	3.0	5	7	3	5	4	5	4	6	4	6
se rbage (G) owth	2.0	3	4	2	3	2	3	2	3	2	3
	2.5	4	5	3	4	3	4	3	4	3	4
	3.0	4	7	3	5	3	5	3	5	3	5
110% G	2.0	3	4	2	3	2	3	2	3	2	3
	2.5	3	5	2	3	2	3	2	4	3	4
	3.0	4	6	3	4	3	4	3	4	3	5
120% G	2.0	2	3	2	2	2	2	2	3	2	3
	2.5	3	4	2	3	2	3	2	3	2	3
	3.0	3	5	2	4	2	4	3	4	3	4
130% G	2.0	2	3	1	2	1	2	2	2	2	2
	2.5	3	4	2	3	2	3	2	3	2	3
	3.0	3	5	2	3	2	3	2	3	2	4

Table 2

<u>Standing Crop remaining after 1 week if Ewe + Lamb intake remains at the required level. Grazing allocation based on NEAREST 8th as Table 1.</u>

Standing Crop (kg DM ha^{-1})		750		1000		1250		1500		1750	
Stock Rate (ewes ha^{-1} overall)		10	15	10	15	10	15	10	15	10	15
	Ewe/lamb Intake (kg DM d^{-1} $unit^{-1}$)										
	2.0	762	746	968	1005	1205	1242	1514	1514	1727	1767
70% G	2.5	753	746	991	991	1228	1228	1514	1494	1727	1744
	3.0	746	****	1005	981	1242	1263	1514	1494	1767	****
	2.0	757	757	1039	992	1278	1232	1495	1532	1708	1745
80% G	2.5	757	737	945	992	1185	1232	1518	1518	1731	1731
	3.0	757	737	992	992	1232	1232	1532	1508	1745	1766
	2.0	713	751	922	922	1166	1306	1569	1522	1782	1736
90% G	2.5	737	737	1016	957	1259	1201	1475	1522	1689	1736
	3.0	751	727	922	978	1306	1222	1522	1522	1736	1736
Base	2.0	764	717	993	993	1239	1239	1456	1456	1670	1670
Herbage (G)	2.5	787	717	1086	1028	1333	1274	1550	1491	1763	1705
growth	3.0	717	777	993	1049	1239	1295	1456	1512	1670	1726
	2.0	814	767	1063	1063	1313	1313	1531	1531	1744	1744
110% G	2.5	720	767	923	923	1173	1173	1391	1566	1837	1779
	3.0	767	767	1063	993	1313	1243	1531	1461	1744	1800
	2.0	677	677	1134	854	1387	1107	1605	1605	1818	1818
120% G	2.5	771	712	994	994	1247	1247	1465	1465	1678	1678
	3.0	677	733	854	1064	1107	1317	1605	1535	1818	1748
	2.0	727	727	644	924	901	1181	1679	1399	1893	1613
130% G	2.5	821	762	1064	1064	1321	1321	1539	1539	1753	1753
	3.0	727	783	924	924	1181	1181	1399	1399	1613	1823

3.3 Upland Sheep System Model

A.R. Sibbald and T.J. Maxwell

The lactation model described in a previous Annual Report (1977,p.B33) has been used as the basis for a further model which represents the lactation/first conservation period of an upland sheep system.

The intended purpose of the model is to test the effects of various management decisions on lamb growth, ewe liveweight change and herbage conserved.

One of these decisions is the level (kg/DM ha) at which the grazed area should be maintained during the conservation period. Herbage growth inputs are therefore based on the net herbage growth curves determined by Bircham (1981) for maintained sheep-grazed swards. Intake, ewe liveweight change and milk production are derived from the lactation model component and milk is utilised by a new lamb growth model component which also takes account of the transition of lamb intake from a milk only diet through a mixed diet to a diet consisting only of grazed herbage.

Management decisions include, as well as herbage mass to be maintained on the grazed area, stocking rate, lambing percentage, date of first closure for conservation and date of cutting for conservation.

Table 1

Example output from Upland Sheep Model for 16 weeks after lambing - 15 ewes/ha

Week No.	Milk kg/d)	Lamb liveweight (mean of twins per ewe - kg)	Ewe liveweight (kg)	Herbage mass on grazed area (kg DM/ha)	Proportion grazed (eighths)
0		4.0	63.0	900	8
1	1.12	4.9	61.4	932	8
2	1.55	6.2	59.7	960	8
3	2.34	8.3	58.1	1165	8
4	2.89	10.5	57.9	1471	6
5	2.54	12.9	58.2	1655	6
6	1.98	15.1	58.5	1825	4
7	1.51	17.0	58.7	1776	4
8	1.13	19.1	59.0	1774	4
9	0.79	20.8	59.2	1781	4
0	0.66	22.3	59.5	1812	4
1	0.56	23.7	60.0	1829	4
2	0.32	24.8	60.8	1800	4harvest
3	0.18	26.7	61.8	1737	4
4	0.09	26.5	63.0	1650	4
5	0.04	27.1	64.4	1538	4
6	0.01	27.7	65.6	1407	4

Total conservation (kg DM) 912
Conservation per ewe (kg) 60.8

Output from the model (see Table 1) currently appears to reflect the real world but further testing and validation need to be carried out before any confidence can be put on its predictions and before the model can be extended to a second conservation/ewe recovery phase.

Reference

Bircham, J. (1981). Herbage growth and utilisation under continuous stocking management. PhD. Thesis, University of Edinburgh.

4. LAND USE

Research objective: Model the consequences of land use decisions with respect to sheep farming and forestry in hill and upland areas (project no. 713).

4.1 Land Use Model

A.R. Sibbald, A.S. Grant (Dept. of Landscape Architecture, Heriot Watt Univ.) and T.J. Maxwell

The model (Maxwell, Sibbald and Eadie, 1979) has been developed to take account of areas across which it would be impossible to build roads, for example steep slopes, bog etc. When introducing roads, so that all afforested areas are within 1200 m of access, the new procedure searches for routes which avoid unroadable areas. The new roading procedure is also used at the agricultural improvement stage to ensure that roading is properly costed against the improvement of agricultural blocks where these may be too far from access to allow cross-country haulage of fencing materials, fertilisers etc.

The model has been further developed so that specified landscape objectives can be achieved and incorporated into the planning phase of the model.

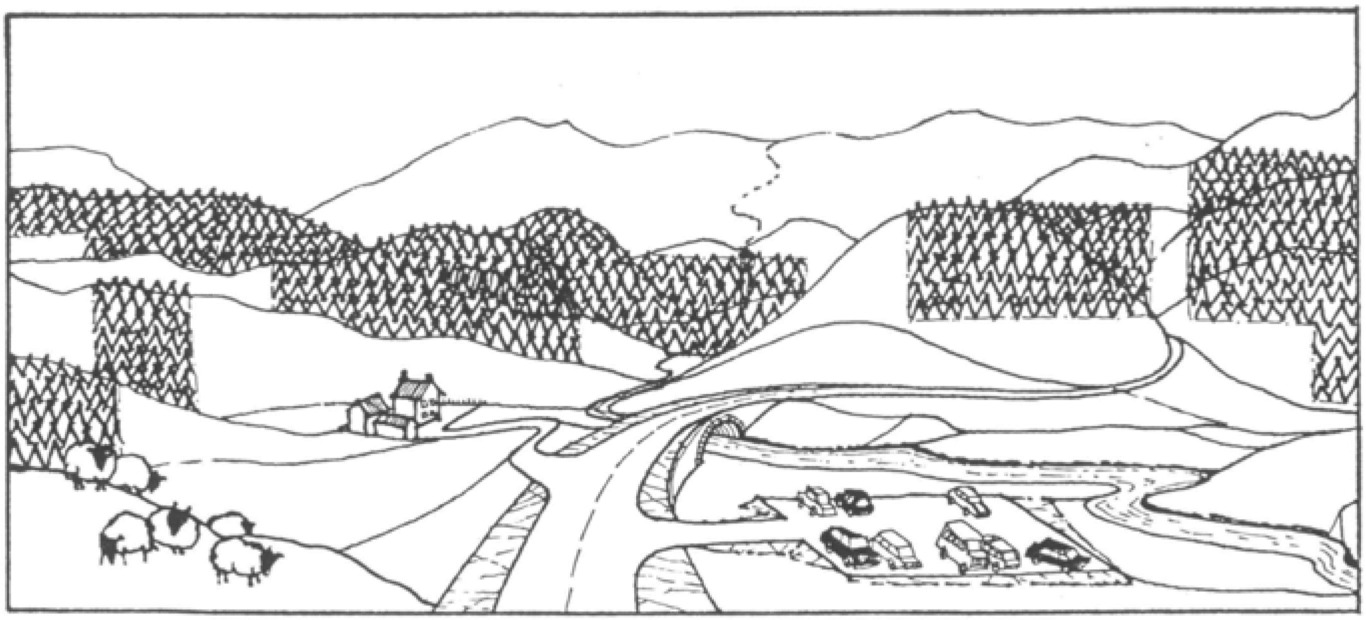
To meet these objectives the descriptive matrices of the model have been reduced from 10 to 2.5 ha. This allows a more detailed representation of the patterns produced by mixing the two land uses, sheep grazing and tree growing, within the area of one farm or estate.

Examples of the landscape objectives being incorporated are

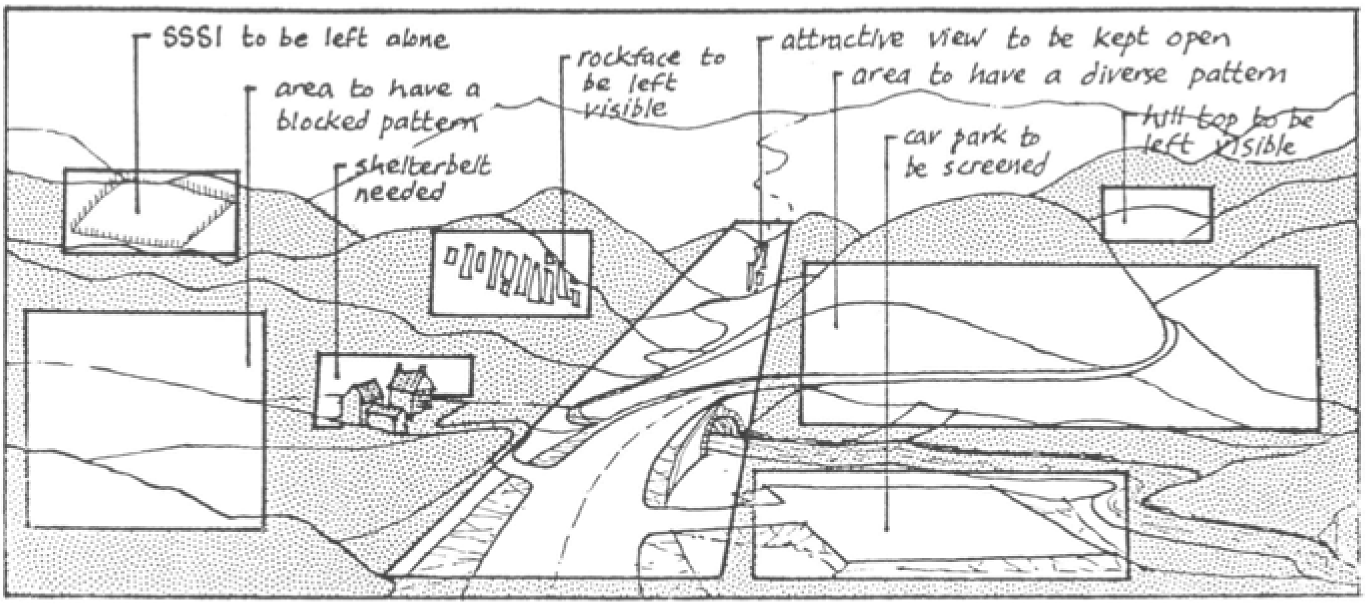
(i) a need to avoid planting areas with trees where they would mask an attractive landscape feature, or a more general view might be screened from a public road,

(ii) a need to plant trees at specific sites to act as a screen,

(iii) to achieve an appropriate scale and degree of diversity in landscape.



A HILL FARMING/FORESTRY 'INTEGRATION' WITHOUT LANDSCAPE INPUT



B ANALYSIS OF SCENE FOR BASIS OF LANDSCAPE INPUT

C HILL FARMING/FORESTRY 'INTEGRATION' WITH LANDSCAPE INPUT

Figure 1. Example of landscape input into land use model.

Consideration is given to the identification of areas where intimate, mixed patterns of land use are desirable and conversely to those areas where large scale patterns are considered to be more appropriate. The planning phase of the model is being modified to allow for land allocations to be made in such a way as to produce either large or small scales of diversity pattern. Figure 1 provides an indication of the extent to which planning with a landscape input can influence the scenic aspect of agricultural and forestry integration.

The cost of taking account of landscape requirements will be determined by the economic assessment component of the model.

Reference

Maxwell, T.J., Sibbald, A.R. and Eadie, J. (1979). The integration of agriculture and forestry - a model. Agricultural Systems 4, pp. 161- 188.

5. VETERINARY MONITORING

Research objective: Develop disease prevention programmes for systems of hill and upland ruminant production (project no. 714)

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

5.1 Research Stations

LEPHINMORE

Sheep

Records are incomplete for the year. In March several sheep in all three hefts were lost because of snow. Apart from an outbreak of pasteurellosis in Lowend hoggs in the shed, losses were attributable to various causes such as dystokias, rotten lambs, pneumonia.

Monitoring of the stock for evidence of liver fluke disease showed that the long range benefits of strategic dosing are still being obtained when nationally in 1981 and 1982 there has been a higher incidence.

Cattle

No losses were reported. The cattle have since been transferred to Glensaugh and an appropriate veterinary prevention programme has been implemented.

HARTWOOD

Sheep: Greyface flock. Respiratory disease continued to be the main cause of losses with 10 deaths due to Jaagsiekte and 9 deaths to chronic pasteurella pneumonia. The flock has now moved on to a combined pasteurella/clostridial vaccine and it is hoped this may reduce some of the losses due to respiratory disease. Other losses were due to a range of diseases but the incidence of such was very low and not of epidemiological significance.

Sheep: Blackface flock. Losses were minimal.

Cattle

In the spring of 1982 cases of pneumonia, joint-ill and enteritis were of low incidence in the calves. An outbreak of enteritis in the autumn born calves was persistent and showed high morbidity but low pathogenicity. The causal organism was a K99 negative E. coli, unaccompanied by viral or cryptosporidial involvement. This organism was remarkable for its resistence to most antibiotics but electrolyte therapy plus routine checks on sensitivity were efficacious in determining satisfactory treatment. One of the problems with housed suckler cows is that spread of enteric disease between calves is difficult to prevent. Whilst the E. coli strain was not one incorporated in the enteric vaccine used, it is probable that vaccination precluded virus involvement and helped in keeping mortality at a negligible level.

One or two cows on low level feeding posed problems at calving and veterinary attention was necessary. As outlined in the farm report measures to contain hypomagnesaemia were effective, but monitoring of the magnesium status of cows from August onwards showed that reliance on magnesium acetate supplementation of the drinking water was not effective in maintaining cows in magnesium sufficiency, some very low serum magnesium levels being encountered. The practice of feeding magnesium cobs during the 'risk' periods in spring and autumn is necessary. Contagious ophthalmia in all stock was troublesome and labour intensive. Monitoring for fascioliasis and routine dosing of cows continues. All purchased cattle are subjected to veterinary screening and prophylactic treatment.

GLENSAUGH

Sheep

Tick borne disease on Cairn occurred in 1982, as in 1981, on the reseeded pastures which have a proportion of indigenous herbage capable of sustaining tick populations. A group of lambs were artificially infected with the Cairn strain of Tick borne fever soon after birth with the objective of achieving immunosuppression prior to their exposure to ticks. However in 1982 the tick rise was very early in the season and both treatment and control lambs acquired artificial and natural infections simultaneously. Lambs were lost with T.B.F./Pasteurellosis and T.B.F./louping ill and no differences were found between the two groups. It is possible that if the treated group had had sufficient time to overcome the immunosuppression then differences might have been observed. Currently 60 ewes have been given the Cairn strain in the pretupping period and this will be followed by a second injection pre-lambing to see if protection to lambs is possible by this means. In addition the use of the new combined pasteurella and clostridial vaccine may be effective in reducing the T.B.F./pasteurella complex. All ewes will receive a booster louping-ill vaccination in the prelambing period. Losses in ewes were related to a variety of causes, it is probable that respiratory disease was the highest single cause.

Cattle

Calves housed in the autumn received full prophylactic treatment on entry. An outbreak of ringworm was contained by spraying both the animals and the wooden portions of their cubicles with an antimycotic agent.

Deer

A trial in which cupric oxide needles were administered to calves grazing improved pasture was of little value because the dry summer and autumn necessitated hand feeding and therefore control animals received copper in the diet.

An outbreak of Yersiniosis (Pasteurella pseudotuberculosis) was responsible for the death of several calves. The epidemiology indicates that calves will acquire this infection from bird faeces on the soil and from infected carrier animals. The organism can be found in the faeces and lodges in the lymphatic system. The effect of stress can produce a systemic illness with rapid deaths. It may be possible in future to develop an autogenous vaccine and this possibility is being examined.

SOURHOPE

Sheep

Losses of ewes and lambs were low. There were only two cases of Scrapie in 1982. An outbreak of contagious ophthalmia in late winter required vigilance and a high labour input in treatment. All other diseases were of low incidence. All stock have been introduced to the new pasteurella/clostridial vaccine.

Cattle

No problems were encountered.

Goats

At entry all goats are tagged, vaccinated, sampled for serological studies, faeces sampled for worm egg counts, and sampled for trace-element status. All are dipped for ectoparasites and males are castrated under general anaesthesia. All are given an anthelmintic. Many have shown very high worm egg counts and ectoparasite burdens of ticks and two species of lice. Serological evidence suggests that they are remarkably free from a wide range of infectious disease. They are quite susceptible to coccidiosis; even adults from certain areas where presumably, they have not encountered the disease before.

Goats being remarkably aggressive to one another has resulted in losses due to trauma. Alimentary dysfunction is not uncommon and some of this may be related to circumstances where they cannot fully exercise their browsing habits. Evidence of liver-fluke infection in goats at Sourhope was followed by prophylactic treatment.

Trace element status. No evidence of hypocupraemia has been found but some groups have shown low serum B12 status.

It is intended to monitor for serological evidence of diseases acquired from sheep or cattle.

5.2 Veterinary Monitoring Samples

The following is a summary of the examination of samples taken in relation to the veterinary monitoring programme.

	1980	1981	1982
Worm Egg Counts	2460	3560	3271
Pasture Larvae Counts	40	79	55
Lung Worm Larvae	50	40	60
Haematology	1764	1823	337
Plasma Copper Estimations*	3639	1889	2387
Liver Copper Estimations*	77	72	257
Glutathions Peroxidase Estimations+	-	26	95
Serum Vitamin B12 Estimations+	-	207	564
Liver Cobalt Estimations+	-	20	-
Serological Examinations~	-	811	485
Snail Site Sampling	12	14	29
Serum Magnesium Estimations~	-	-	241
Serum Calcium Estimations~	-	-	84
Serum Protein Estimations	-	-	56
Serum Vitamin B Estimations~	-	-	487
Total Worm Counts	-	40	134
Semen Examinations	-	20	65
Bacteriological Examinations	-	100	270
Miscellaneous	-	660	410
Post-mortem Examinations (HIDB)	-	-	80

* Biochemistry, E. Skedd, J. Mackenzie

+ Veterinary Investigation Centre, ESCA

~ ADRA, Moredun

SERVICES

1. Glasshouses, Growth Rooms, Microclimate (project no. 901)

D.E. Suckling

Glasshouse use has been low again this year, but the growth rooms have been utilised to full capacity. The placement of a para-web wind break in front of the South West corner of the glasshouse coupled with the use of more new style clips to hold the panes of glass has reduced the incidence of wind damage.

The Automatic Weather Station on Mid Hill at Lephinmore will be retained until the farm is sold in order to attempt to give a complete assessment of the year to year variation in winter and spring temperatures. Much 1982 data still requires analysis. The A.W.S. at the bottom of Birnie at Glensaugh was disconnected in April. Data capture from this logger had on the whole been on the poor side over winter with many sensor faults occurring. The system was renewed and installed on one of the Cairn reseeds later on in April. Little data analysis has been attempted on this site so far. In June an Automatic Weather Station was installed at Hartwood in Reservoir Field. Data capture was fairly successful until August when cows demolished the mast.

2. Analytical Services (project no. 903)

2.1 Biochemistry, inorganic chemistry and forage analysis

E. Skedd, D.R. Campbell, P.E. Moberly and J. Mackenzie

In support of the research programme 49700 analyses were carried out on 30,600 samples of plant tissues, soil extracts, biochemical fluids, animal tissues and animal feeds.

Assistance was given to a post-graduate student from ABRO in setting up methods for determining alkaline phosphatase and total protein in uterine fluid. A comparison of sheep and goat rumen liquor in *in vitro* digestion analysis was carried out and is described on p. The IL 455 Furnace Atomiser was used in an attempt to prepare a method for the determination of molybdenum in soil extracts. Modification of the equipment to allow better temperature control has been carried out and development will now proceed.

2.2 Chromium Analysis by X.R.F.S.

Following a large scale test of comparison of X-ray fluorescence spectrometry (X.R.F.S.) and Atomic Absorption (A/A) for Cr analysis in sheep and cattle faeces, it was realised that X.R.F.S. gave lower values for some materials than A/A (10-20% typically).

Due to an extremely high demand for Cr/Ru determinations by X.R.F.S. in 1982-83 a considerable degree of development work was required to investigate the problem and to attempt streamlining the whole method to increase sample throughput.

Cr concentration by X.R.F.S. is proportional to a count obtained (IP). Different materials e.g. digesta, faeces, feeds, etc., all give different calibration curves due to variations in the major element components. A background count for Cr, (IB) has normally been taken to act as an internal standard, and for similar materials the ratio $\frac{IP}{IB}$ remained a constant. However, for some samples encountered, the background count did not function as intended and hence low values were produced.

Two different elements, Vanadium and Titanium, were tried as internal standards. Both of these have X-ray wavelength similar to Cr and therefore should be affected by the sample matrix in the same way. Vanadium was found to line overlap with Cr, and hence could not be used successfully, but Titanium appeared to work properly as an internal standard, correcting matrices ranging from pure cellulose to pure SiO_2.

Table 1

Comparison of internal standards for Cr analysis using Cr or Ti

0.2% Cr Standard	IP	IB	$\frac{IP}{IB}$	ITi(.2%)	$\frac{IP}{ITi}$
Cellulose	184,000	2600	70.8	37,700	4.88
Faeces	112,000	2000	56.0	23,400	4.79
Clover	108,000	1860	58.1	22,800	4.74
Phleum	131,000	2030	64.5	26,600	4.92
Nardus	129,000	2160	59.7	26,700	4.83
Heather	168,000	2770	60.6	35,200	4.77
SiO_2	44,000	860	51.2	9,200	4.78

As yet this technique for Cr analysis has not been used with samples because of difficulties in adding the Ti quantitatively to each sample. Further work requires to be done to thoroughly investigate the use of an internal standard. It is possible that this technique could correct for variations in particle size, weight of disc, surface finish, interelement effects and density variations, hence eliminating the preparation stage of grinding and pressing from the Cr method. However, the pressure of analytical requirements at present for X.R.F.S. prevents further development.

2.3 PDP 11/03 Micro-computer system

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

The laboratory data capture and processing system has again been used successfully throughout the year. The on-line data collection program was modified during the year to allow more samples per run to be collected. The previous maximum number of samples was 32,767 (2^{15}-1) and this has now been raised by a factor of 4 to 131,068 in order to allow full overnight sampling from GLC's.

The longer sampling runs required by GLC applications has led to a limit on the amount of time that the microcomputer is not collecting data on-line and it is during this time, because of the size of the original peak reduction program, that the first stage of data processing currently takes place. A locally written peak processing module has been developed and can run simultaneously with on-line data capture. The program is currently being evaluated and the results look promising. When it has been fully tested the use of the program will give much greater flexibility in the use of the whole system.

3. Electronics Laboratory (project no. 904)

R.A. Curtis

This year, there has been a fair amount of repair and maintenance on analytical equipment including two drying ovens, an autoclave and the MS10 mass spectrometer (building a programmable timer for the cryostat pump) etc.

Work in the following project areas has been undertaken:-

3.1 Sheep behavioural studies (with J. Hodgson)

During the year, trials have been continued on feeding behaviour sensors, as it was felt previous devices have either:-

(i) practical disadvantages

(ii) inaccurate methods of measurement

(iii) insufficient knowledge of animal jaw movements to correlate to a sensors output to movement

(iv) uncertainty as to what phenomena is actually being recorded.

Various switches used previously in experiments were ruled out (due to (i) and (ii) above).

Accelerometers have previously been used (Chambers et al, 1981) however this falls into class (iv) above. (Many different activities can trigger the device, such as walking); class (iii) above, also applies.

The Penning band* gives the cleanest output but falls into class (iii) above. However, it is very good at indicating the 'type' of behaviour in which the animal is participating.

Interesting results have been obtained in simultaneous recordings of Accelerometer and Penning band, these however shed no further insight into a detail of jaw movement.

To resolve detail, EMG (Electro-Myograph) equipment has been built and traces are to be compared with the above two sensors in the near future.

*Penning band is a resistive 'rubber band', placed as a loop over the animals snout. Invented by Dr P.D. Penning of GRI, Hurley.

3.2 Foetal Number Determination (with I. White)

Ongoing work has been done in two areas of foetal number determination:-

(i) Use of real time scanning technique

(ii) Use of point probe and signal processing

Category (ii) above involves use of a probe such as an ultrasonic doppler probe or stethoscope type sensor, to investigate if, during a short period, and using advanced signal processing techniques, data on foetal number may be obtained with accuracy. Some work has also been done in conjunction with Dr R. Parkes of SIAE who has the requisite, powerful signal processing software packages already available.

Work on real time scanning was done in the spring of 1982 using a Sonicaid real time scanner, which proved to be of very low resolution and not suited to this type of application.

In January 1983 Dr D. Fowler from Australia, came as a visiting worker, and using much more up to date, high resolution machines, has obtained excellent results (see p.

It should be noted, although a good solution is thus now available from (i) above, option (ii) is still worth considering as it has the potential of dramatically reducing costs and allowing "less-specialised" personnel to use it.

3.3 Analytical Service Data Logging

There is a growing requirement for a general purpose bench-top data logger which will accept and format output information from a variety of analytical instruments.

The initially envisaged system would have the following specifications:-

(i) must allow enough software flexibility for a variety of interface speeds and standards

(ii) must allow the operator to title file blocks and type in identifying header for each entry

(iii) must give the operator a hard copy readout (also essential in case of system failure/accidental data erasure)

(iv) must record data on tape (for long or short term mass storage)

(v) tape should be formatted so that the date can be fed into the main ERCC network where the software for number crunching and statistics already exists via a downloading processor (Superbrain).

The choice of microcomputer equipment to do the logging is very difficult as, at the middle priced end of the market (£200-£1000) there is an extremely wide choice. Furthermore, every month new equipment comes onto the market undercutting and out- performing previous equipment.

At the project onset an Aim 65 (by Rockwell) coupled to a Currah tape drive seemed the best choice, and software to log from a balance was successfully developed. The initial balance to be logged was a Mettler PC-100/03.

3.4 Solarimetric logging display

Some time was spent modifying solarimeter equipment, originally built by my predecessor, to obtain high enough performance and field portability. An adequate solution was found for the 1982 summer field work, however the original design suffered from several drawbacks (the worst of which were drift, and voltage droop due to the sample and hold circuitry).

An eight channel solarimeter has now been designed using dual slope A/D conversion to reduce drift, digital latching, to eliminate 'droop', and liquid crystal display, to reduce power consumption (by a factor of 300), for portability (battery life).

It is hoped this new unit will be built and operational by early summer 1983.

Work on oestrus detectors for cows and a "lock and key" lamb feeder has also been done. These both involved development of biotelemetry equipment on the allocated 104MHz band.

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